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ISO/IEC/IEEE 8802-11

Third edition
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Telecommunications and information exchange between systems — Specific requirements for local and metropolitan area networks —

Part 11: Wireless LAN medium access control (MAC) and physical layer (PHY) specifications

Télécommunications et échange entre systèmes informatiques — Exigences pour les réseaux locaux et métropolitains —

Partie 11: Spécifications du contrôle d'accès du milieu sans fil (MAC) et de la couche physique (PHY)

Reference number
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This third edition cancels and replaces the second edition (ISO/IEC/IEEE 8802-11:2018), which has been technically revised. It also incorporates the Amendments ISO/IEC/IEEE 8802-11:2018/Amd 1:2019, ISO/IEC/IEEE 8802-11:2018/Amd 2:2019, ISO/IEC/IEEE 8802-11:2018/Amd 3:2020, ISO/IEC/IEEE 8802-11:2018/Amd 4:2020, ISO/IEC/IEEE 8802-11:2018/Amd 5:2020.

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IEEE Std 802.11™-2020
(Revision of IEEE Std 802.11-2016)

**IEEE Standard for Information Technology—
Telecommunications and Information Exchange between Systems
Local and Metropolitan Area Networks—
Specific Requirements**

Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

Developed by the

LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 3 December 2020

IEEE SA Standards Board

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Abstract: Technical corrections and clarifications to IEEE Std 802.11 for wireless local area networks (WLANs) as well as enhancements to the existing medium access control (MAC) and physical layer (PHY) functions are specified in this revision. Amendments 1 to 5 published in 2016 and 2018 have also been incorporated into this revision.

Keywords: 2.4 GHz, 256-QAM, 3650 MHz, 4.9 GHz, 5 GHz, 5.9 GHz, 60 GHz, advanced encryption standard, AES, audio, beamforming, carrier sense multiple access/collision avoidance, CCMP, channel switching, clustering, contention based access period, Counter mode with Cipher-block chaining Message authentication code Protocol, confidentiality, CSMA/CA, DFS, direct link, directional multi-gigabit, dynamic allocation of service period, dynamic extension of service period, dynamic frequency selection, dynamic truncation of service period, E911, EDCA, emergency alert system, emergency services, fast session transfer, forwarding, GCMP, generic advertisement service, high throughput, IEEE 802.11™, international roaming, interworking, interworking with external networks, LAN, local area network, MAC, management, measurement, medium access control, media-independent handover, medium access controller, mesh, MIS, millimeter-wave, MIMO, MIMO-OFDM, multi-band operation, multi-hop, multi-user MIMO, multiple input multiple output, network advertisement, network discovery, network management, network selection, noncontiguous frequency segments, OCB, path-selection, personal basic service set, PHY, physical layer, power saving, QoS, quality of service, quality-of-service management frame, radio, radio frequency, RF, radio resource, radio management, relay operation, spatial sharing, SSPN, subscriber service provider, television white spaces, TPC, transmit power control, video, wireless access in vehicular environments, wireless LAN, wireless local area network, WLAN, wireless network management, zero-knowledge proof

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Introduction

This introduction is not part of IEEE Std 802.11-2020, IEEE Standard for Information Technology—Telecommunications and Information Exchange between Systems—Local and Metropolitan Area Networks—Specific Requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.

This revision gives users, in one document, the IEEE 802.11 standard for wireless local area networks (WLANs) with all of the amendments that have been published to date.

Incorporating published amendments

The original standard was published in 1997, revised in 1999 with MIB changes, and reaffirmed in 2003.

A revision was published in 2007, which incorporated into the 1999 edition the following amendments:

- IEEE Std 802.11a™-1999: High-speed Physical Layer in the 5 GHz Band (Amendment 1)
- IEEE Std 802.11b™-1999: Higher-Speed Physical Layer Extension in the 2.4 GHz Band (Amendment 2)
- IEEE Std 802.11b-1999/Corrigendum 1-2001: Higher-speed Physical Layer (PHY) extension in the 2.4 GHz band (Corrigendum 1 to Amendment 2)
- IEEE Std 802.11d™-2001: Specification for operation in additional regulatory domains (Amendment 3)
- IEEE Std 802.11g™-2003: Further Higher Data Rate Extension in the 2.4 GHz Band (Amendment 4)
- IEEE Std 802.11h™-2003: Spectrum and Transmit Power Management Extensions in the 5 GHz band in Europe (Amendment 5)
- IEEE Std 802.11i™-2004: Medium Access Control (MAC) Security Enhancements (Amendment 6)
- IEEE Std 802.11j™-2004: 4.9 GHz–5 GHz Operation in Japan (Amendment 7)
- IEEE Std 802.11e™-2005: Medium Access Control (MAC) Quality of Service Enhancements (Amendment 8)

A revision was published in 2012, which incorporated into the 2007 revision the following amendments:

- IEEE Std 802.11k™-2008: Radio Resource Measurement of Wireless LANs (Amendment 1)
- IEEE Std 802.11r™-2008: Fast Basic Service Set (BSS) Transition (Amendment 2)
- IEEE Std 802.11y™-2008: 3650–3700 MHz Operation in USA (Amendment 3)
- IEEE Std 802.11w™-2009: Protected Management Frames (Amendment 4)
- IEEE Std 802.11n™-2009: Enhancements for Higher Throughput (Amendment 5)
- IEEE Std 802.11p™-2010: Wireless Access in Vehicular Environments (Amendment 6)
- IEEE Std 802.11z™-2010: Extensions to Direct-Link Setup (DLS) (Amendment 7)
- IEEE Std 802.11v™-2011: Wireless Network Management (Amendment 8)
- IEEE Std 802.11u™-2011: Interworking with External Networks (Amendment 9)
- IEEE Std 802.11s™-2011: Mesh Networking (Amendment 10)

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A revision was published in 2016, which incorporated into the 2012 revision the following amendments:

— IEEE Std 802.11ae™-2012: Prioritization of Management Frames (Amendment 1)
— IEEE Std 802.11aa™-2012: MAC Enhancements for Robust Audio Video Streaming (Amendment 2)
— IEEE Std 802.11ad™-2012: Enhancements for Very High Throughput in the 60 GHz Band (Amendment 3)
— IEEE Std 802.11ac™-2013: Enhancements for Very High Throughput for Operation in Bands below 6 GHz (Amendment 4)
— IEEE Std 802.11af™-2013: Television White Spaces (TVWS) Operation (Amendment 5)

This revision is based on IEEE Std 802.11-2016, into which the following amendments have been incorporated:

— IEEE Std 802.11ai™-2016 (second printing): Fast Initial Link Setup (Amendment 1)
— IEEE Std 802.11ah™-2016: Sub 1 GHz License Exempt Operation (Amendment 2)
— IEEE Std 802.11aj™-2018: Enhancements for Very High Throughput to Support Chinese Millimeter Wave Frequency Bands (60 GHz and 45 GHz) (Amendment 3)
— IEEE Std 802.11ak™-2018: Enhancements for Transit Links Within Bridged Networks (Amendment 4)
— IEEE Std 802.11aq™-2018: Preassociation Discovery (Amendment 5)

Technical corrections, clarifications, and enhancements

In addition, this revision specifies technical corrections and clarifications to IEEE Std 802.11 as well as enhancements to the existing medium access control (MAC) and physical layer (PHY) functions. In addition, this revision removes some features previously marked as obsolete and adds new indications of other obsolete features.

Generally, features that are marked deprecated or obsolete are not maintained; there might be technical errors in the material describing these features.

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Renumbering of clauses and annexes

The numbering of certain clauses and annexes has been modified since IEEE Std 802.11-2007.

The evolution of this numbering is shown in Figure 1.

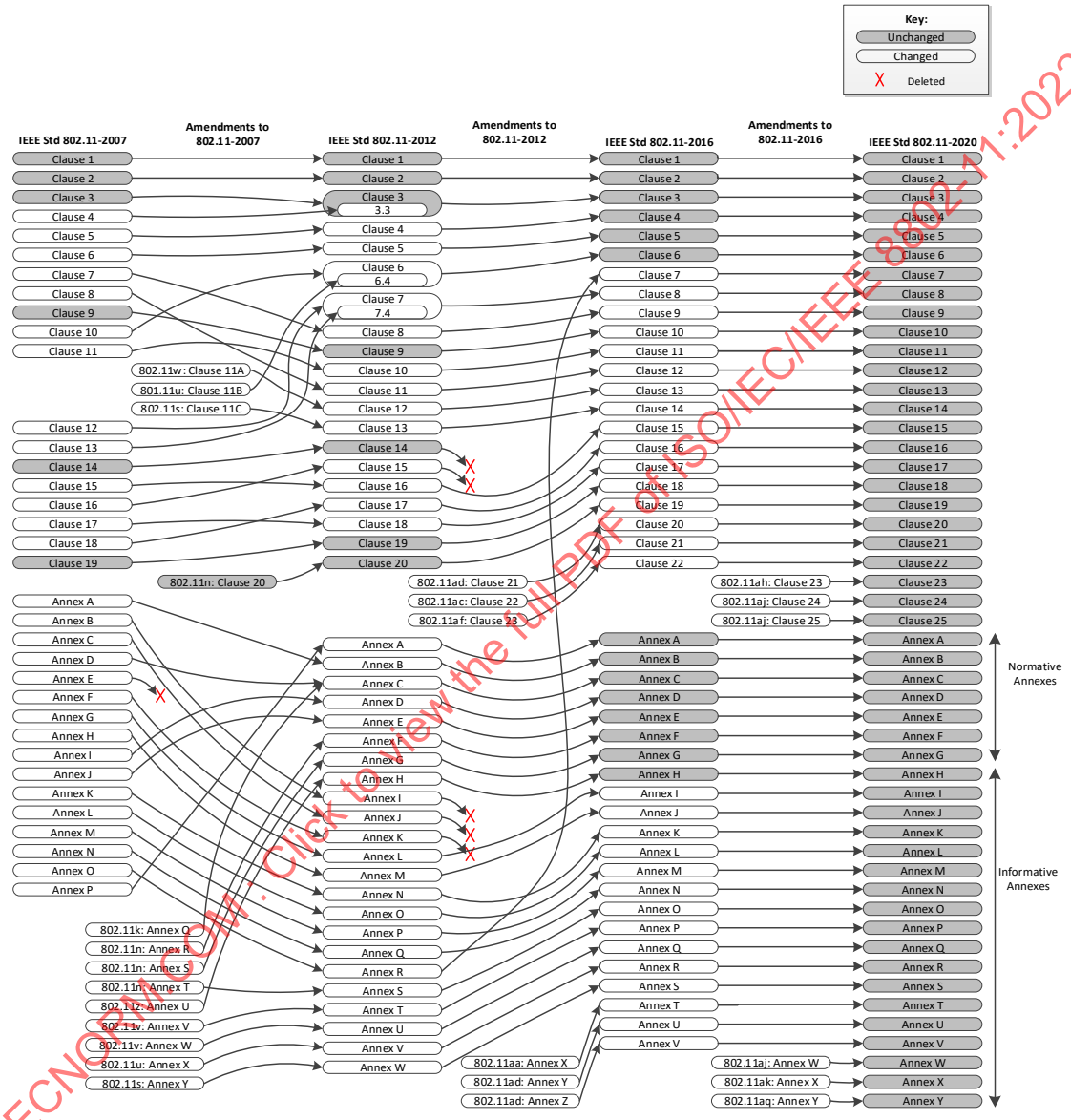

Figure 1—The evolution of numbering in IEEE Std 802.11

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10. MAC sublayer functional description 1631

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IEEE Standard for Information Technology—
Telecommunications and Information Exchange between Systems
Local and Metropolitan Area Networks—
Specific Requirements

Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

1. Overview

1.1 Scope

The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area.

1.2 Purpose

The purpose of this standard is to provide wireless connectivity for fixed, portable, and moving stations within a local area. This standard also offers regulatory bodies a means of standardizing access to one or more frequency bands for the purpose of local area communication.

1.3 Supplementary information on purpose

Specifically, in the context of IEEE 802.11™-compliant devices, this standard

- Describes the functions and services required by a device to operate within independent, personal, and infrastructure networks as well as the aspects of device mobility (transition) within those networks.
- Describes the functions and services that allow a device to communicate directly with another such device outside of an independent or infrastructure network.
- Defines the MAC procedures to support the MAC service data unit (MSDU) delivery services.
- Defines several PHY signaling techniques and interface functions that are controlled by the MAC.
- Permits the operation of a device within a wireless local area network (WLAN) that coexists with multiple overlapping IEEE 802.11 WLANs.
- Describes the requirements and procedures to provide data confidentiality of user information and MAC management information being transferred over the wireless medium (WM) and authentication of devices.
- Defines mechanisms for dynamic frequency selection (DFS) and transmit power control (TPC) that may be used to satisfy regulatory requirements for operation in any band.

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- Defines the MAC procedures to support local area network (LAN) applications with quality-of-service (QoS) requirements, including the transport of voice, audio, and video.
- Defines mechanisms and services for wireless network management of devices that include BSS transition management, channel usage and coexistence, collocated interference reporting, diagnostic, multicast diagnostic and event reporting, flexible multicast, efficient beacon mechanisms, proxy ARP advertisement, location, timing measurement, directed multicast, extended sleep modes, traffic filtering, and management notification.
- Defines functions and procedures aiding network discovery and selection by devices, information transfer from external networks using QoS mapping, and a general mechanism for the provision of emergency services.
- Defines the MAC procedures that are necessary for wireless multi-hop communication to support wireless LAN mesh topologies.
- Defines medium access control mechanisms to support the prioritization of Management frames.
- Defines mechanisms to improve audio video (AV) streaming QoS while maintaining data and voice performance.
- Defines the PHY signaling, MAC, and beamforming procedures required for operation with directional antenna patterns.
- Defines the PHY and MAC enhancements to enable operation in the Chinese millimeter wave frequency bands (60 GHz and 45 GHz).
- Defines the mechanisms for communications over the wireless medium used as a link in an IEEE 802.1Q™ bridged network.
- Defines mechanisms to enable delivery of preassociation service discovery information to IEEE 802.11 stations (STAs).

1.4 Word usage

In this document, the word *shall* is used to indicate a mandatory requirement. The word *should* is used to indicate a recommendation. The word *may* is used to indicate a permissible action. The word *can* is used for statements of possibility and capability.

The construction "between *x* and *y*", "*x* to *y*" or "*x*-*y*" represents an inclusive range (i.e., the range includes both values *x* and *y*).

The construction "up to *y*" represents an inclusive upper bound (i.e., the range includes the value *y*).

Any action specified as relating to a SAP primitive is to be interpreted as an action on an invocation or instance of that primitive.

If <x> represents a scalar field, scalar subfield, scalar parameter or scalar MIB attribute:

- if "<x> is" is used in a context that relates to the testing or setting the value of "<x>" this usage is to be interpreted as though written "the value of <x> is"
- "<x> indicate(s)" is to be interpreted as though written "the value of <x> indicate(s)"
- "indicated by <x>" is to be interpreted as though written "indicated by the value of <x>"
- "<x> that indicate" is to be interpreted as though written "<x> whose value indicates"

If <x> represents a frame, element, subelement, structured field, structured subfield, structured parameter or structured MIB attribute:

- "<x> indicate(s)" is to be interpreted as though written "the contents of <x> indicate"
- "indicated by <x>" is to be interpreted as though written "indicated by the contents of <x>"
- "<x> that indicate" is to be interpreted as though written "<x> whose contents indicate"

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If <x> represents a SAP primitive:

— "<x> indicate(s)" is to be interpreted as though written "the (or an) invocation of <x> indicates"

— "indicated by <x">" is to be interpreted as though written "indicated by the (or an) invocation of <x>"

The construction of descriptions for uses of the SHA family of hash algorithms [HMAC-]SHA-<1,256,384>[-*n*] is used to refer to hash algorithms/HMACs where square brackets indicate optional information, and *n* is an integer indicating the length, in bits, of the output when truncating.

A construction of the form "the x element can be included in a, b and c frames" or "the x element can be present in a, b and c frames" is not to be understood as being a complete list of frames in which the element might be present.

Constructions of the form that a frame, MPDU or A-MPDU is transmitted with a certain TXVECTOR parameter, or received with a certain RXVECTOR parameter, are to be understood as referring to the TXVECTOR or RXVECTOR parameter, respectively, corresponding to the PSDU containing the frame, MPDU or A-MPDU. Similarly, constructions of the form that a PPDU is transmitted with a certain TXVECTOR parameter, or received with a certain RXVECTOR parameter, are to be understood as referring to the TXVECTOR or RXVECTOR parameter, respectively, corresponding to the PSDU contained in the PPDU.

References in this standard to a "<name> frame", where <name> corresponds to one of the Management frame subtypes, are to be understood as being to a "<name> MMPDU, where the MMPDU is carried in the frame body of one or more Management frames with the Subtype field value corresponding to <name>, plus information from the MPDU headers (the Management frame subtype and the addresses)".

References in this standard to a "<name> request", where <name> corresponds to one of the Measurement Types in Table 9-98 is equivalent to (according to context) a) "a Spectrum Measurement Request frame or Radio Measurement Request frame carrying a Measurement Request element with the Measurement Type field equal to <name>" or b) "a Measurement Request element with the measurement type field equal to <name>".

An ASCII or UTF-8 string is a sequence of ASCII or UTF-8 encoded code points, respectively, without a terminating null.

References in this standard to "<adjective> STA" correspond to a specific instance of a STA implementation that will statically support and execute the <adjective> feature or role for the lifetime of the instance. Such a STA implementation may be capable of a different configuration where <adjective> is not supported (or even a mutually exclusive state is supported instead), but the switch from support to nonsupport of <adjective> is beyond the scope of this standard. The <adjective> support is to be understood as static for the lifetime of the instance, unless explicitly discussed otherwise.

References in this standard to "FILS authentication frame" or "SAE authentication frame" are to be understood as references to an Authentication frame that contains fields and elements for FILS or SAE (respectively) operation per Table 9-41.

1.5 Terminology for mathematical, logical, and bit operations

Floor (x), also written as $\lfloor x \rfloor$, is the largest integer smaller than or equal to x. For example, Floor (2.3) is 2 and Floor (–2.3) is –3. The two parameter form, Floor (x, y), is the largest multiple of y smaller than or equal to x; this operator is not used in this standard if y is negative. For example, Floor (3.3, 2) is 2 and Floor (–3.3, 2) is –4.

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Ceil (x), also written as $\lceil x \rceil$ is the smallest integer larger than or equal to x. For example, Ceil (2.3) is 3 and Ceil (–2.3) is –2. The two parameter form, Ceil (x, y), is the smallest multiple of y larger than or equal to x; this operator is not used in this standard if y is negative. For example, Ceil (2.3, 2) is 4 and Ceil (–2.3, 2) is –2.

Round (x) is the integer closest to x, rounding values with a fractional part of 0.5 away from zero. For example, Round (2.3) is 2, Round (2.5) is 3, Round (–2.3) is –2 and Round (–2.5) is –3.

x mod y is the remainder when x is divided by y; this operator is not used in this standard if y is negative; the result is positive even if x is negative. For example, 5 mod 3 is 2 and –5 mod 3 is 1.

The symbol ⊕ represents bitwise exclusive OR (XOR).

log2 (x) is the logarithm of x to the base 2. For example, log2 (32) is 5.

Re (z) is the real part of complex number z. Im (z) is the imaginary part of complex number z (not including the factor i). For example, Re ($1 – 2i$) is 1 and Im ($1 – 2i$) is –2.

x && y is the short-circuiting Boolean AND.

x || y is the concatenation of x and y, except in code, where it sometimes is the short-circuiting Boolean OR (as determined by the context).

!x is the Boolean NOT.

x >> y is x logically shifted right (i.e., zeros are inserted at the most significant end) by y; this operator is not used in this standard if y is negative.

x << y is x shifted left (i.e., zeros are inserted at the least significant end) by y; this operator is not used in this standard if y is negative.

x == y is Boolean equality.

x != y Boolean inequality.

x & y, where x and y are numbers, is the bitwise AND of x and y.

x | y, where x and y are numbers, is the bitwise OR of x and y.

0x introduces a hexadecimal number. For example, 0x12 is 18 decimal.

L(S, F, N) is bits F to F+N–1 of the bit string S starting from the left, using the IEEE 802.11 bit conventions from 9.2.2.

Truncate-N(S) is bits 0 to N–1 of the bit string S starting from the left, using the IEEE 802.11 bit conventions from 9.2.2). Other bits are irretrievably deleted.

exp(x) is e to the power x, where e is the base of natural logarithms.

A[b:c] is the bit string consisting of bits b to c of A, where bit 0 of the output is the value of bit b. This operator is not used in this standard with b larger than c.

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int(*S*) is the numeric value of bit string *S*, where bit 0 of S is the least significant bit, using the IEEE 802.11 bit conventions from 9.2.2.

NOTE—The *int* operator applied to a (portion of a) MAC address implies that octet 0 of the MAC address is the least significant octet under this operator.[1]

bin[*x*, *k*] is the operator that casts decimal value *x* into *k* bits binary vector, where *x* is less than 2^k.

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[1] NOTEs in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement the standard. Lettered footnotes to tables and figures, however, are normative.

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2. Normative references

The following referenced documents are indispensable for the application of this standard (i.e., they must be understood and used; therefore, each referenced document is cited in the text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) at the time of publication of this standard applies.

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IEEE Std 802.1X™-2010, IEEE Standard for Local and Metropolitan Area Networks—Port-Based Network Access Control.

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IEEE Std 802.21™-2017, IEEE Standard for Local and metropolitan area networks—Part 21: Media Independent Services Framework.

[2] 3GPP™ documents are available from the 3rd Generation Partnership Project Web site (http://www.3gpp.org).
[3] ETSI documents are available from the European Telecommunications Standards Institute (http://www.etsi.org).
[4] FIPS publications are available from the National Technical Information Service (NTIS) (http://csrc.nist.gov).
[5] The IEEE standards or products referred to in this clause are trademarks owned by The Institute of Electrical and Electronics Engineers, Inc.
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[7] IEFT documents (i.e., RFCs) are available from the Internet Engineering Task Force (http://tools.ieft.org/).

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[8] ISO publications are available from the ISO Central Secretariat (http://www.iso.ch/).

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[9] See http://www.currency-iso.org/en/home/tables/table-a1.html

[10] ISO/IEC publications are available from the ISO Central Secretariat (http://www.iso.ch/). ISO/IEC publications are also available in the United States from the American National Standards Institute (http://www.ansi.org/).

[11] The numbers in brackets correspond to the numbers of the bibliography in Annex A.

[12] ITU publications are available from the International Telecommunications Union (http://www.itu.int/).

[13] NIST publications are available from the National Institute of Standards and Technology (http://csrc.nist.gov/).

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3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this standard, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be referenced for terms not defined in this clause.[15]

access control: The prevention of unauthorized usage of resources.

access point (AP): An entity that contains one station (STA) and provides access to the distribution system services, via the wireless medium (WM) for associated STAs. An AP comprises a STA and a distribution system access function (DSAF).

access point (AP) reachability: An AP is reachable by a station (STA) if preauthentication messages can be exchanged between the STA and the target AP via the distribution system (DS).

NOTE—Preauthentication is defined in 12.6.10.2.

additional authentication data (AAD): Data that are not encrypted, but are cryptographically protected.

admission control: An algorithm intended to prevent the violation of parameterized service commitments made by the network to admitted flows by controlling the admittance of a new flow into a resource constrained network.

aggregate medium access control (MAC) protocol data unit (A-MPDU): A structure that contains one or more MPDUs and is transported by a physical layer (PHY) as a single PHY service data unit (PSDU).

aggregate medium access control (MAC) protocol data unit (A-MPDU) subframe: A portion of an A-MPDU that contains a delimiter and optionally contains an MPDU plus any necessary padding.

aggregate medium access control (MAC) service data unit (A-MSDU): A structure that contains one or more MSDUs and is transported within a single (unfragmented) data medium access control (MAC) protocol data unit (MPDU).

aggregate medium access control (MAC) service data unit (A-MSDU) subframe: A portion of an A-MSDU that contains a header and associated MSDU.

antenna connector: The measurement point of reference for radio frequency (RF) measurements in a station (STA). The antenna connector is the point in the STA architecture representing the input of the receiver (output of the antenna) for radio reception and the input of the antenna (output of the transmitter) for radio transmission. In systems using multiple antennas or antenna arrays, the antenna connector is a virtual point representing the aggregate output of (or input to) the multiple antennas. In systems using active antenna arrays with processing, the antenna connector is the output of the active array, which includes any processing gain of the active antenna subsystem.

antenna selection (ASEL) receiver: A station (STA) that performs receive ASEL.

antenna selection (ASEL) transmitter: A station (STA) that performs transmit ASEL.

[14] OMA publications are available from the Open Mobile Alliance (http://openmobilealliance.org/).

[15] *IEEE Standards Dictionary Online* is available at http://dictionary.ieee.org/. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

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antenna weight vector (AWV): A vector of weights describing the excitation (amplitude and phase) for each element of an antenna array.

association: The service used to establish a mapping between an access point (AP) or personal basic service set (PBSS) control point (PCP), and a station (STA) and enable STA invocation of the distribution system services (DSSs).

authenticated encryption with associated data (AEAD): A cipher mode that performs authenticated encryption of a plaintext, with associated data that is authenticated but not encrypted.

authentication: The service used to establish the identity of one station (STA) as a member of the set of STAs authorized to associate with another STA.

Authentication Server (AS): An entity that provides an authentication service to an Authenticator. This service determines, from the credentials provided by the Supplicant, whether the Supplicant is authorized to access the services provided by the Authenticator. (IEEE Std 802.1X-2010[16])

Authenticator: An entity at one end of a point-to-point local area network (LAN) segment that facilitates authentication of the entity attached to the other end of that link. (IEEE Std 802.1X-2010)

authenticator address (AA): The medium access control (MAC) address of the IEEE 802.1X Authenticator's STA.

authorization: The act of determining whether a particular right such as access to a resource, is granted to an entity.

NOTE—See IETF RFC 2903 [B35].

authorized: To be explicitly allowed.

average noise plus interference power indicator (ANIPI): A medium access control (MAC) indication of the average noise plus interference power measured on a channel that meets the two simultaneous conditions: 1) the station (STA) is not transmitting a frame, and 2) the station (STA) is not receiving a frame addressed to it.

azimuth: The horizontal orientation of the front surface of a station or of a radio antenna system's main lobe measured clockwise from true north.

basic service area (BSA): The area containing the members of a basic service set (BSS). It might contain members of other BSSs.

basic service set (BSS): A set of stations (STAs) that have successfully synchronized using the JOIN service primitives[17] and one STA that has used the START primitive. Alternatively, a set of STAs that have used the START primitive specifying matching mesh profiles where the match of the mesh profiles has been verified via the scanning procedure. Membership in a BSS does not imply that wireless communication with all other members of the BSS is possible.

basic service set (BSS) max idle period: A time period during which the access point (AP) does not disassociate a station (STA) due to nonreceipt of frames from that STA.

[16] Information on references can be found in Clause 2.

[17] Description of these primitives can be found in 6.3.4.

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basic service set (BSS) transition: Change of association by a station (STA) from one BSS to another BSS in the same extended service set (ESS).

beamformee: A station (STA) that receives a physical layer (PHY) protocol data unit (PPDU) that was transmitted using a beamforming steering matrix.

beamformer: A station (STA) that transmits a physical layer (PHY) protocol data unit (PPDU) using a beamforming steering matrix.

beamforming: A spatial filtering mechanism used at a transmitter to improve the received signal power or signal-to-noise ratio (SNR) at an intended receiver. *Syn:* **beam steering**.

beamforming steering matrix: A matrix determined using knowledge of the channel between a transmitter and an intended receiver that maps from space-time streams to transmit antennas with the goal of improving the signal power or signal-to-noise ratio (SNR) at the intended receiver.

beacon integrity group temporal key (BIGTK): A random value, assigned by the access point (AP), that is used to protect Beacon frames from that AP.

big endian: The concept that, for a given multi-octet numeric representation, the most significant octet has the lowest address.

broadcast address: A unique group address that specifies all stations (STAs).

calibration initiator: A station (STA) that initiates a calibration sequence.

calibration responder: A station (STA) that transmits during a calibration sequence in response to a transmission by a calibration initiator.

candidate peer mesh station (STA): A neighbor mesh STA to which a mesh peering has not been established but meets eligibility requirements to become a peer mesh STA.

certificate authority (CA): An entity that vouches for the binding between a device's identity, its public key, and associated keying material (such as key validity period and key usage).

channel: An instance of wireless medium (WM) use for the purpose of passing physical layer (PHY) protocol data units (PDUs) between two or more stations (STAs).

channel spacing: The difference between the center frequencies of two nonoverlapping and adjacent channels of the radio transmitter.

cipher suite: A set of one or more algorithms, designed to provide data confidentiality, data authenticity or integrity, and/or replay protection.

clear channel assessment (CCA) function: The logical function in the physical layer (PHY) that determines the current state of use of the wireless medium (WM).

collocated interference: Interference that is caused by another radio or station (STA) emitting radio energy located in the same physical device as the reporting STA, where the reported characteristics of the interference are known a priori without interference detection, measurement, or characterization by the reporting STA.

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collocated radio: A radio capable of emitting radio-frequency energy located in the same physical device as the reporting station (STA), where the radio's type and some link characteristics are known without signal detection or measurement by the reporting STA.

configuration profile: A collection of parameters identified by a profile identifier (ID) that represent a current or available configuration of a station (STA).

contiguous transmission: A transmission that uses only one frequency segment.

coordination function: The logical function that determines when a station (STA) is permitted to transmit protocol data units (PDUs) via the wireless medium (WM).

counter mode with cipher-block chaining message authentication code (CCM): A symmetric key block cipher mode providing confidentiality using counter mode (CTR) and data origin authenticity using cipher-block chaining message authentication code (CBC-MAC).

NOTE—See IETF RFC 3610.

cryptographic encapsulation: The process of generating the cryptographic payload from the plaintext data. This comprises the cipher text as well as any associated cryptographic state required by the receiver of the data, e.g., initialization vectors (IVs), sequence numbers, message integrity codes (MICs), key identifiers.

data confidentiality: A property of information that prevents disclosure to unauthorized individuals, entities, or processes.

deauthentication service: The service that voids an existing authentication relationship.

decapsulate: To recover an unprotected frame from a protected one.

decapsulation: The process of generating plaintext data by decapsulating an encapsulated frame.

dependent station (STA): A STA that is not registered and whose operational parameters are dictated by messages it receives from an enabling STA. Once enabled by the dynamic STA enablement (DSE) process, a dependent STA's continued operation becomes contingent upon being able to receive messages from its enabling STA over the wireless medium (WM).

destination mesh station (STA): A mesh STA that is the final destination of a MAC service data unit (MSDU). This mesh STA might reside in a proxy mesh gate that might forward the MSDU to a STA outside of the mesh basic service set (MBSS). A destination mesh STA might be an end station as defined in IEEE Std 802.

direct link: A bidirectional link from one quality-of-service (QoS) station (STA) to another QoS STA operating in the same infrastructure QoS basic service set (BSS) that does not pass through a QoS access point (AP). Once a direct link has been set up, all frames between the two QoS STAs are exchanged directly.

directed frame: *See:* **individually addressed**.

directed multicast service (DMS): A service in which the access point (AP) transmits group addressed frames as individually addressed frames to the requesting non-AP station (STA).

disassociation service: The service that removes an existing association.

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distributed coordination function (DCF): A class of coordination function where the same coordination function logic is active in every station (STA) in the basic service set (BSS) whenever the network is in operation.

distribution system (DS): A system used to interconnect a set of basic service sets (BSSs) and integrated local area networks (LANs) to create an extended service set (ESS).

distribution system access function (DSAF): A function within an access point (AP) or mesh gate that uses the medium access control (MAC) service and distribution system service (DSS) to provide access between the distribution system (DS) and the wireless medium (WM). Within a general link (GLK) AP or GLK mesh station (STA), the DSAF also switches GLK traffic to the GLK convergence function and from there to the IEEE 802.1Q bridge port.

distribution system medium (DSM): The medium or set of media used by a distribution system (DS) for communications between access points (APs), mesh gates, and the portal of an extended service set (ESS).

distribution system service (DSS): The set of services provided by the distribution system (DS) that enable the medium access control (MAC) to transport MAC service tuples between stations (STAs) that are not in direct communication with each other over a single instance of the wireless medium (WM).

NOTE 1—These services include transport of MAC service tuples between the access points (APs) of basic service sets (BSSs) within an extended service set (ESS), transport of MAC service tuples between the portal and BSSs within an ESS, transport of MAC service tuples between mesh gates in the same or different mesh basic service sets (MBSSs), transport of MAC service tuples between mesh gates and APs, transport of MAC service tuples between mesh gates and a portal, and transport of MAC service tuples between STAs in the same BSS when the MAC service tuples has a group destination address or the destination is an individual address and the STA is associated with an AP.

NOTE 2—DSSs are provided between pairs of MACs not on the same instance of the WM.

dynamic frequency selection (DFS): Facilities mandated to satisfy requirements in some regulatory domains for radar detection and uniform channel spreading in the 5 GHz band. These facilities might also be used for other purposes, such as automatic frequency planning.

dynamic station (STA) enablement (DSE): The process by which an enabling STA grants permission and dictates operational procedures to STAs that are subject to its control.

effective isotropic radiated power (EIRP): The equivalent power of a transmitted signal in terms of an isotropic (omnidirectional) radiator. The EIRP equals the product of the transmitter power and the antenna gain (reduced by any coupling losses between the transmitter and antenna).

emergency alert system (EAS): A U.S. national public warning system.

enabling station (STA): A registered STA that has the authority to control when and how a dependent STA can operate. An enabling STA communicates an enabling signal to its dependents over the wireless medium (WM). An enabling STA chooses whether other dynamic STA enablement (DSE) messages are exchanged over the air, over the distribution system (DS), or by mechanisms that rely on transport via higher layers.

encapsulate: To construct a protected frame from an unprotected frame.

encapsulation: The process of generating a protected frame by encapsulating plaintext data.

extended service area (ESA): The area within which members of an extended service set (ESS) can communicate. An ESA is larger than or equal to a basic service area (BSA) and might involve several basic service sets (BSSs) in overlapping, disjointed, or both configurations.

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extended service set (ESS): A set of one or more interconnected basic service sets (BSSs) that appears as a single BSS to the logical link control (LLC) layer at any station (STA) associated with one of those BSSs.

extended service set (ESS) transition: Change of association by a station (STA) from one basic service set (BSS) in one ESS to another BSS in a different ESS.

fast basic service set (BSS) transition: Change of association by a station (STA) that is from one BSS in one extended service set (ESS) to another BSS in the same ESS and that minimizes the amount of time that the data connectivity is lost between the STA and the distribution system (DS).

fast session transfer (FST): The transfer of a session from a channel to another channel, in the same or different frequency bands. The term "session" refers to non-physical layer state information kept by a pair of stations (STAs) that communicate directly (i.e., excludes forwarding).

fixed station (STA): A STA that is physically attached to a specific location. In licensed bands, a fixed STA might be authorized to operate only at a specific location.

forwarding information: The information maintained by a mesh station (STA) that allows the mesh STA to perform its path selection and forwarding functions.

frame: A unit of data exchanged between peer protocol entities.

frame exchange sequence: A sequence of frames specified by Annex G.

frequency segment: A contiguous block of spectrum used by a transmission.

Gaussian frequency shift keying (GFSK): A modulation scheme in which the data are first filtered by a Gaussian filter in the baseband and then modulated with a simple frequency modulation.

geolocation: A location within an earth-centric frame of reference.

group: The entities in a wireless network, e.g., an access point (AP) and its associated stations (STAs), or all of the STAs in an independent basic service set (IBSS) network.

group address: A medium access control (MAC) address that has the group bit equal to 1. *Syn*: **multicast address**.

group addressed: When applied to a medium access control (MAC) service data unit (MSDU), it is an MSDU with a group address as the destination address (DA). When applied to a MAC protocol data unit (MPDU), it is an MPDU with a group address in the Address 1 field. *Syn*: **multicast**.

group master key (GMK): An auxiliary key that might be used to derive a group temporal key (GTK).

group temporal key (GTK): A random value, assigned by the group source, which is used to protect group addressed medium access control (MAC) protocol data units (MPDUs) from that source. The GTK might be derived from a group master key (GMK).

hidden station (STA): A STA whose transmissions are not detected using carrier sense (CS) by a second STA, but whose transmissions interfere with transmissions from the second STA to a third STA

homogeneous extended service set (ESS): A collection of basic service sets (BSSs), which may or may not be within the same extended service set (ESS), in which every subscription service provider network (SSPN) or other external network reachable at one BSS is reachable at all of them.

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idle power indicator (IPI): A physical layer (PHY) indication of the total channel power (noise and interference) as measured in the channel at the receiving antenna connector while the station (STA) is idle, i.e., neither transmitting nor receiving a frame.

IEEE 802.1X authentication: Extensible Authentication Protocol (EAP) authentication transported by the IEEE 802.1X protocol.

independent basic service set (IBSS): A basic service set (BSS) that forms a self-contained network, and in which no access to a distribution system (DS) is available.

independent basic service set (IBSS) station (STA): A STA that has started or joined an IBSS.

individual address: A medium access control (MAC) address in which the group bit is 0. *Syn:* **directed address**, **unicast address**.

individually addressed: When applied to a medium access control (MAC) service data unit (MSDU), it is an MSDU with an individual address as the destination address (DA). When applied to a MAC protocol data unit (MPDU), it is an MPDU with an individual address in the Address 1 field. *Syn:* **directed, unicast**.

infrastructure: An infrastructure comprises a distribution system (DS), one or more more access points(APs), zero or one portals, and zero or more mesh gates. It is also the logical location of distribution and integration service functions of an extended service set (ESS).

infrastructure authorization information: The information that specifies the access rights of the user of a non-access-point (non-AP) station (STA). This information might include the rules for routing the user traffic, a set of permissions about services that a user is allowed to access, quality-of-service (QoS) configuration information, or the accounting policy to be applied by the infrastructure.

integration service: The service that enables delivery of medium access control (MAC) service data units (MSDUs) between the distribution system (DS) and a local area network (LAN) (via a portal).

integrity group temporal key (IGTK): A random value, assigned by the broadcast/multicast source station (STA), which is used to protect group-addressed medium access control (MAC) management protocol data units (MMPDUs) from that source STA.

link margin: Ratio of the received signal power to the minimum required by the station (STA). The STA might incorporate rate information and channel conditions, including interference, into its computation of link margin. The specific algorithm for computing the link margin is implementation dependent.

link metric: A criterion used to characterize the performance, quality, and eligibility of a link.

little endian: The concept that, for a given multi-octet numeric representation, the least significant octet has the lowest address.

liveness: A demonstration that the peer is actually participating in this instance of communication.

location subject local: The term used when a location request is for the location of the requesting station (STA), i.e., when the requesting STA asks, “Where am I?”

location subject remote: The term used when a location request is for the location of the reporting station (STA), i.e., when the requesting STA asks, “Where are you?”

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location subject third party: The term used when the location request is for the location of a station (STA) other than the requesting STA or the requested STA, (i.e., when the requesting STA asks, "Where is he/she?")

master session key (MSK): Keying material that is derived between the Extensible Authentication Protocol (EAP) peer and exported by the EAP method to the Authentication Server (AS).

NOTE—In this standard, this key is at least 64 octets in length.

medium access control (MAC) frame: The unit of data exchanged between MAC entities. *Syn:* **medium access control (MAC) protocol data unit (MPDU)**.

NOTE—In contexts in which the MAC is clearly the subject, "frame" is an implicit reference to a MAC frame.

medium access control (MAC) protocol data unit (MPDU): The unit of data exchanged between two peer MAC entities using the services of the physical layer (PHY). *Syn:* **medium access control (MAC) frame**.

medium access control (MAC) service data unit (MSDU): Information that is delivered as a unit between MAC service access points (SAPs).

medium access control (MAC) service tuple: The collection of a MAC service data unit (MSDU) along with the associated source address, destination addresses, priority, drop eligibility, service class, optional set of service_access_point_identifiers, and optional indication of whether the supplied MSDU is in Ethertype protocol discrimination (EPD) or logical link control (LLC) protocol discrimination (LPD) format, which are all passed as parameters across the MAC service access point (SAP) and are all except the service_access_point_identifiers delivered across the distribution system between access points (APs), mesh gates, and the portal of an extended service set (ESS).

mesh basic service set (MBSS): A basic service set (BSS) that forms a self-contained network of mesh stations (STAs) that use the same mesh profile. An MBSS contains zero or more mesh gates, and can be formed from mesh STAs that are not in direct communication.

mesh facility: The set of enhanced functions, channel access rules, frame formats, mutual authentication methods, and managed objects used to provide data transfer among autonomously operating stations (STAs) that might not be in direct communication with each other over a single instance of the wireless medium. Communication between STAs using the mesh facility takes place using only the wireless medium. The mesh facility transports a medium access control (MAC) service data unit (MSDU) between source and destination STAs over potentially multiple hops of the wireless medium without transiting the MAC service access point (SAP) at intermediate STAs.

mesh gate: Any entity that has a mesh station (STA) function and a distribution system access function (DSAF) to provide access to a single distribution system for the mesh basic service set (MBSS).

mesh link: A link from one mesh station (STA) to a neighbor mesh STA that have a mesh peering with each other.

mesh neighborhood: The set of all neighbor mesh stations (STAs) of a particular mesh STA.

mesh path: A concatenated set of mesh links from a source mesh station (STA) to a destination mesh STA.

mesh path selection: The process of selecting a mesh path.

mesh peering: A relationship between two mesh stations (STAs) that is required for direct communication over a single instance of the wireless medium (WM). A mesh peering is established with a mesh peering protocol.

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mesh profile: A set of values of parameters that identifies the attributes of the mesh basic service set (MBSS) and that is used in a single MBSS.

NOTE—The mesh profile consists of the identifiers that are the values for the parameters: mesh identifier (ID), active path selection protocol, active path selection metric, congestion control mode, synchronization method, and authentication protocol.

mesh services: The set of services that enable the creation and operation of a mesh basic service set (MBSS).

mesh station (STA): A quality-of-service (QoS) STA that implements the mesh facility.

message integrity code (MIC): A value generated by a cryptographic function. If the input data are changed, a new value cannot be correctly computed without knowledge of the cryptographic key(s) used by the cryptographic function.

NOTE—This is traditionally called a *message authentication code* (MAC), but the acronym MAC is already reserved for another meaning in this standard.

mobile station (STA): A type of STA that uses network communications while in motion.

mobility domain: A set of basic service sets (BSSs), within the same extended service set (ESS), that support fast BSS transitions between themselves and that are identified by the set's mobility domain identifier (MDID).

mobility domain identifier (MDID): An identifier that names a mobility domain.

multicast: *See:* **group addressed**.

multicast address: *See:* **group address**.

multicast-group address: A medium access control (MAC) address associated by higher level convention with a group of logically related stations (STAs).

multi-level precedence and preemption (MLPP): A framework used with admission control for the treatment of traffic streams based on precedence, which supports the preemption of an active traffic stream by a higher precedence traffic stream when resources are limited. Preemption is the act of forcibly removing a traffic stream in progress in order to free up resources for another higher precedence traffic stream.

multiple basic service set identifier (BSSID) capability: The capability to advertise information for multiple BSSIDs using a single Beacon or Probe Response frame instead of using multiple Beacon or Probe Response frames, each corresponding to a single BSSID, and the capability to indicate buffered frames for these multiple BSSIDs using a single traffic indication map (TIM) element in a single Beacon or TIM frame.

multiple input, multiple output (MIMO): A physical layer (PHY) configuration in which both transmitter and receiver use multiple antennas.

multiple medium access control (MAC) station management entity (SME) (MM-SME): Component of station management that manages multiple cooperating stations (STAs).

multi-user multiple input, multiple output (MU-MIMO): A technique by which multiple stations (STAs), each with one or more antennas, either simultaneously transmit to a single STA or simultaneously receive from a single STA independent data streams over the same radio frequencies.

NOTE—IEEE Std 802.11 supports only downlink (DL) MU-MIMO. *See* downlink multi-user multiple input, multiple output (DL-MU-MIMO) (in 3.2).

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neighbor access point (AP): Any AP that is a potential service set transition candidate.

neighbor station (STA): A STA in the following relationship: STA A is a neighbor to STA B if STA A can both directly transmit to and receive from STA B over the wireless medium.

network access identifier (NAI): The user identity submitted by the Supplicant during IEEE 802.1X authentication.

NOTE—See IETF RFC 4282.

network access server (NAS) client: The client component of a NAS that communicates with the Authentication Server (AS).

network allocation vector (NAV): An indicator, maintained by each station (STA), of time periods when transmission onto the wireless medium (WM) is not initiated by the STA regardless of whether the STA's clear channel assessment (CCA) function senses that the WM is busy.

next-hop mesh station (STA): The next peer mesh STA on the mesh path to the destination mesh STA.

non-access-point (non-AP) station (STA): A STA that is not contained within an access point (AP).

nonce: A numerical value, used in cryptographic operations associated with a given cryptographic key, that is not to be reused with that key, including over all reinitializations of the system through all time.

noncontiguous transmission: A transmission that uses nonadjacent frequency segments.

nonoperating channel: A channel that is not the operating channel of the basic service set (BSS) of which the station (STA) is a member.

non-quality-of-service (non-QoS) access point (AP): An AP that does not support the quality-of-service (QoS) facility.

non-quality-of-service (non-QoS) basic service set (BSS): A BSS that does not support the quality-of-service (QoS) facility.

non-quality-of-service (non-QoS) station (STA): A STA that does not support the quality-of-service (QoS) facility.

operating channel: The operating channel is the channel in which beacons are transmitted.

NOTE—In IEEE Std 802.11, the serving access point (AP) of an infrastructure basic service set (BSS) or the dynamic frequency selection (DFS) owner of an independent basic service set (IBSS) transmits beacons.

operating channel width: The channel width in which the station (STA) is currently able to receive.

overlapping basic service set (OBSS): A basic service set (BSS) operating on the same channel as the station's (STA's) BSS and within (either partly or wholly) its basic service area (BSA).

over-the-air fast basic service set (BSS) transition (FT): An FT method in which the station (STA) communicates over a wireless medium (WM) link to the target access point (AP).

over-the-DS (distribution system) fast basic service set (BSS) transition (FT): An FT method in which the station (STA) communicates with the target access point (AP) via the current AP.

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pairwise: Referring to, or an attribute of, two entities that are associated with each other, e.g., an access point (AP) and an associated station (STA), or two STAs in an independent basic service set (IBSS) network. This term is used to refer to a type of encryption key hierarchy pertaining to keys shared by only two entities.

pass-phrase: A secret text string employed to corroborate the user's identity.

password: A shared, secret, and potentially low-entropy word, phrase, code, or key used as a credential for authentication purposes.

NOTE—The method of distribution of a password to the units in the system is outside the scope of this standard.

path metric: An aggregate multi-hop criterion used to characterize the performance, quality, and eligibility of a mesh path.

peer mesh station (STA): A mesh STA to which a mesh peering has been established.

peer-to-peer link: A direct link within a quality-of-service (QoS) basic service set (BSS), a tunneled direct-link setup (TDLS) link, or a station-to-station (STA-to-STA) communication in an independent basic service set (IBSS).

peer-to-peer traffic specification (PTP TSPEC): The quality-of-service (QoS) characteristics of a data flow between non-access point (non-AP) QoS stations (STAs).

perfect forward secrecy (PFS): A property of a key agreement protocol that protects a session key derived from a set of long-term public and private keys from being compromised if one of the (long-term) private keys is compromised in the future.

per-frame encryption key: A unique encryption key constructed for each medium access control (MAC) protocol data unit (MPDU).

physical layer (PHY) frame: The unit of data exchanged between PHY entities. *Syn:* **physical layer (PHY) protocol data unit (PPDU)**.

NOTE—In contexts in which the PHY is clearly the subject, "frame" is an implicit reference to a PHY frame.

physical layer (PHY) protocol data unit (PPDU): The unit of data exchanged between two peer PHY entities to provide the PHY data service.

piggyback: The overloading of data with an acknowledgment of a previously received frame to the station (STA) to which the data is directed.

portable station (STA): A type of station (STA) that might be moved from location to location, but that uses network communications only while at a fixed location.

portal: The logical point at which the integration service is provided.

NOTE—For the purposes of this Standard, there is at most one portal in a given extended service set's (ESS's) infrastructure. In an implementation, a single logical portal function may be provided by multiple devices that provide integration services for the ESS. How such multiple devices coordinate to appear as a single logical portal is implementation dependent.

precursor mesh station (STA): A neighbor peer mesh STA on the mesh path to the destination mesh STA, that identifies the mesh STA as the next-hop mesh STA.

preshared key (PSK): A static key that is distributed to the units in the system by some out-of-band means.

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primary channel: The common channel of operation for all stations (STAs) that are members of the basic service set (BSS). For example, in a 20 MHz, 40 MHz, 80 MHz, 160 MHz or 80+80 MHz BSS the primary channel is a primary 20 MHz channel.

prioritized quality of service (QoS): The provisioning of service in which the medium access control (MAC) protocol data units (MPDUs) with higher priority are given a preferential treatment over MPDUs with a lower priority.

NOTE—Prioritized QoS is provided through the enhanced distributed channel access (EDCA) mechanism.

protection mechanism: Any procedure that attempts to update the network allocation vector (NAV) of all receiving stations (STAs) prior to the transmission of a frame that might or might not be detected as valid network activity by the physical layer (PHY) entities at those receiving STAs.

protection mechanism frame: Any frame that is sent as part of a protection mechanism procedure.

protocol instance: An execution of a particular protocol that consists of the state of the communicating parties as well as the messages exchanged.

proxy mesh gate: A mesh gate acting as an intermediary for IEEE 802 stations (STAs) outside the mesh basic service set (MBSS).

pseudorandom function (PRF): A function that hashes various inputs to derive a pseudorandom value. In order to ensure liveness of a communication in which a pseudorandom value is used, a nonce is used as one of the inputs to the function.

public safety answering point (PSAP): A physical location where emergency calls are received and routed to the appropriate emergency service dispatch center.

NOTE—See NENA 08-002 [B57].

quadrature binary phase shift keying (QBPSK): A binary phase shift keying modulation in which the binary data is mapped onto the imaginary (Q) axis.

quality-of-service (QoS) access point (AP): An AP that supports the QoS facility.

NOTE—In IEEE Std 802.11, the functions of a QoS AP are a superset of the functions of a non-QoS AP, and thus a QoS AP is able to function as a non-QoS AP to non-QoS stations (STAs).

quality-of-service (QoS) basic service set (BSS): A BSS that provides the QoS facility. An infrastructure QoS BSS contains a QoS access point (AP).

quality-of-service (QoS) facility: The set of enhanced functions, channel access rules, frame formats, frame exchange sequences and managed objects used to provide parameterized and prioritized QoS.

quality-of-service (QoS) independent basic service set (IBSS): An IBSS in which one or more of its stations (STAs) support the QoS facility.

quality-of-service (QoS) station (STA): A STA that implements the QoS facility.

NOTE—A QoS STA acts as a non-QoS STA when associated in a non-QoS basic service set (BSS).

radio frequency (RF) chain: The physical entity that is able to act as a receive chain or transmit chain, or both.

reassociation service: The service that enables an established association [between access point (AP) and station (STA)] to be transferred from one AP to another (or the same) AP.

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receive chain: The physical entity that implements any necessary signal processing to provide the received signal to the digital baseband. Such signal processing includes filtering, amplification, down-conversion, and sampling.

receive power: Mean power measured at the antenna connector.

received channel power indicator (RCPI): An indication of the total channel power (signal, noise, and interference) of a received frame measured on the channel and at the antenna connector used to receive the frame.

received power indicator (RPI): A quantized measure of the received power level as seen at the antenna connector.

registered location: The geolocation of a station (STA) registered in accordance with the requirements for the regulatory domain.

registered location query protocol (RLQP): The query protocol for registered location information that is received and transported by generic advertisement service (GAS) Public Action frames.

registered location secure server (RLSS): An entity that accesses and manages a database that organizes storage of information by geographic location and securely holds the location and some operating parameters of one or more basic service sets (BSSs).

registered station (STA): A STA for which information needs to be submitted to an appropriate regulatory or coordination authority before it is allowed to transmit.

remote request broker (RRB): The component of the station management entity (SME) of an access point (AP) that supports fast basic service set (BSS) transitions over the distribution system (DS).

roaming consortium: A group of subscription service providers (SSPs) having inter-SSP roaming agreements.

service hash: A value used for representing a service. This value is formed from a hash of the service name.

service set identifier (SSID): A string used to identify the infrastructure basic service sets (BSSs) that comprise an extended service set (ESS), or to identify a non-infrastructure BSS.

service set transition: A station (STA) movement from one basic service set (BSS) to another BSS, i.e., either a BSS transition or an extended service set (ESS) transition.

serving access point (AP): The AP to which the station (STA) is associated.

single-user multiple input, multiple output (SU-MIMO): A technique by which a station (STA) with more than one antenna either transmits to or receives from a single STA independent space-time streams over the same radio frequencies.

single-user (SU) physical layer (PHY) protocol data unit (PPDU): A PPDU with a format that is capable of carrying only a single PHY service data unit (PSDU), or no PSDU.

sounding: The use of preamble training fields to measure the channel for purposes other than demodulation of the Data portion of the physical layer (PHY) protocol data unit (PPDU) containing the training fields.

NOTE—These uses include calculation of transmit steering, calculation of recommended modulation and coding scheme (MCS), and calculation of calibration parameters.

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source mesh station (STA): A mesh STA from which a medium access control (MAC) service data unit (MSDU) enters the mesh basic service set (MBSS). A source mesh STA is either a mesh STA that is the source of an MSDU or a proxy mesh gate that receives an MSDU from a STA outside of the MBSS and forwards the MSDU on a mesh path.

space-time stream (STS): Stream of modulation symbols created by applying a combination of spatial and temporal processing to one or more spatial streams of modulation symbols.

spatial multiplexing (SM): A transmission technique in which data streams are transmitted on multiple spatial channels that are provided through the use of multiple antennas at the transmitter and the receiver.

spatial stream: One of several streams of bits or modulation symbols that might be transmitted over multiple spatial dimensions that are created by the use of multiple antennas at both ends of a communications link.

station (STA): A logical entity that is a singly addressable instance of a medium access control (MAC) and physical layer (PHY) interface to the wireless medium (WM).

NOTE—For IEEE 802.11 purposes, a station is any MAC/PHY entity providing the IEEE 802.11 MAC services. This differs from the IEEE 802 definition of 'station,' which includes bridges (or 'end stations') that are endpoints of link layer data traffic.

station service (SS): The set of services that support transport of medium access control (MAC) service data units (MSDUs) between stations (STAs) within a basic service set (BSS).

subscription service provider (SSP): An organization (operator) offering connection to network services, perhaps for a fee.

subscription service provider network (SSPN): The network controlled by a subscription service provider (SSP). The network maintains user subscription information.

Supplicant: An entity at one end of a point-to-point local area network (LAN) segment that is being authenticated by an Authenticator attached to the other end of that link. (IEEE Std 802.1X-2010)

Supplicant address (SPA): The medium access control (MAC) address of the IEEE 802.1X Supplicant's STA.

television white spaces (TVWS): The opportunistic use of allocated but not assigned spectrum—spectrum allocated for broadcast television, but with no assignment at a particular location.

time unit (TU): A measurement of time equal to 1024 μs.

traffic category (TC): A label for medium access control (MAC) service data units (MSDUs) that have a distinct user priority (UP), as viewed by higher layer entities, relative to other MSDUs provided for delivery over the same link. Traffic categories are meaningful only to MAC entities that support quality of service (QoS) within the MAC data service. These MAC entities determine the UP for MSDUs belonging to a particular traffic category using the priority value provided with those MSDUs at the MAC service access point (MAC SAP).

traffic classification (TCLAS): The specification of one of several types of matching filter to classify protocol data units (PDUs) or medium access control (MAC) service data units (MSDUs) as belonging to a particular traffic stream (TS). Depending on the type of classification, the filter is applied within the MAC sublayer management entity (MLME), above the MAC, or within the MAC itself.

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traffic filter: A set of traffic specifications defined by the use of traffic classification (TCLAS) elements that are utilized by the traffic filtering service (TFS) to identify specific allowed frames.

traffic filtering service (TFS): A service provided by an access point (AP) to a non-AP station (STA) to reduce the number of frames sent to the non-AP STA by not forwarding individually addressed frames addressed to the non-AP STA that do not match traffic filters specified by the non-AP STA.

traffic identifier (TID): Any of the identifiers usable by higher layer entities to distinguish medium access control (MAC) service data units (MSDUs) to MAC entities that support quality of service (QoS) within the MAC data service.

NOTE—There are 16 possible TID values; eight identify traffic categories (TCs), and the other eight identify parameterized traffic streams (TSs). The TID is assigned to an MSDU in the layers above the MAC.

traffic specification (TSPEC): The quality-of-service (QoS) characteristics of a data flow to and from a QoS station (STA).

traffic stream (TS): A set of medium access control (MAC) service data units (MSDUs) to be delivered subject to the quality-of-service (QoS) parameter values provided to the MAC in a particular traffic specification (TSPEC). TSs are meaningful only to MAC entities that support QoS within the MAC data service. These MAC entities determine the TSPEC applicable for delivery of MSDUs belonging to a particular TS using the priority parameter provided with those MSDUs at the MAC service access point (MAC SAP).

transmission opportunity (TXOP): An interval of time during which a particular quality-of-service (QoS) station (STA) has the right to initiate frame exchange sequences onto the wireless medium (WM).

NOTE—A TXOP is defined by a starting time and a maximum duration.

transmit chain: The physical entity that implements any necessary signal processing to generate the transmit signal from the digital baseband. Such signal processing includes digital to analog conversion, filtering, amplification and upconversion.

trusted third party (TTP): An entity that is relied upon to vouch for two parties in a pairwise authentication protocol.

type/length/value (TLV): A format that consists of a type, a length, and a value.

unauthorized disclosure: The process of making information available to unauthorized individuals, entities, or processes.

unauthorized resource use: The use of a resource not consistent with the defined security policy.

unicast: *See*: **individually addressed**.

unicast address: *See:* **individual address**.

uniform spreading: A regulatory requirement for a channel selection mechanism that provides uniform usage across a minimum set of channels in the regulatory domain.

unreachable destination: A destination mesh station (STA) for which the link to the next hop of the mesh path to this destination mesh STA is no longer usable.

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user priority (UP): A value associated with an medium access control (MAC) service data unit (MSDU) that indicates how the MSDU is to be handled. The UP is assigned to an MSDU in the layers above the MAC.

validated AP: An AP that has either been explicitly configured as a neighbor or learned through a mechanism such as the Beacon report.

wildcard basic service set identifier (BSSID): A BSSID value used to represent all BSSIDs.

NOTE—In IEEE Std 802.11, this is represented by all binary 1s.

wildcard service set identifier (SSID): An SSID value used to represent all SSIDs.

NOTE—In IEEE Std 802.11, this is represented by the value "null".

wireless medium (WM): The medium used to implement the transfer of protocol data units (PDUs) between peer physical layer (PHY) entities of a wireless local area network (LAN).

3.2 Definitions specific to IEEE Std 802.11

The following terms and definitions are specific to terms or references in this standard and are not appropriate for inclusion in the *IEEE Standards Dictionary Online*.

1 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 1 MHz transmit spectral mask defined in Clause 23 and that is a 1 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1).

1 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 23 1 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1).

2 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 2 MHz transmit spectral mask defined in Clause 23 and that is one of the following:

a) A 1 MHz sub 1 GHz (S1G) non-duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1).
b) A 2 MHz S1G non-duplicate or S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2).

2 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 23 2 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2) or a Clause 23 2 MHz S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2).

4 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 4 MHz transmit spectral mask defined in Clause 23 and that is one of the following:

a) A 1 MHz sub 1 GHz (S1G) non-duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1).
b) A 2 MHz S1G non-duplicate or S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2).
c) A 4 MHz S1G non-duplicate, or S1G 1 MHz duplicate, or S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4).

4 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 23 4 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4), a Clause 23 4 MHz S1G 1 MHz duplicate

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PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4), or a Clause 23 4 MHz S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4).

4-way handshake: A pairwise key management protocol defined by this standard. This handshake confirms mutual possession of a pairwise master key (PMK) by two parties and distributes a group temporal key (GTK).

8 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 8 MHz transmit spectral mask defined in Clause 23 and that is one of the following:

a) A 1 MHz sub 1 GHz (S1G) non-duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1).
b) A 2 MHz S1G non-duplicate or S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2).
c) A 4 MHz S1G non-duplicate, or S1G 1 MHz duplicate, or S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4).
d) An 8 MHz S1G non-duplicate, or S1G 1 MHz duplicate, or S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW8).

8 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 23 8 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW8), a Clause 23 8 MHz S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW8), or a Clause 23 8 MHz S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW8).

16 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 16 MHz transmit spectral mask defined in Clause 23 and that is one of the following:

a) A 1 MHz sub 1 GHz (S1G) non-duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1).
b) A 2 MHz S1G non-duplicate or S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2).
c) A 4 MHz S1G non-duplicate, or S1G 1 MHz duplicate, or S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4).
d) An 8 MHz S1G non-duplicate, or S1G 1 MHz duplicate, or S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW8).
e) A 16 MHz S1G non-duplicate, or S1G 1 MHz duplicate, or S1G 2 MHz duplicate (TXVECTOR parameter CH_BANDWIDTH equal to CBW16).

16 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 23 16 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW16), a Clause 23 16 MHz S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW16), or a Clause 23 16 MHz S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW16).

20 MHz basic service set (BSS): A BSS in which there is a primary 20 MHz channel and no secondary channel.

20 MHz high-throughput (HT): A Clause 19 transmission with the TXVECTOR parameter FORMAT equal to HT_MF or HT_GF and TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20.

20 MHz mask physical layer (PHY) protocol data unit (PPDU): One of the following PPDUs:

a) A Clause 17 PPDU transmitted using the 20 MHz transmit spectral mask defined in Clause 17.
b) A Clause 18 orthogonal frequency division multiplexing (OFDM) PPDU transmitted using the transmit spectral mask defined in Clause 18.

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c) A high-throughput (HT) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 and the CH_OFFSET parameter equal to CH_OFF_20 transmitted using the 20 MHz transmit spectral mask defined in Clause 19.

d) A very high throughput (VHT) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW20 transmitted using the 20 MHz transmit spectral mask defined in Clause 21.

e) A Clause 17 PPDU transmitted by a VHT STA using the 20 MHz transmit spectral mask defined in Clause 21.

f) An HT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 and the CH_OFFSET parameter equal to CH_OFF_20 transmitted by a VHT STA using the 20 MHz transmit spectral mask defined in Clause 21.

20 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 15 PPDU, Clause 17 PPDU (when using 20 MHz channel spacing), Clause 16 PPDU, Clause 18 orthogonal frequency division multiplexing (OFDM) PPDU, Clause 19 20 MHz high-throughput (HT) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20, or Clause 21 20 MHz very high throughput (VHT) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW20.

20/40 MHz basic service set (BSS): A BSS in which the supported channel width of the access point (AP) or dynamic frequency selection (DFS) owner (DO) station (STA) is 20 MHz and 40 MHz (Channel Width field is equal to 1) and the Secondary Channel Offset field is equal to a value of secondary channel above (SCA) or secondary channel below (SCB).

40 MHz high-throughput (HT): A Clause 19 transmission with the TXVECTOR parameter FORMAT equal to HT_MF or HT_GF and TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40.

40 MHz mask physical layer (PHY) protocol data unit (PPDU): One of the following PPDUs:

a) A 40 MHz high-throughput (HT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40) transmitted using the 40 MHz transmit spectral mask defined in Clause 19.

b) A 40 MHz non-HT duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to NON_HT_CBW40) transmitted by a non-very high throughput (non-VHT) STA using the 40 MHz transmit spectral mask defined in Clause 19.

c) A 40 MHz non-HT duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40) transmitted by a very high throughput (VHT) STA using the 40 MHz transmit spectral mask defined in Clause 21.

d) A 20 MHz HT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 and the CH_OFFSET parameter equal to either CH_OFF_20U or CH_OFF_20L transmitted using the 40 MHz transmit spectral mask defined in Clause 19.

e) A 20 MHz VHT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW20 transmitted using the 40 MHz transmit spectral mask defined in Clause 21.

f) A 40 MHz VHT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW40 transmitted using the 40 MHz transmit spectral mask defined in Clause 21.

g) A 40 MHz HT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40) transmitted by a VHT STA using the 40 MHz transmit spectral mask defined in Clause 21.

h) A 20 MHz non-HT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20) transmitted using the 40 MHz transmit spectral mask defined in Clause 19.

i) A 20 MHz non-HT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20) transmitted by a VHT STA using the 40 MHz transmit spectral mask defined in Clause 21.

40 MHz physical layer (PHY) protocol data unit (PPDU): A 40 MHz high-throughput (HT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40), or a 40 MHz non-HT duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to NON_HT_CBW40 or TXVECTOR parameter

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CH_BANDWIDTH equal to CBW40), or a 40 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40).

40-MHz-capable (40MC) high-throughput (HT) access point (AP): An HT AP that included a value of 1 in the Supported Channel Width Set subfield (indicating its capability to operate on a 40 MHz channel) of its most recent transmission of a frame containing an HT Capabilities element.

40-MHz-capable (40MC) high-throughput (HT) access point (AP) 2G4: An HT AP 2G4 that is also a 40MC HT AP.

40-MHz-capable (40MC) high-throughput (HT) access point (AP) 5G: An HT AP 5G that is also a 40MC HT AP.

40-MHz-capable (40MC) high-throughput (HT) station (STA): An HT STA that included a value of 1 in the Supported Channel Width Set subfield (indicating its capability to operate on a 40 MHz channel) of its most recent transmission of a frame containing an HT Capabilities element.

40-MHz-capable (40MC) high-throughput (HT) station (STA) 2G4: An HT STA 2G4 that is also a 40MC HT STA.

40-MHz-capable (40MC) high-throughput (HT) station (STA) 5G: An HT STA 5G that is also a 40MC HT STA.

80 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 80 MHz transmit spectral mask defined in Clause 21 and that is one of the following:

a) An 80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80).
b) An 80 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80).
c) A 20 MHz non-HT, high-throughput (HT), or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20).
d) A 40 MHz non-HT duplicate, HT, or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40).

80 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 21 80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80) or a Clause 21 80 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80).

80+80 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 80+80 MHz transmit spectral mask defined in Clause 21 and that is one of the following:

a) An 80+80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80).
b) An 80+80 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80).

80+80 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 21 80+80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80) or a Clause 21 80+80 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80).

160 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 160 MHz transmit spectral mask defined in Clause 21 and that is one of the following:

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a) A 160 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160).
b) A 160 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160).
c) A 20 MHz non-HT, high-throughput (HT), or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20).
d) A 40 MHz non-HT duplicate, HT, or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40).
e) An 80 MHz non-HT duplicate or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80).

160 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 21 160 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160) or a Clause 21 160 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160).

access category (AC): A label for the common set of enhanced distributed channel access (EDCA) parameters that are used by a quality-of-service (QoS) station (STA) to contend for the channel in order to transmit medium access control (MAC) service data units (MSDUs) with certain priorities.

access network query protocol (ANQP): The query protocol for access network information retrieval transported by generic advertisement service (GAS) Public Action frames.

access period: A time period during a beacon interval established in a directional multi-gigabit (DMG) basic service set (BSS).

access point (AP) path: Path between two tunneled direct-link setup (TDLS) peer stations (STAs) via the AP with which the STAs are currently associated.

active mode: A power management mode in which a nonmesh station (STA) remains in the awake state, and a mesh power management mode with respect to a neighbor peer mesh STA in which a mesh station remains in the awake state and is expected to receive frames from this neighbor peer mesh STA.

advanced groupcast with retries (GCR): A set of features comprising the GCR block acknowledgment retransmission policy and the GCR service period (GCR-SP) delivery method.

advertisement protocol: Access network query protocol (ANQP) and higher layer protocols defined external to this standard that are used for network and service discovery.

advertisement server: A logical server that provides the information repository for a specific advertisement protocol. The location of the physical server that instantiates the advertisement server is outside the scope of this standard.

aggregated schedule: The aggregation of delivery and/or poll schedules by the quality-of-service (QoS) access point (AP) for a particular QoS station (STA) into a single service period (SP).

attached bridge: An IEEE 802.1Q bridge that has one or more bridge port Enhanced Internal Sublayer Service (EISS) interfaces supported by general links (GLKs) provided by a GLK access point (AP), GLK non-AP station (STA), GLK mesh STA, or GLK independent basic service set (IBSS) STA.

authentication and key management (AKM) suite: A set of one or more algorithms designed to provide authentication and key management, either individually or in combination with higher layer authentication and key management algorithms outside the scope of this standard.

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average noise power indicator (ANPI): A medium access control (MAC) indication of the average noise plus interference power measured when the channel is idle as defined by three simultaneous conditions: 1) the virtual carrier sense (CS) mechanism indicates idle channel, 2) the station (STA) is not transmitting a frame, and 3) the STA is not receiving a frame.

awake beacon interval (A-BI): In a directional multi-gigabit (DMG) basic service set (BSS) or personal basic service set (PBSS), a beacon interval of a power save mode wakeup schedule during which a station (STA) is expected to be in the awake state during several portions of the beacon interval.

bandwidth signaling transmitter address (TA): A TA that is used by a very high throughput (VHT) station (STA) to indicate the presence of additional signaling related to the bandwidth to be used in subsequent transmission in an enhanced distributed channel access (EDCA) transmission opportunity (TXOP). It is represented by the IEEE medium access control (MAC) individual address of the transmitting VHT STA but with the Individual/Group bit set to 1.

base channel: Primary channel of the basic service set (BSS) of the access point (AP) with which the tunneled direct-link setup (TDLS) peer station (STA) is associated with an access point (AP).

basic channel unit (BCU): For television very high throughput (TVHT) operation, 6 MHz, 7 MHz, or 8 MHz, depending on the regulatory domain.

basic modulation and coding scheme (MCS) set: The set of MCS values that are supported by all high-throughput (HT) stations (STAs) that are members of an HT basic service set (BSS).

basic space-time block coding (STBC) modulation and coding scheme (MCS): An MCS value and STBC encoder specification used in the transmission of STBC-encoded Control frames and STBC-encoded group addressed frames.

beacon header interval (BHI): The period of time that starts at the target beacon transmission time (TBTT) of a beacon interval of a directional multi-gigabit (DMG) basic service set (BSS) and that ends no later than the beginning of the data transfer interval (DTI) of the beacon interval.

beacon interval: The time interval between two consecutive target beacon transmission times (TBTTs).

beacon transmission interval (BTI): The time interval between the start of the first Directional Multi-gigabit (DMG) Beacon frame transmission by a DMG station (STA) in a beacon interval to the end of the last DMG Beacon frame transmission by the STA in the same beacon interval.

bufferable medium access control (MAC) management protocol data unit (MMPDU): An MMPDU that is eligible to be queued for delivery using a power saving mechanism (see Table 11-2).

bufferable unit (BU): A medium access control (MAC) service data unit (MSDU), aggregate MAC service data unit (MSDU) [quality-of-service (QoS) stations (STAs) only], or bufferable MAC management protocol data unit (MMPDU).

centralized authentication controlled (CAC) station (STA): A sub 1 GHz (S1G) non-access point (non-AP) STA with dot11S1GCentralizedAuthenticationControlActivated equal to true. A CAC STA supports a CAC access point (AP) to alleviate wireless medium contention when a large number of STAs are trying to, or are expected to, reconnect to the AP at about the same time.

centralized authentication controller (CAC) access point (AP): A sub 1 GHz (S1G) AP with dot11S1GCentralizedAuthenticationControlActivated equal to true. A CAC AP is able to alleviate wireless medium contention when a large number of stations (STAs) are trying to, or are expected to, reconnect to the AP at about the same time.

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centralized coordination service root (CCSR): An entity that provides synchronization and configuration services to synchronization access points (S-APs).

centralized coordination service set (CCSS): The collection of one centralized coordination service root (CCSR) and a set of one or more synchronization access points (S-APs) that are stationary with respect to their local environment while operating and are connected to the CCSR.

China directional multi-gigabit (CDMG): Pertaining to directional multi-gigabit (DMG) operation and where the channel is contained within the Chinese 60 GHz frequency band.

China directional multi-gigabit (CDMG) physical layer (PHY) protocol data unit (PPDU): A Clause 24 PPDU.

China directional multi-gigabit small band beacon interval (CDMG SBBI): A value, in units of time units (TUs) represents the length of a beacon interval operating on a 1.08 GHz channel.

China millimeter-wave multi-gigabit (CMMG): Pertaining to operation in a frequency band containing a channel in 42.3 GHz to 47.3 GHz or 47.2 GHz to 48.4 GHz frequency bands.

China millimeter-wave multi-gigabit (CMMG) basic service set (BSS): A BSS in which directional multi-gigabit (DMG) Beacon frames are transmitted by CMMG stations (STAs).

China millimeter-wave multi-gigabit (CMMG) beamformee: A CMMG station (STA) that receives a CMMG physical layer (PHY) protocol data unit (PPDU) that was transmitted using a beamforming steering matrix and that supports the CMMG transmit beamforming feedback mechanism as described in 10.33.

China millimeter-wave multi-gigabit (CMMG) beamformer: A CMMG station (STA) that transmits a CMMG physical layer (PHY) protocol data unit (PPDU) using a beamforming steering matrix.

China millimeter-wave multi-gigabit (CMMG) duplicate physical layer (PHY) protocol data unit (PPDU) format: A PPDU format that duplicates the transmission of a 540 MHz signal over two 540 MHz frequency segments.

China millimeter-wave multi-gigabit (CMMG) physical layer (PHY) protocol data unit (PPDU): A Clause 25 PPDU.

China millimeter-wave multi-gigabit (CMMG) single medium access control (MAC) protocol data unit (CMMG single MPDU): An MPDU that is the only MPDU in an aggregate MPDU (A-MPDU) carried in a CMMG physical layer (PHY) protocol data unit (PPDU) and that is carried in an A-MPDU subframe with the EOF subfield of the MPDU delimiter field equal to 1.

concealed groupcast with retries (GCR) frame: A group addressed frame that is transmitted using the aggregate medium access control (MAC) service data unit (A-MSDU) frame format with the destination address (DA) field set to the GCR concealment address.

contention based access period (CBAP): The time period in the data transfer interval (DTI) of a directional multi-gigabit (DMG) basic service set (BSS) during which enhanced distributed channel access (EDCA) is used.

controlled access phase (CAP): A time period during which the hybrid coordinator (HC) maintains control of the medium. It might span multiple consecutive HCCA transmission opportunities (TXOPs).

data physical layer (PHY) protocol data unit (PPDU): A PPDU containing at least one medium access control (MAC) service data unit (MSDU) or fragment of an MSDU.

deep sleep mode: A mesh power management mode with respect to a neighbor peer mesh STA in which a mesh station (STA) alternates between awake and doze states and is not expected to receive beacons from this neighbor peer mesh STA.

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delivery traffic indication map (DTIM) interval: The interval between the consecutive target beacon transmission times (TBTTs) of beacons containing a DTIM. The value, expressed in time units, is equal to the product of the value in the Beacon Interval field and the value in the DTIM Period subfield in the TIM element in Beacon frames.

delivery-enabled access category (AC): A quality-of-service (QoS) access point (AP) AC where the AP is allowed to use enhanced distributed channel access (EDCA) to deliver traffic from the AC to a QoS station (STA) in an unscheduled service period (SP) triggered by the STA.

destination directional multi-gigabit (DMG) station (STA): A DMG STA identified by the destination association identifier (AID) field contained in a Grant frame or Extended Schedule element that caused the allocation of a service period (SP) or a contention based access period (CBAP).

differentiated initial link setup (DILS): A mechanism for restricting fast initial link setup (FILS) to certain categories of stations.

direct sequence spread spectrum (DSSS) physical layer (PHY) protocol data unit (PPDU): A Clause 15 PPDU.

direct sequence spread spectrum/complementary code keying (DSSS/CCK): A Clause 15 or Clause 16 transmission.

direct sequence spread spectrum/complementary code keying (DSSS/CCK) physical layer (PHY) protocol data unit (PPDU): A Clause 15 or Clause 16 PPDU.

directional multi-gigabit (DMG): Pertaining to operation in a frequency band containing a channel with the channel starting frequency above 45 GHz.

NOTE—The channel starting frequency for IEEE 802.11 stations (STAs) is defined in Annex E.

directional multi-gigabit (DMG) antenna: A DMG antenna is a phased array, a single element antenna, or a set of switched beam antennas covered by a quasi-omni antenna pattern.

directional multi-gigabit (DMG) basic service set (BSS): A BSS in which DMG Beacon frames are transmitted by DMG stations (STAs).

directional multi-gigabit (DMG) frame: A frame transmitted or received within a DMG physical layer (PHY) protocol data unit (PPDU).

directional multi-gigabit (DMG) physical layer (PHY) protocol data unit (PPDU): A Clause 20 PPDU.

directional transmission: A transmission that does not use an omnidirectional antenna pattern or quasi-omni antenna pattern.

downlink: A unidirectional link from an access point (AP) to one or more non-AP stations (STAs) or a unidirectional link from a non-AP destination directional multi-gigabit (DMG) STA to a non-AP source DMG STA.

downlink multi-user multiple input, multiple output (DL-MU-MIMO): A technique by which an access point (AP) with more than one antenna transmits a physical layer (PHY) protocol data unit (PPDU) to multiple receiving non-AP stations (STAs) over the same radio frequencies, wherein each non-AP STA simultaneously receives one or more distinct space-time streams.

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downlink multi-user multiple input, multiple output (DL-MU-MIMO) physical layer (PHY) protocol data unit (PPDU): A PPDU using the DL-MU-MIMO technique.

doze beacon interval (D-BI): In a directional multi-gigabit (DMG) basic service set (BSS) or personal basic service set (PBSS), a beacon interval of a power save mode wakeup schedule during which a station (STA) is expected to be in the doze state for most of the portions of the beacon interval.

dynamic bandwidth operation: A feature of a very high throughput (VHT) station (STA) in which the request-to-send/clear-to-send (RTS/CTS) exchange, using non-high-throughput (non-HT) duplicate physical layer (PHY) protocol data units (PPDUs), negotiates a potentially reduced channel width (compared to the channel width indicated by the RTS) for subsequent transmissions within the current transmission opportunity (TXOP).

dynamic frequency selection (DFS) owner: A station (STA) in an independent basic service set (IBSS) or off-channel tunneled direct link setup (TDLS) direct link that takes responsibility for selecting the next channel after radar is detected operating in a channel. Due to the nature of IBSSs, it cannot be guaranteed that there is a single DFS owner at any particular time and the protocol is robust to this situation.

EAPOL-Key confirmation key (KCK): A key used to integrity-check an EAPOL-Key frame.

EAPOL-Key encryption key (KEK): A key used to encrypt the Key Data field in an EAPOL-Key frame.

EAPOL-Key frame: A Data frame that carries all or part of an IEEE 802.1X EAPOL PDU of type EAPOL-Key.

EAPOL-Key request frame: A Data frame that carries all of part of an IEEE 802.1X EAPOL-Key protocol data unit (PDU) with the Request bit in the Key Information field in the IEEE 802.11 Key Descriptor set to 1.

EAPOL-Start frame: A Data frame that carries all or part of an IEEE 802.1X EAPOL PDU of type EAPOL-Start.

emergency services association: A robust security network association (RSNA) between an access point (AP) and a non-AP station (STA) without security credentials; the non-AP STA is granted access to emergency services using unprotected frames via this association.

energy limited (EL) station (STA): A sub 1 GHz (S1G) STA whose limited energy supply requires the STA to transmit or receive in certain intervals of time determined by an EL Operation element.

enhanced distributed channel access (EDCA): The prioritized carrier sense multiple access with collision avoidance (CSMA/CA) access mechanism used by quality-of-service (QoS) stations (STAs) in a QoS basic service set (BSS) and STAs operating outside the context of a BSS. This access mechanism is also used by the QoS access point (AP) and operates concurrently with hybrid coordination function (HCF) controlled channel access (HCCA).

enhanced distributed channel access function (EDCAF): A logical function in a quality-of-service (QoS) station (STA) that determines, using enhanced distributed channel access (EDCA), when a frame in the transmit queue with the associated access category (AC) is permitted to be transmitted via the wireless medium (WM). There is one EDCAF per AC.

extended centralized access point (AP) or personal basic service set (PBSS) control point (PCP) cluster (ECAPC): The collection of 1) a single centralized coordination service set (CCSS), 2) the set of centralized AP or PCP clusters such that each synchronization AP (S-AP) of a centralized AP or PCP cluster

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is within the CCSS, and 3) all stations (STAs) within the basic service sets (BSSs) of the S-APs and member APs and PCPs of the centralized AP or PCP clusters.

extended channel switching (ECS): A procedure that is used to announce a pending change of operating channel, operating class, or both.

extended rate physical layer (ERP): A physical layer (PHY) compliant with Clause 18.

extended rate physical layer (ERP) physical layer (PHY) protocol data unit (PPDU): A Clause 18 PPDU that is not a Clause 16 PPDU.

extended rate physical layer (PHY) using complementary code keying (CCK) modulation (ERP-CCK): A mode of operation of a PHY operating under Clause 18 rules, where MODULATION=ERP-CCK.

extended rate physical layer (PHY) using direct sequence spread spectrum (DSSS) modulation (ERP-DSSS): A PHY operating under Clause 18 rules, where MODULATION=ERP-DSSS.

extended rate physical layer (PHY) using direct sequence spread spectrum (DSSS) or complementary code keying (CCK) modulation (ERP-DSSS/CCK): A PHY operating under Clause 18 rules, where MODULATION=ERP-CCK or MODULATION=ERP-DSSS.

extended rate physical layer (PHY) using orthogonal frequency division multiplexing (OFDM) modulation (ERP-OFDM): A mode of operation of a PHY operating under Clause 18 rules, where MODULATION=ERP-OFDM.

extended service set (ESS) link: In the context of an IEEE 802.11 medium access control (MAC) entity, a connection path through the wireless medium between a non-access-point (non-AP) station (STA) and one of the APs that is a member of the ESS.

Extensible Authentication Protocol (EAP) reauthentication protocol (EAP-RP): A protocol, using the EAP framework, that allows single round trip reauthentication with an Authentication Server after an initial EAP authentication.

NOTE—IETF RFC 6696 uses “ERP” for the abbreviation of EAP reauthentication protocol; IEEE Std 802.11 uses “EAP-RP” because “ERP” stands for “Extended Rate PHY” in IEEE Std 802.11.

fast basic service set (BSS) transition (FT) 4-way handshake: A pairwise key management protocol used during FT initial mobility domain association. This handshake confirms mutual possession of a pairwise master key, the PMK-R1, by two parties and distributes a group temporal key (GTK).

fast basic service set (BSS) transition (FT) initial mobility domain association: The first association or first reassociation procedure within a mobility domain, during which a station (STA) indicates its intention to use the FT procedures.

fast basic service set (BSS) transition (FT) originator: A station (STA) that initiates the FT protocol by sending an FT Request frame or an Authentication frame with Authentication Algorithm Number field equal to Fast BSS Transition.

fast initial link setup (FILS): A collection of mechanisms that enable IEEE Std 802.11 networks to minimize initial link setup time.

fast initial link setup (FILS) access point (AP): An access point that implements FILS and for which dot11FILSActivated is true.

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fast initial link setup (FILS) association: A type of association used in fast initial link setup.

fast initial link setup (FILS) authentication: A type of authentication used in fast initial link setup.

fast initial link setup (FILS) station (STA): A station that implements fast initial link setup (FILS) and for which dot11FILSActivated is true.

fine timing measurement (FTM) procedure: A procedure that allows a station (STA) to determine its distance from another STA.

flexible multicast service (FMS): A service that enables a non-access-point (non-AP) station (STA) to request a multicast delivery interval longer than the delivery traffic indication map (DTIM) interval for the purposes of lengthening the period of time a STA can be in a power save state.

flexible multicast service (FMS) stream: A succession of frames transmitted by the access point (AP) that correspond to a single flexible multicast stream identifier (FMSID).

flexible multicast service (FMS) stream set: A collection of FMS streams identified by the value of the FMS Token field, used during the FMS Request procedure.

flexible multicast stream identifier (FMSID): An identifier assigned by the access point (AP) to a particular group addressed stream subsequent to a successful FMS Request.

fragmentation: The process of partitioning a medium access control (MAC) service data unit (MSDU) or MAC management protocol data unit (MMPDU) into a sequence of smaller MAC protocol data units (MPDUs) prior to transmission. The process of recombining a set of fragment MPDUs into an MSDU or MMPDU is known as defragmentation. These processes are described in 5.8.1.9 of ISO/IEC 7498-1:1994.

future channel guidance: future channel guidance communicates likely future channel information so that STAs can efficiently move their activity when the absence of Beacon frames is noticed.

general link (GLK): A point-to-point connection between two instances of the IEEE 802.1D Internal Sublayer Service that uses an IEEE 802.11 wireless link between stations (STAs). A general link is suitable for use in an IEEE 802.1Q bridged network.

general link (GLK) convergence function: The convergence function defined in IEEE Std 802.1AC-2016 between an IEEE 802.11 medium access control (MAC) and an IEEE 802.1Q bridge.

general link groupcast with retries (GLK-GCR): A variant of GCR that specifies the use of GCR for general link.

general link (GLK) station (STA): A STA that implements GLK functionality.

generic advertisement service (GAS): An over-the-air transportation service that provides over-the-air transportation for frames of higher layer advertisements between stations (STAs) or between an advertisement server and a non-access-point (non-AP) STA. The protocol(s) used to relay frames between an AP, portal, and advertisement server is outside the scope of this standard. GAS supports higher layer protocols that employ a query/response mechanism.

geolocation database (GDB): A database whose operation is mandated or authorized by a regulatory authority and that organizes storage of information by geographic location.

geolocation database dependent (GDD): A modifier describing when station (STA) operation is dependent on information received from a geolocation database (GDB).

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geolocation database dependent (GDD) access point (AP): A station (STA) dependent on information received from a geolocation database (GDB) in order to initiate and maintain a network.

geolocation database dependent (GDD) dependent station (STA): A STA that is under the control of a GDD enabling STA.

geolocation database dependent (GDD) enabling station (STA): A STA that has the authority to control the operation of GDD dependent STAs after obtaining available spectrum for use at its own location.

geolocation database dependent (GDD) fixed station (STA): A STA whose geographical location information is fixed and maintained in a geolocation database (GDB) and whose operation depends on information received from that database.

geolocation database dependent (GDD) geolocated non-access point (non-AP) station (STA): A STA that is not an AP and is authorized by a geolocation database (GDB) to operate at its current location.

geolocation database dependent (GDD) non-access point (non-AP) station (STA): A STA that is not an AP but operates under the control of a GDD enabling STA.

global operating class: An operating class value that is any of the nonreserved values in Table E-4.

group addressed bufferable unit (BU): A group addressed medium access control (MAC) service data unit (MSDU) or group addressed bufferable MAC management protocol data unit (MMPDU).

group addressed quality-of-service management frame (GQMF): A group addressed Management frame that is transmitted using the quality-of-service management frame (QMF) service.

group addressed transmission service (GATS): A mechanism comprising directed multicast service (DMS) and groupcast with retries (GCR), for delivery of group addressed frames.

group key handshake: A group key management protocol defined by this standard. It is used only to issue a new group temporal key (GTK) to peers with whom the local station (STA) has already formed security associations.

group temporal key (GTK): A temporal key that is used to protect information exchanged in group addressed Data frames.

group temporal key security association (GTKSA): The context resulting from a successful group temporal key (GTK) distribution exchange via either a group key handshake, a 4-way handshake, or fast initial link setup (FILS) authentication.

groupcast with retries (GCR) active (GCR-A) delivery: A delivery method for a group addressed stream subject to a GCR agreement wherein the frames are transmitted without regard to the power state of non-access-point (non-AP) stations (STAs).

groupcast with retries (GCR) concealment address: A medium access control (MAC) address that is used to prevent group addressed frames transmitted via the GCR unsolicited retry or GCR block ack retransmission policies from being passed up the medium access control service access point (MAC SAP) of GCR-incapable stations (STAs).

groupcast with retries (GCR) frame: A group addressed frame subject to a GCR agreement between the access point (AP) and at least one station (STA) within the infrastructure basic service set (BSS) or between peer mesh STAs in a mesh BSS.

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groupcast with retries (GCR) group address: A group address subject to a GCR agreement between the access point (AP) and at least one station (STA) within the basic service set (BSS) or between peer mesh STAs in a mesh BSS.

groupcast with retries (GCR) service: A means for transmission and retransmission of medium access control (MAC) service data units (MSDUs) to a destination that is a group address. The GCR service provides greater reliability by using group addressed retransmissions, concealed from GCR-incapable stations (STAs).

groupcast with retries (GCR) service period (GCR-SP) aggregate medium access control (MAC) service data unit (A-MSDU): An A-MSDU subject to the GCR service with the delivery method equal to GCR-SP.

groupcast with retries (GCR) service period (GCR-SP) frame: A frame subject to the GCR service when the delivery method is GCR-SP.

groupcast with retries (GCR) service period (GCR-SP) medium access control (MAC) service data unit (MSDU): An MSDU subject to the GCR service with the delivery method equal to GCR-SP.

groupcast with retries (GCR) transmission opportunity (TXOP): An interval of time during which an access point (AP) or a mesh station (STA) has the right to initiate frame exchange sequences onto the wireless medium (WM) for the purpose of transmitting multiple frames that are subject to the GCR service.

high rate direct sequence spread spectrum (HR/DSSS) physical layer (PHY) protocol data unit (PPDU): A Clause 16 PPDU that is not a Clause 15 PPDU.

high-throughput (HT) basic service set (BSS): A BSS in which Beacon frames transmitted by an HT station (STA) include the HT Capabilities element.

high-throughput (HT) beamformee: An HT station (STA) that receives an HT physical layer (PHY) protocol data unit (PPDU) that was transmitted using a beamforming steering matrix and that supports an HT transmit beamforming feedback mechanism.

high-throughput (HT) beamformer: An HT station (STA) that transmits an HT physical layer (PHY) protocol data unit (PPDU) using a beamforming steering matrix.

high-throughput (HT) greenfield (HT-greenfield) format: A physical layer (PHY) protocol data unit (PPDU) format of the HT PHY using the HT-greenfield format preamble.

high-throughput (HT) immediate (HT-immediate) block acknowledgment (Ack): An immediate block ack mechanism that requires the use of the compressed BlockAck frame and an implicit block ack request and allows partial-state operation at the recipient. This block ack scheme is negotiated between two HT or directional multi-gigabit (DMG) stations (STAs).

high-throughput (HT) mixed (HT-mixed) format: A physical layer (PHY) protocol data unit (PPDU) format of the HT PHY using the HT-mixed format preamble.

high-throughput (HT) modulation and coding scheme (HT-MCS): A specification of the HT physical layer (PHY) parameters that consists of modulation order (e.g., BPSK, QPSK, 16-QAM, 64-QAM), forward error correction (FEC) coding rate (e.g., 1/2, 2/3, 3/4, 5/6), and number of spatial streams (NSS) and that is used in an HT PHY protocol data unit (PPDU).

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high-throughput (HT) null data PPDU (NDP) announcement: A physical layer (PHY) protocol data unit (PPDU) that contains one or more +HTC frames (i.e., frames with an HT Control field) that have the HT NDP Announcement subfield equal to 1.

high-throughput (HT) physical layer (PHY) protocol data unit (PPDU): A Clause 19 PPDU that is not a Clause 15, Clause 16, Clause 17, or Clause 18 PPDU.

high-throughput (HT) station (STA) 2G4: An HT STA that is also a STA 2G4.

high-throughput (HT) station (STA) 5G: An HT STA that is also a STA 5G.

hybrid coordination function (HCF): A coordination function that combines and enhances aspects of the contention based and contention free access methods to provide quality-of-service (QoS) stations (STAs) with prioritized and parameterized QoS access to the wireless medium (WM), while continuing to support non-QoS STAs for best-effort transfer. The HCF includes the functionality provided by both enhanced distributed channel access (EDCA) and HCF controlled channel access (HCCA).

hybrid coordination function (HCF) controlled channel access (HCCA): The channel access mechanism utilized by the hybrid coordinator (HC) to coordinate contention free media use by quality-of-service (QoS) stations (STAs) for downlink individually addressed, uplink, and direct-link transmissions.

hybrid coordinator (HC): A type of coordinator, defined as part of the quality-of-service (QoS) facility, that implements the frame exchange sequences and medium access control (MAC) service data unit (MSDU) handling rules defined by the hybrid coordination function (HCF).

IEEE 802.11 station (STA): Any station that is compliant with IEEE Std 802.11. Any reference to the term station (STA) in this standard that is not qualified by the term *IEEE 802.11* implicitly refers to an IEEE 802.11 station.

individually addressed bufferable unit (BU): An individually addressed medium access control (MAC) service data unit (MSDU), individually addressed aggregate MAC service data unit (A-MSDU) [quality-of-service (QoS) stations (STAs) only], or individually addressed bufferable MAC management protocol data unit (MMPDU).

individually addressed quality-of-service management frame (IQMF): An individually addressed Management frame that is transmitted using the quality-of-service management frame (QMF) service.

integrity check key (ICK): A key used to integrity check FILS Authentication frames.

interworking service: A service that supports use of an IEEE 802.11 network with non-IEEE-802.11 networks. Functions of the interworking service assist non-access-point (non-AP) stations (STAs) in discovering and selecting IEEE 802.11 networks, in using appropriate quality-of-service (QoS) settings for transmissions, in accessing emergency services, and in connecting to subscription service providers (SSPs).

key counter: A 256-bit (32-octet) counter that is used in the pseudorandom function (PRF) to generate initialization vectors (IVs). There is a single key counter per station (STA) that is global to that STA.

key data encapsulation (KDE): A format for data other than elements in the EAPOL-Key Data field.

key management service: A service to distribute and manage cryptographic keys within a robust security network (RSN).

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light sleep mode: A mesh power management mode with respect to a neighbor peer mesh STA in which a mesh station (STA) alternates between awake and doze states and is expected to receive beacons from this neighbor peer mesh STA.

link: In the context of an IEEE 802.11 medium access control (MAC) entity, a physical path consisting of exactly one traversal of the wireless medium (WM) that is usable to transfer MAC service data units (MSDUs) between two stations (STAs).

link setup: The process of discovering an extended service set (ESS), (secure) association and authentication, and gaining the ability to send higher layer [e.g., Internet Protocol (IP)] traffic with a valid higher layer address through an access point (AP).

location configuration information (LCI): As defined in IETF RFC 6225: includes latitude, longitude, and altitude, with uncertainty indicators for each.

medium access control (MAC) management protocol data unit (MMPDU): The unit of data exchanged between two peer MAC entities, using services of the physical layer (PHY), to implement the MAC management protocol. The MMPDU is transported in one or more Management frames. The MMPDU might include a Mesh Control field or management message integrity code element (Management MIC element), but does not include a MAC header, a frame check sequence (FCS), or any other security encapsulation overhead.

NOTE—The MMPDU occupies a position in the management plane similar to that of the MAC service data unit (MSDU) in the data plane. An MSDU or MMPDU is transmitted in one or more MAC protocol data units (MPDUs) (with the Type field set to Data or Management, respectively). An MSDU can be carried in an aggregate MAC service data unit (A-MSDU). An A-MSDU is transmitted in one MPDU. An MSDU, A-MSDU, or MMPDU can be carried (in an MPDU) in an aggregate MAC protocol data unit (A-MPDU).

mesh awake window: A period of time during which the mesh station (STA) operates in awake state after its Beacon or Probe Response frame transmission that contained the Mesh Awake Window element.

mesh coordination function (MCF): A coordination function that combines aspects of the contention based and scheduled access methods. The MCF includes the functionality provided by both enhanced distributed channel access (EDCA) and MCF controlled channel access (MCCA).

mesh coordination function (MCF) controlled channel access (MCCA): A coordination function for the mesh basic service set (MBSS).

mesh coordination function (MCF) controlled channel access opportunity (MCCAOP): A period of time scheduled for frame transmissions between mesh stations (STAs) using MCF controlled channel access (MCCA).

mesh Data frame: A Data frame that is transmitted by a mesh station (STA).

mesh peer service period: A period of time during which one or more individually addressed frames are transmitted between two peer mesh stations (STAs) with at least one of those mesh STAs operating in light sleep or deep sleep mode. A mesh peer service period is directional and might contain one or more transmission opportunities (TXOPs).

mesh peer service period owner: A mesh station (STA) that obtains transmission opportunities (TXOPs), transmits individually addressed frames to the recipient mesh STA in the mesh peer service period, and terminates the mesh peer service period.

mesh peering management: A group of protocols to facilitate mesh peering establishment and closure.

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mesh power management mode: The activity level identifier of a mesh station (STA) set per mesh peering or for nonpeer neighbor STAs. A lower activity level enables a mesh STA to reduce its power consumption.

mesh power management mode tracking: Operation to observe the peering-specific mesh power management modes from the peer mesh STAs and to maintain the peering-specific mesh power management modes for each peer mesh STA.

message integrity code (MIC) key: Temporal key integrity protocol (TKIP) only: The portion of a transient key used to validate the integrity of medium access control (MAC) service data units (MSDUs) or MAC protocol data units (MPDUs).

method-specific service access point (SAP) (MS SAP): The point at which an instance of the IEEE 802.11 method-specific medium access control (MAC) service is offered.

michael: The message integrity code (MIC) for the temporal key integrity protocol (TKIP).

minimum downlink transmission time (DTT) to uplink transmission time (UTT) [DTT2UTT] spacing: The minimum time within a power save multi-poll (PSMP) sequence between the end of a station's (STA's) PSMP-DTT and the start of its PSMP-UTT.

modulation and coding scheme (MCS): A specification of the physical layer (PHY) parameters that consists of modulation order (e.g., BPSK, QPSK, 16-QAM, 64-QAM, and 256-QAM), forward error correction (FEC) coding rate (e.g., 1/2, 2/3, 3/4, 5/6), and, depending on the context, the number of space-time streams.

modulation and coding scheme 32 (MCS 32) format: A physical layer (PHY) protocol data unit (PPDU) format of the high-throughput (HT) PHY in which signals in two halves of the occupied channel width contain the same information. This HT PPDU format supports the lowest rate.

modulation and coding scheme (MCS) feedback (MFB) requester: A station (STA) that transmits a physical layer (PHY) protocol data unit (PPDU) containing an HT Control field in which the MCS request (MRQ) subfield is equal to 1.

modulation and coding scheme (MCS) feedback (MFB) responder: A station (STA) that transmits a physical layer (PHY) protocol data unit (PPDU) containing an HT Control field with the MFB field containing an MCS index or the value 127 in response to a PPDU containing an HT Control field in which the MCS request (MRQ) subfield is equal to 1.

multiple basic service set identifier (BSSID) set: A collection of cooperating access points (APs), such that all of the APs use a common operating class, channel, and antenna connector.

multiple medium access control (MAC) sublayers link (MMSL): A link between two stations (STAs), wherein one of the STAs is coordinated by a multiple MAC station management entity (MM-SME) that delivered a Multiple MAC Sublayers (MMS) element to the peer STA.

multiple medium access control (MAC) sublayers link (MMSL) cluster: The set of all MMSLs between a pair of stations (STAs).

multi-user (MU) beamformee: A non-access-point (non-AP) station (STA) that receives a physical layer (PHY) protocol data unit (PPDU) that was transmitted using a multi-user beamforming steering matrix and that supports the very high throughput (VHT) transmit beamforming feedback mechanism with a VHT null data PPDU (NDP) Announcement frame that includes more than one STA Info field.

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multi-user (MU) beamformer: An access point (AP) that transmits a physical layer (PHY) protocol data unit (PPDU) using a multi-user beamforming steering matrix.

multi-user (MU) physical layer (PHY) protocol data unit (PPDU): A PPDU that carries one or more PHY service data units (PSDUs) for one or more stations (STAs) using the downlink multi-user multiple input, multiple output (DL-MU-MIMO) technique.

no acknowledgment/no retry (No-Ack/No-Retry): A retransmission policy for group addressed frames in which each frame is transmitted once and without acknowledgment.

non-40-MHz-capable (non-40MC) high-throughput (HT) station (STA): A STA that is not a 40-MHz-capable (40MC) HT STA.

nonaggregate medium access control (MAC) protocol data unit (non-A-MPDU) frame: A frame that is transmitted in a Clause 15 physical layer (PHY) protocol data unit (PPDU), Clause 17 PPDU, Clause 16 PPDU, or Clause 18 orthogonal frequency division multiplexing (OFDM) PPDU; or is transmitted with the TXVECTOR AGGREGATION parameter present and equal to NOT_AGGREGATED; or is a single medium access control (MAC) protocol data unit (S-MPDU).

nonbandwidth signaling transmitter address (TA): An address in the TA field of an medium access control (MAC) protocol data unit (MPDU) in which the Individual/Group bit has the value 0.

nonbufferable medium access control (MAC) management protocol data unit (MMPDU): An MMPDU that is not a bufferable MMPDU.

nonconcealed groupcast with retries (GCR) frame: A group addressed frame that is not transmitted to the GCR concealment address.

nonextended rate physical layer (non-ERP): A physical layer (PHY) compliant with Clause 15 or Clause 16, but not with Clause 18.

nongroupcast with retries (non-GCR): A method for delivering group addressed frames without using the groupcast with retries (GCR) unsolicited retry retransmission policy, the GCR block acknowledgment retransmission policy, or the GCR service period (GCR-SP) delivery method.

nongroupcast with retries service period (non-GCR-SP): A method for the delivery of group addressed frames without the use of a groupcast with retries service period (GCR-SP).

non-high-throughput (non-HT): A modifier meaning neither high throughput (HT) nor very high throughput (VHT).

non-high-throughput (non-HT) duplicate: A transmission format of the physical layer (PHY) that duplicates a 20 MHz non-HT transmission in two or more 20 MHz channels and allows a station (STA) in a non-HT basic service set (BSS) on any one of the 20 MHz channels to receive the transmission. A non-HT duplicate format is one of the following:

a) 40 MHz non-HT duplicate: A transmission format of the PHY that replicates a 20 MHz non-HT transmission in two adjacent 20 MHz channels.
b) 80 MHz non-HT duplicate: A transmission format of the PHY that replicates a 20 MHz non-HT transmission in four adjacent 20 MHz channels.
c) 160 MHz non-HT duplicate: A transmission format of the PHY that replicates a 20 MHz non-HT transmission in eight adjacent 20 MHz channels.

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d) 80+80 MHz non-HT duplicate: A transmission format of the PHY that replicates a 20 MHz non-HT transmission in two frequency segments of four adjacent 20 MHz channels where the two frequency segments of channels are not adjacent.

non-high-throughput (non-HT) duplicate frame: A frame transmitted in a non-HT duplicate physical layer (PHY) protocol data unit (PPDU).

non-high-throughput (non-HT) duplicate in television white spaces (TVWS) band: A transmission format of the physical layer (PHY) that duplicates a single basic channel unit (BCU) non-HT transmission in two or more BCUs and allows a station (STA) in a non-HT basic service set (BSS) on any one BCU to receive the transmission. A non-HT duplicate format is one of the following:

a) TVHT_W non-HT duplicate: A PHY transmission that replicates a non-HT PHY protocol data unit (PPDU) two times in a single BCU.
b) TVHT_2W non-HT duplicate: A PHY transmission that replicates a non-HT PPDU four times in two contiguous BCUs.
c) TVHT_4W non-HT duplicate: A PHY transmission that replicates a non-HT PPDU eight times in four contiguous BCUs.
d) TVHT_W+W non-HT duplicate: A PHY transmission that replicates a non-HT PPDU two times in each single BCU.
e) TVHT_2W+2W non-HT duplicate: A PHY transmission that replicates a non-HT PPDU four times in each of two contiguous BCUs.

non-high-throughput (non-HT) duplicate physical layer (PHY) protocol data unit (PPDU): A PPDU transmitted by a Clause 19 or Clause 21 PHY with the TXVECTOR FORMAT parameter equal to NON_HT and the CH_BANDWIDTH parameter equal to NON_HT_CBW40, CBW40, CBW80, CBW160, or CBW80+80.

non-high-throughput (non-HT) duplicate physical layer (PHY) protocol data unit (PPDU) in television white spaces (TVWS) band: A PPDU transmitted by a Clause 22 PHY with the TXVECTOR parameter FORMAT set to NON_HT and the TXVECTOR parameter CH_BANDWIDTH set to TVHT_W, TVHT_2W, TVHT_4W, TVHT_W+W, or TVHT_2W+2W.

non-high-throughput (non-HT) physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted by a Clause 15, Clause 16, Clause 17, or Clause 18 PHY, or not using a TXVECTOR FORMAT parameter equal to HT_MF, HT_GF or VHT.

non-high-throughput (non-HT) SIGNAL field (L-SIG) transmit opportunity (TXOP) protection: A protection mechanism in which protection is established by the non-HT SIG Length and Rate fields indicating a duration that is longer than the duration of the PPDU itself.

nonpeer mesh power management mode: The activity level identifier of a mesh station (STA) toward nonpeer neighbor mesh STAs. Two nonpeer mesh power management modes are defined: active mode and deep sleep mode.

non-personal basic service set (BSS) control point (non-PCP) station (STA): A STA that is not a personal BSS control point (PCP).

nonprimary channel: In a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz basic service set (BSS), any 20 MHz channel other than the primary 20 MHz channel.

non-quality-of-service management frame (non-QMF) access point (AP): An AP that does not implement the quality-of-service management frame (QMF) service.

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non-quality-of-service management frame (non-QMF) station (STA): A STA that does not implement the quality-of-service management frame (QMF) service.

non-sensor station (STA): A sub 1 GHz (S1G) non-access point (non-AP) STA transmitting or receiving Data frames not subject to limitation of payload size. A non-sensor STA might not have the power and traffic volume limitation expected for a sensor STA.

non-space-time-block-coding (non-STBC) frame: A frame that is transmitted in a physical layer (PHY) protocol data unit (PPDU) that has the TXVECTOR STBC parameter equal to 0, or a frame that is received in a PPDU that has the RXVECTOR STBC parameter equal to 0.

non-traffic indication map (non-TIM) mode: A sub 1 GHz (S1G) non-access point (non-AP) station (STA) power save mode in which an S1G non-AP STA need not listen for traffic indication map (TIM) Beacon frames but transmits at least one PS-Poll or trigger frame to the associated access point (AP) every listen interval.

non-traffic indication map (non-TIM) station (STA): A sub 1 GHz (S1G) non-access point (non-AP) STA that has entered the non-TIM mode.

nontransmitted basic service set (BSS) identifier (BSSID): A BSSID that is not transmitted explicitly, but that can be derived from the information encoded in Probe Response, Beacon and directional multi-gigabit (DMG) Beacon frames and neighbor reports.

null data PPDU (NDP): A physical layer (PHY) protocol data unit (PPDU) that carries no Data field.

null data PPDU (NDP) 1M (NDP_1M): An NDP carrying medium access control (MAC) information (CMI) frame that is transmitted using the S1G_1M format.

null data PPDU (NDP) 2M (NDP_2M): An NDP carrying medium access control (MAC) information (CMI) frame that is transmitted using the S1G_SHORT format.

null data PPDU (NDP) carrying medium access control information (CMAC) PPDU: A physical layer (PHY) protocol data unit (PPDU) with no Data field used by the PHY to provide to the medium access control (MAC) the service of carrying MAC information in the SIGNAL field of the sub 1 GHz (S1G) PPDU.

off-channel: A channel used by a tunneled direct link setup (TDLS) station (STA) that does not overlap the channel(s) used by the access point (AP) with which the TDLS STA is associated.

operating class: An E.1 index into a set of values for radio operation in one or more regulatory domains.

operational modulation and coding scheme (MCS) set: The set of MCSs that a station (STA) is capable of receiving. The operational MCS set is typically advertised in the physical layer (PHY) capabilities element(s), e.g. HT and VHT Capabilities elements.

operational rate set: The set of data rates that a station (STA) is capable of receiving. The operational rate set is advertised in the Supported Rates and BSS Membership Selectors element and, if present, the Extended Supported Rates and BSS Membership Selectors element.

orthogonal frequency division multiplexing (OFDM) physical layer (PHY) protocol data unit (PPDU): A Clause 17 PPDU.

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outside the context of a basic service set (BSS) (OCB): A mode of operation in which a station (STA) is not a member of a BSS and does not utilize IEEE 802.11 authentication, association, or data confidentiality services.

paged association identifier (AID): An AID of a sub 1 GHz (S1G) non-access point (non-AP) station (STA) whose corresponding bit value in a transmitted traffic indication map (TIM) encoded in AID with differential encoding (ADE) mode is 1.

pairwise master key (PMK): The key derived from a key generated by an Extensible Authentication Protocol (EAP) method or obtained directly from a preshared key (PSK).

pairwise master key (PMK) R0 (PMK-R0): The key at the first level of the fast basic service set (BSS) transition (FT) key hierarchy.

pairwise master key (PMK) R0 key holder (R0KH): The component of robust security network association (RSNA) key management of the Authenticator that is authorized to derive and hold the PMK-R0, derive the PMK-R1s, and distribute the PMK-R1s to the R1KHs.

pairwise master key (PMK) R0 key holder identifier (R0KH-ID): An identifier that names the holder of the PMK-R0 in the Authenticator.

pairwise master key (PMK) R0 name (PMKR0Name): An identifier that names the PMK-R0.

pairwise master key (PMK) R1 (PMK-R1): A key at the second level of the fast basic service set (BSS) transition (FT) key hierarchy.

pairwise master key (PMK) R1 key holder (R1KH): The component of robust security network association (RSNA) key management of the Authenticator that receives a PMK-R1 from the R0KH, holds the PMK-R1, and derives the pairwise transient keys (PTKs).

pairwise master key (PMK) R1 key holder identifier (R1KH-ID): An identifier that names the holder of a PMK-R1 in the Authenticator.

pairwise master key (PMK) R1 name (PMKR1Name): An identifier that names a PMK-R1.

pairwise master key (PMK) S0 key holder (S0KH): The component of robust security network association (RSNA) key management of the Supplicant that derives and holds the PMK-R0, derives the PMK-R1s, and provides the PMK-R1s to the S1KH.

pairwise master key (PMK) S0 key holder identifier (S0KH-ID): An identifier that names the holder of the PMK-R0 in the Supplicant.

pairwise master key (PMK) S1 key holder (S1KH): The component of robust security network association (RSNA) key management in the Supplicant that receives a PMK-R1 from the S0KH, holds the PMK-R1, and derives the pairwise transient keys (PTKs).

pairwise master key (PMK) S1 key holder identifier (S1KH-ID): An identifier that names the holder of the PMK-R1 in the Supplicant.

pairwise master key security association (PMKSA): The context resulting from a successful IEEE 802.1X authentication exchange between the peer and Authentication Server (AS) or from a preshared key (PSK).

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pairwise transient key (PTK): A concatenation of session keys derived from the pairwise master key (PMK) or from the PMK-R1.

pairwise transient key (PTK) name (PTKName): An identifier that names the PTK.

pairwise transient key security association (PTKSA): The context resulting from a successful 4-way handshake between a peer and Authenticator or from a successful fast initial link setup (FILS) authentication.

parameterized quality of service (QoS): The treatment of the medium access control (MAC) protocol data units (MPDUs) depends on the parameters associated with the MPDU. Parameterized QoS is primarily provided through the hybrid coordination function (HCF) controlled channel access (HCCA) mechanism, but is also provided by the enhanced distributed channel access (EDCA) mechanism if used with a traffic specification (TSPEC) for admission control.

payload protected (PP) aggregate medium access control (MAC) service data unit (A-MSDU): An A-MSDU that is protected with counter mode (CTR) with cipher-block chaining message authentication code (CBC-MAC) protocol (CCMP) or Galois/counter mode (GCM) protocol (GCMP) but does not include the A-MSDU Present field (bit 7 of the QoS Control field) in the construction of the additional authentication data (AAD).

peer trigger frame: A Mesh Data or quality-of-service (QoS) Null frame that initiates a mesh peer service period.

peer-specific mesh power management mode: The activity level identifier of a mesh station (STA) set per mesh peering. Three peer-specific mesh power management modes are defined: active mode, light sleep mode, and deep sleep mode.

per-frame sequence counter: For temporal key integrity protocol (TKIP), the counter that is used as the nonce in the derivation of the per-frame encryption key. For counter mode with cipher-block chaining message authentication code protocol (CCMP) or Galois/counter mode (GCM) protocol (GCMP), the per-frame initialization vector (IV).

personal basic service set (PBSS): A directional multi-gigabit (DMG) basic service set (BSS) that includes one station (STA) that is in a PBSS control point (PCP), and in which access to a distribution system (DS) is not present.

personal basic service set (PBSS) control point (PCP): An entity that contains one station (STA) and coordinates access to the wireless medium (WM) by STAs that are members of a PBSS.

personal basic service set (PBSS) control point (PCP) or access point (AP) cluster: A single directional multi-gigabit (DMG) synchronization AP or synchronization PCP, plus zero or more neighboring DMG APs or PCPs (or a mixture of both) that join as member APs and PCPs to the synchronization AP or synchronization PCP.

physical layer (PHY) header: The portion of a PHY protocol data unit (PPDU) up to and excluding the first symbol that contains part of the PHY service data unit (PSDU).

power save (PS) mode: A power management mode in which a nonmesh station (STA) alternates between awake and doze states.

power save multi-poll (PSMP): A mechanism that provides a time schedule that is used by an access point (AP) and its stations (STAs) to access the wireless medium. The mechanism is controlled using the PSMP frame.

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power save multi-poll (PSMP) burst: A series of one or more PSMP sequences, separated by short interframe space (SIFS).

power save multi-poll downlink transmission time (PSMP-DTT): A period of time described by a PSMP frame during which the access point (AP) transmits.

power save multi-poll (PSMP) sequence: A sequence of frames in which the first frame is a PSMP frame that is followed by transmissions in zero or more power save multi-poll downlink transmission times (PSMP-DTTs) and then by transmissions in zero or more power save multi-poll uplink transmission times (PSMP-UTTs). The schedule of the PSMP-DTTs and PSMP-UTTs is defined in the PSMP frame.

power save multi-poll (PSMP) session: The relationship between an access point (AP) and one or more stations (STAs) that exists while any traffic stream (TS) exists that uses the PSMP mechanism with the same service period.

power save multi-poll uplink transmission time (PSMP-UTT): A period of time described by a PSMP frame during which a non-access-point (non-AP) station (STA) can transmit.

power save multi-poll uplink transmission time (PSMP-UTT) spacing: The period of time between the end of one PSMP-UTT and the start of the following PSMP-UTT within the same power save multi-poll (PSMP) sequence.

power save (PS) station (STA): A station that is in power save mode.

pre-robust security network association (pre-RSNA): The type of association used by a pair of stations (STAs) if the procedure for establishing authentication or association between them did not include the 4-way handshake, was not fast initial link setup (FILS) authentication, and did not use the fast basic service set (BSS) transition (FT) protocol.

pre-robust security network association (pre-RSNA) station (STA): A STA that is not able to create robust security network associations (RSNAs).

primary 1 MHz channel: In a 2 MHz, 4 MHz, 8 MHz, or 16 MHz sub 1 GHz (S1G) basic service set (BSS), the 1 MHz channel that is used to transmit 1 MHz physical layer (PHY) protocol data units (PPDUs).

primary 2 MHz channel: In a 4 MHz, 8 MHz, or 16 MHz sub 1 GHz (S1G) basic service set (BSS), the 2 MHz channel that is used to transmit 2 MHz physical layer (PHY) protocol data units (PPDUs).

primary 4 MHz channel: In an 8 MHz or 16 MHz sub 1 GHz (S1G) basic service set (BSS), the 4 MHz channel that is used to transmit 4 MHz physical layer (PHY) protocol data units (PPDUs).

primary 8 MHz channel: In a 16 MHz sub 1 GHz (S1G) basic service set (BSS), the 8 MHz channel that is used to transmit 8 MHz physical layer (PHY) protocol data units (PPDUs).

primary 20 MHz channel: In a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz basic service set (BSS), the 20 MHz channel that is used to transmit 20 MHz physical layer (PHY) protocol data units (PPDUs). In a high-throughput (HT) or very high throughput (VHT) BSS, the primary 20 MHz channel is also the primary channel.

primary 40 MHz channel: In an 80 MHz, 160 MHz, or 80+80 MHz basic service set (BSS), the 40 MHz channel that is used to transmit 40 MHz physical layer (PHY) protocol data units (PPDUs).

primary 80 MHz channel: In a 160 MHz or 80+80 MHz basic service set (BSS), the 80 MHz channel that is used to transmit 80 MHz physical layer (PHY) protocol data units (PPDUs).

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primary access category (AC): The AC associated with the enhanced distributed channel access function (EDCAF) that gains channel access.

protected dual of public action frame: An Action frame with the category value specified in 9.4.1.11 (Table 9-51). For each Protected Dual of Public Action frame, there is a dual Action frame in a category that is specified with No in the Robust column of Table 9-51.

protected frame: A frame that has been encrypted and/or whose integrity can be verified cryptographically.

protocol version 0 (PV0) medium access control (MAC) protocol data unit (MPDU): An MPDU that has the Protocol Version field of the Frame Control field of the MPDU header equal to 0.

protocol version 1 (PV1) medium access control (MAC) protocol data unit (MPDU): An MPDU that has the Protocol Version field of the Frame Control field of the MPDU header equal to 1.

quality-of-service (QoS) frame: A frame containing the QoS Control field.

quality-of-service management frame (QMF): A Management frame that is transmitted using the QMF service.

quality-of-service management frame (QMF) access point (AP): A quality-of-service AP that implements the QMF service.

quality-of-service management frame (QMF) policy: A policy defining the access category of Management frames. QMF stations (STAs) transmit their Management frames using the access category defined by the policy.

quality-of-service management frame (QMF) service: A service in which the enhanced distributed channel access (EDCA) access category with which a Management frame is sent is determined according to a configured policy.

quality-of-service management frame (QMF) station (STA): A quality-of-service STA that implements the QMF service.

quasi-omni antenna pattern: A directional multi-gigabit (DMG) antenna operating mode with the widest beamwidth attainable.

receive sector sweep (RXSS): Reception of Sector Sweep (SSW) frames via different sectors, in which a sweep is performed between consecutive receptions.

received signal-to-noise indicator (RSNI): An indication of the signal-to-noise plus interference ratio of a received frame.

resource information container (RIC): A sequence of elements that include resource request and response parameters.

restricted access window (RAW): A medium access interval for a group of stations (STAs) during which a STA in the RAW group indicated by the RAW parameter set (RPS) element is allowed to contend for access to the medium.

reverse direction (RD) initiator: A station (STA) that is a transmit opportunity (TXOP) holder that transmits a medium access control (MAC) protocol data unit (MPDU) in which the reverse direction grant/more physical layer protocol data unit (RDG/More PPDU) subfield is equal to 1.

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reverse direction (RD) responder: A station (STA) that is not the RD initiator and whose medium access control (MAC) address matches the value of the Address 1 field of a received MAC protocol data unit (MPDU) in which the RDG/More PPDU subfield is equal to 1.

robust Action frame: An Action frame with a category value specified in 9.4.1.11 (Table 9-51 with Yes in the Robust column).

robust Management frame: A Management frame that is eligible for protection.

robust security network (RSN): A security network that allows only the creation of robust security network associations (RSNAs). An RSN can be identified by the indication in the RSN element (RSNE) of Beacon frames that the group cipher suite specified is not wired equivalent privacy (WEP).

robust security network association (RSNA): The type of association used by a pair of stations (STAs) if the procedure to establish authentication or association between them includes the 4-way handshake or the fast basic service set (BSS) transition (FT) protocol, or is fast initial link setup (FILS) authentication. Note that existence of an RSNA between two STAs does not of itself provide robust security. Robust security is provided when all STAs in the network use RSNAs.

robust security network association (RSNA) key management: Key management that includes the 4-way handshake, the group key handshake, authenticated mesh peering exchange, mesh group key handshake, and the PeerKey handshake. If fast basic service set (BSS) transition (FT) is enabled, the FT 4-way handshake and FT authentication sequence are also included. If fast initial link setup (FILS) is enabled, FILS authentication is also included.

sub 1 GHz (S1G) band: Frequency band for which an S1G operating class is defined in Annex E.

scheduled service period (SP): An SP that is scheduled by a quality-of-service (QoS) access point (AP) or a personal basic service set (PBSS) control point (PCP).

secondary 1 MHz channel: In a 2 MHz sub 1 GHz (S1G) basic service set (BSS), the 1 MHz channel adjacent to the primary 1 MHz channel that with the primary 1 MHz channel forms the 2 MHz channel of the 2 MHz S1G BSS. In a 4 MHz, 8 MHz, and 16 MHz S1G BSS, the 1 MHz channel adjacent to the primary 1 MHz channel that together form the primary 2 MHz channel of the S1G BSS.

secondary 2 MHz channel: In a 4 MHz sub 1 GHz (S1G) basic service set (BSS), the 2 MHz channel adjacent to the primary 2 MHz channel that with the primary 2 MHz channel forms the 4 MHz channel of the 4 MHz S1G BSS. In an 8 MHz and 16 MHz S1G BSS, the 2 MHz channel adjacent to the primary 2 MHz channel that together form the primary 4 MHz channel of the S1G BSS.

secondary 4 MHz channel: In an 8 MHz sub 1 GHz (S1G) basic service set (BSS), the 4 MHz channel adjacent to the primary 4 MHz channel that with the primary 4 MHz channel forms the 8 MHz channel of the 8 MHz S1G BSS. In a 16 MHz S1G BSS, the 4 MHz channel adjacent to the primary 4 MHz channel that together form the primary 8 MHz channel.

secondary 8 MHz channel: In a 16 MHz sub 1 GHz (S1G) basic service set (BSS), the 8 MHz channel adjacent to the primary 8 MHz channel that with the primary 8 MHz channel forms the 16 MHz channel of the 16 MHz S1G BSS.

secondary 20 MHz channel: In a 40 MHz very high throughput (VHT) basic service set (BSS), the 20 MHz channel adjacent to the primary 20 MHz channel that together form the 40 MHz channel of the 40 MHz VHT BSS. In an 80 MHz VHT BSS, the 20 MHz channel adjacent to the primary 20 MHz channel that together form the primary 40 MHz channel of the 80 MHz VHT BSS. In a 160 MHz or 80+80 MHz VHT BSS, the 20 MHz channel adjacent to the primary 20 MHz channel that together form the primary 40 MHz

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channel of the 160 MHz or 80+80 MHz VHT BSS. In a VHT BSS, the secondary 20 MHz channel is also the secondary channel.

secondary 40 MHz channel: In an 80 MHz very high throughput (VHT) basic service set (BSS), the 40 MHz channel adjacent to the primary 40 MHz channel that together form the 80 MHz channel of the 80 MHz VHT BSS. In a 160 MHz or 80+80 MHz VHT BSS, the 40 MHz channel adjacent to the primary 40 MHz channel that together form the primary 80 MHz channel.

secondary 80 MHz channel: In a 160 MHz or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 80 MHz channel not including the primary 20 MHz channel, that together with the primary 80 MHz channel form the 160 MHz or 80+80 MHz channel of the 160 MHz or 80+80 MHz VHT BSS.

secondary access category (AC): An AC that is not associated with the enhanced distributed channel access function (EDCAF) that gains channel access.

NOTE—Traffic associated with a secondary AC can be included in a multi-user (MU) physical layer (PHY) protocol data unit (MU PPDU) that includes traffic associated with the primary AC. There could be multiple secondary ACs at a given time. A single medium access control protocol data unit (S-MPDU) is a special form of MPDU that is carried in an A-MPDU.

secondary channel: A channel associated with a primary channel used to create a channel wider than the primary channel. In a 40 MHz, 80 MHz, 160 MHz or 80+80 MHz basic service set (BSS) the secondary channel is a secondary 20 MHz channel.

sector: A transmit or receive antenna pattern corresponding to a sector identifier (ID).

security network: A basic service set (BSS) in which the station (STA) starting the BSS provides information about the security capabilities and configuration of the BSS by including the robust security network element (RSNE) in Beacon frames.

self-protected action frame: An Action frame that is not eligible for protection by the robust management frame service. The protection on each Self-protected Action frame is provided by the protocol that uses the frame.

sensor station (STA): A sub 1 GHz (S1G) non-access point (non-AP) STA that has certain traffic and device characteristics (e.g., limited payload size, limited traffic volume, battery operated device) and is allowed to associate with an access point (AP) that transmits an S1G Beacon, a Probe Response, or a PV1 Probe Response frame containing the S1G Capabilities element with the STA Type Support subfield indicating a sensor basic service set (BSS) or a mixed BSS.

service information client (SIC): A logical entity that initiates station (STA) service discovery.

service information registry (SIR): A logical entity that contains caches of information about services that are available via the basic service set (BSS).

service interval (SI): The interval between the starts of two successive scheduled service periods (SPs).

service period (SP): A period of time during which one or more downlink individually addressed frames are transmitted to a quality-of-service (QoS) station (STA) and/or one or more transmission opportunities (TXOPs) are granted to the same STA. SPs are either scheduled or unscheduled.

NOTE—A non-access-point (non-AP) STA can have at most one nongroupcast with retries SP (non-GCR-SP) active at any time.

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session key: A key that is generated for a single session, to be used, e.g., for encryption and integrity protection, such as a temporal key (TK), group temporal key (GTK), EAPOL-Key encryption key (KEK) or EAPOL-Key confirmation key (KCK).

NOTE—A session key is not necessarily a temporal key.

shared bands: Radio frequency bands in which dissimilar services are permitted.

short beacon interval: The interval between the consecutive target short beacon transmission times (TSBTTs) of beacons containing a minimal set of elements.

signaling and payload protected (SPP) aggregate medium access control (MAC) service data unit (A-MSDU): An A-MSDU that is protected with counter mode (CTR) with cipher-block chaining message authentication code (CBC-MAC) protocol (CCMP) or Galois/counter mode (GCM) protocol (GCMP) and that includes the A-MSDU Present field (bit 7 of the QoS Control field) in the construction of the additional authentication data (AAD).

single medium access control (MAC) protocol data unit (S-MPDU): An MPDU that is the only MPDU in an aggregate MPDU (A-MPDU) and that is carried in an A-MPDU subframe with the EOF subfield of the MPDU delimiter field equal to 1.

sounding physical layer (PHY) protocol data unit (PPDU): A PPDU that is intended by the transmitting station (STA) to enable the receiving STA to estimate the channel between the transmitting STA and the receiving STA. The Not Sounding field in the High Throughput SIGNAL field (HT-SIG) is equal to 0 in sounding PPDUs.

source directional multi-gigabit (DMG) station (STA): A DMG STA identified by the source association identifier (AID) field contained in a Grant frame or Extended Schedule element that caused the allocation of a service period (SP) or contention based access period (CBAP).

space-time block coding (STBC) beacon: A beacon that is transmitted using the basic STBC modulation and coding scheme (MCS) to enable discovery of the basic service set (BSS) by high-throughput (HT) stations (STAs) that support the HT STBC feature in order to extend the range of the BSS.

space-time block coding (STBC) delivery traffic indication map (DTIM): An STBC beacon transmission that is a DTIM Beacon frame.

space-time block coding (STBC) frame: A frame that is transmitted in a physical layer (PHY) protocol data unit (PPDU) that has a nonzero value of the TXVECTOR STBC parameter, or a frame that is received in a PPDU that has a nonzero value of the RXVECTOR STBC parameter.

spatial sharing (SPSH): Use of a frequency channel by multiple stations (STAs) that are located in the same vicinity, and whose directional transmissions might overlap in time.

staggered preamble: A physical layer (PHY) preamble in a sounding PHY protocol data unit (PPDU) that is not a null data PPDU (NDP) and that includes one or more Data Long Training fields (DLTFs) and one or more Extension Long Training fields (ELTFs).

staggered sounding: The use of a sounding physical layer (PHY) protocol data unit (PPDU) that is not a null data PPDU (NDP) and that includes one or more Data Long Training fields (DLTFs) and one or more Extension Long Training fields (ELTFs).

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station (STA) 2G4: A STA that is operating on a channel that belongs to any operating class that has a value of 25 or 40 for the entry in the Channel spacing column and that has a value of 2.407 or 2.414 for the entry in the Channel starting frequency column of any of the tables found in E.1.

station (STA) 5G: A STA that is operating on a channel that belongs to any operating class that has a value of 20 or 40 for the entry in the Channel spacing column and that has a value of 5 for the entry in the Channel starting frequency column of any of the tables found in E.1.

sub 1 GHz 1M (S1G_1M) physical layer (PHY) protocol data unit (PPDU): A 1 MHz PPDU or 1 MHz duplicate PPDU that is transmitted with S1G_1M preamble.

sub 1 GHz long (S1G_LONG) physical layer (PHY) protocol data unit (PPDU): A Clause 23 PPDU.

sub 1 GHz modulation and coding scheme (S1G-MCS): A specification of the S1G physical layer (PHY) parameters that consists of modulation order (e.g., BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM) and forward error correction (FEC) coding rate (e.g., 1/2 rep2, 1/2, 2/3, 3/4, 5/6) that is used in an S1G PHY protocol data unit (PPDU).

sub 1 GHz (S1G) physical layer (PHY) protocol data unit (PPDU): A PPDU transmitted with the TXVECTOR parameter FORMAT equal to S1G, S1G_DUP_1M, or S1G_DUP_2M. The PPDU is transmitted with the S1G_SHORT, S1G_LONG, or S1G_1M preamble.

sub 1 GHz short (S1G_SHORT) physical layer (PHY) protocol data unit (PPDU): A 2 MHz, 4 MHz, 8 MHz, 16 MHz, or 2 MHz duplicate PPDU with short preamble format.

subchannel selective transmission (SST) channel: A channel that is permitted for the subchannel selective transmission indicated by either an SST element or an RPS element.

subscription service provider (SSP) roaming: The act when a station (STA) uses an SSP's IEEE 802.11 infrastructure, with which the terminal has no direct agreement, based on a subscription and formal agreement with the STA's own SSP.

successful transmission: A transmission and the reception of its expected immediate response or a transmission for which no immediate response is expected.

sweep: A sequence of transmissions, separated by a short beamforming interframe space (SBIFS), in which the antenna configuration at the transmitter or receiver is changed between transmissions.

synchronization access point (AP) (S-AP): An AP that provides synchronization and other services to an AP cluster or personal basic service set (PBSS) control point (PCP).

synchronization personal basic service set (PBSS) control point (PCP) (S-PCP): A PCP that provides synchronization and other services to an access point (AP) cluster or PCP cluster.

synchronizing access point (AP) or personal basic service set (PBSS) control point (PCP): A China directional multi-gigabit (CDMG) AP or PCP that is operating on a 1.08 GHz channel but still transmitting its DMG Beacon frames on the relevant 2.16 GHz channel with the AP or PCP Role subfield of the Dynamic Bandwidth Control element (9.4.2.220) set to 0 and providing synchronization service to a synchronized AP or PCP on the relevant 2.16 GHz channel.

synchronized access point (AP) or personal basic service set (PBSS) control point (PCP): A CDMG AP or PCP that is operating on a 1.08 GHz channel but still transmitting its DMG Beacon frames on the relevant 2.16 GHz channel with the AP or PCP Role subfield of the Dynamic Bandwidth Control element (9.4.2.220) set to 1 and synchronizing with the synchronizing AP or PCP on the relevant 2.16 GHz channel.

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synthetic receiver address (SYNRA): A constructed group address used by a general link (GLK) access point (AP) as a receiver address to forward frames to a subset of GLK non-AP stations (STAs), as required by IEEE 802.1Q bridges.

target wake time (TWT): A specific time or set of times for individual stations (STAs) to wake in order to exchange frames with other STAs.

target wake time (TWT) requester: A station (STA) that has had a requested TWT agreement accepted by another STA and that receives TWT service period (SP) start times from that STA.

target wake time (TWT) responder: A station (STA) that has accepted a TWT agreement that was requested by another STA and that assigns TWT service period (SP) start times to the requesting STA.

target wake time (TWT) service period (SP): A period of time during which a TWT station (STA) is awake to transmit and/or receive frames.

target wake time (TWT) service period (SP) start time: The value of the timing synchronization function (TSF) at the beginning of a TWT SP.

television very high throughput 2W (TVHT_2W): Two contiguous basic channel units (BCUs) in television white spaces (TVWS).

television very high throughput 2W+2W (TVHT_2W+2W): Two noncontiguous frequency segments, each of which comprises two contiguous basic channel units (BCUs) in television white spaces (TVWS).

television very high throughput 4W (TVHT_4W): Four contiguous basic channel units (BCUs) in television white spaces (TVWS).

television very high throughput (TVHT) basic service set (BSS): A set of stations (STAs) that consists of a geolocation database dependent (GDD) enabling STA operating in television white spaces (TVWS) and one or more of its GDD STAs.

television very high throughput W (TVHT_W): One basic channel unit in television white spaces (TVWS).

television very high throughput W+W (TVHT_W+W): Two noncontiguous basic channel units (BCUs) in television white spaces (TVWS).

temporal encryption key: The portion of a pairwise transient key (PTK) or group temporal key (GTK) used directly or indirectly to encrypt data in medium access control (MAC) protocol data units (MPDUs).

temporal key (TK): Temporal key integrity protocol (TKIP) only: The combination of temporal encryption key and a message integrity code (MIC) key. Non-TKIP only: A temporal encryption key.

NOTE—A temporal key is a session key.

time priority Management frame: A Management frame that is transmitted using specific frame type channel access rules.

traffic indication map (TIM) broadcast: A service that enables a non-access-point (non-AP) station (STA) to request periodic transmission of a TIM frame by the AP. TIM frames have shorter duration than Beacon frames and can be transmitted at a higher physical layer (PHY) rate, which allows the STA to save additional power while periodically checking for buffered traffic in standby mode, relative to the power consumed if the station (STA) were to periodically wake up to receive a Beacon frame.

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traffic stream identifier (TSID): Any of the identifiers usable by higher layer entities to distinguish medium access control (MAC) service data units (MSDUs) to MAC entities for parameterized quality of service (QoS) [i.e., the traffic stream (TS) with a particular traffic specification (TSPEC)] within the MAC data service. The TSID is assigned to an MSDU in the layers above the MAC.

transition security network (TSN): A security network that allows the creation of pre-robust security network associations (pre-RSNAs) as well as RSNAs. A TSN is identified by the indication in the robust security network element (RSNE) of Beacon frames that the group cipher suite in use is wired equivalent privacy (WEP).

transmission opportunity (TXOP) holder: A quality-of-service (QoS) station (STA) that has either been granted a TXOP by the hybrid coordinator (HC) or successfully contended for a TXOP.

transmission opportunity (TXOP) responder: A station (STA) that transmits a frame in response to a frame received from a TXOP holder during a frame exchange sequence, but that does not acquire a TXOP in the process.

transmit power: The effective isotropic radiated power (EIRP) when referring to the operation of an orthogonal frequency division multiplexing (OFDM) physical layer (PHY) in a country where so regulated.

transmit sector sweep (TXSS): Transmission of multiple sector sweep (SSW) or directional multi-gigabit (DMG) Beacon frames via different sectors, in which a sweep is performed between consecutive transmissions.

transmit sector sweep (TXSS) contention based access period (CBAP): A CBAP that is available to all stations (STAs) in an extended centralized personal basic service set (PBSS) control point (PCP) or access point (AP) cluster outside which TXSSs in the data transfer interval (DTI) can be prohibited.

transmitted basic service set identifier (BSSID): The BSSID included in the medium access control (MAC) header transmitter address field of a Beacon frame when the multiple BSSID capability is supported.

trigger frame: A frame type or a frame transmission occurrence within a specific context, intended to solicit the peer entity into a responding action.

trigger-enabled access category (AC): A quality-of-service (QoS) station (STA) AC where frames of subtype QoS Data and QoS Null from the STA that map to the AC trigger an unscheduled service period (SP) if one is not in progress.

tunneled direct-link setup (TDLS): A protocol that uses a specific Ethertype encapsulation to TDLS frames through an access point (AP) to establish a TDLS direct link.

tunneled direct-link setup (TDLS) direct link: Direct link between two non-access-point (non-AP) stations (STAs) that has been established using the TDLS protocol.

tunneled direct-link setup (TDLS) initiator station (STA): A STA that transmits a TDLS Setup Request frame or a TDLS Discovery Request frame.

tunneled direct-link setup (TDLS) peer power save mode (PSM): A PSM that is based on periodically scheduled service periods (SPs), which can be used between two stations (STAs) that have set up a TDLS direct link.

tunneled direct-link setup (TDLS) peer power save mode (PSM) initiator: A station (STA) that transmits a TDLS Peer PSM Request frame.

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tunneled direct-link setup (TDLS) peer power save mode (PSM) responder: A station (STA) that transmits a TDLS Peer PSM Response frame.

tunneled direct-link setup (TDLS) peer station (STA): A STA with which another STA has, or is in the process of establishing, a TDLS direct link.

tunneled direct-link setup (TDLS) peer unscheduled automatic power save delivery (U-APSD) [TDLS peer U-APSD (TPU)]: A power save mode based on unscheduled service periods that can be used between two stations (STAs) that have set up a TDLS direct link.

tunneled direct-link setup (TDLS) peer unscheduled automatic power save delivery (U-APSD) [TDLS peer U-APSD (TPU)] buffer station (STA): A TDLS peer STA that buffers traffic for a TPU sleep STA.

tunneled direct-link setup (TDLS) peer unscheduled automatic power save delivery (U-APSD) [TDLS peer U-APSD (TPU)] sleep station (STA): A TDLS STA that entered power save mode on a TDLS direct link and that is using TPU for the delivery of buffered traffic.

tunneled direct-link setup (TDLS) power save mode (PSM): TDLS peer PSM or peer unscheduled automatic power save delivery (U-APSD).

tunneled direct-link setup (TDLS) responder station (STA): A STA that receives or is the intended recipient of a TDLS Setup Request frame or TDLS Discovery Request frame.

TVHT_2W mask physical layer (PHY) protocol data unit (PPDU): One of the following PPDUs:

a) A Clause 22 TVHT_2W very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_2W and TXVECTOR parameter FORMAT set to VHT) transmitted using the TVHT_2W transmit spectral mask defined in 22.3.17.1.

b) A Clause 22 TVHT_2W NON_HT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_2W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM) transmitted using the TVHT_2W transmit spectral mask defined in 22.3.17.1.

c) A Clause 22 TVHT_W VHT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W and TXVECTOR parameter FORMAT set to VHT) transmitted using the TVHT_2W transmit spectral mask defined in 22.3.17.1.

d) A Clause 22 TVHT_W NON_HT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM) transmitted using the TVHT_2W transmit spectral mask defined in 22.3.17.1.

TVHT_2W+2W mask physical layer (PHY) protocol data unit (PPDU): One of the following PPDUs:

a) A Clause 22 TVHT_2W+2W very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_2W+2W and TXVECTOR parameter FORMAT set to VHT) transmitted using the TVHT_2W+2W transmit spectral mask defined in 22.3.17.1.

b) A Clause 22 TVHT_2W+2W NON_HT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_2W+2W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM) transmitted using the TVHT_2W+2W transmit spectral mask defined in 22.3.17.1.

c) A Clause 22 TVHT_2W VHT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_2W and TXVECTOR parameter FORMAT set to VHT) transmitted using the TVHT_2W+2W transmit spectral mask defined in 22.3.17.1.

d) A Clause 22 TVHT_2W NON_HT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_2W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter

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NON_HT_MODULATION set to NON_HT_DUP_OFDM) transmitted using the TVHT_2W+2W transmit spectral mask defined in 22.3.17.1.

e) A Clause 22 TVHT_W VHT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W and TXVECTOR parameter FORMAT set to VHT) transmitted using the TVHT_2W+2W transmit spectral mask defined in 22.3.17.1.

f) A Clause 22 TVHT_W NON_HT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM) transmitted using the TVHT_2W+2W transmit spectral mask defined in 22.3.17.1.

TVHT_4W mask physical layer (PHY) protocol data unit (PPDU): One of the following PPDUs:

a) A Clause 22 TVHT_4W very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_4W and TXVECTOR parameter FORMAT set to VHT) transmitted using the TVHT_4W transmit spectral mask defined in 22.3.17.1.

b) A Clause 22 TVHT_4W NON_HT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_4W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM) transmitted using the TVHT_4W transmit spectral mask defined in 22.3.17.1.

c) A Clause 22 TVHT_2W VHT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_2W and TXVECTOR parameter FORMAT set to VHT) transmitted using the TVHT_4W transmit spectral mask defined in 22.3.17.1.

d) A Clause 22 TVHT_2W NON_HT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_2W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM) transmitted using the TVHT_4W transmit spectral mask defined in 22.3.17.1.

e) A Clause 22 TVHT_W VHT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W and TXVECTOR parameter FORMAT set to VHT) transmitted using the TVHT_4W transmit spectral mask defined in 22.3.17.1.

f) A Clause 22 TVHT_W NON_HT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM) transmitted using the TVHT_4W transmit spectral mask defined in 22.3.17.1.

TVHT_MODE_1 physical layer (PHY) protocol data unit (PPDU): One of the following PPDUs: A Clause 22 TVHT_W VHT PPDU or TVHT_W NON_HT PPDU.

TVHT_MODE_2C physical layer (PHY) protocol data unit (PPDU): One of the following PPDUs: A Clause 22 TVHT_2W VHT PPDU or TVHT_2W NON_HT PPDU.

TVHT_MODE_2N physical layer (PHY) protocol data unit (PPDU): One of the following PPDUs: A Clause 22 TVHT_W+W VHT PPDU or TVHT_W+W NON_HT PPDU.

TVHT_MODE_4C physical layer (PHY) protocol data unit (PPDU): One of the following PPDUs: A Clause 22 TVHT_4W VHT PPDU or TVHT_4W NON_HT PPDU.

TVHT_MODE_4N physical layer (PHY) protocol data unit (PPDU): One of the following PPDUs: A Clause 22 TVHT_2W+2W VHT PPDU or TVHT_2W+2W NON_HT PPDU.

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TVHT_W mask physical layer (PHY) protocol data unit (PPDU): One of the following PPDUs:

a) A Clause 22 TVHT_W very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W and TXVECTOR parameter FORMAT set to VHT) transmitted using the TVHT_W transmit spectral mask defined in 22.3.17.1.

b) A Clause 22 TVHT_W NON_HT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM) transmitted using the TVHT_W transmit spectral mask defined in 22.3.17.1.

TVHT_W+W mask physical layer (PHY) protocol data unit (PPDU): One of the following PPDUs:

a) A Clause 22 TVHT_W+W very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W+W and TXVECTOR parameter FORMAT set to VHT) transmitted using the TVHT_W+W transmit spectral mask defined in 22.3.17.1.

b) A Clause 22 TVHT_W+W NON_HT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W+W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM) transmitted using the TVHT_W+W transmit spectral mask defined in 22.3.17.1.

c) A Clause 22 TVHT_W VHT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W and TXVECTOR parameter FORMAT set to VHT) transmitted using the TVHT_W+W transmit spectral mask defined in 22.3.17.1.

d) A Clause 22 TVHT_W NON_HT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM) transmitted using the TVHT_W+W transmit spectral mask defined in 22.3.17.1.

unscheduled service period (SP): The period that is started when a quality-of-service (QoS) station (STA) transmits a trigger frame to the QoS access point (AP).

uplink: A unidirectional link from a non-access point (non-AP) station (STA) to an access point (AP) or a unidirectional link from a non-AP source directional multi-gigabit (DMG) STA to a non-AP destination DMG STA.

upstream network: An integrated local area network (LAN) to which an access point (AP) is connected through a portal.

very high throughput (VHT) basic service set (BSS): A BSS in which a Beacon frame transmitted by a VHT station (STA) includes the VHT Operation element.

very high throughput (VHT) beamformee: A VHT station (STA) that receives a VHT physical layer (PHY) protocol data unit (PPDU) that was transmitted using a beamforming steering matrix and that supports the VHT transmit beamforming feedback mechanism.

very high throughput (VHT) beamformer: A VHT station (STA) that transmits a VHT physical layer (PHY) protocol data unit (PPDU) using a beamforming steering matrix.

very high throughput (VHT) modulation and coding scheme (VHT-MCS): A specification of the VHT physical layer (PHY) parameters that consists of modulation order (e.g., BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM) and forward error correction (FEC) coding rate (e.g., 1/2, 2/3, 3/4, 5/6) and that is used in a VHT PHY protocol data unit (PPDU).

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very high throughput (VHT) multi-user (MU) physical layer (PHY) protocol data unit (PPDU): A VHT PPDU that is capable of carrying up to four PHY service data units (PSDUs) for up to four users and is transmitted using the downlink multi-user multiple input, multiple output (DL-MU-MIMO) technique.

very high throughput (VHT) physical layer (PHY) protocol data unit (PPDU): A Clause 21 PPDU that is not a Clause 17 or Clause 19 PPDU.

very high throughput (VHT) single-user (SU) physical layer (PHY) protocol data unit (PPDU): A VHT PPDU that carries one PHY service data unit (PSDU) for one user and is not transmitted using the downlink multi-user multiple input, multiple output (DL-MU-MIMO) technique.

very high throughput (VHT) single-user-only (SU-only) beamformee: A VHT beamformee that does not receive VHT multi-user (MU) physical layer (PHY) protocol data units (PPDUs).

very high throughput (VHT) single-user-only (SU-only) beamformer: A VHT beamformer that does not transmit VHT multi-user (MU) physical layer (PHY) protocol data units (PPDUs).

white space map (WSM): Information on identified available frequencies that is obtained from a geolocation database (GDB) and that is used by IEEE 802.11 stations (STAs).

wired equivalent privacy (WEP): An obsolete cryptographic data confidentiality algorithm specified by this standard.

wireless network management (WNM) sleep mode: An extended power save mode for non-access-point (non-AP) stations (STAs) whereby a non-AP STA need not listen for every delivery traffic indication map (DTIM) Beacon frame and does not perform group temporal key/integrity group temporal key/beacon integrity group temporal key (GTK/IGTK/BIGTK) updates.

3.3 Definitions specific to IEEE 802.11 operation in some regulatory domains

ISO 3166-1 defines the international two-letter designation for country names, and these designations are included [in square brackets] at the end of each definition that has clear attribution to a regulatory domain.

contact verification signal (CVS): A signal sent by a geolocation database dependent (GDD) enabling station (STA) to validate the list of available frequencies and to verify that the receiving GDD STA is within reception range of the master white space device (WSD) [US].

personal/portable station (STA): A STA that uses network communications at unspecified locations [US].

television band device (TVBD): An intentional radiator that operates on an unlicensed basis on available channels in the broadcast television frequency bands [US].

white space device (WSD): An entity that employs cognitive facilities to use white space spectrum without causing harmful interference to protected services [EU].

3.4 Acronyms and abbreviations

3GPP	3rd Generation Partnership Project
40MC	40-MHz-capable
802.x LAN	IEEE 802-based local area networks such as IEEE Std 802.3 and IEEE Std 802.11
AA	authenticator address
AAA	authentication, authorization, and accounting

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AAD	additional authentication data
AAI	administratively assigned identifier
A-BFT	association beamforming training
A-BI	awake beacon interval
AC	access category
ACI	access category index
Ack	acknowledgment
ACM	admission control mandatory
ACU	admission control unit
ADDBA	add block acknowledgment
ADDTS	add traffic stream
ADE	AID with differential encoding
AEAD	authenticated encryption with associated data
AES	advanced encryption standard
AES-128-CMAC	advanced encryption standard (with 128-bit key) cipher-based message authentication code
AFC	automatic frequency control
AGC	automatic gain control
AID	association identifier
AIFS	arbitration interframe space
AIFSN	arbitration interframe space number
AKM	authentication and key management
AKMP	authentication and key management protocol
A-MPDU	aggregate MAC protocol data unit
AMPE	authenticated mesh peering exchange
A-MSDU	aggregate MAC service data unit
ANIPI	average noise plus interference power indicator
ANO	access network options
ANonce	authenticator nonce
ANPI	average noise power indicator
ANQP	access network query protocol
AP	access point
AP-CSN	AP configuration sequence number
APSD	automatic power save delivery
ARP	Address Resolution Protocol
AS	authentication server
ASEL	antenna selection
ASN.1	Abstract Syntax Notation One
ASRA	additional step required for access
ATI	announcement transmission interval
ATIM	announcement traffic indication message
AV	audio video
AWV	antenna weight vector
BA	block acknowledgment
BAR	block acknowledgment request
BAT	block acknowledgment TWT

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BC	beam combining
BCC	binary convolutional code
BCU	basic channel unit
BDT	bidirectional TXOP
BF	beamforming
BHI	beacon header interval
BIP	broadcast/multicast integrity protocol
BIGTK	beacon integrity group temporal key
BIGTKSA	beacon integrity group temporal key security association
BIPN	BIGTK packet number
BPN	base packet number
BPSK	binary phase shift keying
BRP	beam refinement protocol
BRPIFS	beam refinement protocol interframe space
BSA	basic service area
BSS	basic service set
BSSID	basic service set identifier
BT	bit time
BTI	beacon transmission interval
BU	bufferable unit
BW	bandwidth
CA	certificate authority
CAC	centralized authentication controller (for access points) or controlled (for stations)
CAG	Common Advertisement Group
CAP	controlled access phase
CAQ	channel availability query
CBAP	contention based access period
CBC	cipher-block chaining
CBC-MAC	cipher-block chaining message authentication code
CBP	contention based protocol
CCA	clear channel assessment
CCK	complementary code keying
CCM	CTR with CBC-MAC
CCMP	CTR with CBC-MAC Protocol
CCSR	centralized coordination service root
CCSS	centralized coordination service set
CDMG	China directional multi-gigabit
CEF	channel estimation field
CF	contention free
CID	Company ID
CMMG	China millimeter-wave multi-gigabit
C-MPDU	coded MPDU
C-PSDU	coded PSDU
CRC	cyclic redundancy code
CS	carrier sense
CSD	cyclic shift diversity

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CSI	channel state information
CSM	channel schedule management
CSMA/CA	carrier sense multiple access with collision avoidance
CTR	counter mode
CTS	clear to send
CTS1	clear to send 1
CTS2	clear to send 2
CVS	contact verification signal
CW	contention window
DA	destination address
DBC	dynamic bandwidth control
D-BI	doze beacon interval
DBPSK	differential binary phase shift keying
DCF	distributed coordination function
DCLA	dc level adjustment
DCS	dynamic channel selection
DEI	drop eligibility indicator
DELBA	delete block acknowledgment
DELTS	delete traffic stream
DFS	dynamic frequency selection
DFT	discrete Fourier transform
DIFS	distributed (coordination function) interframe space
DILS	differentiated initial link setup
DLL	data link layer
DL-MU-MIMO	downlink multi-user multiple input, multiple output(
DLTF	Data Long Training field
DMG	directional multi-gigabit
DMS	directed multicast service
DMSID	directed multicast service identifier
DN	destination network
DO	DFS owner
DQPSK	differential quadrature phase shift keying
DR	data rate
DS	distribution system
DSAF	distribution system access function
DSCP	differentiated services code point
DSE	dynamic station enablement
DSM	distribution system medium
DSS	distribution system service
DSSS	direct sequence spread spectrum
DST	daylight saving time
DTI	data transfer interval
DTIM	delivery traffic indication map
EAP	Extensible Authentication Protocol (IETF RFC 3748)
EAPOL	Extensible Authentication Protocol over LANs (IEEE Std 802.1X-2010)
EAP-RP	EAP reauthentication protocol

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EAS	emergency alert system
EBR	expedited bandwidth request
ECAPC	extended centralized AP or PCP cluster
ECS	extended channel switching
ED	energy detection
EDCA	enhanced distributed channel access
EDCAF	enhanced distributed channel access function
EDT	eastern daylight time
EHCC	extended hyperbolic congruence code
EIFS	extended interframe space
EIRP	equivalent isotropically radiated power
EL	energy limited
ELI	extended local identifier
ELTF	Extension Long Training field
EOF	end-of-frame
EOM	end of multi-user
EOSP	end of service period
EPD	Ethertype Protocol Discrimination (IEEE Std 802)
ERP	extended rate PHY
ERP-CCK	extended rate PHY using CCK modulation
ERP-DSSS	extended rate PHY using DSSS modulation
ERP-DSSS/CCK	extended rate PHY using DSSS or CCK modulation
ERP-OFDM	extended rate PHY using OFDM modulation
ESA	extended service area
ESP	estimated service parameters
ESR	emergency services reachable
ESS	extended service set
EST	eastern standard time
EVM	error vector magnitude
FCS	frame check sequence
FD	FILS discovery
FD-AF	full-duplex amplify-and-forward
FEC	forward error correction
FER	frame error ratio
FFC	finite field cryptography
FFE	finite field element
FFT	Fast Fourier Transform
FIFO	first in first out
FILS	fast initial link setup
FMS	flexible multicast service
FMSID	flexible multicast stream identifier
FOV	field of view
FSM	finite state machine
FST	fast session transfer
FSTS	fast session transfer session
FT	fast BSS transition

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FTAA	fast BSS transition authentication algorithm
FTE	fast BSS transition element
FTM	fine timing measurement
FTO	fast BSS transition originator
GANN	gate announcement
GAS	generic advertisement service
GATS	group addressed transmission service
GCM	Galois/counter mode
GCMP	Galois/Counter Mode Protocol
GCR	groupcast with retries
GCR-A	groupcast with retries active
GCR-SP	groupcast with retries service period
GDB	geolocation database
GDD	geolocation database dependent
GFSK	Gaussian frequency shift key or keying
GI	guard interval
GID	group identifier
GLK	general link
GLK-GCR	general link groupcast with retries
GMK	group master key
GNonce	group nonce
GP	grant period
GPRS	general packet radio service
GPS	Global Positioning System
GQMF	group addressed quality-of-service Management frame
GTK	group temporal key
GTKSA	group temporal key security association
HC	hybrid coordinator
HCC	hyperbolic congruence code
HCCA	HCF controlled channel access
HCF	hybrid coordination function
HD-DF	half-duplex decode-and-forward
HEC	header error check
HELD	HTTP-enabled location delivery
HEMM	HCCA, EDCA mixed mode
HESSID	homogeneous extended service set identifier
HIPERLAN	high-performance radio local area network
HLP	higher layer protocol
HPA	high power amplifier
HR/DSSS	high rate direct sequence spread spectrum using the long preamble and header
HR/DSSS/short	high rate direct sequence spread spectrum using the optional short preamble and header mode
HT	high-throughput
HTC	high-throughput control
HT-GF-STF	high-throughput Greenfield Short Training field
HT-SIG	high-throughput SIGNAL field

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HT-STF	high-throughput Short Training field
HTTP	hyptertext transfer protocol
HTTPS	hyptertext transfer protocol secure
HWMP	hybrid wireless mesh protocol
IBSS	independent basic service set
ICK	integrity check key
ICMP	Internet Control Message Protocol
ICV	integrity check value
IDFT	inverse discrete Fourier transform
IFFT	inverse Fast Fourier Transform
IFS	interframe space
IGTK	integrity group temporal key
IGTKSA	integrity group temporal key security association
IMp	intermodulation protection
INonce	initiator nonce
IPI	idle power indicator
IPN	IGTK packet number
I/Q	in phase and quadrature
IQMF	individually addressed quality-of-service Management frame
ISM	industrial, scientific, and medical
ISS	initiator sector sweep
IUT	implementation under test
IV	initialization vector
KCK	EAPOL-Key confirmation key
KDE	key data encapsulation
KDF	key derivation function
KEK	EAPOL-Key encryption key
LAN	local area network
LBIFS	long beamforming interframe space
LCI	location configuration information
LDPC	low-density parity check
LFSR	linear feedback shift register
LGR	legendre symbol
LLC	logical link control
L-LTF	non-HT Long Training field
LME	layer management entity
LNA	low noise amplifier
LP	low power
LPD	LLC Protocol Discrimination (IEEE Std 802)
LRC	long retry count
LSB	least significant bit
L-SIG	non-HT SIGNAL field
L-STF	non-HT Short Training field
LTF	Long Training field
MAC	medium access control
MAC_I	initiator mac address

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MAC_P	peer mac address
MAD	maximum away duration
MAF	MCCA access fraction
MBCA	mesh beacon collision avoidance
MBIFS	medium beamforming interframe space
MBSS	mesh basic service set
MCCA	MCF controlled channel access
MCCAOP	MCF controlled channel access opportunity
MCF	mesh coordination function
MCS	modulation and coding scheme
MDE	Mobility Domain element
MDID	mobility domain identifier
MFB	MCS feedback
MFPC	management frame protection capable
MFPR	management frame protection required
MFSI	MCS feedback sequence identifier
MGTK	mesh group temporal key
MIB	management information base
MIC	message integrity code
MID	multiple sector identifier
MIDC	multiple sector identifier capture
MIMO	multiple input, multiple output
MIS	media independent service
MLME	MAC sublayer management entity
MLPP	multi-level precedence and preemption
MME	Management MIC element
MMPDU	MAC management protocol data unit
MMS	multiple MAC sublayers
MMSL	multiple MAC sublayers link
MM-SME	multiple MAC station management entity
MPDU	MAC protocol data unit
MPM	mesh peering management
MRQ	MCS request
MSB	most significant bit
MSDU	MAC service data unit
MSGCF	MAC state generic convergence function
MSI	MRQ sequence identifier
MSK	master session key
MS SAP	method specific service access point
MTK	mesh temporal key
MU	multi-user
MU-MIMO	multi-user multiple input, multiple output
N/A	not applicable
NAI	network access identifier
NAS	network access server
NAV	network allocation vector

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NCC	network channel control
NDP	null data PPDU
non-ERP	nonextended rate PHY
NSS	number of spatial streams
NTP	Network Time Protocol (IETF RFC 5905 [B46])
OBSS	overlapping basic service set
OCB	outside the context of a BSS
OCEF	OFDM channel estimation field
OCI	operating channel information
OCT	on-channel tunneling
OCVC	operating channel validation capable
OFDM	orthogonal frequency division multiplexing
OI	organization identifier
OLB	offset length bitmap
OSI	Open Systems Interconnection (ISO/IEC 7498-1:1994)
OSTF	OFDM short training field
OUI	Organizationally Unique Identifier
PAD	preassociation discovery
PAE	port access entity (IEEE Std 802.1X-2010)
PBAC	protected block ack agreement capable
PBSS	personal basic service set
PCP	PBSS control point
PCPS	PBSS control point service
PDU	protocol data unit
PER	packet error ratio
PERR	path error
PFS	perfect forward secrecy
PHB	per-hop behavior
PHY	physical layer
PHYCS	PHY carrier sense
PHYED	PHY energy detection
PICS	protocol implementation conformance statement
PIFS	priority interframe space
PLME	physical layer management entity
PLW	PSDU length word
PMK	pairwise master key
PMKID	pairwise master key identifier
PMK-R0	pairwise master key, first level
PMK-R1	pairwise master key, second level
PMKSA	pairwise master key security association
PN	packet number
PN	pseudonoise (code sequence)
PNonce	peer nonce
PP	polling period
PP A-MSDU	payload protected aggregate MAC service data unit
PPDU	PHY protocol data unit

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PRAW	periodic restricted access window
PREP	path reply
PREQ	path request
PRF	pseudorandom function
PRNG	pseudorandom number generator
PS	power save (mode)
PSAP	public safety answering point
PSDU	PHY service data unit
PSF	PHY Signaling field
PSK	preshared key
PSM	power save mode
PSMP	power save multi-poll
PSMP-DTT	power save multi-poll downlink transmission time
PSMP-UTT	power save multi-poll uplink transmission time
PTI	peer traffic indication
PTK	pairwise transient key
PTKSA	pairwise transient key security association
PTP	peer-to-peer
PV0	protocol version 0
PV1	protocol version 1
PWE	password element of an ECC group
PXU	proxy update
PXUC	proxy update confirmation
QAB	quieting adjacent BSS
QACM	QMF access category mapping
QAM	quadrature amplitude modulation
QBPSK	quadrature binary phase shift keying
QMF	quality-of-service Management frame
QoS	quality of service
QPSK	quadrature phase shift keying
QSRC	QoS STA retry count
R0KH	PMK-R0 key holder in the Authenticator
R0KH-ID	PMK-R0 key holder identifier in the Authenticator
R1KH	PMK-R1 key holder in the Authenticator
R1KH-ID	PMK-R1 key holder identifier in the Authenticator
RA	receiver address or receiving station address
RADIUS	remote authentication dial-in user service (IETF RFC 2865 [B33])
RANN	root announcement
RAV	resource allocation vector
RAW	restricted access window
RCPI	received channel power indicator
RD	reverse direction
RDE	RIC Data element
RDG	reverse direction grant
RDS	relay DMG STA
REDS	relay endpoint DMG STA

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RF	radio frequency
RFC	request for comments
RIC	resource information container
RID	response indication deferral
RIFS	reduced interframe space
RLAN	radio local area network
RLQP	registered location query protocol
RLS	relay link setup
RLSS	registered location secure server
ROC	relay operation type change
RPI	receive power indicator
RPS	RAW parameter set
RRB	remote request broker
RSC	receive sequence counter
RSN	robust security network
RSNA	robust security network association
RSNE	Robust Security Network element
RSNI	received signal-to-noise indicator
RSNXE	Robust Security Network Extension element
RSPI	receiver service period initiated
RSS	responder sector sweep
RSSI	receive signal strength indicator
RTS	request to send
RTT	round trip time
RX	receive or receiver
RXASSI	receive antenna selection sounding indication
RXASSR	receive antenna selection sounding request
RXSS	receive sector sweep
S0KH	PMK-R0 key holder in the Supplicant
S0KH-ID	PMK-R0 key holder identifier in the Supplicant
S1G	sub 1 GHz
S1KH	PMK-R1 key holder in the Supplicant
S1KH-ID	PMK-R1 key holder identifier in the Supplicant
SA	source address
SAE	simultaneous authentication of equals
SAI	standard assigned identifier
S-AP	synchronization access point
SAP	service access point
S-APSD	scheduled automatic power save delivery
SA Query	security association query
SBBI	small band beacon interval
SBIFS	short beamforming interframe space
SC	single carrier
SCA	secondary channel above
SCB	secondary channel below
SCEF	single carrier channel estimation field

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SCN	no secondary channel
SCS	stream classification service
SCSID	stream classification service identifier
SDL	specification and description language
SDU	service data unit
SEMM	SPCA-EDCA mixed mode
SFD	start frame delimiter
SI	service interval
SIC	service information client
SID	short identifier
SIFS	short interframe space
SIR	service information registry
SLAP	structured local address plan
SLRC	station long retry count
SLS	sector-level sweep
SM	spatial multiplexing
SME	station management entity
S-MPDU	single MAC protocol data unit
SMT	station management
SN	sequence number
SNAP	Sub-Network Access Protocol
SNonce	supplicant nonce
SNR	signal-to-noise ratio
SP	service period
SPA	supplicant address
SPCA	service period channel access
S-PCP	synchronization PBSS control point
SPP A-MSDU	signaling and payload protected aggregate MAC service data unit
SPR	service period request
SPSH	spatial sharing
SQ	signal quality (PN code correlation strength)
SRC	short retry count
SS	station service
SSID	service set identifier
SSP	subscription service provider
SSPN	subscription service provider network
SSRC	station short retry count
SST	subchannel selective transmission
SSW	sector sweep
STA	station
STACK	short TWT acknowledgment
STBC	space-time block coding
STF	Short Training field
STS	space-time stream
STT	selective translation table
SU	single-user

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SU-MIMO	single-user multiple input, multiple output
SYNC	synchronization
SYNRA	synthetic receiver address
TA	transmitter address or transmitting station address
TACK	TWT acknowledgment
TAI	Temps Atomique International (International Atomic Time)
TBTT	target beacon transmission time
TC	traffic category
TCLAS	traffic classification
TDDTI	time division data transfer interval
TDLS	tunneled direct-link setup
TFS	traffic filtering service
TID	traffic identifier
TIE	Timeout Interval element
TIM	traffic indication map
TK	temporal key
TKIP	temporal key integrity protocol
TLV	type/length/value
TMPTT	target measurement pilot transmission time
TOA	time of arrival
TOD	time of departure
TPA	transmission time-point adjustment
TPC	transmit power control
TPK	TDLS PeerKey
TPKSA	TDLS PeerKey security association
TPU	TDLS peer U-APSD
TRN-R	receive training
TRN-T	transmit training
TRQ	training request
TS	traffic stream
TSBTT	target short beacon transmission time
TSC	TKIP sequence counter
TSF	timing synchronization function
TSID	traffic stream identifier
TSN	transition security network
TSPEC	traffic specification
TTAK	TKIP-mixed transmitter address and key
TTL	time to live
TTP	trusted third party
TTTT	target TIM transmission time
TU	time unit
TVHT	television very high throughput
TVWS	television white spaces
TWT	target wake time
TX	transmit or transmitter
TXASSI	transmit antenna selection sounding indication

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TXASSR	transmit antenna selection sounding request
TXE	transmit enable
TXOP	transmission opportunity
TXSS	transmit sector sweep
U-APSD	unscheduled automatic power save delivery
UCT	unconditional transition
UESA	unauthenticated emergency service accessible
ULS	Universal Licensing System
U-NII	unlicensed national information infrastructure
UP	user priority
UPSIM	unscheduled power save indication map
URI	Uniform Resource Identifier
URL	Universal Resource Locator
URN	Uniform Resource Name
UTC	Coordinated Universal Time
VHT	very high throughput
VLAN	virtual local area network
VoIP	voice over Internet Protocol (IP)
WEP	wired equivalent privacy
WLAN	wireless local area network
WM	wireless medium
WNM	wireless network management
WS	wakeup schedule
WSM	white space map
ZCZ	zero correlation zone

3.5 Acronyms and abbreviations in some regulatory domains

ISO 3166-1 defines the international two-letter designation for country names, and these designations are included [in square brackets] at the end of each abbreviation that has clear attribution to a regulatory domain.

PLMR/CRS	private land mobile radio/cellular radio service [US]
TVBD	television band device [US]
WSD	white space device [EU]

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4. General description

4.1 General description of the architecture

This clause presents the concepts and terminology used within this standard. Specific terms are defined in Clause 3. Illustrations convey key IEEE 802.11 concepts and the interrelationships of the architectural components. IEEE Std 802.11 uses an architecture to describe functional components of an IEEE 802.11 LAN. The architectural descriptions are not intended to represent any specific physical implementation of IEEE Std 802.11.

4.2 How wireless local area networks (WLANs) are different

4.2.1 Introduction

Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs.

4.2.2 Wireless station (STA)

In the design of wired LANs it is implicitly assumed that an address is equivalent to a physical location. In wireless networks, this is not always the case. In IEEE Std 802.11, the addressable unit is a station (STA). Physical and operational characteristics are defined by modifiers that are placed in front of the term STA. For example, in the case of location and mobility, the addressable units are the fixed STA, the portable STA, and the mobile STA. The STA is an addressable destination, but not (in general) a fixed location.

A STA might take on multiple distinct characteristics, each of which shape its function. For example, a single addressable unit might simultaneously be a portable STA, a quality-of-service (QoS) STA, a dependent STA, and a hidden STA.

4.2.3 Media impact on design and performance

The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs:

a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with PHY transceivers are known to be unable to receive network frames
b) Are unprotected from other signals that are sharing the medium
c) Communicate over a medium significantly less reliable than wired PHYs
d) Have dynamic topologies
e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs might be “hidden” from each other)
f) Have time-varying and asymmetric propagation properties
g) Might experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances can be built from basic coverage building blocks. When providing QoS services, the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees are possible.

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4.2.4 The impact of handling mobile STAs

One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is used only while at a fixed location. *Mobile* STAs access the LAN while in motion.

For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.

Mobile STAs typically are battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver is always powered on.

4.2.5 Interaction with other IEEE 802® layers

IEEE Std 802.11 is required to appear to higher layers [logical link control (LLC) sublayer] as a general-purpose IEEE 802 LAN. This requires that the IEEE 802.11 network handle STA mobility within the MAC sublayer. To meet reliability assumptions (that LLC makes about lower layers), it is necessary for IEEE Std 802.11 to incorporate functionality that is untraditional for MAC sublayers.

In a robust security network association (RSNA), IEEE Std 802.11 provides functions to protect Data frames, IEEE Std 802.1X-2010 provides authentication and a Controlled Port, and IEEE Std 802.11 and IEEE Std 802.1X-2010 collaborate to provide key management. All STAs in an RSNA have a corresponding IEEE 802.1X entity that handles these services. This standard defines how an RSNA utilizes IEEE Std 802.1X-2010 to access these services. Within IEEE Std 802.11, EAPOL PDUs are carried as MSDUs within one or more Data frames, as described in Clause 12 of IEEE Std 802.1X-2010. Within this standard, Data frames used for this purpose are generally referred to as *EAPOL-Key frames*, *EAPOL-Key request frames*, and *EAPOL-Start frames*.

When used to support applications that have QoS requirements, each IEEE 802.11 LAN provides a link within an end-to-end QoS environment that can be established between, and managed by, higher layer entities. To handle QoS traffic in a manner comparable to other IEEE 802 LANs, the IEEE 802.11 QoS facility requires the IEEE 802.11 MAC sublayers to incorporate functionality that is not traditional for MAC sublayers. In addition, it might be necessary for certain higher layer management entities to be "WLAN aware" at least to the extent of understanding that the available bandwidth and other QoS characteristics of a WLAN are subject to frequent, and sometimes substantial, dynamic changes due to causes other than traffic load and are outside the direct control of network management entities.

4.2.6 Interaction with non-IEEE-802 protocols

An RSNA utilizes non-IEEE-802 protocols for its authentication and key management (AKM) services. Some of these protocols are defined by other standards organizations, such as the Internet Engineering Task Force (IETF).

4.3 Components of the IEEE 802.11 architecture

4.3.1 General

The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers.

The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 4-1 shows two BSSs, each of which has two STAs that are members of the BSS.

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It is useful to think of each oval depicting a BSS as the coverage area within which the member STAs of the BSS can remain in communication. In the case of transmissions such as in a directional multi-gigabit (DMG) BSS, the individual coverage area of a transmission from one member STA to another can be thought of as a cone and hence is referred to as a *directional transmission*. The collection of all possible directional transmissions by a member STA defines the coverage area. (The concept of area, while not precise, is often good enough.) This area is called the *Basic Service Area (BSA)*. If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.

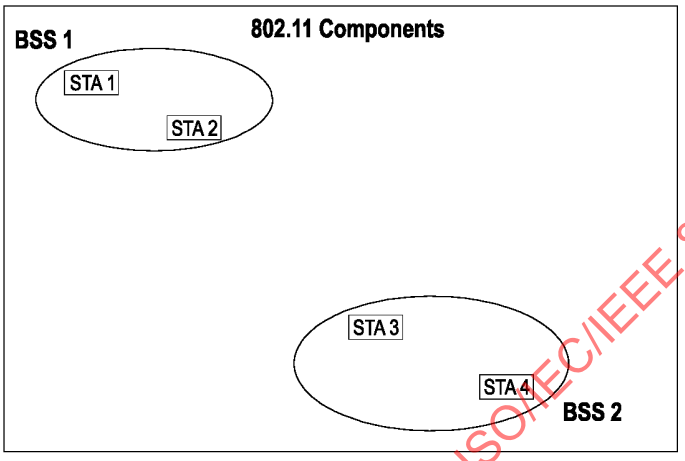

Figure 4-1—BSSs

4.3.2 Independent BSS (IBSS)

The IBSS is the most basic type of IEEE 802.11 LAN. Since the BSSs shown in Figure 4-1 are simple and lack other components (contrast this with Figure 4-2), the two can be taken to be representative of two IBSSs.

This mode of operation is possible when IEEE 802.11 STAs are able to communicate directly. This type of IEEE 802.11 LAN is often formed without preplanning.

4.3.3 Personal BSS (PBSS)

Similar to the IBSS, the PBSS is a type of IEEE 802.11 LAN in which STAs communicate directly with each other.

In contrast to the IBSS, in the PBSS one STA assumes the role of the PBSS control point (PCP). The PCP provides the basic timing for the PBSS through DMG Beacon and Announce frames as well as allocation of service periods and contention based access periods.

A PBSS can be established only by DMG STAs. Not every DMG BSS is a PBSS. A DMG BSS can be a PBSS, an infrastructure BSS, or an IBSS.

4.3.4 STA membership in a BSS is dynamic

A STA's membership in a BSS is dynamic (STAs turn on, turn off, come within range, and go out of range). To become a member of an infrastructure BSS or an IBSS, a STA joins the BSS using the synchronization procedure described in 11.1.4.5. To start a new mesh BSS or to become a member of a mesh BSS, a STA starts the transmission of Beacon frames and performs the synchronization maintenance procedure described in 14.13. To access all of the services of an infrastructure BSS, a STA becomes "associated." These

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associations are dynamic and involve the use of the distribution system service (DSS), which is described in 4.4.4. A mesh STA does not become associated as there is no central entity in a mesh BSS (MBSS). Instead, a mesh STA peers with other mesh STAs.

4.3.5 Distribution system (DS) concepts

4.3.5.1 Overview

PHY limitations determine the direct station-to-station distance that is supported. For some networks this distance is sufficient; for other networks, increased coverage is required.

Instead of existing independently, an infrastructure BSS might also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect infrastructure BSSs is the DS for non-general link (non-GLK) operation. The DS and extended service set (ESS) are mechanisms for expanding connectivity for non-GLK operation. For GLK operation, an IEEE 802.1Q™ bridge might be used to form an extended network (see 4.3.28).

IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.

Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.

The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.

An access point (AP) is any entity that has STA functionality and a distribution system access function (DSAF), which enables access to the DS, via the WM for associated STAs.

Figure 4-2 adds the DS, DSM, and AP components to the IEEE 802.11 architecture picture.

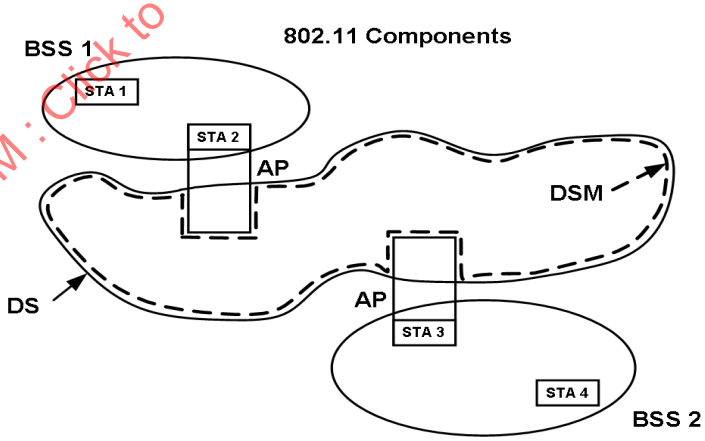

Figure 4-2—DSs and APs

Data move between a BSS and the DS via the DSAF in an AP. An AP contains a STA and is addressable on the WM using its STA address. The addresses used by an AP for communication on the WM and on the DSM are not necessarily the same.

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Data sent to the AP's STA address by one of the STAs associated with it are always received at the uncontrolled port for processing by the IEEE 802.1X port access entity. In addition, if the controlled port is authorized, these frames conceptually transit the DS.

4.3.5.2 Extended service set (ESS): the large coverage network

The DS and infrastructure BSSs allow IEEE Std 802.11 to create a wireless network of arbitrary size and complexity. IEEE Std 802.11 refers to this type of network as the ESS. An ESS is the union of the infrastructure BSSs with the same SSID connected by a DS. The ESS does not include the DS.

The key concept is that the ESS appears the same to an LLC layer as an IBSS. STAs within an ESS can communicate and mobile STAs might move from one BSS to another (within the same ESS) transparently to LLC.

Owing to its distributed nature, a mesh BSS (MBSS) has no central entity like the AP of an infrastructure BSS. Instead, an MBSS forms a single set of independent mesh STAs. This set is indivisible and cannot be further unified. The ESS concept does not apply to the MBSS. However, it is possible to use a Mesh BSS as all or part of the DS that connects an ESS.

Nothing is assumed by IEEE Std 802.11 about the relative physical locations of the BSSs in Figure 4-3.

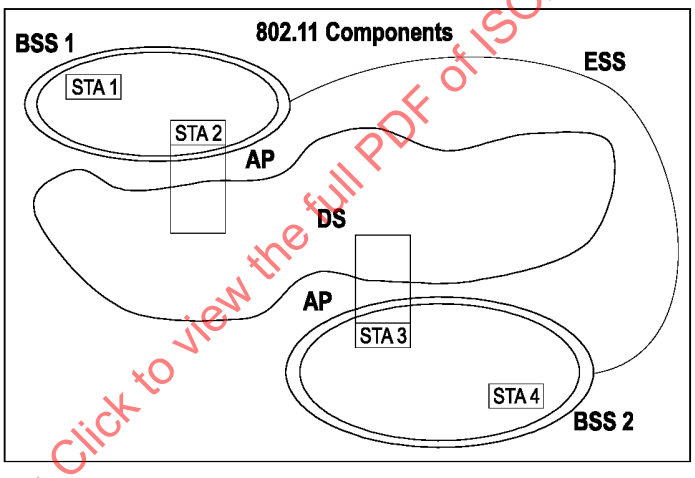

Figure 4-3—ESS

All of the following are possible:

a) The BSSs partially overlap. This is commonly used to arrange coverage within a physical volume.
b) The BSSs could be physically disjoint. Logically there is no limit to the distance between BSSs.
c) The BSSs are physically collocated. This could be done to provide redundancy.
d) One (or more) IBSSs or ESSs are physically present in the same location as one (or more) ESSs. This could arise for a number of reasons. Some examples are when an IBSS is operating in a location that also has an ESS, when physically overlapping IEEE 802.11 networks have been set up by different organizations, and when two or more different access and security policies are needed in the same location.

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4.3.6 Area concepts

For wireless PHYs, well-defined coverage areas simply do not exist. Propagation characteristics are dynamic and unpredictable. Small changes in position or direction might produce dramatic differences in signal strength. Similar effects occur whether a STA is stationary or mobile (as moving objects might impact station-to-station propagation).

Figure 4-4 shows a signal strength map for a simple square room with a standard metal desk and an open doorway. This figure is a static snapshot; the propagation patterns change dynamically as STAs and objects in the environment move. The dark (solid) blocks in the lower left are a metal desk and there is a doorway at the top right of the figure. The figure indicates relative differences in field strength with different intensities and indicates the variability of field strength even in a static environment. The difference between the greatest signal strength and the least signal strength in this figure is 50 dB.

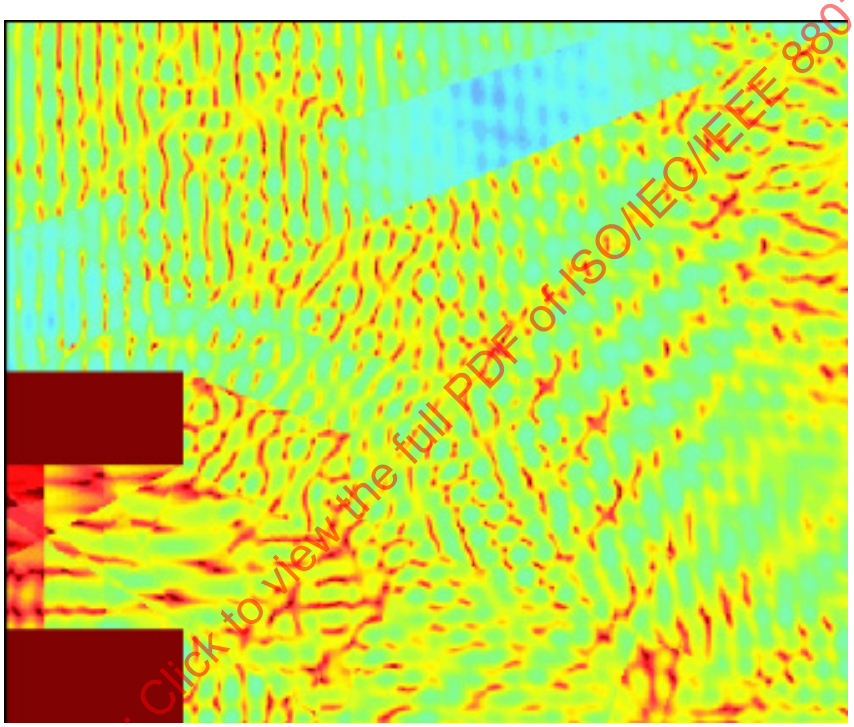

Figure 4-4—A representative signal intensity map

While the architecture diagrams show sharp boundaries for BSSs, this is an artifact of the pictorial representation, not a physical reality. Because dynamic three-dimensional field strength pictures are difficult to draw, well-defined shapes are used by IEEE 802.11 architectural diagrams to represent the coverage of a BSS.

Further description difficulties arise when attempting to describe collocated coverage areas. Consider Figure 4-5, in which STA 6 could belong to BSS 2 or BSS 3.

While the concept of sets of STAs is correct, it is often convenient to talk about areas. For many topics the concept of area is sufficient. *Volume* is a more precise term than area, though still not technically correct. For historical reasons and convenience, this standard uses the common term *area*.

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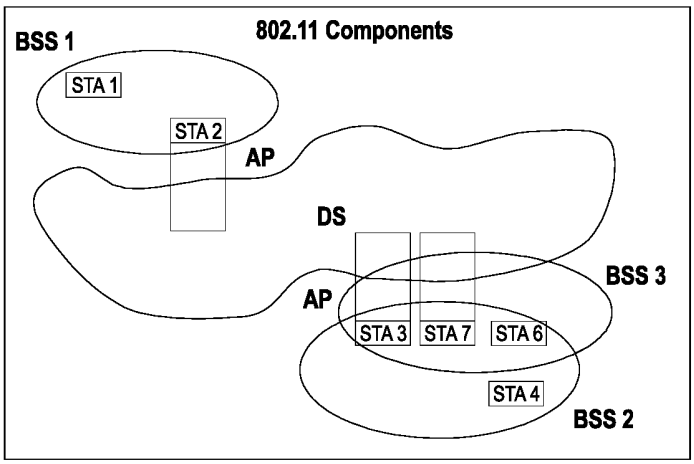

Figure 4-5—Collocated coverage areas

4.3.7 Integration with non-IEEE-802.11 LANs

To integrate the IEEE 802.11 non-GLK architecture with a non-IEEE-802.11 LAN, including a traditional wired LAN, a final logical architectural component is introduced—a *portal*. The IEEE 802.11 GLK architecture (see 4.3.28) does not include the concept of a portal.

A portal is the logical point at which the integration service is provided. All data from or to non-IEEE-802.11 LANs enter or leave the IEEE 802.11 architecture via a portal. The integration service is responsible for any addressing changes or other logical mappings that might be required when MSDUs pass between the DS and the integrated LAN. It is possible for one device to offer both the functions of an AP and a portal. For example, a portal to a wired IEEE 802 LAN is shown in Figure 4-6.

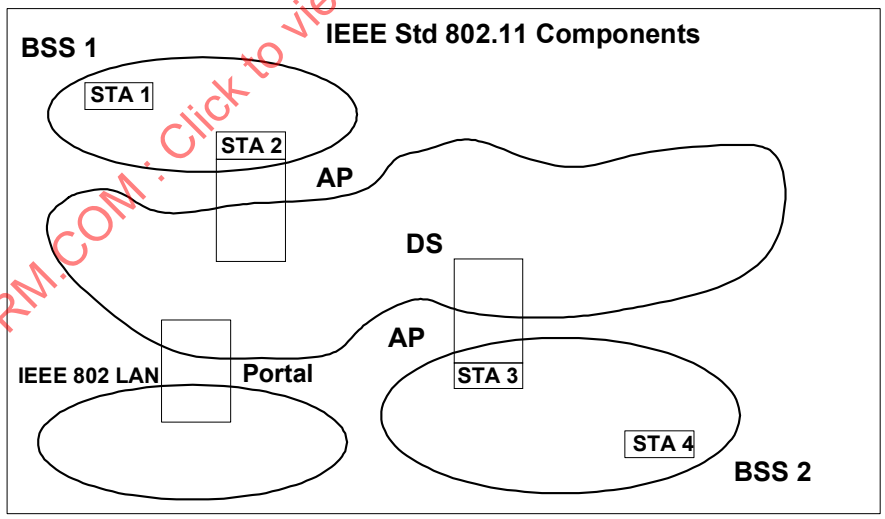

Figure 4-6—Connecting to other IEEE 802 LANs

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4.3.8 Robust security network association (RSNA)

The following features are defined for an RSNA:

- Enhanced authentication mechanisms for STAs
- Key management algorithms
- Cryptographic key establishment
- Enhanced data cryptographic encapsulation mechanisms, such as counter mode with cipher-block chaining message authentication code protocol (CCMP), Galois/counter mode protocol (GCMP), and, optionally, temporal key integrity protocol (TKIP)
- Fast basic service set (BSS) transition (FT) mechanism
- Enhanced cryptographic encapsulation mechanisms for robust Management frames

An RSNA might rely on components external to the IEEE 802.11 architecture.

The first component is an IEEE 802.1X port access entity (PAE). PAEs are present on all STAs in an RSNA and control the forwarding of data to and from the medium access control (MAC). An AP always implements the Authenticator PAE and Extensible Authentication Protocol (EAP) Authenticator roles, and a non-AP STA always implements the Supplicant PAE and EAP peer roles. In an IBSS or PBSS, each STA implements both the Authenticator PAE and Supplicant PAE roles and both EAP Authenticator and EAP peer roles.

A second component is the Authentication Server (AS). The AS authenticates the elements of the RSNA itself, i.e., the STAs provide material that the RSNA elements use to authenticate each other. The AS communicates through the IEEE 802.1X Authenticator with the IEEE 802.1X Supplicant on each STA, enabling the STA to be authenticated to the AS and vice versa. An RSNA depends upon the use of an EAP method that supports mutual authentication of the AS and the STA, such as those that meet the requirements in IETF RFC 4017. In certain applications, the AS might be integrated into the same physical device as the AP, or into a STA in an IBSS or PBSS.

In some applications, there is no need for a PAE or AS, and a STA and AP, or two IBSS STAs, or two mesh STAs in an MBSS, might authenticate each other using a password.

An RSNA using fast BSS transition relies on an external protocol to distribute keys between the pairwise master key (PMK) R0 key holder (R0KH) and PMK-R1 key holder (R1KH) Authenticator components. The requirements for this protocol are described in 13.2.2.

4.3.9 Centralized coordination service set (CCSS) and extended centralized AP or PCP clustering (ECAPC)

AP or PBSS control point (PCP) clustering is a protocol between a DMG synchronization AP or DMG synchronization PCP (S-AP or S-PCP) and other APs and PCPs within the cluster, known as member APs and PCPs. This protocol is used to improve spatial sharing and interference mitigation among the DMG BSSs of the S-AP or S-PCP and member APs and PCPs. AP or PCP clustering allows an AP or PCP within a cluster to schedule transmissions in nonoverlapping time periods with respect to other APs and PCPs that are in the same cluster. There are two types of clustering:

- In decentralized AP or PCP clustering, there is a single S-AP or S-PCP in the BSA of the S-AP or S-PCP.
- In centralized AP or PCP clustering, there can be multiple S-APs in the BSA of any one S-AP and all S-APs are coordinated via a single centralized coordination service set (CCSS).

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A CCSS comprises a centralized coordination service root (CCSR) and a set of one or more synchronization APs that while operating are stationary with respect to their local environment and are connected to the CCSR via, for instance, one of the following:

— The DS to an AP (or beyond, to a STA associated to the AP)
— A combination of distribution system, portal, and external network

The CCSR provides coordination services for the CCSS, such as selecting the target beacon transmission time of S-APs within the CCSS to minimize interference. The CCSR might logically reside within an S-AP or in another entity as long as it has a globally administered MAC address. A CCSS is suited to an area and a frequency band having the following propagation characteristics:

— The BSAs of the S-APs within the CCSS cover the area, and
— Transmissions within the area are isolated to a high degree.

An extended centralized AP or PCP cluster (ECAPC) comprises a single CCSS and an accompanying set of centralized AP or PCP clusters. Each S-AP of one of the centralized AP or PCP clusters is inside the CCSS. The ECAPC also includes all STAs in the BSSs of the S-APs and member APs and PCPs of the centralized AP or PCP clusters. An example is shown in Figure 4-7, in which:

— STA3a and STA3b are two STAs coordinated by a one MM-SME component.
— STA4a and STA4b are two STAs coordinated by a second MM-SME component.
— The CCSR happens to be located in an external network.

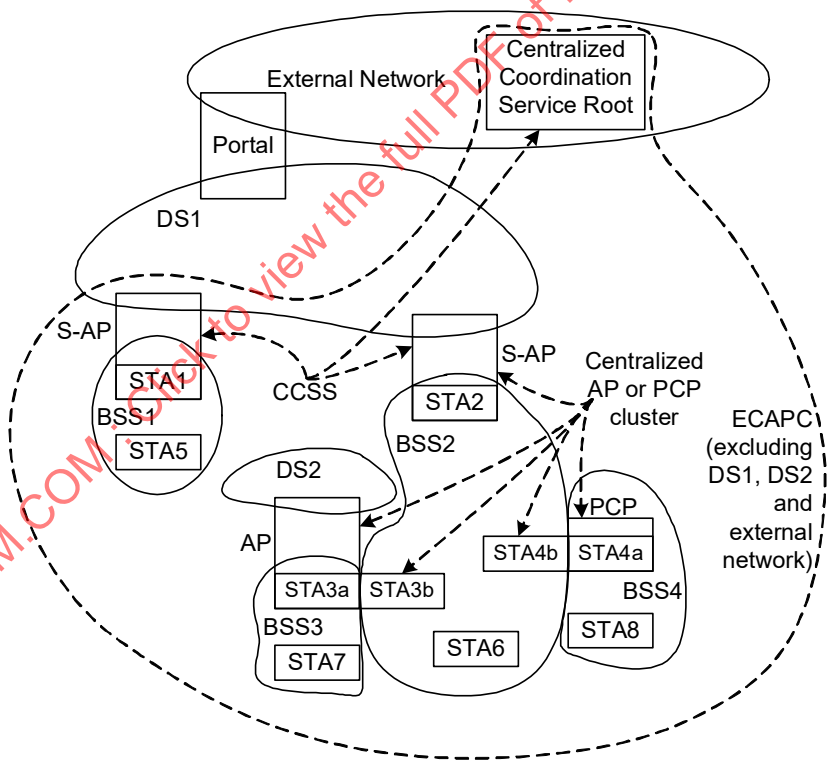

Figure 4-7—CCSS and ECAPC

The CCSS might contain whole ESSs, subsets of ESSs, or some combination of them.

Decentralized AP or PCP clustering can be employed without establishing a CCSS, CCSR, or ECAPC.

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4.3.10 QoS BSS

The IEEE 802.11 QoS facility provides MAC enhancements to support LAN applications with QoS requirements. The QoS enhancements are available to QoS STAs associated with a QoS access point or PCP in a QoS BSS. A subset of the QoS enhancements is available for use between STAs that are members of the same QoS IBSS.

Similarly, a subset of the QoS enhancements is available for use between neighbor peer mesh STAs. A mesh BSS is one type of QoS BSS and it is described in 4.3.21.

A QoS STA that is a non-DMG STA might associate with a non-QoS access point in a non-QoS BSS, to provide the non-QoS MAC data service, for example, when there is no QoS access point with which to associate.

As a mesh STA does not implement the necessary service, the mesh STA does not associate with any access point.

A DMG STA is a QoS STA. A DMG BSS is a QoS BSS.

The enhancements that distinguish QoS STAs from non-QoS STAs and QoS APs from non-QoS APs are collectively termed the *QoS facility*. Which of the QoS-specific mechanisms a QoS STA supports might vary among QoS implementations, as well as between QoS STAs and QoS APs, over ranges specified in subsequent clauses. All service primitives, frame formats, coordination function and frame exchange rules, and management interface functions except for the block acknowledgment (block ack) function, and automatic power save delivery (APSD) are part of the core QoS facility. A QoS STA or QoS AP implements those core QoS facility necessary for its QoS functions to interoperate with other QoS STAs. Functions such as the block ack, and APSD are separate from the core QoS facility; and the presence of these functions is indicated by STAs separately from the core QoS facility.

For infrastructure BSS and IBSS, this standard provides four mechanisms for the support of applications with QoS requirements.

The first mechanism, designated the *enhanced distributed channel access* (EDCA), delivers traffic based on differentiating user priorities (UPs). This differentiation is achieved by varying the following for different UP values:

— Amount of time a STA senses the channel to be idle before backoff or transmission, or
— The length of the contention window to be used for the backoff, or
— The duration a STA transmits after it acquires the channel.

These transmissions might also be subject to certain channel access restrictions in the form of admission control. A DMG STA uses EDCA only within a contention based access period (CBAP). Details of EDCA are provided in 10.23.2 and, for DMG STAs, additional details are provided in 10.39.4, 10.39.5, and 10.39.6.3.

The second mechanism, designated the *hybrid coordination function* (HCF) *controlled channel access* (HCCA), which is not applicable to DMG STAs, allows for the reservation of transmission opportunities (TXOPs) with the hybrid coordinator (HC). A STA requests the HC for TXOPs, both for its own transmissions as well as for transmissions from the AP to it.[18] The request is initiated by the station management entity (SME) of the STA. The HC, which is collocated at the AP, either accepts or rejects the request based on an admission control policy. If the request is accepted, the HC schedules TXOPs for both STAs (both the AP and the non-AP STA). For transmissions from the non-AP STA, the HC polls the STA

[18] In the case of downlink traffic streams (TSs).

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based on the parameters supplied by the STA at the time of its request. For transmissions to the STA, the AP directly obtains TXOPs from the collocated HC and delivers the queued frames to the STA, again based on the parameters supplied by the STA. Details of the mechanism are provided in 10.23.3 and 11.4. This mechanism might be used for applications such as voice and video, which need periodic service from the HC. If the application constraints dictate the use of this mechanism, the application initiates this mechanism by using the management service primitives.

The third mechanism, designated the *service period* (SP) *access* or *service period channel access* (SPCA), is applicable only to DMG STAs and allows for the reservation of channel time by the AP or PCP. A non-AP and non-PCP STA requests SPs from an AP or PCP. These SPs can be used for transmission to any other STA in the BSS. The request is initiated by the SME of the non-AP and non-PCP STA. The AP or PCP either accepts or rejects the request based on an admission control policy. If the request is accepted, the AP or PCP uses the Extended Schedule element to schedule SPs for communication between the source and destination DMG STAs indicated within the request. Details of this mechanism are provided in 10.39.6.2, 10.39.6.4, 10.39.6.6, and 11.4.

The fourth mechanism, designated as *dynamic allocation*, is applicable only to DMG STAs and allows for near-real-time reservation of channel time with an AP or PCP. This type of access is used in addition to the service period and contention based access period mechanisms. An AP or PCP can poll a STA and receive requests for channel time allocation. Based on the received requests, the AP or PCP can accept a request and immediately allocate (within the same beacon interval) channel time for the STA to communicate with another STA by using a Grant frame. Details of this mechanism are provided in 10.39.7, 10.39.8, and 10.39.9.

The AP of a QoS BSS might allow non-QoS STAs to associate. All individually addressed frames that are sent to non-QoS STAs by an AP do not use the frame formats associated with the QoS facility.

A QoS STA associated in a non-QoS BSS acts as a non-QoS STA.

4.3.11 Wireless LAN radio measurements

4.3.11.1 General

Wireless LAN (WLAN) radio measurements enable STAs to understand the radio environment in which they exist. WLAN radio measurements enable STAs to observe and gather data on radio link performance and on the radio environment. A STA can choose to make measurements locally, request a measurement from another STA, or be requested by another STA to make one or more measurements and return the results. Radio measurement data is made available to STA management and upper protocol layers where it might be used for a range of applications. The measurements enable adjustment of STA operation to better suit the radio environment. The radio measurement service includes measurements that extend the capability, reliability, and maintainability of WLANs by providing standard measurements across vendors, and the service provides the resulting measurement data to upper layers in the communications stack.

In addition to featuring standard measurements and delivering measurement information to upper layers, there are applications that require quantifiable radio environment measurements in order to attain the necessary performance levels. These applications include VoIP, video over IP, location based applications, as well as applications requiring mitigation of harsh radio environments (e.g., multifamily dwellings, airplanes, factories, municipalities). Radio measurements address most of the existing issues in using unlicensed radio spectrum to meet the requirements of these emerging technologies.

To address the mobility requirements of technologies, such as VoIP and video streaming, radio measurements, such as Channel Load request/report and the Neighbor request/report, can be used to collect transition information, which can drastically speed up handoffs between BSSs within the same ESS. By accessing and using this information, the STAs (either in APs or in non-AP STAs) can make intelligent

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decisions about the most effective way to utilize the available spectrum, power, and bandwidth for their communications.

The request/report measurements are as follows:

- Beacon
- Frame
- Channel Load
- Noise Histogram
- STA Statistics
- LCI (location configuration information)
- Neighbor Report
- Link Measurement
- Transmit Stream/Category Measurement

The request-only mechanism is as follows:

- Measurement Pause

The report-only mechanism is as follows:

- Measurement pilot

These measurement mechanisms provide the capability for a STA to manage and query its radio environment, and to make appropriate assessments about its health and efficiency. It is the first step in making WLAN smart and capable of making appropriate decisions for fast transition, for mesh connectivity, and for managing the radio environment for all wireless devices.

4.3.11.2 Beacon

The Beacon request/report pair enables a STA to request from another STA a list of APs whose beacons it can receive on a specified channel or channels. The Beacon report request/response provides a means for a requesting STA to obtain received beacon, probe response, and measurement pilot information from a responding STA.

4.3.11.3 Measurement pilot

The Measurement Pilot frame provides a subset of the information provided in a Beacon frame, is smaller than a Beacon frame, and is transmitted more often than a Beacon frame. The purpose of the Measurement Pilot frame is to assist a STA with scanning.

4.3.11.4 Frame

The Frame request/report pair returns a picture of all of the channel traffic and a count of all of the frames received at the measuring STA. For each unique Transmitter Address, the STA reports the Transmitter Address, number of frames received from this transmitter, average power level (RCPI) for these frames, and BSSID indicated by the transmitter.

4.3.11.5 Channel load

The Channel Load request/report pair returns the channel utilization measurement as observed by the measuring STA.

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4.3.11.6 Noise histogram

The Noise Histogram request/report pair returns a power histogram measurement of non-IEEE-802.11 noise power by sampling the channel when virtual carrier sense indicates idle and the STA is neither transmitting nor receiving a frame.

4.3.11.7 STA statistics

The STA Statistics request/report pair returns groups of values for STA counters and for BSS Average Access Delay. The STA counter group values include transmitted fragment counts, group addressed transmitted frame counts, failed counts, retry counts, multiple retry counts, frame duplicate counts, Request to Send (RTS) success counts, RTS failure counts, Acknowledgment (Ack) failure counts, received fragment counts, group addressed received frame counts, FCS error counts, and transmitted frame counts. BSS Average Access Delay group values include AP average access delay, average access delay for each access category, associated STA count, and channel utilization.

4.3.11.8 Location

The Location request/report pair returns a requested location in terms of latitude, longitude, and altitude. It includes types of altitude such as floors. A requested location can be the location of the requester (e.g., “Where am I?”) or the location of the reporting STA (e.g., “Where are you?”) or the location of another STA.

4.3.11.9 Measurement pause

The Measurement Pause request is defined, but no report comes back from this request. The measurement pause permits the inclusion of a quantified delay between the execution of individual measurements that are provided in a series within a Radio Measurement Request frame. The measurement pause used as the last measurement in a frame provides control of the measurement period when Radio Measurement Request frames are to be repeated.

4.3.11.10 Neighbor report

The neighbor report request is sent to an AP, which returns a neighbor report containing information about known neighbor APs that are candidates for a service set transition. This request/report pair enables a STA to gain information about the neighbors of the associated AP to be used as potential roaming candidates.

4.3.11.11 Link measurement

The link measurement request/report exchange provides measurements of the RF characteristics of a STA-to-STA link. This measurement indicates the instantaneous quality of a link.

4.3.11.12 Transmit stream/category measurement

When two QoS STAs have an ongoing traffic stream between them, the Transmit Stream/Category Measurement request/report pair enables either STA to query the other about the conditions of the stream. The transmit stream/category measurement report provides the transmit-side performance metrics for the measured traffic stream. Trigger conditions included in the Transmit Stream/Category Measurement request can initiate triggered Transmit Stream/Category Measurement reports upon detection of the trigger condition.

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4.3.12 Operation in licensed frequency bands

4.3.12.1 General

IEEE 802.11 devices can operate on frequencies that are licensed by national regulatory bodies. Although this standard has been generalized so that it is independent of license type, band, and country of operation, only the bands and associated regulations listed in Annex D have been specifically considered.

4.3.12.2 Dynamic STA enablement (DSE) in licensed bands

The DSE operating procedures are used to automate the channel provisioning and regulatory controls needed for unregistered IEEE 802.11 STAs to operate as dependent STAs in licensed spectrum.[19]

4.3.12.3 Contention based protocol (CBP) in nonexclusively licensed bands

The granting of licenses on a nonexclusive, uncoordinated basis in the same area leads to the possibility of overlapping networks. When overlapping networks cause co-channel interference, regulations, such as those governing the 3650 MHz band in the United States, require the use of a CBP "by which a transmitter provides reasonable opportunities for other transmitters to operate."[20] IEEE 802.11 carrier sense multiple access with collision avoidance (CSMA/CA) is suitable for this purpose in most situations.

4.3.12.4 Using DSE STA identification to resolve interference

When CSMA/CA is not able to sufficiently sense the presence of another licensee's STA (i.e., a hidden STA) or if a secondary licensee causes inference to a primary licensee, the secondary licensee is obliged to resolve complaints that result from interference caused by any STA under its control (including dependent STAs). In order to facilitate the interference resolution processes, all STAs operating in nonexclusively licensed spectrum use the DSE STA and location information procedures.

The STA identification and location information procedures are tied because, by default, registered STAs broadcast their actual location as their unique identifier. Dependent STAs broadcast the location of the STA that has enabled them as well as a unique code selected by the licensee. This method puts a victim of the interference in contact with the party responsible for rectifying the problem, and, at the same time, it protects the privacy of the dependent STA's operator.

4.3.12.5 Further coexistence enhancements in nonexclusively licensed bands

While not explicitly required to meet specific rules, a number of optional IEEE 802.11 mechanisms, when used together, are able to meet general requirements for spectrum sharing, incumbent detection, and other cognitive radio functions in licensed bands. The specific mechanisms for each band are detailed in E.2.

4.3.13 High-throughput (HT) STA

The IEEE 802.11 HT STA provides PHY and MAC features that can support a throughput of 100 Mb/s and greater, as measured at the MAC data service access point (SAP). An HT STA supports HT features as identified in Clause 10 and Clause 19. An HT STA operating in the 5 GHz band supports transmission and reception of frames that are compliant with mandatory PHY specifications as defined in Clause 17. An HT STA operating in the 2.4 GHz band supports transmission and reception of frames that are compliant with

[19] In some licensed frequency bands, wireless equipment can be owned and operated by individuals who do not hold a license. In such instances, devices are permitted to operate only if they are either communicating with, or receiving permission to transmit from, a STA that is maintained by a licensed operator. The Japanese 4.9 GHz band and the U.S. 4.94–4.99 GHz public safety band are examples in which IEEE 802.11 STAs operate under such arrangements.

[20] Definition of CBP from FCC 05-56, Report and Order and Memorandum Opinion and Order, clause 58.

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mandatory PHY specifications as defined in Clause 16 and Clause 18. An HT STA is also a QoS STA. The HT features are available to HT STAs associated with an HT AP. A subset of the HT features is available for use between two HT STAs that are members of the same IBSS. Similarly, a subset of the HT features is available for use between two HT STAs that have established mesh peering (see 9.4.2.55 for details).

An HT STA has PHY features consisting of the modulation and coding scheme (MCS) set described in 19.3.5 and physical layer (PHY) protocol data unit (PPDU) formats described in 19.1.4. Some PHY features that distinguish an HT STA from a non-HT STA are referred to as *multiple input, multiple output (MIMO)* operation; spatial multiplexing (SM); spatial mapping (including transmit beamforming); space-time block coding (STBC); low-density parity check (LDPC) encoding; and antenna selection (ASEL). The allowed PPDU formats are non-HT format, HT-mixed format, and HT-greenfield format (see 19.1.4). The PPDUs can be transmitted with 20 MHz bandwidth and might be transmitted with 40 MHz bandwidth.

An HT STA has MAC features that include frame aggregation, some block ack features, power save multi-poll (PSMP) operation, reverse direction (RD), and protection mechanisms supporting coexistence with non-HT STAs.

4.3.14 Sub 1 GHz (S1G) STA

4.3.14.1 Overview

The IEEE 802.11 S1G STA operates in frequency bands below 1 GHz excluding the TV White Space bands.

An S1G STA supports S1G features identified in Clause 9, Clause 10, Clause 11, Clause 12, and Clause 23.

The main PHY features in an S1G STA are the following:

- Mandatory support for 1 MHz and 2 MHz channel width
- Mandatory support for S1G_1M PPDU
- Mandatory support for S1G_SHORT PPDU
- Mandatory support for S1G_LONG PPDU if ≥ 4 MHz channel width is supported
- Mandatory support for detection and decode of SIG-A field of the S1G_LONG preamble
- Mandatory support for single spatial stream S1G-MCS 0 to S1G-MCS 2 and S1G-MCS 10 (for 1 MHz PPDU only)
- Mandatory support for single spatial stream S1G-MCS 3 to S1G-MCS 7 in an S1G AP
- Mandatory support for binary convolutional code (BCC) coding
- Mandatory support for normal guard interval
- Mandatory support for fixed pilots
- Optional support for 2, 3, and 4 spatial streams (transmit and receive)
- Optional support for S1G_LONG PPDU if ≥ 4 MHz channel width is not supported
- Optional support for beamforming sounding (by sending an S1G NDP)
- Optional support for compressed beamforming feedback
- Optional support for STBC, LDPC (transmit and receive)
- Optional support for S1G MU PPDUs (transmit and receive)
- Optional support for 4 MHz, 8 MHz, or 16 MHz channel width
- Optional support for S1G-MCSs 8 and 9 (transmit and receive)
- Optional support for short guard interval
- Optional support for traveling pilots

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The main MAC features supported for S1G STA are the following:

- Mandatory support for NDP Ack, NDP BlockAck, and NDP CTS frames; mandatory support for the reception of NDP Probe Request frame for S1G AP; optional support for other NDP CMAC PPDUs
- Mandatory support for the reception of PV1 MPDUs but optional support for the transmission of PV1 MPDUs
- Mandatory support for the second virtual carrier sensing mechanism, i.e., response indication deferral (RID)
- Mandatory support for the hierarchical structure of TIM element by an S1G AP
- Mandatory support for extended BSS max idle periods and extended listen intervals with unified scaling factor
- Optional support for RAW
- Optional support for relay
- Optional support for grouping of non-AP STAs and group AID
- Optional support for TWT
- Optional support for BDT
- Optional support for sectorization
- Optional support for non-TIM mode
- Optional support for asymmetric BA, fragment BA
- Optional support for page slicing, dynamic AID assignment for an S1G AP
- Optional support for authentication control
- Optional support for SST
- Optional support for rescheduling STA's doze/awake cycle
- Optional support for either a sensor STA or a non-sensor STA
- Optional support for an EL STA

NOTE—Some NDP CMAC PPDUs are mandatory under certain conditions as indicated in B.4.4.2.

Most S1G features help either reduce a STA's energy consumption or increase the usable range between an AP and a non-AP STA.

An S1G STA is a nonmesh STA and a QoS STA that does not support HCCA.

4.3.14.2 S1G relay

The S1G relay is a mechanism for expanding the coverage area of an AP. The AP is referred to as the root AP. An S1G relay consists of an S1G relay AP and an S1G relay STA. An S1G relay forwards frames between STAs associated to its S1G relay AP and the AP to which its S1G relay STA is associated.

4.3.15 Very high throughput (VHT) STA

A VHT STA is an HT STA that, in addition to features supported as an HT STA, supports VHT features identified in Clause 9, Clause 10, Clause 11, Clause 14, Clause 17, and Clause 21, but operates only in the 5 GHz band in the cited text.

The main PHY features in a VHT STA that are not present in an HT STA are the following:

- Mandatory support for 40 MHz and 80 MHz channel widths
- Mandatory support for VHT single-user (SU) PPDUs
- Optional support for 160 MHz and 80+80 MHz channel widths
- Optional support for VHT sounding protocol to support beamforming

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— Optional support for VHT multi-user (MU) PPDUs
— Optional support for VHT-MCSs 8 and 9

The main MAC features in a VHT STA that are not present in an HT STA are the following:

— Mandatory support for the A-MPDU padding of a VHT PPDU
— Mandatory support for S-MPDU
— Mandatory support for responding to a bandwidth indication (provided by the RXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT) in a non-HT and non-HT duplicate RTS frame
— Optional support for MPDUs of up to 11 454 octets
— Optional support for A-MPDU pre-end-of-frame (pre-EOF) padding (see 9.7.1) of up to 1 048 575 octets
— Optional support for VHT link adaptation

Most VHT features, among other benefits, increase the maximum throughput achievable between two VHT STAs over that achievable using HT features alone. The VHT features are available to VHT STAs associated with a VHT AP. A subset of the VHT features is available for use between two VHT STAs that are members of the same IBSS. Similarly, a subset of the VHT features is available for use between two VHT STAs that have established mesh peering. A subset of the VHT features is available for use between two VHT STAs that have established a TDLS link.

The support for VHT transmit beamforming sounding and VHT MU PPDUs in a VHT AP and more than one VHT STA within a VHT BSS enables the optional use of downlink MU multiple input, multiple output (DL-MU-MIMO). With DL-MU-MIMO the AP can create up to four A-MPDUs, each carrying MPDUs destined for an associated MU beamformee capable STA. The AP uses group identifiers (GIDs) to signal potential recipient STAs. The AP transmits the A-MPDUs simultaneously in separate space-time streams such that each recipient STA is able to demodulate the space-time streams carrying its A-MPDU. The simultaneous transmission of A-MPDUs in a single VHT MU PPDU provides a means to increase aggregate throughput over that achieved by sending the A-MPDUs in separate SU PPDUs.

The use of certain HT features, such as reduced interframe space (RIFS), is not permitted for VHT STAs.

4.3.16 Television very high throughput (TVHT) STA

The IEEE 802.11 TVHT STA operates in television white spaces (TVWS) bands.

A TVHT STA supports all mandatory features of a VHT STA as mandatory features except for HT-mixed format PPDUs and 20 MHz, 40 MHz, and 80 MHz channel widths. A TVHT STA supports all optional features of a VHT STA as optional features except for HT-greenfield format PPDUs, 160 MHz or 80+80 MHz channel widths, more than 4 spatial streams, and Short GI (which is mandatory).

The 20 MHz, 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz channel widths and more than 4 spatial streams are not used in STAs operating as TVHT STAs. The features and behaviors of VHT STAs specified in Clause 6, Clause 8, Clause 9, Clause 10, Clause 11, Clause 14, and Annex G apply to TVHT STAs as well, unless stated otherwise.

For Clause 6, Clause 8, Clause 9, Clause 10, Clause 11, and Clause 14, the following replacements are applied for TVHT STAs:

— “TVHT_W/TVHT_2W” replaces “20/40 MHz”.
— “TVHT_W/TVHT_2W/TVHT_4W” replaces “20/40/80/160 MHz”.

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- "TVHT_W", "TVHT_2W", and "TVHT_4W" replace "20 MHz", "40 MHz", and "80 MHz," respectively.
- "TVHT_W" replaces "CBW20".
- "TVHT_2W" replaces "CBW40".
- "TVHT_4W" replaces "CBW80" and "CBW80+80".
- "secondaryTVHT_2W" replaces "secondary40".
- "TVHT STA" replaces "VHT STA".
- "TVHT AP" replaces "VHT AP".
- "TVHT BSS" replaces "VHT BSS".
- "TVHT-MCS" replaces "VHT-MCS".
- "TVHT Operation" replaces "VHT Operation".
- "dot11TVHTOptionImplemented" replaces "dot11VHTOptionImplemented".
- "dot11TVHTControlFieldOptionImplemented" replaces both "dot11VHTControlFieldOptionImplemented" and "dot11HTControlFieldSupported".
- "dot11TVHTShortGIOptionIn4WActivated" replaces "dot11VHTShortGIOptionIn80Activated".
- "dot11TVHTSUBeamformerOptionImplemented" replaces "dot11VHTSUBeamformerOptionImplemented".
- "dot11TVHTSUBeamformeeOptionImplemented" replaces "dot11VHTSUBeamformeeOptionImplemented".
- "dot11TVHTMUBeamformerOptionImplemented" replaces "dot11VHTMUBeamformerOptionImplemented".
- "dot11TVHTMUBeamformeeOptionImplemented" replaces "dot11VHTMUBeamformeeOptionImplemented".
- "dot11TVHTTXOPPowerSaveOptionImplemented" replaces "dot11VHTTXOPPowerSaveOptionImplemented".
- "dot11TVHTOBSSScanCount" replaces "dot11VHTOBSSScanCount".
- "dot11TVHTExtendedNSSBWCapable" replaces "dot11VHTExtendedNSSBWCapable".
- Reference to 9.4.1.50 replaces reference to 9.4.1.49.
- Reference to 9.4.1.52 replaces reference to 9.4.1.51.
- Reference to 9.4.2.171 replaces reference to 9.4.2.158.
- Reference to 11.41 replaces reference to 11.38.1.
- Reference to Clause 22 and its subclauses replace reference to Clause 21 and its subclauses.

For Annex G, the following replacements are applied for TVHT STAs:

- "TVHT" replaces "VHT".
- "tvht" replaces "vht".

The main PHY features in a TVHT STA that are not present in a VHT STA are the following:

- Mandatory support for TVHT_W channel width.
- Optional support for TVHT_W+W channel width.
- Optional support for TVHT_2W channel width.
- Optional support for TVHT_4W channel width.
- Optional support for TVHT_2W+2W channel width.

These TVHT features are available to TVHT STAs associated with a TVHT AP. A subset of the TVHT features is available for use between two TVHT STAs that are members of the same IBSS.

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4.3.17 STA transmission of Data frames outside the context of a BSS

In addition to defining procedures for STA communication within a BSS, this standard also defines procedures for a STA that is not a member of a BSS to transmit Data frames. Such Data frames are defined as being transmitted outside the context of a BSS (OCB). A STA transmits a Data frame outside the context of a BSS only if dot11OCBActivated is true.

NOTE—The specific frame subtypes that a STA is allowed to send when it has dot11OCBActivated true are specified in 11.18.

When dot11OCBActivated is true, a Data frame can be sent to either an individual or a group destination MAC address. This type of communication is possible only between STAs that are able to communicate directly over the wireless medium. It allows immediate communication, avoiding the latency associated with establishing a BSS. When dot11OCBActivated is true, a STA is not a member of a BSS and it does not utilize the IEEE 802.11 authentication, association, or data confidentiality services. This capability is particularly well suited for use in rapidly varying communication environments such as those involving mobile STAs in which the interval over which the communication exchanges take place is of very short duration (e.g., on the order of tens or hundreds of milliseconds). Since IEEE 802.11 MAC sublayer authentication services are not used when dot11OCBActivated is true, any required authentication services are provided by the station management entity (SME) or by applications outside of the MAC sublayer, such as those described in the IEEE 1609 [B22] family of standards.

A STA whose MIB does not include dot11OCBActivated operates as if the attribute is false.

Communication of Data frames when dot11OCBActivated is true might take place in a frequency band that is dedicated for its use, and such a band might require licensing depending on the regulatory domain (see Annex E). A STA for which dot11OCBActivated is true initially transmits and receives on a channel known in advance, either through regulatory designation or some other out-of-band communication. A STA's SME determines PHY parameters, as well as any changes in the operating channel, e.g., using information obtained via out-of-band communication or over-the-air frame exchange. When dot11OCBActivated is true, a sending STA sets the BSSID field to the wildcard BSSID value (see 9.2.4.3.4).

The Vendor Specific frame (see 9.6.5) provides one means for STAs to exchange management information prior to communicating Data frames outside the context of a BSS.

4.3.18 Tunneled direct-link setup

Tunneled direct-link setup (TDLS) is characterized by the use of signaling frames that are encapsulated in Data frames so that the signaling frames are transmitted through an AP transparently. Therefore, the AP does not need to be direct-link aware, nor does it have to support the same set of capabilities that are used on the direct link, in order for TDLS to be used. To allow a STA to enter a TDLS power save mode, TDLS provides two power save mechanisms: TDLS peer unscheduled automatic power save delivery (U-APSD) (TPU) and TDLS peer power save mode (PSM). TDLS allows STAs to use the TDLS PeerKey (TPK) handshake to provide data confidentiality and message authentication. STAs that set up a TDLS direct link remain associated with the AP and transmit frames directly to the other TDLS peer STA.

4.3.19 Wireless network management

4.3.19.1 Overview

Wireless network management (WNM) enables STAs to exchange information for the purpose of improving the overall performance of the wireless network. STAs use WNM protocols to exchange operational data so that each STA is aware of the network conditions, allowing STAs to be more cognizant of the topology and state of the network. WNM protocols provide a means for STAs to be aware of the presence of collocated interference, and enable STAs to manage RF parameters based on network conditions.

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In addition to providing information on network conditions, WNM also provides a means to exchange location information, provide support for the multiple BSSID capability on the same wireless infrastructure, support efficient delivery of group addressed frames, and enable a WNM sleep mode in which a STA can sleep for long periods of time without receiving frames from the AP.

The WNM service includes the following:

— BSS max idle period management
— BSS transition management
— Channel usage
— Collocated interference reporting
— Diagnostic reporting
— Directed multicast service (DMS)
— Event reporting
— Flexible multicast service (FMS)
— Location services
— Multicast diagnostic reporting
— Multiple BSSID capability
— Proxy Address Resolution Protocol (ARP)
— QoS traffic capability
— SSID list
— Triggered STA statistics
— TIM broadcast
— Timing measurement
— Traffic filtering service
— U-APSD coexistence
— WNM notification
— WNM sleep mode

4.3.19.2 BSS max idle period management

BSS max idle period management enables an AP to indicate a time period during which the AP does not disassociate a STA due to nonreceipt of frames from the STA. This supports improved STA power saving and AP resource management.

4.3.19.3 BSS transition management

BSS transition management enables an AP to request non-AP STAs to transition to a specific AP, or to indicate to a non-AP STA a set of preferred APs, due to network load balancing or BSS Termination.

4.3.19.4 Channel usage

Channel usage information is provided by the AP to the non-AP STA to recommend channels for BSSs that are not infrastructure BSSs or an off-channel TDLS direct link. The non-AP STAs can use the channel usage information as part of channel selection processing for a BSS that is not an infrastructure BSS or an off-channel TDLS direct link.

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4.3.19.5 Collocated interference reporting

Collocated interference reporting enables the requesting STA to obtain information on interference due to collocated radios at the reporting STA. The requesting STA can use that information to schedule its transmissions to minimize the effects of the interference.

4.3.19.6 Diagnostic reporting

Diagnostic requests enable a STA to request a non-AP STA to report information that might be helpful in diagnosing and resolving problems with the WLAN. Diagnostic reports include information on hardware, configuration, and STA capabilities.

4.3.19.7 Directed multicast service (DMS)

The DMS enables a non-AP STA to request the AP to transmit group addressed frames destined to the requesting STA as individually addressed frames.

4.3.19.8 Event reporting

Event requests enable a STA to request a non-AP STA to send particular real-time event reports. The types of events include transition, RSNA, WNM log, and peer-to-peer link events. A transition event is transmitted after a non-AP STA successfully completes a BSS transition. Transition events are used to diagnose transition performance problems. An RSNA event report describes the type of Authentication used for the RSNA. RSNA events are used to diagnose security and authentication performance problems. A WNM log event report enables a non-AP STA to transmit a set of WNM log event messages to the requesting STA. WNM log event reports are used to access the contents of a STA's WNM log. A peer-to-peer link event report enables a non-AP STA to inform the requesting STA that a peer-to-peer link has been established. Peer-to-peer link event reports are used to monitor the use of peer-to-peer links in the network.

4.3.19.9 Flexible multicast service (FMS)

The flexible multicast service enables a non-AP STA to request an alternate delivery traffic indication map (DTIM) delivery interval for one or more sets of group addressed streams that the non-AP STA receives. This enables the non-AP STA to wake up at the alternate DTIM interval rather than every DTIM and enables significant power saving when a non-AP STA receives group addressed traffic. The FMS also enables a STA to establish a data rate and delivery interval for group addressed traffic higher than the minimum data rate available.

Delivery of group addressed data to power saving STAs using a DTIM beacon is described in 11.2.3.4.

4.3.19.10 Location services

Location Configuration Request and Response frames enable STAs to configure a collection of location related parameters for Location Track Notification frames. The AP can indicate that it can provide location data to support applications such as emergency services. Location services also provide the ability for STAs to exchange location information using Radio Measurement Request and Radio Measurement Report frames. The protocol supports exchange-by-value and exchange-by-reference mechanisms. The location value can be exchanged in geospatial (LCI) and civic formats. The location reference is a URL that defines from where the location value is retrieved.

4.3.19.11 Multicast Diagnostic report

Multicast Diagnostic reports enable a non-AP STA to report statistics for multicast traffic it received from a transmitting STA. This can be used by an AP to measure quality of multicast reception by a non-AP STA.

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4.3.19.12 Multiple BSSID capability

The Multiple BSSID capability enables the advertisement of information for BSSIDs using a single Beacon or Probe Response frame instead of multiple Beacon and Probe Response frames, each corresponding to a single BSSID. The Multiple BSSID capability also enables the indication of buffered frames for multiple BSSIDs using a single TIM element in a single beacon.

4.3.19.13 Proxy ARP

The Proxy ARP service enables an AP to respond to ARP and Neighbor Discovery frames on behalf of associated non-AP STAs. Associated STAs do not receive ARP or IPv6 Neighbor Discovery frames. The Proxy ARP service enables associated STAs to remain in power save for longer periods of time.

4.3.19.14 QoS traffic capability

QoS traffic capability procedures enable the QoS STA to indicate that it is capable of transmitting traffic belonging to the corresponding user priority (UP) from applications that require generation of such traffic. The QoS Traffic Capability might be used for example as an input to estimate the blocking probability of a voice application based on the number of voice capable non-AP STAs.

4.3.19.15 SSID list

The SSID List element enables the non-AP STA to request information on a list of SSIDs. This is intended to reduce the number of Probe Request frames sent by the non-AP STA.

4.3.19.16 Triggered STA statistics

The Triggered STA Statistics reporting capability enables generation of a STA statistics report (see 4.3.11.9) when the statistics of interest reach a predefined threshold.

4.3.19.17 TIM broadcast

The TIM broadcast protocol defines a mechanism to enable a STA to receive an indication of buffered individually addressed traffic, independent of the Beacon frame, reducing the wake time of the STA.

4.3.19.18 Timing measurement

Timing Measurement frames allow a recipient STA to accurately measure the offset of its clock relative to a clock in the sending STA. With the regular transfer of Timing Measurement frames from one STA to another, it is possible for the recipient STA to track changes in the offset of its clock with respect to the sending STA over time and thus detect and compensate for any drift between the clocks.

4.3.19.19 Fine timing measurement

Fine timing measurement allows a STA to accurately measure the round trip time (RTT) between it and another STA. With the regular transfer of Fine Timing Measurement frames it is possible for the recipient STA to track changes in its relative location with other STAs in the environment.

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4.3.19.20 Traffic filtering service

The traffic filtering service enables an AP to determine if MSDUs and Management frames destined for a STA match a specific set of traffic filters that are enabled at the AP per the request of the STA. Individually addressed frames that do not match any of the traffic filters in the set are discarded. Individually addressed frames that do match at least one of the set of the enabled traffic filters are delivered to the STA. The STA can also negotiate to have a notification frame sent prior to the delivery of the frame matching the traffic filter.

4.3.19.21 U-APSD coexistence

The U-APSD coexistence capability enables the non-AP STA to indicate a requested transmission duration to the AP for use of U-APSD service periods. Use of the transmission duration enables the AP to transmit frames during the service period and improve the likelihood that the non-AP STA receives the frames when the non-AP STA is experiencing interference. The U-APSD coexistence capability reduces the likelihood that the AP transmits frames during the service period that are not received.

4.3.19.22 WNM notification

WNM notification provides a mechanism for a STA to notify another STA of a management event. The following events are defined:

— Firmware update notification
— Beacon protection failure

4.3.19.23 WNM sleep mode

WNM sleep mode is an extended power save mode for non-AP STAs in which a non-AP STA need not listen for every DTIM Beacon frame, and need not perform GTK/IGTK/BIGTK updates. WNM sleep mode enables a non-AP STA to signal to an AP that it might sleep for a specified length of time. This enables a non-AP STA to reduce power consumption and remain associated while the non-AP STA has no traffic to send to or receive from the AP.

4.3.20 Subscription service provider network (SSPN) interface

An AP can interact with external networks using a SSPN interface for the purpose of authenticating users and provisioning services, as shown in Figure 4-8. The exchange of authentication and provisioning information between the SSPN and the AP passes transparently through the portal. The protocol used to exchange this information is outside the scope of this standard. The logical SSPN interface provides the means for an AP to consult an SSPN for authenticating and authorizing a specific non-AP STA and to report statistics and status information to the SSPN. Authentication and provisioning information for non-AP STAs received from the SSPN are stored in the AP management information base (MIB) and are used to limit layer-2 services provided to that non-AP STA. Detailed interactions describing the SSPN interface are provided in 11.22.5.

The SSPN interface provides the non-AP STA access to the services provisioned in the SSPN via the currently associated BSS. Services might include virtual local area network (VLAN) mapping and tunnel establishment that are transparent to the non-AP STA and outside the scope of this standard. The SSPN interface also allows the non-AP STA to access services in destination networks (DNs) other than the SSPN. An example of a DN other than SSPN is the provision of Internet access via the IEEE 802 LAN, or an intermediary network that connects the IEEE 802.11 infrastructure and the SSPN.

NOTE—The SSPN Interface Service is not supported in an IBSS.

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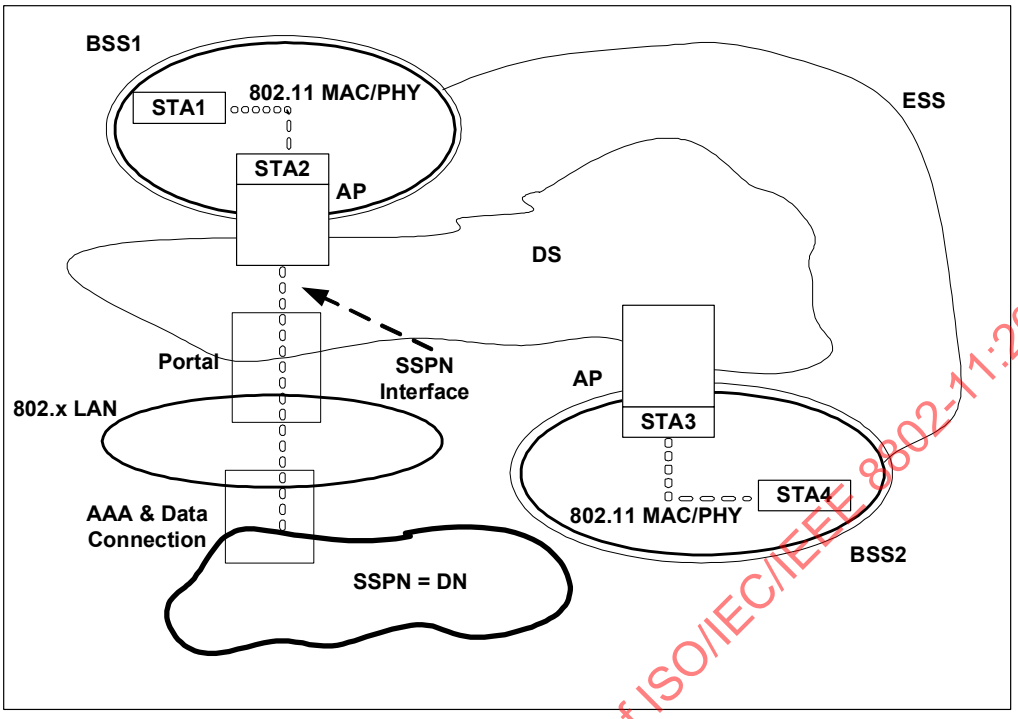

Figure 4-8—SSPN interface service architecture

4.3.21 Mesh BSS

4.3.21.1 General

The IEEE 802.11 mesh facility provides MAC enhancements to support wireless LAN mesh topologies. The mesh facilities are available to mesh STAs that belong to a mesh BSS (MBSS). Only the mesh discovery service is available to a mesh STA that has not become a member of an MBSS. The enhancements that distinguish mesh STAs from nonmesh STAs are collectively termed the “mesh facility.” The mesh-specific mechanisms vary among implementations.

4.3.21.2 Overview of the mesh BSS

A mesh BSS is an IEEE 802.11 LAN consisting of autonomous STAs. Inside the mesh BSS, all STAs establish wireless links with neighbor STAs to mutually exchange MSDUs. Further, using the multi-hop capability, MSDUs and Management frames can be transferred between STAs that are not in direct communication with each other over a single instance of the wireless medium. From the data delivery point of view, it appears as if all STAs in a mesh BSS are directly connected at the MAC layer even if the STAs are not within range of each other. The multi-hop capability enhances the range of the STAs and benefits wireless LAN deployments.

STAs in a mesh BSS might be sources, sinks, or propagators of traffic; some mesh STAs might propagate traffic for other STAs, but do not act as a source or sink of traffic. As described in 4.3.21.4, a mesh BSS might have interfaces to external networks and can be a DSM for infrastructure BSSs.

Within a mesh BSS, STAs utilize the mesh coordination function (MCF) to access the channel. MCF is based on the core QoS facility described in 4.3.10, and a mesh BSS is categorized as one type of QoS BSS. MCF is specified in 10.24.

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4.3.21.3 Mesh STA

A STA that belongs to a mesh BSS is termed a "mesh station" (mesh STA). Mesh STAs are QoS STAs that support mesh services, i.e., they participate in formation and operation of a mesh basic service set (MBSS). A mesh STA implements a subset of the QoS functionality:

— Use of QoS frame format
— EDCA (as a part of MCF)
— Block acknowledgment (optional)
— No acknowledgment (optional)
— Use of TSPEC, TCLAS, and TCLAS Processing elements to establish DMS or GCR agreements (optional)

A mesh BSS does not incorporate the full hybrid coordinator (HC) and BSS QoS functionality. MBSSs do not incorporate the following:

— HCCA
— Traffic stream (TS) management
— Admission control
— Automatic power save delivery (APSD)
— Tunneled direct-link setup (TDLS)

4.3.21.4 IEEE 802.11 components and mesh BSS

Example mesh and infrastructure BSSs are illustrated in Figure 4-9. Only mesh STAs participate in mesh functionalities such as formation of the mesh BSS, path selection, and forwarding. Accordingly, a mesh STA is not a member of an IBSS or an infrastructure BSS. Consequently, mesh STAs do not communicate with nonmesh STAs.

However, instead of existing independently, an MBSS might also interconnect with other BSSs through the distribution system (DS) or a bridged LAN. Then, mesh STAs can communicate with nonmesh STAs. A logical architectural component is introduced in order to integrate the non-GLK mesh STA with the DS: the mesh gate. Data move between a non-GLK MBSS and the DS via one or more mesh gates. Thus the mesh gate is the logical point at which MSDUs from a non-GLK MBSS enter the DS. In a GLK MBSS, mesh STAs can communicate with nonmesh STAs via a GLK mesh STA with an attached bridge port and from there to the bridged LAN. Once an MBSS contains a mesh gate that connects it to the DS or a GLK mesh STA that connects it to a bridge port, the MBSS can be integrated with other infrastructure BSSs, given that their APs connect to the same DS or bridged network. Several mesh gates are shown in Figure 4-9 connecting different MBSSs to the DS.

When an MBSS accesses the DS or a bridged network, the MBSS can be integrated with a non-IEEE-802.11 LAN. To integrate the a DS to which this MBSS connects, the DS needs to contain a portal. See 4.3.7. Consequently, mesh gate and portal are different entities. The portal integrates the IEEE 802.11 architecture with a non-IEEE-802.11 LAN (e.g., a traditional wired LAN). The mesh gate integrates the MBSS with the DS. A GLK mesh STA integrates the MBSS with the bridged network.

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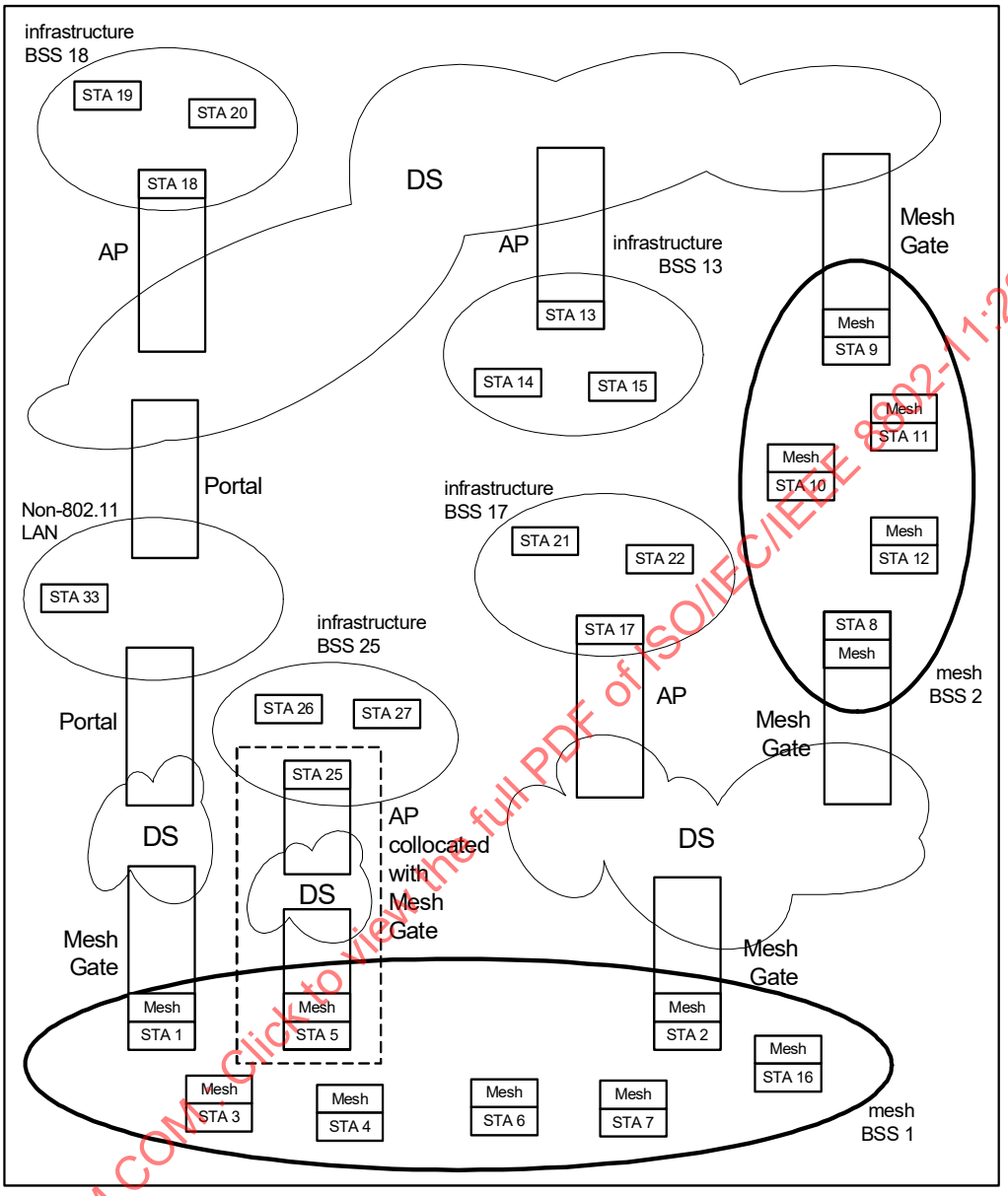

Figure 4-9—Example MBSS containing mesh STAs, mesh gates, APs, and portals

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It is possible for one device to offer any combination of the functions of an AP, a portal, and a mesh gate; see 14.11.5. An example device combining the functions of an AP and a mesh gate is shown in Figure 4-10. The implementation of such collocated entities is beyond the scope of this standard. The configuration of a mesh gate that is collocated with an access point allows the utilization of the mesh BSS as a distribution system medium. In this case, two different entities (mesh STA and access point) exist in the collocated device and the mesh BSS is hidden to STAs that associate to the access point. The mesh STA collocation is outlined in 14.11.5, which states that the usage of a distinct MAC address for each collocated STA avoids ambiguities.

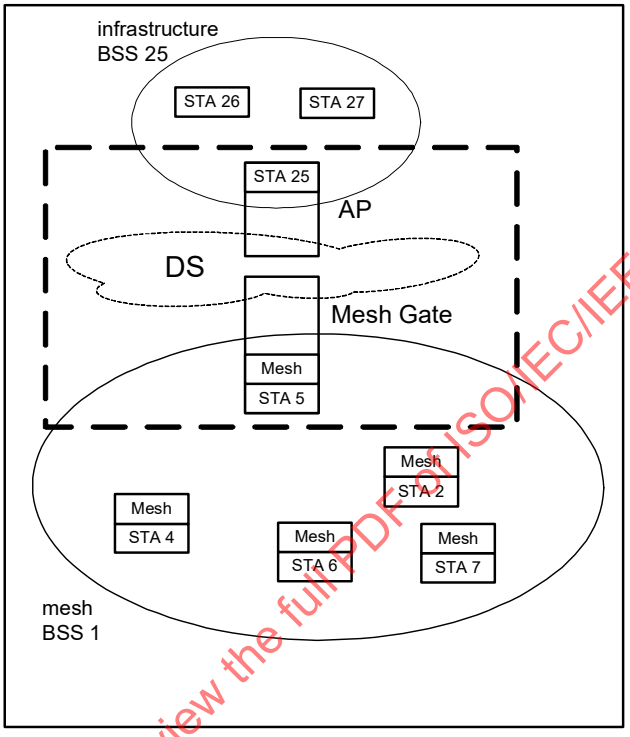

Figure 4-10—Example device consisting of mesh STA and AP STA to connect an MBSS and an infrastructure BSS

4.3.21.5 Introduction to mesh functions

4.3.21.5.1 General

A mesh BSS is formed and operated by the set of services called *mesh services*. Mesh services are provided by the following major mesh facilities:

— Mesh discovery
— Mesh peering management
— Mesh security
— Mesh beaconing and synchronization
— Mesh coordination function
— Mesh power management
— Mesh channel switching
— Three address, four address, and extended address frame formats
— Mesh path selection and forwarding

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— Interworking with external networks
— Intra-mesh congestion control
— Emergency service support in mesh BSS

4.3.21.5.2 Mesh discovery

A mesh STA performs either active scanning or passive scanning to discover an operating mesh BSS. Each mesh STA transmits Beacon frames periodically and responds with Probe Response frames when a Probe Request frame is received, so that neighbor mesh STAs can perform mesh discovery appropriately. The identification of the mesh BSS is given by the Mesh ID element contained in the Beacon and the Probe Response frames. The details for the mesh discovery facility are described in 14.2.

4.3.21.5.3 Mesh peering management (MPM)

Within a mesh BSS, direct communication between neighbor mesh STAs is allowed only when they are peer mesh STAs. After mesh discovery, two neighbor mesh STAs agree to establish a mesh peering to each other, and, after successfully establishing the mesh peering, they become peer mesh STAs. A mesh STA can establish a mesh peering with multiple neighbor mesh STAs. The mesh peering management (MPM) facilitates the mesh peering establishment and closure of the mesh peerings. The details of MPM are described in 14.3.

4.3.21.5.4 Mesh security

In an MBSS, mesh link security protocols are used to authenticate a pair of mesh STAs and to establish session keys between them. Mesh authentication protocols establish a shared, common pairwise master key (PMK), and authenticate a peer mesh STA. The authenticated mesh peering exchange protocol relies on the existence of the PMK between the two mesh STAs to establish an authenticated peering and derive session keys. The details of mesh security are described in 12.4, 14.3.3, 14.5, and 14.6.

4.3.21.5.5 Mesh beaconing and synchronization

In order to assist mesh discovery, mesh power management, and synchronization in a mesh BSS, all mesh STAs periodically transmit Beacon frames. Synchronization in a mesh BSS is maintained by the MBSS's active synchronization method. The default synchronization method is the neighbor offset synchronization method. Mesh beacon collision avoidance (MBCA) mitigates collisions of Beacon frames among hidden nodes. The details of mesh beaconing and synchronization are described in 14.13.

4.3.21.5.6 Mesh coordination function (MCF)

A mesh STA uses the mesh coordination function (MCF) for channel access. MCF consists of EDCA (contention based channel access defined in 10.24.2) and MCCA (controlled channel access defined in 10.24.3). MCCA is a reservation based channel access method and aims to optimize the efficiency of frame exchanges in a mesh BSS.

4.3.21.5.7 Mesh power management

A mesh STA can manage the activity level of its links per mesh peering. A mesh STA sets the activity level of each of its mesh peerings to either active mode, light sleep mode, or deep sleep mode. The mesh STA performs mesh power management mode tracking for each of its neighbor peer mesh STAs, and delivers the frames based on the rules defined in 14.14.

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4.3.21.5.8 Mesh channel switching

When a mesh STA switches the operating channel, it uses the channel switching protocol defined in 11.8.8 and 11.9. The channel switching protocol enables the propagation of channel switch notifications throughout the mesh BSS, prior to the channel switch execution.

4.3.21.5.9 Frame addressing in an MBSS

Three address, four address, and extended address frame formats enable the distribution of MSDUs over multiple instances of the wireless medium within a mesh BSS and integration to the ESS. Frame format details are described in Clause 9 and 9.3.5.

4.3.21.5.10 Mesh path selection and forwarding

Mesh path selection enables path discovery over multiple instances of the wireless medium within a mesh BSS. The overview of the mesh path selection framework is described in 14.8. The hybrid wireless mesh protocol (HWMP) is defined as the default path selection protocol for the mesh BSS. HWMP provides both proactive path selection and reactive path selection. The details of HWMP are described in 14.10. The path selection protocol uses link metrics in the assessment of a mesh path to the destination. The details of link metrics are described in Table 14.9. The airtime link metric is the default link metric. The high PHY rate airtime link metric is another link metric intended for mesh STAs that are capable of transmitting frames with PHY rate higher than 54 Mb/s. The details of the airtime link metric and high PHY rate airtime link metric are described in 14.9.2.

Once the mesh path of a particular pair of the source mesh STA and the destination mesh STA is found through the mesh path selection function, mesh STAs propagate the data by the forwarding function. The details of the forwarding function are described in 10.38.

As a result of the mesh path selection and forwarding, MSDUs are transmitted among all of the mesh STAs in a mesh BSS, even if the mesh STAs are not neighbor STAs of each other. Figure 4-11 depicts the MSDU transfer within a mesh BSS.

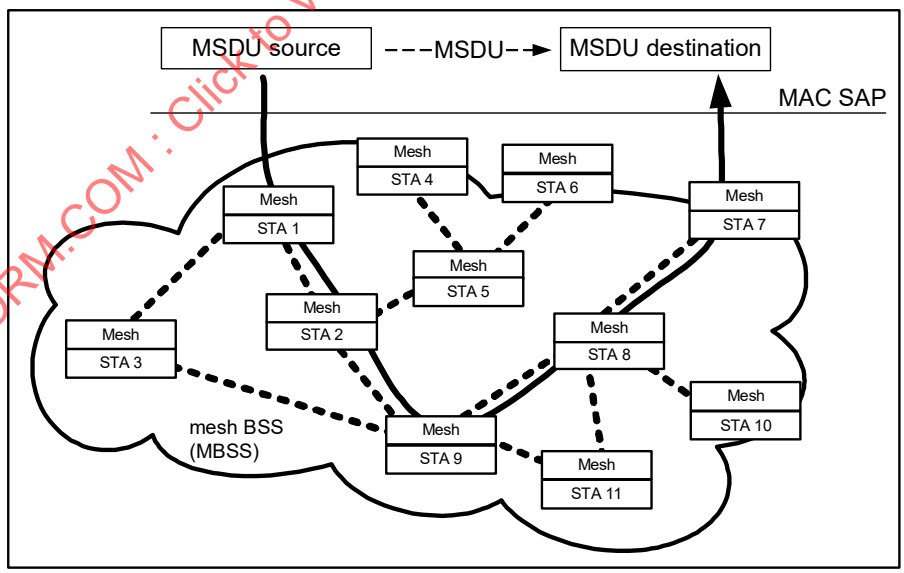

Figure 4-11—MAC data transport over an MBSS

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4.3.21.5.11 Interworking with the DS

A mesh BSS might contain one or more mesh gates that connect to one or more distribution systems. A mesh gate can announce its presence in the mesh BSS by sending Gate Announcement frames. Alternatively a mesh gate can announce its presence in the mesh BSS by sending HWMP Path Selection frames with the RANN element or the PREQ element indicating mesh gate announcement, when it is configured as a root mesh STA. Typically a mesh gate announces its presence when it is collocated with a portal or it has access to a portal. Gate announcements allow mesh STAs to select the appropriate mesh gate and build a path toward it. Note that, when multiple mesh gates that have access to the same DS are present in the mesh BSS, proper configuration is necessary.

When a mesh gate has access to IEEE 802 STAs outside the mesh BSS, the mesh gate acts as a proxy for the IEEE 802 STAs outside the MBSS. Such a mesh gate is called a *proxy mesh gate*. The details of the proxy functionality are described in 14.11.3.

The details of the mesh BSS interworking are described in 14.11.

4.3.21.5.12 Intra-mesh congestion control

Intra-mesh congestion control is used to provide flow control over the multi-hop communication. Intra-mesh congestion control is useful to mitigate wasteful wireless medium utilization caused by buffer overflow at mesh STAs. Intra-mesh congestion control consists of three main mechanisms: local congestion monitoring and congestion detection, congestion control signaling, and local rate control. The details of the intra-mesh congestion control are described in 14.12.

4.3.21.5.13 Emergency service support in mesh BSS

Depending on regulations, emergency services support might be mandated over the mesh network. In this case the Beacon and Probe Response frames inform whether a mesh STA supports emergency services, advertising to other mesh STAs that mesh peering for emergency services is possible. If a mesh STA subsequently requires emergency services, an emergency indication is then set within the Mesh Peering Open frame. Mesh STAs that support emergency services, accept peering from other mesh STAs requiring emergency services, transferring frames to an emergency server (such as a PSAP).

4.3.22 DMG STA

The IEEE 802.11 DMG STA provides PHY and MAC features that can support a throughput of 1 Gb/s and greater, as measured at the MAC data service access point (SAP). A DMG STA supports DMG features as identified in Clause 10, Clause 11, and Clause 20. A DMG STA operates in a DMG BSS and supports transmission and reception of frames that are compliant with PHY specifications as defined in Clause 20. A DMG STA is also a QoS STA. The basic channel access of a DMG STA (see 10.39) allows it to operate in an Infrastructure BSS, in an IBSS, and in a PBSS. Certain DMG features such as service period allocation are available only to DMG STAs that are associated with an AP or with a PCP, while other DMG features such as EDCA operation in a PBSS do not require association. A DMG STA supports beamforming (BF) as described in 10.42 and 20.9 and GCM encryption as described in 12.5.5.

A DMG STA supports the PHY signaling as described in 20.4, 20.5, and 20.6. At a minimum, a DMG STA supports the mandatory modulation and coding scheme (MCS) and PHY protocol data unit (PPDU) formats described in 20.4 and 20.5. A DMG STA has PHY features that include a low-density parity check (LDPC) encoding, a preamble making use of Golay sequences, and beamforming. The PPDUs are always transmitted with the same channel spacing as described in Annex E.

A DMG STA supports MAC features that provide channel access in an environment in which transmissions use a directional antenna pattern. A DMG STA has MAC features that include frame aggregation, block ack

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features, service periods, contention based access periods, DMG protected period, AP or PCP clustering, dynamic channel time management, reverse direction, spatial sharing, beamforming, and operation (fast session transfer) in a multi-band device. A DMG STA is not a mesh STA. A DMG STA does not use any of the following: HCCA, power save multi-poll (PSMP), TDLS, GCR.

4.3.23 DMG relay

The IEEE 802.11 DMG relay function allows a source relay endpoint DMG STA (REDS) to transmit frames to a destination REDS with the assistance of another DMG STA, the relay DMG STA (RDS), as shown in Figure 4-12. Relaying can improve the reliability of communication in a DMG BSS in the case the direct link between the source REDS and the destination REDS has poor quality or is disrupted. Following the DMG relay setup procedures, a source REDS can discover and select an appropriate RDS to act as the relay for a particular destination REDS, prior to Data frame transmission using the relay. A relay operating as a link switching type of relay uses the RDS to forward frames between the source and destination REDS if the direct link between the REDS is disrupted. In a link cooperation of relay operation, the RDS simultaneously repeats the transmission of frames between the source and destination REDS, which can possibly increase the signal quality received at the destination REDS.

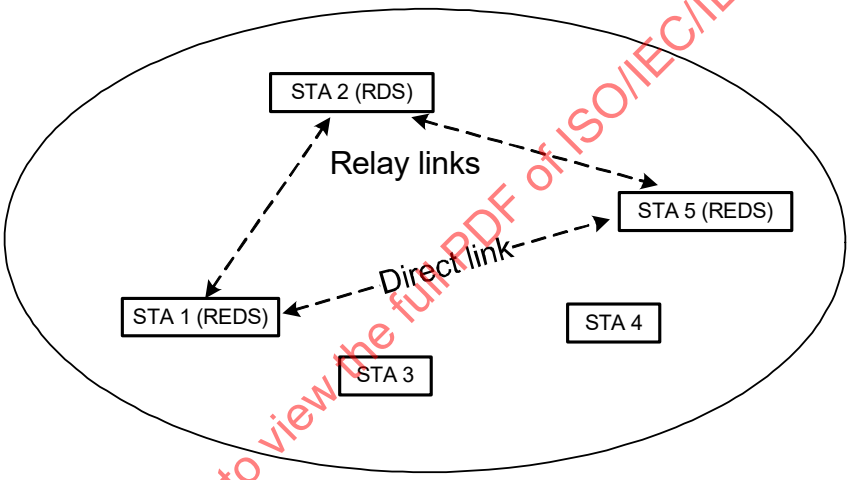

Figure 4-12—DMG relay in a DMG BSS

4.3.24 Robust audio video (AV) streaming

4.3.24.1 Introduction

Robust AV streaming improves AV streaming performance when using IEEE Std 802.11 for consumer and enterprise applications.

4.3.24.2 Groupcast with retries (GCR)

The GCR service allows a STA to request greater reliability for one or more group addressed streams that the STA receives. Greater reliability is provided via unsolicited retries or the block ack mechanism. A non-AP STA can request delivery so that the AP transmits the frames via EDCA within GCR service periods when all associated non-AP STAs are in active mode or the awake state of the PS mode.

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4.3.24.3 Stream classification service (SCS)

SCS enables the establishment of a classification using layer 2 and/or layer 3 signaling to match incoming individually addressed MSDUs. Once classified, individually addressed MSDUs matching the classification are assigned to an access category and are tagged with their drop eligibility. When intra-access category prioritization is enabled (see 4.3.24.7), SCS allows MSDUs matching the classification to be assigned to the primary or alternate transmit queues so that finer grained prioritization can be applied.

4.3.24.4 Mirrored stream classification service (MSCS)

MSCS enables the establishment of classification using layer 2 and/or layer 3 signaling to classify incoming individually addressed MSDUs into streams. Once classified, individually addressed MSDUs in each stream are assigned to a user priority based on the user priority of MSDUs matching the stream in the reverse direction.

4.3.24.5 Overlapping BSS (OBSS) management

The objective of OBSS management is to facilitate cooperative sharing of the medium between APs that operate in the same channel and that are able to receive or obtain frames from each other, including Beacon frames. These frames might be received directly or via associated STAs that support the Beacon request capability (see 11.10.10).

OBSS management provides the means to

— Provide additional information for channel selection
— Extend the admission control mechanism to a distributed environment
— Enable the coordination of scheduled TXOPs between OBSSs

OBSS management enables stationary and portable APs to provide to neighboring APs information for the selection of a channel and for the cooperative sharing of that channel. The main component of OBSS management is the QLoad report that provides information on

— The reporting AP's overlap situation
— The reporting AP's QoS traffic load
— The total QoS traffic load of BSSs directly overlapping the reporting AP's BSS

This information might be used to aid an AP when searching for a channel and also when sharing a channel in an overlap situation.

To coordinate the TXOPs of overlapping HCCA APs, OBSS management provides a means for an AP to advertise its TXOP allocations so another AP might schedule its own TXOPs to avoid those already scheduled.

4.3.24.6 Interworking with IEEE 802.1Q Stream Reservation Protocol (SRP)

Support for SRP from IEEE Std 802.1Q enables integration of the TSPEC ADDTS request/response protocol with IEEE 802.1Q SRP to enable end-to-end SRP reservations when one or more IEEE 802.11 links are part of a path from IEEE 802.1Q Talker to IEEE 802.1Q Listener.

4.3.24.7 Intra-access category prioritization

Intra-access category prioritization provides six transmit queues that map to four enhanced distributed channel access functions (EDCAFs) to enable differentiation between traffic streams that are in the same access category in order for finer grained prioritization to be applied between individual AV streams or voice streams.

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4.3.25 Operation under geolocation database (GDB) control

Regulators designate television broadcast bands for the deployment of dynamic sharing technologies. Different schemes result in different times that elapse from the moment an authorized database is told to change access to a particular slice of spectrum and the time that sharing radios are required to change their operations.

One current system design allows the GDBs to utilize a fully populated map of all protected services, and the databases have precalculated maps that are effective on timescales of one to two days.

Another system design allows the protected services to negotiate with controllers of unlicensed devices so that both can share available broadcast channels and facilitate response times of less than an hour where necessary and even within minutes if desired.

Another system design has the GDB fully control all white space devices by requiring them to tell the database their intended location and emissions footprint and receive permission before any broadcast band transmission starts. Any change of intended frequencies or powers is told to the database, and permission is received before the change takes place.

The architectural role of components depends on the security and timeliness requirements in particular regulatory domains. Figure 4-13 shows two infrastructure BSSs in which APs are geolocation database dependent (GDD) enabling STAs and the other STAs are GDD dependent STAs.

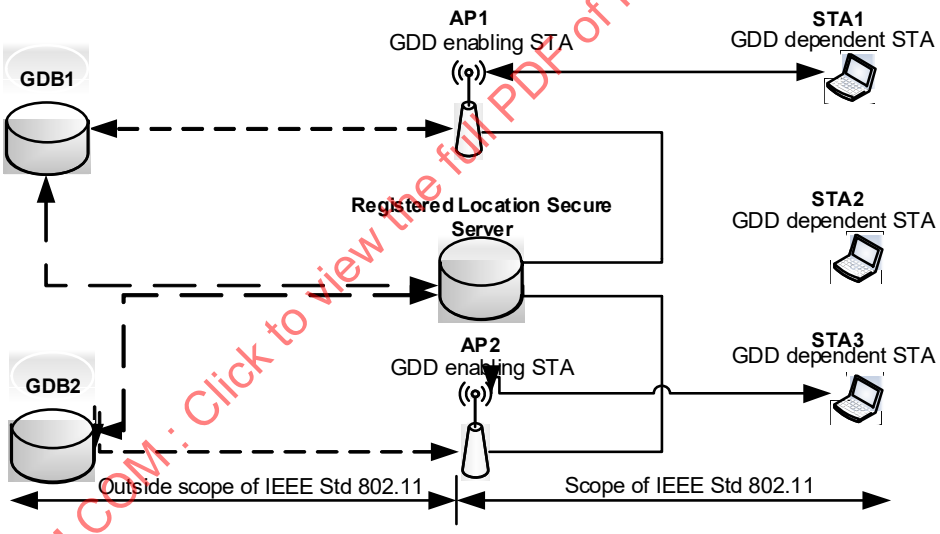

Figure 4-13—Multiple APs and multiple GDBs

In most regulatory domains, GDD enabling STAs are required to

- Securely communicate with GDBs
- Maintain the white space maps (WSMs) and other information received from GDBs
- Create and transmit a contact verification signal to inform GDD dependent STAs that the map they received is still valid

A registered location query protocol (RLQP) is provided to share the WSMs and current channel use among GDD enabling STAs in a neighborhood. GDD dependent STAs can query both their GDD enabling STA and the registered location secure server (RLSS) about WSMs and channel utilization. In some regulatory domains, a RLSS can provide GDBs with the current channel use information for all of the BSSs and IBSSs

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that communicate with it. In some regulatory domains, the RLSS communicates with controllers of other white space systems to coordinate emissions footprints of their services. By accessing and using this information, the STAs can make intelligent decisions about the most effective way to utilize the available spectrum, power, and bandwidth for their communications.

The specific mechanisms are as follows:

— Channel availability query, used to obtain one or more WSMs of available channels for an area or a geolocation
— Channel schedule management, used to obtain start and ending times for each available white space channel
— Contact verification signal, used by a GDD dependent STA to verify it is still receiving frames from its GDD enabling STA
— GDD enablement, the procedure where a GDD enabling STA forms a network and maintains the network under the control of a GDB
— Network channel control, used to inform a local channel controller that has a view of nearby transmitters and their emissions footprints
— WSM, used to retrieve the available white space channels and their transmit power restrictions

The use of the mechanisms in a particular regulatory domain depends on the specific regulatory requirements. Table 4-1 gives a view of the use of specific mechanisms to meet regulatory requirements in terms of daily, hourly, and minute timescales. Implementers are referred to the regulatory sources in Table D.1 for further information. Operation in countries within defined regional regulatory domains might be subject to additional or alternative national regulations.

Table 4-1—GDD mechanisms and timescales

Mechanism	Daily consultation required	Hourly consultation required	Minute responsiveness
Channel availability query	Informative	Informative	Not applicable
Channel schedule management	Informative	Informative	Not applicable
Contact verification signal	Required to be secure	Might be secure	Loss of consecutive signals requires action
GDD enablement	Required	Required	Required
Network channel control	Informative	Informative	Not applicable
WSM	Required for GDD enabling STA, might be translated for GDD dependent STA	Required for GDD enabling STA, might be translated for GDD dependent STA	Required for GDD enabling STA, might be translated for GDD dependent STA

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These mechanisms allow a BSS to manage and query its radio environment and a GDB to control the radio environment for all wireless services.

4.3.26 CDMG STA

An IEEE 802.11 CDMG STA is a DMG STA that supports CDMG operation in the Chinese 60 GHz frequency band, and has dot11CDMGOptionImplemented equal to true. In addition to CDMG features, a CDMG STA supports DMG features as described in 4.3.22. A CDMG STA also supports CDMG features as

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identified in Clause 10, Clause 11, and Clause 24. A CDMG STA supports transmission and reception of frames that are compliant with PHY specifications as defined in Clause 24. A CDMG STA is also a QoS STA. The basic channel access of a CDMG STA (see 10.39 and 10.64) allows it to operate in an Infrastructure BSS or in an IBSS or in a PBSS.

Besides supporting DMG PHY features defined in Clause 20, a CDMG STA also supports the PHY signaling as described in 24.4, 24.5, and 24.6. At a minimum, a CDMG STA supports the mandatory modulation and coding scheme (MCS) and PHY protocol data unit (PPDU) formats described in 24.4 and 24.5.

4.3.27 CMMG STA

The IEEE 802.11 CMMG STA operates in 42.3 GHz to 47.3 GHz or 47.2 GHz to 48.4 GHz frequency bands.

The main PHY features in a CMMG STA are the following:

- 540 MHz channel width
- Control mode and SC mode (directional transmit and receive)
- Single spatial stream MCS 0 (control mode transmit and receive) in all supported channel widths
- Single spatial stream MCSs 1 to 3 (SC mode transmit and receive) in all supported channel widths
- LDPC coding with length 672
- Normal guard interval as defined in Table 25-3
- Optional support for 1080 MHz channel width
- Optional support for CMMG-MCSs 4 to 8 (SC mode transmit and receive)
- Optional support for CMMG-MCSs 9 to 16 (OFDM mode transmit and receive)
- Optional support for short guard interval (transmit and receive)
- Optional support for LDPC coding with length 2016
- Optional support MIMO transmission (SC mode and OFDM mode transmit and receive)
- Optional support for STBC (transmit and receive)
- Optional support for transmit beamforming sounding (by sending a CMMG NDP)
- Optional support for responding to transmit beamforming sounding

The CMMG STA provides PHY and MAC features that can support a throughput of 1 Gb/s and greater, as measured at the MAC data service access point (SAP). A CMMG STA supports CMMG features as identified in Clause 10, Clause 11, and Clause 25. A CMMG STA operates in a CMMG BSS and supports transmission and reception of frames that are compliant with PHY specifications as defined in Clause 25. A CMMG STA is also a QoS STA. The basic channel access of a CMMG STA (see 10.39) allows it to operate in an Infrastructure BSS, in an IBSS, or in a PBSS. Certain CMMG features such as service period allocation are available only to CMMG STAs that are associated with an AP or with a PCP, while other CMMG features such as EDCA operation in a PBSS do not require association. A CMMG STA supports beamforming (BF) as described in 10.42 and 20.10 and GCM encryption as described in 12.5.5.

A CMMG STA supports the PHY signaling as described in 25.4, 25.5, and 25.6. At a minimum, a CMMG STA supports the mandatory modulation and coding scheme (MCS) and PHY protocol data unit (PPDU) formats described in 25.4 and 25.5. A CMMG STA has PHY features that include a low-density parity check (LDPC) encoding, a preamble making use of zero correlation zone (ZCZ) sequences, and beamforming. The PPDUs are always transmitted with the same channel spacing as described in Annex E.

A CMMG STA supports MAC features that provide channel access in an environment in which transmissions use a directional antenna pattern or use multiple input multiple output antenna pattern. A

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CMMG STA has MAC features that include frame aggregation, block ack features, service periods, contention based access periods, CMMG protected period, AP or PCP clustering, dynamic channel time management, reverse direction, spatial sharing, beamforming, and fast session transfer in a multi-band device. A CMMG STA is not a mesh STA. A CMMG STA follows the same channel access rules irrespective of the type of BSS in which it operates.

4.3.28 General link (GLK)

4.3.28.1 General

GLK STAs establish general links with other GLK STAs. These general links are suitable to be used as links inside an IEEE 802.1Q network. For an infrastructure general link example, see Figure 4-15 (in 4.3.28.3.3).

A GLK STA coordinates with a GLK convergence function to provide the Internal Sublayer Service, as defined in IEEE Std 802.1AC-2016, to an IEEE 802.1Q bridge for each peer GLK STA with which it is communicating. GLK STAs also provides link metrics for the use of external path selection protocols such as spanning tree protocol.

A GLK STA that starts a BSS uses membership selector values to set the BSS policy of requiring or not requiring general link or Ethertype protocol discrimination (EPD) support for any STA that joins the BSS.

A non-AP STA acts as either a GLK STA or a non-GLK STA. A GLK AP might permit associations from non-GLK STAs and acts as a non-GLK AP for those associated non-GLK STAs. GLK DMG STAs can establish a general link through a DMG relay. GLK S1G STAs cannot use or be an S1G relay.

The four-address MAC header can be used in GLK transmissions of Data frames. The use of the four-address MAC header or basic A-MSDU format is necessary for such MPDUs if the frame's SA, TA, RA, and DA fields (source address, transmitter address, receiver address, and destination address, respectively) are all different from each other. The three-address frame format can be used, as defined by Table 9-3, provided the addresses are consistent with Table 9-30.

A SYNRA is an RA that is a group address used by a GLK AP to forward frames to a subset of GLK non-AP STAs, as required by IEEE 802.1Q bridges. The use of a SYNRA can improve bandwidth usage in some cases. SYNRAs are used in GLK AP transmissions.

As described in 4.3.28.2, when a GLK AP transmits a Data frame with a four-address MAC header whose RA contains a group address, the contents of the RA is a synthetic receiver address (SYNRA), and therefore its RA and DA values are not equal. A GLK non-AP STA supports selective reception of group addressed frames by supporting SYNRA reception.

4.3.28.2 Selective reception of group addressed frames

For the reasons given below, when transmitting a Data frame that has an RA that is a group address to a set of receiving STAs, the GLK transmitter needs to transmit those MSDUs so that they are accepted by a specified subset of the associated GLK STAs indicated by the IEEE 802.1Q bridge.

The reason for such selective reception is to support requirements of IEEE 802.1Q bridges and can include the MAC service requirements that, when an MSDU is sent, it is not subsequently received and processed by the transmitting station or to break loops in the network topology. When a GLK STA associated with a GLK AP sends an MSDU to that AP with a group address destination, the AP retransmits it and uses the selective reception facility to stop the originating GLK STA from accepting it. Also, since the AP Internal Sublayer Service SAPs are mapped to IEEE 802.1Q bridge ports, loop prevention might need the traffic to be blocked to one or more of the associated GLK STAs. Such blocking can be implemented by the selective reception facility.

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Implementation of this selective reception facility in a BSS case includes use of an RA that is a synthetic group address (SYNRA addressing, see 9.3.2.1.2). As an alternative to the use of a SYNRA, selective reception includes sending a copy of the Data frame to each intended receiver using individually addressed MPDUs. In either case, an appropriate address format is needed because the DA is different from the RA (since the RA is either the SYNRA or a serial individual RA). SYNRA addressed MPDUs are transmitted by APs only.

All GLK non-AP STAs in an infrastructure BSS support receipt of SYNRAs (see 9.3.2.1.2 and 10.65). A GLK AP that is requested to deliver an MPDU to multiple GLK STAs can choose to construct and transmit a SYNRA addressed MPDU, use a sequence of individually addressed MPDUs, or both.

Parameters exchanged during the association (or reassociation) of a GLK STA with a GLK AP determine the mechanism used by the GLK AP to enable selective reception at the GLK STA of group addressed frames transmitted by the GLK AP. One such mechanism is GLK-GCR, which is a subset of GCR customized for general links (see 11.21.16). In GLK-GCR the group address is a SYNRA. Features of GCR that do not apply to GLK-GCR are as follows:

a) DMS Request and DMS Response frame exchange to set up GLK-GCR service
b) ADDBA Request/Response frame exchange to setup block ack agreement
c) GCR-SP delivery method
d) Unsolicited DMS Response frame for “GCR Advertise”
e) Concealment address

4.3.28.3 GLK Service Sets

4.3.28.3.1 Provision of the MAC service

MAC service data unit (MSDU) delivery services in an IEEE 802.1Q network can be supported by the IEEE 802.1AC™ MAC service. GLK STAs coordinate with an IEEE 802.1AC-compliant GLK convergence function, to provide access to the WM via one or more Internal Sublayer Service SAPs. The routing of all MSDUs that are provided by an IEEE 802.1Q relay entity via GLK STAs is controlled by the routing protocols of the IEEE 802.1Q network to which the GLK STA is attached. This enables the routing protocols to use all the general links available to the GLK STA.

4.3.28.3.2 GLK IBSS and PBSS

A GLK IBSS or GLK PBSS can provide access to the WM via general links that are suitable for use in an IEEE 802.1Q network. Figure 4-14 shows an example of a GLK IBSS (or equivalently a PBSS) involving three GLK non-AP STAs. Each participating STA provides MAC services at the MS SAP, with the inclusion of a station vector that is then mapped to one or more Internal Sublayer Service SAPs by the IEEE 802.1AC GLK Convergence Function. Three general links are shown that connect three pairs of Internal Sublayer Service SAPs in a point-to-point manner. Each of the Internal Sublayer Service SAPs is then mapped to either an Enhanced Internal Sublayer Service (EISS) SAP or MAC SAP, by the IEEE 802.1Q Media Independent Function or the Internal Sublayer Service to MAC SAP function, respectively. The EISS SAP provides EISS services to the MAC relay entity of a VLAN bridge component (IEEE 802.1Q MAC Relay Entity). The MAC SAP provides services to the LLC Sublayer.

NOTE—IEEE Std 802.11 does not specify the details of the IEEE 802.1AC GLK Convergence Function, the IEEE 802.1Q Media Independent Function, the Internal Sublayer Service to MAC SAP function, the IEEE 802.1Q MAC Relay Entity, and the LLC Sublayer. These entities are specified in other documents such as IEEE Std 802.1AC-2016 and IEEE Std 802.1Qbz™-2016 [B20]. These entities are shown with dashed outlines in the figure. Entities that IEEE Std 802.11 does specify are shown with solid outlines and are within the box labeled “802.11 GLK IBSS/PBSS”.

A difference from a non-GLK STA’s IEEE 802.11 IBSS/PBSS is that either or both MAC SAPs could directly connect to an IEEE 802.1Q bridge.

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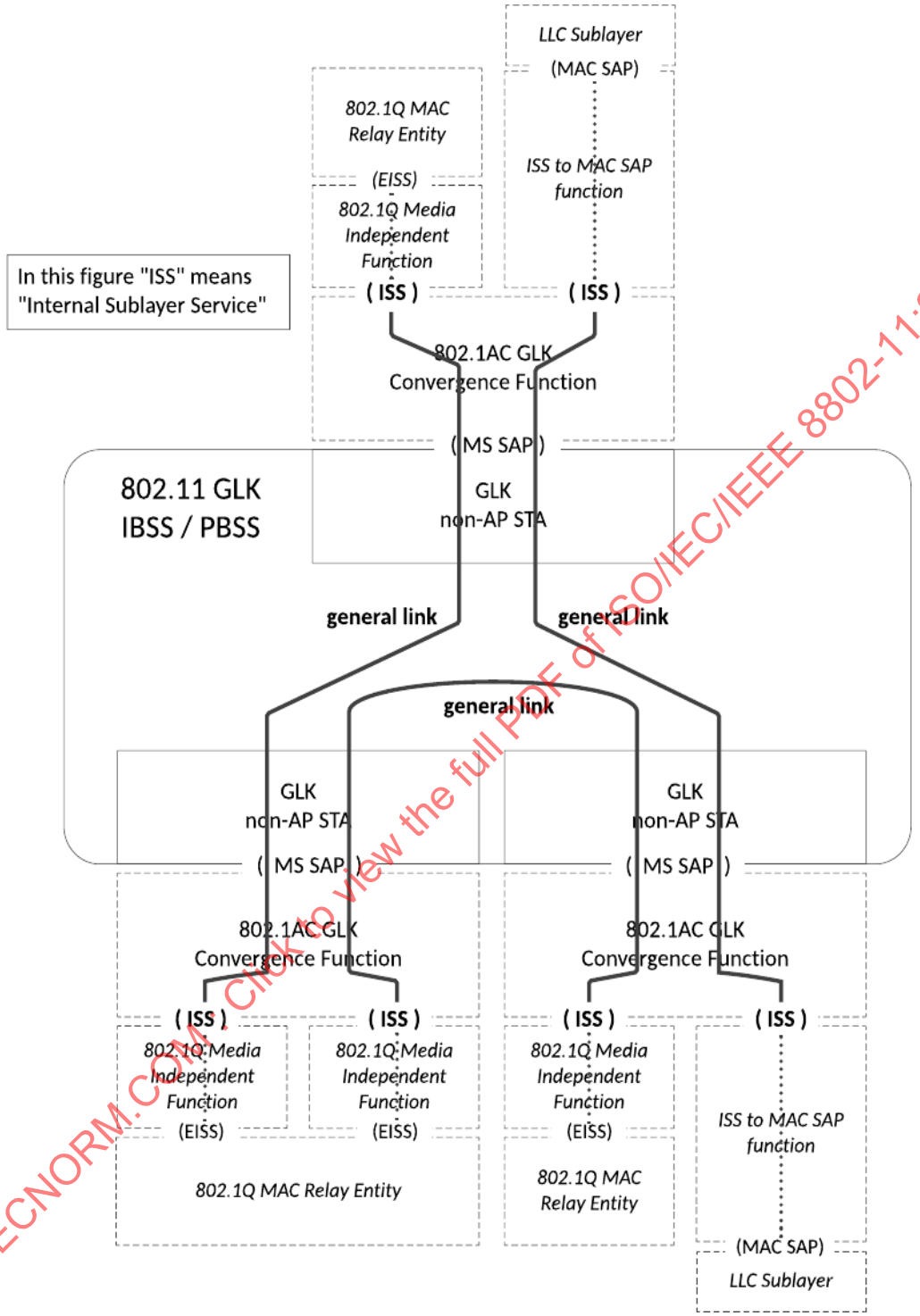

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Figure 4-14—Example of GLK IBSS or PBSS

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For example, each of the STAs and attached bridges (including the IEEE 802.1Q MAC Relay Entities) shown could be at the top of a rack in a data center to provide inter-rack connectivity. The two MAC SAPs shown could even be safely connected to the same IEEE 802.1Q network, since such a network provides protection from loops.

Also, shown in the figure is the possibility to provide a point-to-point link between two LLC Sublayer entities that are each attached to a GLK non-AP STA. For example, this link could allow a computer attached to a GLK STA to directly connect to a network attached storage device attached to a GLK STA.

4.3.28.3.3 Infrastructure BSS with general links

A GLK infrastructure BSS can provide access to the WM via general links that are suitable for use in an IEEE 802.1Q network. Figure 4-15 shows an example of a GLK infrastructure BSS with three GLK non-AP STAs and one GLK AP. Each participating STA provides MAC services at the MS SAP, with the inclusion of a station vector that is then mapped to one or more Internal Sublayer Service SAPs by the IEEE 802.1AC GLK Convergence Function. Four general links are shown that connect four pairs of Internal Sublayer Service SAPs in a point-to-point manner. Each of the Internal Sublayer Service SAPs is then mapped, by the IEEE 802.1Q Media Independent Function or the Internal Sublayer Service to MAC SAP function, to either an EISS SAP or a MAC SAP, respectively. The EISS SAP provides EISS services to the MAC relay entity of a VLAN bridge component (IEEE 802.1Q MAC Relay Entity). The MAC SAP provides services to the LLC Sublayer.

NOTE—IEEE Std 802.11 does not specify the details of the IEEE 802.1AC GLK Convergence Function, the IEEE 802.1Q Media Independent Function, the Internal Sublayer Service to MAC SAP function, the IEEE 802.1Q MAC Relay Entity, and the LLC Sublayer. These entities are specified in other documents such as IEEE Std 802.1AC-2016 and IEEE Std 802.1Qbz-2016 [B20]. These entities are shown with dashed outlines in the figure. Entities that IEEE Std 802.11 does specify are shown with solid outlines and are within the box labeled “802.11 BSS”.

Although transmissions by an AP are typically received by all STAs associated with that AP, the service provided by a GLK infrastructure BSS might be considered as separate point-to-point links between the corresponding Internal Sublayer Service SAPs. Provisioning of such apparent point-to-point links is natural for MPDUs with an RA that is an individual address. In order to provide such apparent point-to-point links for group addressed frames, the GLK AP can transmit them so that they are accepted by a subset of the associated GLK STAs. Such selective transmission can be provided through the GLK SYNRA addressing facility (see 4.3.28.2) or by serial transmissions to the desired receivers.

Three types of example general links are shown in Figure 4-15:

— The first type is an infrastructure general link that connects a non-AP GLK STA attached bridge port of an IEEE 802.1Q MAC Relay Entity with an GLK AP attached bridge (two of these general links are shown in the figure). These links could be used to enhance the reliability and routing options of an IEEE 802.1Q-compliant LAN by providing redundant wireless links between the bridges in the LAN.

— The second type is a non-AP GLK STA to non-AP GLK STA link that connects the STAs’ attached bridges (IEEE 802.1Q MAC Relay Entities). This type of general link is similar to the IBSS or PBSS STA to STA link.

— The third type of general link is a “leaf-node” type of general link that connects entities in the LLC layer attached to a non-AP GLK STA via a general link and an IEEE 802.1Q bridge attached to the GLK AP to another entity available via the IEEE 802.1Q network attached to the GLK AP. Such a general link could provide a connection between a network printer attached to the LAN and a computer attached to the non-AP GLK STA.

A difference between a GLK AP’s IEEE 802.11 links and a non-GLK AP’s IEEE 802.11 links, which can only be connected to an Internal Sublayer Service SAP via a DS and portal, is that an Internal Sublayer Service SAP could directly connect to an IEEE 802.1Q bridge.

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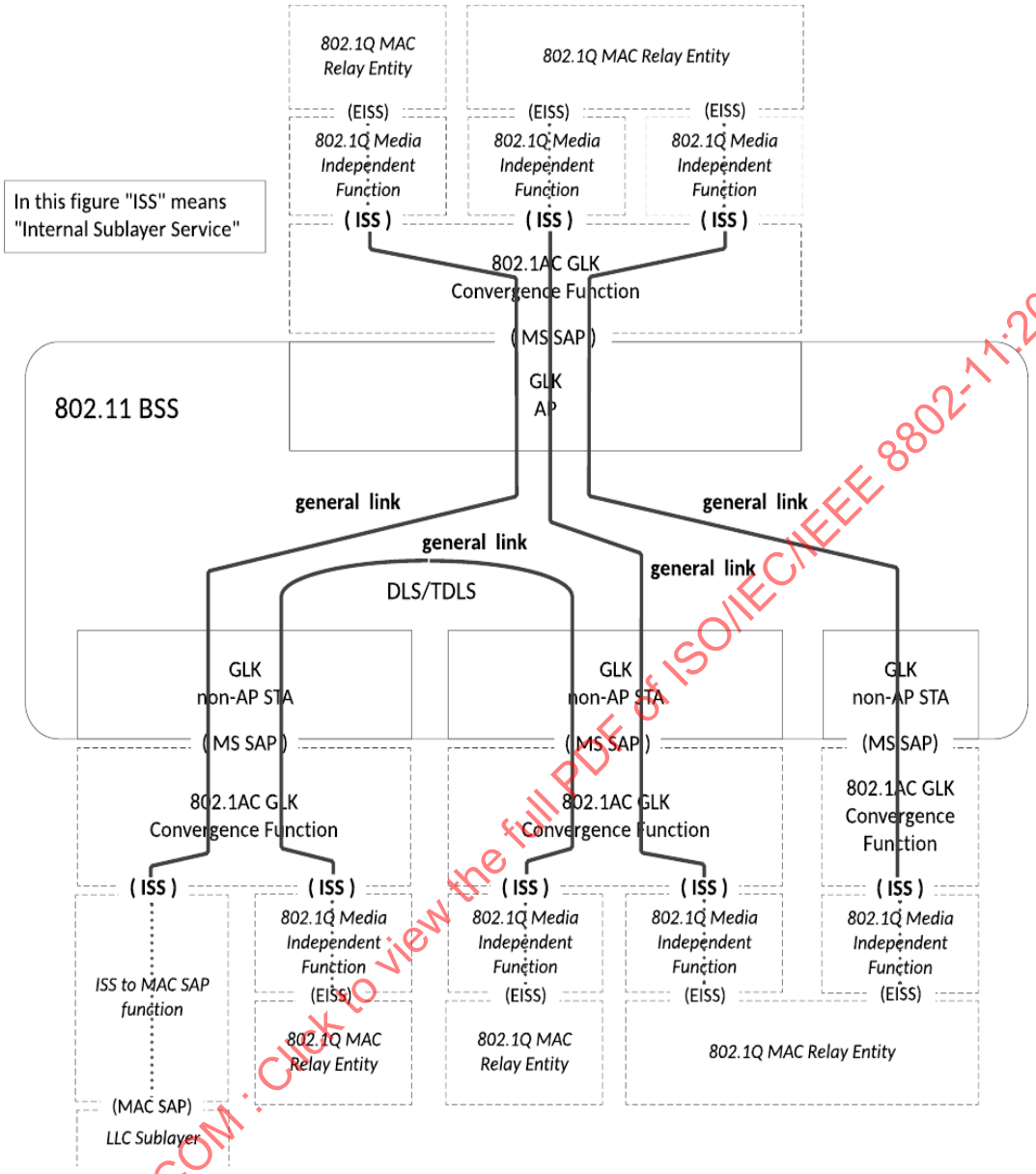

Figure 4-15—Example of infrastructure BSS with general links

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4.3.28.3.4 Infrastructure BSSs with general links in the presence of an ESS

BSSs that support general links can be components of an extended form of network by using the general links within an IEEE 802.1Q bridged network. In such a bridged network, the concept of the DS in a non-GLK ESS is replaced by the other components of the IEEE 802.1Q network. However, such a GLK topology is more general than the non-GLK infrastructure mode. For example, Figure 4-16 shows a network consisting of three types of BSSs: a GLK infrastructure BSS (with only GLK STAs), an infrastructure BSS (with both GLK and non-GLK STAs), and an infrastructure BSS (containing only non-GLK STAs). The example ESS shown in the figure consists of all the non-GLK non-AP STAs, the non-GLK AP, and the portion of the GLK AP that has associated non-GLK non-AP STAs. In the ESS the portal that is connected

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to the DS does not show any additional connection because the portal could be connected to any type of bridge, switch, or LAN. Hence no specific interconnection is shown. The general links shown in Figure 4-16 are similar to those shown in Figure 4-15 and provide point-to-point links as described in 4.3.28.3.3. Also, shown in the figure is an example of the possible configuration of more than one IEEE 802.1Q MAC relay entity being attached to a GLK AP or GLK non-AP STA and the possible configuration of more than one GLK AP or GLK non-AP STA being attached to the same IEEE 802.1Q MAC relay entity. These configurations show the flexibility available with general links.

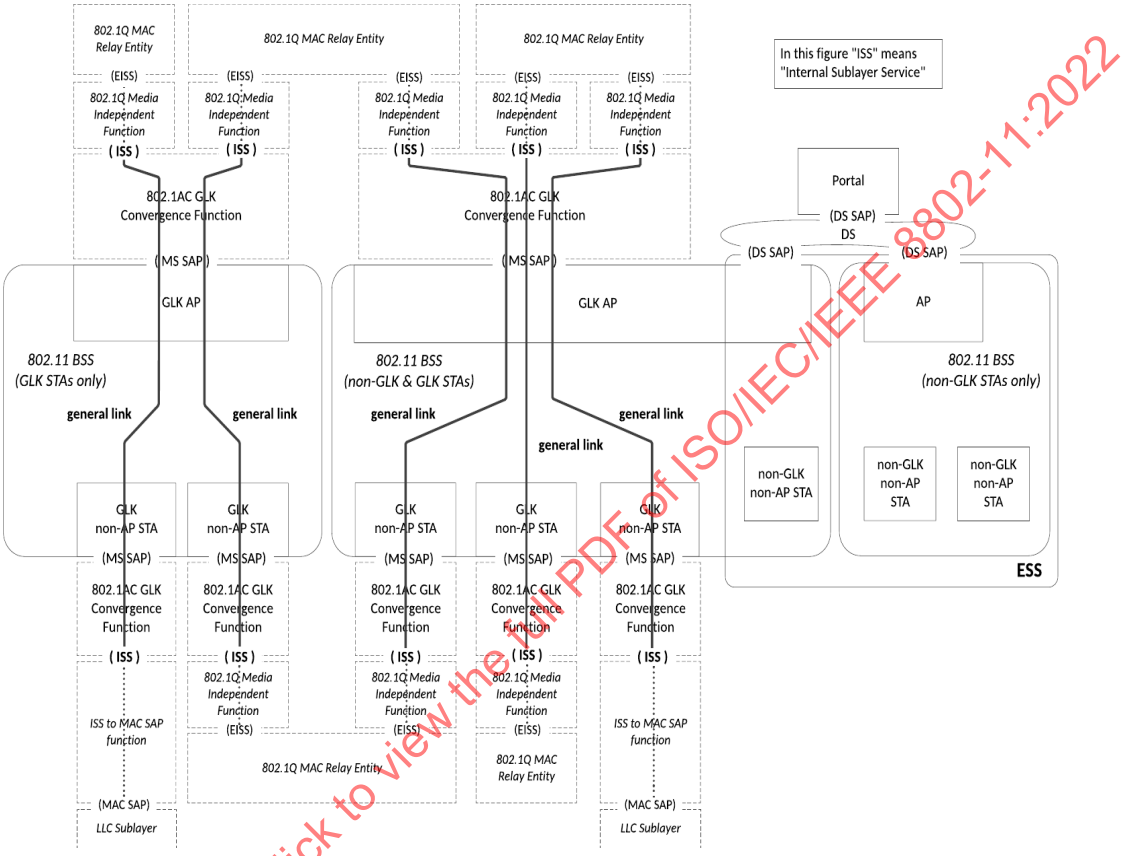

Figure 4-16—Example of an ESS and extended network with general links

NOTE—IEEE Std 802.11 explicitly does not specify the details of the IEEE 802.1AC GLK Convergence Function, the IEEE 802.1Q Media Independent Function, the Internal Sublayer Service to MAC SAP function, the IEEE 802.1Q MAC Relay Entity, and the LLC Sublayer. These entities are specified in other documents such as IEEE Std 802.1AC-2016 and IEEE Std 802.1Qbz-2016 [B20]. These entities are shown with dashed outlines in the figure. Entities that IEEE Std 802.11 does specify are shown with solid outlines.

4.3.29 Ethertype protocol discrimination (EPD)

IEEE Std 802 describes the two LLC sublayer protocols: Ethertype protocol discrimination (EPD) and LLC protocol discrimination (LPD). LPD is the default for IEEE 802.11 MSDUs with the exception of the 5.9 GHz bands where EPD is used for the transmission of all MSDUs (see E.2.3 and E.2.4). While not the default, EPD might be used in other bands when it is known that the addressed STAs and the transmitting STA support EPD.

An EPD STA is a STA that supports EPD format MSDUs. EPD STAs, other than those operating in the 5.9 GHz bands, indicate their support through a bit in the Capability Information field, DMG STA Capability Information field, and Relay Capabilities element. An EPD STA, when transmitting an MPDU

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with an RA that is an individual address, uses EPD if the recipient supports EPD; otherwise, such individually addressed transmissions use LPD.

In an MPDU transmitted with a groupcast RA, the choice between of EPD or LPD format of MSDUs in the MPDU is controlled by the policy of the BSS (see 5.1.4).

4.4 Logical service interfaces

4.4.1 General

IEEE Std 802.11 explicitly does not specify the details of implementations. Instead, IEEE Std 802.11 specifies services to aid understanding how the architectural components are logically organized. The services are associated with different components of the architecture. There are three categories of IEEE 802.11 service—the station service (SS), the PCP service (PCPS), and the distribution system service (DSS). These categories of service are used by the IEEE 802.11 MAC sublayer.

The complete set of IEEE 802.11 architectural services are as follows:

a) Authentication
b) Association
c) Deauthentication
d) Disassociation
e) Distribution
f) Integration
g) Data confidentiality
h) Reassociation
i) MSDU delivery
j) DFS
k) TPC
l) Higher layer timer synchronization (QoS facility only)
m) QoS traffic scheduling (QoS facility only)
n) Radio measurement
o) DSE

This set of services is divided into three groups: the SS, the PCPS, and the DSS. The SS is part of every STA. The PCPS is provided by the PCP of a PBSS. The DSS is provided by the DS.

4.4.2 SS

The service provided by STAs is known as the SS.

The SS is present in every IEEE 802.11 STA (including APs, as APs include STA functionality). The SS is specified for use by MAC sublayer entities. All STAs provide the SS.

The SS is as follows:

a) Authentication (not used when dot11OCBActivated is true)
b) Deauthentication (not used when dot11OCBActivated is true)
c) Data confidentiality (not used when dot11OCBActivated is true)
d) MSDU delivery

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e) DFS
f) TPC
g) Higher layer timer synchronization (QoS facility only)
h) QoS traffic scheduling (QoS facility only)
i) Radio measurement
j) DSE

4.4.3 PBSS control point service (PCPS)

The service provided by the PCP of a PBSS is known as the PCPS. Since each STA within a PBSS can operate as a PCP, each STA in the PBSS is capable of providing the PCPS, if it becomes the PCP of the PBSS. Non-PCP STAs do not provide the PCPS.

The services that comprise the PCPSs are the following:

a) Association
b) Disassociation
c) Reassociation
d) QoS traffic scheduling

The PCPS is specified for use by MAC sublayer entities.

4.4.4 DSS

The service provided by the DS is known as the DSS. IEEE Std 802.11 explicitly does not specify the details of DS implementation structure. Instead, IEEE Std 802.11 specifies the services that are provided by a DS implementation. A DS can be created from many different technologies including current IEEE 802 wired LANs. IEEE Std 802.11 does not constrain the DS to be either data link or network layer based. Nor does IEEE Std 802.11 constrain a DS to be either centralized or distributed in nature.

This service is represented in the IEEE 802.11 architecture by arrows within APs and mesh gates, indicating that the service is used to cross media and possibly address space logical boundaries. An AP and a mesh gate are logical entities, and the functions described might be shared by one or more physical entities.

The services that comprise the DSS are as follows:

a) Association (not mesh facility)
b) Disassociation (not mesh facility)
c) Distribution
d) Integration
e) Reassociation (not mesh facility)
f) QoS traffic scheduling (QoS facility only)
g) DSE
h) Interworking with the DS (mesh facility only)

DSSs are specified for use by MAC sublayer entities.

Figure 4-17 combines the components from previous figures with the three types of services to show the IEEE 802.11 architecture for infrastructure BSS and PBSS.

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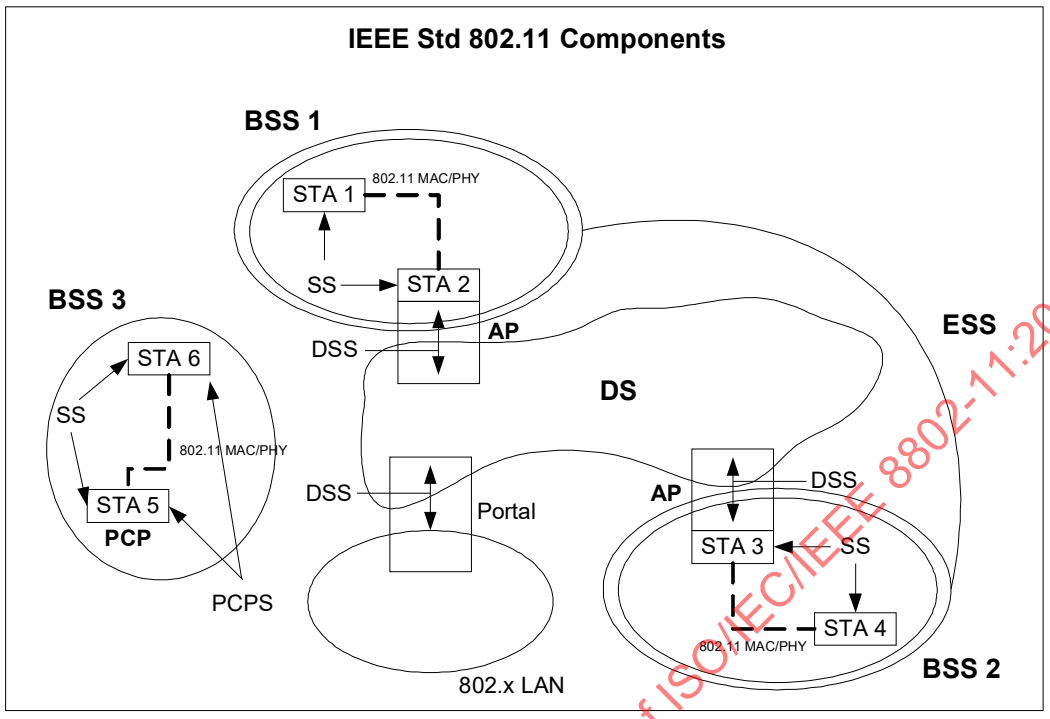

Figure 4-17—IEEE 802.11 architecture for infrastructure BSS and PBSS

4.5 Overview of the services

4.5.1 General

There are many services specified by IEEE Std 802.11. Six of the services are used to support medium access control (MAC) service data unit (MSDU) delivery between STAs. Three of the services are used to control IEEE 802.11 LAN access and confidentiality. Two of the services are used to provide spectrum management. One of the services provides support for LAN applications with QoS requirements. Another of the services provides support for higher layer timer synchronization. One of the services is used for radio measurement.

This subclause presents the services, an overview of how each service is used, and a description of how each service relates to other services and the IEEE 802.11 architecture. The services are presented in an order designed to help build an understanding of the operation of an IEEE 802.11 network. As a result, the services that comprise the SS and DSS are intermixed in order (rather than being grouped by category). The services that comprise the PCPS are a subset of the services provided by the SS and DSS.

Each of the services is supported by one or more MAC frame types. Some of the services are supported by MAC management PDUs, which are transported in MAC Management frames. The MSDU delivery service is supported by MAC Data frames. All of these frames gain access to the WM via the IEEE 802.11 MAC sublayer medium access method specified in Clause 10.

The IEEE 802.11 MAC sublayer uses four types of frame—*Data*, *Management*, *Extension,* and *Control* (see Clause 9). Data frames are handled by the MAC data plane (see Figure 5-1).

MAC Management frames and MAC Extension frames (see 9.3.4) are handled via the MAC management plane.

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MAC Control frames are used to support the delivery of IEEE 802.11 Data, Management, and Extension frames.

The examples here assume an ESS environment. The differences among the ESS, the PBSS, and the IBSS environments are discussed separately in 4.7.

4.5.2 Distribution of MSDUs within a DS

4.5.2.1 Distribution

This is the primary service used by IEEE 802.11 non-GLK STAs. It is conceptually invoked by every data message to or from an IEEE 802.11 non-GLK STA operating in an ESS (when the frame is sent via the DS). Distribution is via the DSS.

Refer to the ESS in Figure 4-18 and consider an MSDU being sent from STA 1 to STA 4. One or more frames containing the MSDU are sent from STA 1 and received by STA 2 (the "input" AP). The AP gives a MAC service tuple containing the MSDU to the DSS. It is the job of the distribution system to deliver the MAC service tuple within the DS in such a way that it arrives at the appropriate DS destination for the intended recipient. In this example, the MAC service tuple is distributed to STA 3 (the "output" AP) and STA 3 accesses the WM to send one or more frames containing the MSDU to STA 4 (the intended destination).

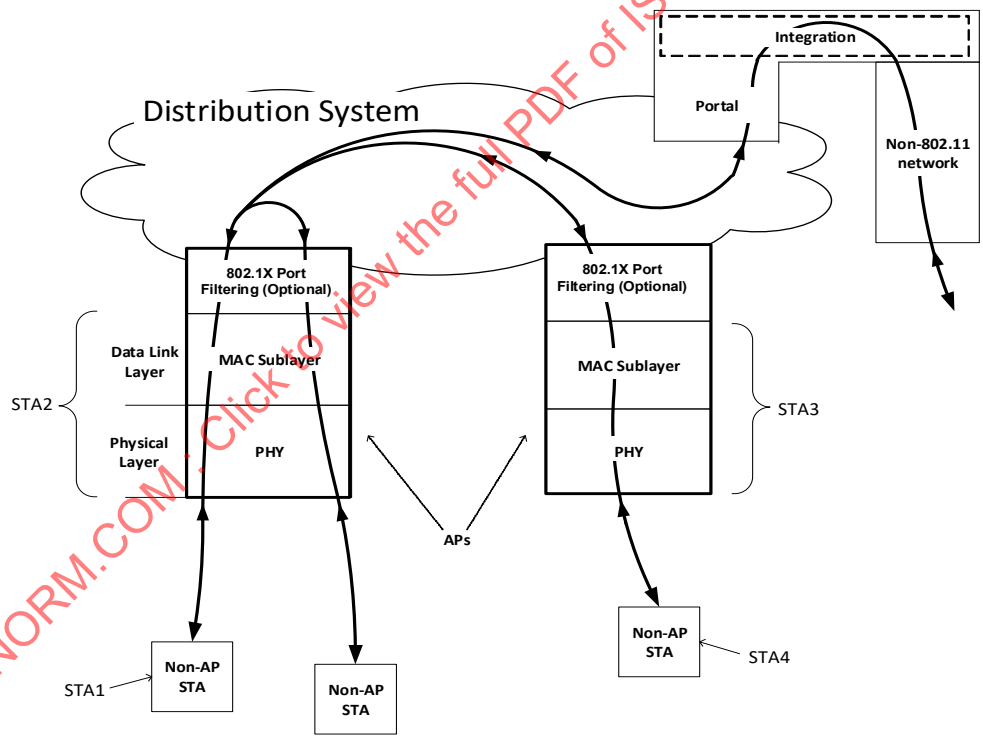

Figure 4-18—IEEE 802.11 Infrastructure model

The previous example was a case in which the AP that invoked the distribution system service was different from the AP that received the distributed MAC service tuple. If the MSDU had been intended for a STA that was a member of the same BSS as the sending STA, then the "input" and "output" APs for the MAC service tuple would have been the same.

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If a MAC service tuple with a group addressed destination is provided to the DS, the DS is responsible for delivering that MAC service tuple to all appropriate APs in the ESS, including the "input" AP, to allow the AP to send frame(s) containing the MSDU to other associated non-AP STAs in its BSS. Generally, the DS delivers the MAC service tuple to all the APs in the ESS. Optionally, an implementation-specific or higher layer filtering might be applied to restrict the delivery to a known subset of the APs in the ESS; such filtering is beyond the scope of this standard.

How the MAC service tuple is distributed within the DS is not specified by IEEE Std 802.11. All IEEE Std 802.11 is required to do is to provide the DS with enough information for the DS to be able to determine the "output" point that corresponds to the intended recipient. The necessary information is provided to the DS by the three association related services (association, reassociation, and disassociation).

In all the examples above, the distribution system service was logically invoked. Whether the MAC service tuple actually had to traverse the physical DSM or not is a DS implementation matter and is not specified by this standard.

While IEEE Std 802.11 does not specify DS implementations, it does recognize and support the use of the WM as one possible DSM. This is specifically supported by the IEEE 802.11 frame formats. (Refer to Clause 9 for details.) A mesh BSS might form an entire DS or a part of a DS using the WM, as shown in Figure 4-9. Mesh services are used to form a mesh BSS and distribute MSDUs. Clause 14 defines how mesh BSSs are formed and how MSDUs are distributed through a mesh BSS.

4.5.2.2 Integration

When the distribution system service determines that the intended recipient of an MSDU is a member of an integrated LAN, the "output" point of the DS is a portal instead of an AP.

MAC service tuples that are distributed to a portal cause the DS to invoke the Integration function (conceptually after the distribution system service). The Integration function is responsible for accomplishing whatever is needed to deliver a MAC service tuple from the DSM to the integrated LAN media (including any required media or address space translations).

MSDUs received from an integrated LAN invoke the Integration function before the MAC service tuple is distributed by the distribution system.

The details of an Integration function are dependent on a specific portal implementation and are outside the scope of this standard.

4.5.2.3 QoS traffic scheduling

QoS traffic scheduling provides intra-BSS QoS frame transfers under the HCF, using either contention based or controlled channel access. At each TXOP, a traffic scheduling entity at the STA selects a frame for transmission, from the set of frames at the heads of a plurality of traffic queues, based on requested UP and/or parameter values in the traffic specification (TSPEC) for the requested MSDU. Additional information is available in 10.23.

4.5.3 Connectivity-related services

4.5.3.1 General

The primary purpose of a MAC sublayer is to transfer MSDUs between MAC sublayer entities. The information required for the distribution system service to operate is provided by the association services. Before an MSDU can be handled by the distribution system service, a STA is "associated."

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To understand the concept of association, it is necessary first to understand the concept of mobility.

4.5.3.2 Mobility types

The three transition types of significance to this standard that describe the mobility of STAs within a network are as follows:

a) ***No-transition:*** In this type, two subclasses that are usually indistinguishable are identified:
   1) Static—no motion.
   2) Local movement—movement within the PHY range of the communicating STAs, i.e., movement within a basic service area (BSA).

b) ***BSS-transition:*** This type is defined as a STA movement from one BSS in one ESS to another BSS within the same ESS. A fast BSS transition is a BSS transition that establishes the state necessary for data connectivity before the reassociation rather than after the reassociation.

c) ***ESS-transition:*** This type is defined as STA movement from a BSS in one ESS to a BSS in a different ESS. This case is supported only in the sense that the STA might move. Maintenance of upper-layer connections cannot be guaranteed by IEEE Std 802.11; in fact, disruption of service is likely to occur.

The FT protocol provides a mechanism for a STA to perform a BSS transition between access points (APs) in a robust security network (RSN) or when quality-of-service (QoS) admission control is enabled in the ESS.

The different association services support the different categories of mobility.

4.5.3.3 Association

To deliver an MSDU within an ESS via the DS, the DS needs to know which AP within the ESS to deliver the MSDU, so that the MSDU might ultimately be delivered to the addressed IEEE 802.11 STA. This information is provided to the DS by the concept of association. Association is necessary, but not sufficient, to support BSS-transition mobility. Association is sufficient to support no-transition mobility. Association is one of the services in the DSS.

Before a STA is allowed to send an MSDU via an AP, it first becomes associated with the AP.

For a non-GLK STA, the act of becoming associated invokes the association service, which provides the STA to AP mapping to the DS. How the information provided by the association service is stored and managed within the DS is not specified by this standard.

For a GLK STA, the act of becoming associated invokes the association service, which establishes a general link between two instances of the IEEE 802.1D Internal Sublayer Service. This link provides a point-to-point link between the two Internal Sublayer Service SAPs. The GLK AP STA and the GLK non-AP STA each coordinate with higher layer services and each other to create the point-to-point link. The higher layer services create or enable the Internal Sublayer Service SAPs, inform the GLK convergence function of the mapping of the Internal Sublayer Service SAPs, and inform the network routing protocol of the existence of the general link. The GLK AP and the GLK non-AP STA each establish a service_access_point_identifier for each general link, for their respective MS SAPs. This process allows for the establishment of a point-to-point link suitable for use in an IEEE 802.1Q network.

Within a robust security network (RSN), association is handled differently. In an RSNA, the IEEE 802.1X Port determines when to allow data traffic across an IEEE 802.11 link. A single IEEE 802.1X Port maps to one association, and each association maps to an IEEE 802.1X Port. An IEEE 802.1X Port consists of an IEEE 802.1X Controlled Port and an IEEE 802.1X Uncontrolled Port. The IEEE 802.1X Controlled Port is

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blocked from passing general data traffic between two STAs until an IEEE 802.1X authentication procedure completes successfully over the IEEE 802.1X Uncontrolled Port. Once the AKM completes successfully, data protection is enabled to prevent unauthorized access, and the IEEE 802.1X Controlled Port unblocks to allow protected data traffic. IEEE 802.1X Supplicants and Authenticators exchange protocol information via the IEEE 802.1X Uncontrolled Port. It is expected that most other protocol exchanges use the IEEE 802.1X Controlled Ports. However, a given protocol might need to bypass the authorization function and make use of the IEEE 802.1X Uncontrolled Port.

NOTE—See IEEE Std 802.1X-2010 for a discussion of Controlled Port and Uncontrolled Port.

At any given instant, a STA is associated with no more than one AP. This allows the DS to determine a unique answer to the question, "Which AP is serving STA X?" Once an association is completed, a STA can make full use of a DS (via the AP) to communicate. Association is always initiated by the non-AP STA, not the AP.

An AP might be associated with many STAs at the same time.

A STA learns what APs are present and what operational capabilities are available from each of those APs and then invokes the association service to establish an association. A FILS STA is able to discover, authenticate and associate with the AP with a reduced number of frame transmissions. For details of how a STA learns about what APs are present, see 11.1.4.

4.5.3.4 Reassociation

Association is sufficient for no-transition MSDU delivery between IEEE 802.11 STAs. Additional functionality is needed to support BSS-transition mobility. The additional required functionality is provided by the reassociation service. Reassociation is one of the services in the DSS.

The reassociation service is invoked to "move" a current association of a non-AP STA from one AP to another. In an ESS with a DS, the reassociation service informs the DS of the current mapping between AP and STA as the STA moves from BSS to BSS within the ESS. For a general link in an IEEE 802.1Q network, the reassociation service informs higher layer services how the link is reconfigured, commonly, with which BSS the GLK non-AP STA is a member of. The higher layer services will then destroy, disable, or maintain the existing Internal Sublayer Service SAPs, create or enable new Internal Sublayer Service SAPs, inform the GLK convergence function of the reconfigured general link mapping of the Internal Sublayer Service SAPs, and inform the network routing protocol of the updated general link. The GLK AP and GLK non-AP STA each then establish or maintain a service_access_point_identifier for the reconfigured general link, for their respective MS SAPs. Reassociation also enables changing association attributes of an established association while the non-AP STA remains associated with the same AP. Reassociation is always initiated by the non-AP STA.

Only the fast BSS transition facility can move an RSNA during reassociation. Therefore, if FT is not used, the old RSNA is deleted and a new RSNA is constructed.

4.5.3.5 Disassociation

The disassociation service is invoked when an existing association is to be terminated. Disassociation is one of the services in the DSS.

For a non-GLK STA, the act of becoming disassociated invokes the disassociation service, which voids any existing STA to AP mapping known to the DS, for the disassociating STA. How the information provided by the disassociation service is managed within the DS is not specified by this standard. For a general link, disassociation removes or disables the corresponding Internal Sublayer Service SAPs that were configured

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for the general link. The IEEE 802.1Q bridge uses this information to update bridging for the GLK non-AP STA.

For an IEEE 802.11 link that is the basis of a general link, the disassociation service informs higher layer services of the IEEE 802.1Q network that the general link has been destroyed. The GLK AP and the GLK non-AP STA each coordinate with higher layer services and each other to destroy the point-to-point link. The higher layer services destroy or disable the Internal Sublayer Service SAPs, inform the GLK convergence function of the deletion of the mapping of the Internal Sublayer Service SAPs, and inform the network routing protocol of the destruction of the general link, for their respective MS SAPs. This process destroys the previously existing point-to-point link that was suitable for use in an IEEE 802.1Q network.

The disassociation service can be invoked by either party in an association (non-AP STA or AP). Disassociation is a notification, not a request. Disassociation cannot be refused by the receiving STA except when management frame protection is negotiated and the message integrity check fails.

An AP can disassociate STAs to enable the AP to be removed from a network for service or for other reasons.

STAs attempt to disassociate when they leave a network. However, the MAC protocol does not depend on STAs invoking the disassociation service. (MAC management is designed to accommodate loss of communication with an associated STA.)

4.5.4 Access control and data confidentiality services

4.5.4.1 General

Two services are required for IEEE Std 802.11 to provide functionality equivalent to that which is inherent to wired LANs. The design of wired LANs assumes the physical attributes of wire. In particular, wired LAN design assumes the physically closed and controlled nature of wired media. The physically open medium nature of an IEEE 802.11 LAN violates those assumptions.

In a WLAN that does not support RSNA, two services, authentication and data confidentiality, are defined. IEEE 802.11 authentication is used instead of the wired media physical connection. WEP encryption was defined to provide the data confidentiality aspects of closed wired media.

An RSNA uses the IEEE 802.1X authentication service along with enhanced data cryptographic encapsulation mechanisms, such as TKIP, CCMP, and GCMP, to provide access control. The IEEE 802.11 station management entity (SME) provides key management via an exchange of EAPOL-Key frames. Data confidentiality and data integrity are provided by RSN key management together with the enhanced data cryptographic encapsulation mechanisms.

4.5.4.2 Authentication

IEEE 802.11 authentication operates at the link level between IEEE 802.11 STAs. IEEE Std 802.11 does not provide either end-to-end (MSDU origin to MSDU destination) or user-to-user authentication.

IEEE Std 802.11 attempts to control LAN access via the authentication service. IEEE 802.11 authentication is an SS. This service might be used by all STAs to establish their identity to STAs with which they communicate, in both ESSs and IBSSs. If a mutually acceptable level of authentication has not been established between two STAs, an association is not established.

IEEE Std 802.11 defines five IEEE 802.11 authentication methods: Open System authentication, Shared Key authentication, FT authentication, simultaneous authentication of equals (SAE), and FILS authentication. Open System authentication admits any STA to the DS. Shared Key authentication relies on

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WEP to demonstrate knowledge of a WEP encryption key. FT authentication relies on keys derived during the initial mobility domain association to authenticate the stations as defined in Clause 13. SAE authentication uses finite field cryptography to prove knowledge of a shared password. FILS authentication allows for faster connection to the network for FILS non-AP STAs by providing authentication, association, and key confirmation information in an efficient number of frame exchanges (see 4.10.3.6). The IEEE 802.11 authentication mechanism also allows definition of new authentication methods.

An RSNA might support SAE authentication, FILS authentication, or both. An RSNA also supports authentication based on IEEE Std 802.1X-2010, or preshared keys (PSKs) after Open System authentication. IEEE 802.1X authentication utilizes the EAP to authenticate STAs and the AS with one another. This standard does not specify an EAP method that is mandatory to implement. See 12.6.5 for a description of the IEEE 802.1X authentication and PSK usage within an IEEE 802.11 IBSS.

In an RSNA, IEEE 802.1X Supplicants and Authenticators exchange protocol information via the IEEE 802.1X Uncontrolled Port. The IEEE 802.1X Controlled Port is blocked from passing general data traffic between two STAs until an IEEE 802.1X authentication procedure completes successfully over the IEEE 802.1X Uncontrolled Port.

SAE authentication and Open System IEEE 802.11 authentication are used by STAs in an RSN for an infrastructure BSS. FILS authentication can be used by FILS STAs in an RSN for an infrastructure BSS. SAE authentication, Open System IEEE 802.11 authentication, or no IEEE 802.11 authentication is used in an RSN for an IBSS. SAE authentication is used for an MBSS. In an RSN, Shared Key IEEE 802.11 authentication is not used. In an RSN for DMG BSS, Open System IEEE 802.11 authentication is not used (12.2.4).

A STA might be authenticated with many other STAs at the same time.

Because the IEEE 802.1X authentication process could be time-consuming (depending on the authentication protocol in use), the authentication service can be invoked independently of the association service.

This type of preauthentication is typically done by a STA while it is already associated with an AP (with which it previously authenticated). IEEE Std 802.11 does not require that STAs preauthenticate with APs. However, authentication is required before an association establishment is complete.

If the authentication is left until reassociation time, this might impact the speed with which a STA reassociates between APs, limiting BSS-transition mobility performance. The use of preauthentication takes the authentication service overhead out of the time-critical reassociation process.

SAE authentication is performed prior to association and a STA can take advantage of the fact that it can be IEEE 802.11 authenticated to many APs simultaneously by completing the SAE protocol with any number of APs while still being associated to another AP. RSNA security can be established after association using the resulting shared key.

4.5.4.3 Deauthentication

The deauthentication service is invoked when an existing Open System, Shared Key, FT, SAE, or FILS authentication is to be terminated. Deauthentication is an SS.

In an ESS, because authentication is a prerequisite for association, the act of deauthentication causes the STA to be disassociated. The deauthentication service can be invoked by either authenticated party (non-AP STA or AP). Deauthentication is not a request; it is a notification. The association at the transmitting STA is terminated when the STA sends a deauthentication notice to an associated STA. Deauthentication, and if associated, disassociation cannot be refused by the receiving STA except when management frame protection is negotiated and the message integrity check fails.

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In an RSN ESS, deauthentication results in termination of any association for the deauthenticated STA. It also results in the IEEE 802.1X Controlled Port for that STA, if used for this association, being disabled and deletes the pairwise transient key security association (PTKSA). The deauthentication notification is provided to IEEE Std 802.1X-2010 via the MAC layer.

In an RSNA, deauthentication also deletes any related pairwise transient key security association (PTKSA), group temporal key security association (GTKSA), TPK security association (TPKSA), integrity group temporal key security association (IGTKSA), beacon integrity group temporal key security association (BIGTKSA), mesh GTKSA, and mesh TKSA that exist in the STA and closes the associated IEEE 802.1X Controlled Port, if used for this association. If pairwise master key security association (PMKSA) caching is not enabled, deauthentication also deletes the PMKSA or mesh PMKSA.

In an RSN IBSS, Open System authentication is optional, but a STA is required to recognize Deauthentication frames. Deauthentication results in the IEEE 802.1X Controlled Port for that STA being disabled and deletes the PTKSA.

4.5.4.4 Data confidentiality

In a wired LAN, only those STAs physically connected to the wire can send or receive LAN traffic. With a wireless shared medium, there is no physical connection, and all STAs and certain other RF devices in or near the LAN might be able to send, receive, and/or interfere with the LAN traffic. A STA receives traffic that is within range and transmits to any other STA within range. Thus, the connection of a single wireless link (without data confidentiality) to an existing wired LAN might seriously degrade the security level of the wired LAN.

To bring the security of the WLAN up to the level implicit in wired LAN design, IEEE Std 802.11 provides the ability to protect the contents of frames. This functionality is provided by the data confidentiality service. Data confidentiality is an SS.

IEEE Std 802.11 provides several cryptographic algorithms to protect data traffic, including: WEP, TKIP, CCMP, and GCMP. WEP and TKIP are based on the ARC4[21] algorithm, and CCMP and GCMP are based on the advanced encryption standard (AES). A means is provided for STAs to select the algorithm(s) to be used for a given association.

IEEE Std 802.11 provides the following security protocols for protection of individually addressed robust Management frames: CCMP and GCMP. This standard provides data confidentiality for certain Action frames as indicated in Table 9-51.

IEEE Std 802.11 provides one security protocol, CCMP, for protection of individually addressed and group addressed Data frames between mesh STAs.

The default data confidentiality state for all IEEE 802.11 STAs is “in the clear,” i.e., without protection. If the data confidentiality service is not invoked, all frames are sent unprotected. If this policy is unacceptable to the sender, it does not send Data frames; and if the policy is unacceptable to the receiver, it discards any received Data frames. Unprotected Data frames and unprotected robust Management frames received at a STA configured for mandatory data confidentiality, as well as protected Data frames and protected robust Management frames using a key not available at the receiving STA, are discarded without an indication to LLC (or without indication to distribution system services in the case of “To DS” frames received at an AP).

[21] Details of the ARC4 algorithm are available from RSA Security, Inc. Contact RSA Security, 174 Middlesex Turnpike, Bedford, MA 01730 (http://www.rsasecurity.com/), for algorithm details and the uniform ARC4 license terms that RSA offers to anyone wishing to use ARC4 for the purpose of implementing the IEEE 802.11 WEP option. If necessary, contact the IEEE Standards Department Intellectual Property Rights Administrator for details on how to communicate with RSA.

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These frames are acknowledged on the WM [if received without frame check sequence (FCS) error] to avoid wasting WM bandwidth on retries of frames that are being discarded.

4.5.4.5 Key management

The enhanced data confidentiality, data authentication, and replay protection mechanisms require fresh cryptographic keys and corresponding security associations. The procedures defined in this standard provide fresh keys by means of protocols called the 4-way handshake, FT 4-way handshake, FT protocol, FT resource request protocol, group key handshake, and FILS authentication protocol.

4.5.4.6 Data origin authenticity

The data origin authenticity mechanism defines a means by which a STA that receives a Data or robust Management frame can determine which STA transmitted the MAC protocol data unit (MPDU). This feature is required in an RSNA to prevent one STA from masquerading as a different STA.

Data origin authenticity is applicable only to individually addressed Data frames, and individually addressed robust Management frames. The protocols do not guarantee data origin authenticity for group addressed frames, as this cannot be accomplished using symmetric keys and public key methods are too computationally expensive.

4.5.4.7 Replay detection

The replay detection mechanism defines a means by which a STA that receives a Data or robust Management frame from another STA can detect whether the received frame is an unauthorized retransmission. This replay protection mechanism is provided for Data frames for STAs that use enhanced data cryptographic encapsulation mechanisms. The replay protection mechanism is also provided for robust Management frames for STAs that use CCMP, GCMP, and broadcast/multicast integrity protocol (BIP).

4.5.4.8 Fast BSS transition

The FT mechanism defines a means for a STA to set up security and QoS parameters prior to reassociation to a new AP. This mechanism allows time-consuming operations to be removed from the time-critical reassociation process. During a handover across mobility domains, the overhead incurred during the FT initial mobility domain association in an RSN can be reduced using FILS authentication.

4.5.4.9 Management frame protection

Robust Management frames are a set of Management frames that can be protected by the management frame protection service.

Management frame protection protocols in an infrastructure BSS or IBSS apply to robust Management frames after RSNA PTK establishment for protection of individually addressed frames is completed and after delivery of the IGTK to protect group addressed frames. Beacon frames are protected in an infrastructure BSS after delivery of the BIGTK.

Management frame protection protocols in an MBSS apply to the following frames:

— Individually addressed robust Management frames after establishment of the RSNA MTK,
— Group addressed robust Management frames that are specified with Yes in the “Group Addressed Privacy” column of Table 9-51 after establishment of the RSNA MGTK, and
— Group addressed robust Management frames that are specified with No in the “Group Addressed Privacy” column of Table 9-51 after establishment of the RSNA IGTK.

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See 14.7 for details.

Management frame protection is implemented by CCMP, GCMP, and BIP confidentiality protocols and the SA Query procedure.

4.5.4.10 MAC privacy enhancements

When a non-AP STA searches for, and connects to, an infrastructure BSS, IBSS, or PBSS or attempts to discover services on a network preassociation, it defines the addressing of its MAC layer for the particular connection. If the STA uses a fixed MAC address it is trivial to track the STA. An MSDU transmitted by a STA is assigned a sequence number that, if never reset, can also be used to track a device irrespective of the MAC address. If OFDM is used, the PHY DATA scrambler used can enable tracking of a device irrespective of the MAC address if it is not reseeded. The dynamic nature of BSS membership combined with this tracking information allows for construction of a network of connections, locations, and behavior. This network can be used to glean private and sensitive information regarding the individual behind the device.

Furthermore, even without establishing a connection, a mobile or portable STA that gratuitously transmits Probe Request frames containing SSIDs of favored infrastructure BSS networks, or announces the existence of IBSS networks, can reveal potentially sensitive information about its location and location history.

To mitigate this sort of traffic analysis a STA can support the ability to periodically and randomly change its MAC addresses and reset counters and seeds prior to association. While discovering networks, a STA can refrain from gratuitously transmitting Probe Request frames containing SSIDs of favored BSS networks.

4.5.5 Spectrum management services

4.5.5.1 General

Two services are required to satisfy requirements in some regulatory domains (see Annex D and Annex E) for operation in the 5 GHz band. These services are called *transmit power control (TPC)* and *dynamic frequency selection (DFS)*.

4.5.5.2 TPC

Regulations that apply to the 5 GHz band in certain regulatory domains require RLANs operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel. The TPC service is used to satisfy this regulatory requirement.

The TPC service provides for the following:

— Association of STAs with an AP based on the STAs' power capability
— Specification of regulatory and local maximum transmit power levels for the current channel
— Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements
— Adaptation of transmit power based on a range of information, including path loss and link margin estimates

4.5.5.3 DFS

Regulations that apply to the 5 GHz band in certain regulatory domains require RLANs operating in the 5 GHz band to avoid co-channel operation with radar systems and to provide uniform utilization of available channels. The DFS service is used to satisfy these regulatory requirements.

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The DFS service provides for the following:

- Association of STAs with an AP based on the STAs' supported channels.
- Quieting the current channel so it can be tested for the presence of radar with less interference from other STAs.
- Testing channels for radar before using a channel and while operating in a channel.
- Discontinuing operations after detecting radar in the current channel to avoid interference with radar.
- Detecting radar in the current and other channels based on regulatory requirements.
- Requesting and reporting of measurements in the current and other channels.
- Selecting and advertising a new channel to assist the migration of a BSS after radar is detected.

4.5.6 Traffic differentiation and QoS support

4.5.6.1 General

IEEE Std 802.11 uses a shared medium and provides differentiated control of access to the medium to handle data transfers with QoS requirements. The QoS facility (per MSDU traffic category and TSPEC negotiation) allows an IEEE 802.11 LAN to become part of a larger network providing end-to-end QoS delivery or to function as an independent network providing transport on a per-link basis with specified QoS commitments. The specifications regarding the integration and operability of the QoS facility with any other end-to-end QoS delivery mechanism like Resource Reservation Protocol (RSVP) are beyond the scope of this standard.

4.5.6.2 Quality-of-service management frame support

When the quality-of-service management frame (QMF) service is enabled, some Management frames might be transmitted using an access category other than the access category assigned to voice traffic (access category AC_VO, see 9.4.2.28) in order to improve the quality of service of other traffic streams. This is achievable by the use of a QMF policy. A QMF policy defines the access categories of different Management frames. Only QoS STAs are able to implement QMF policy. A non-AP QMF STA uses the default QMF policy or the QMF policy accepted from a peer QMF STA to transmit Management frames to that peer QMF STA. A QMF AP sets its own QMF policy for the transmission of QMFs to its associated STAs. A QMF STA uses access category AC_VO to transmit Management frames to STAs that do not support the QMF service.

4.5.7 Support for higher layer timer synchronization

Some applications, e.g., the transport and rendering of audio or video streams, require synchronized timers shared among different STAs. Greater accuracy (in terms of jitter bounds) or finer timer granularity than that provided by a BSS timing synchronization function (TSF) might be an additional requirement. In support of such applications, this standard defines a MAC service that enables layers above the MAC to accurately synchronize application-dependent timers shared among STAs. The service is usable by more than one application at a time.

Although the timer synchronization methods and accuracy requirements are application-dependent and are beyond the scope of this standard, they rely on an indication from each MAC that is provided essentially simultaneously, via group addressed transmissions, to the STAs. The MAC accomplishes this by indicating the occurrence of the end of the last symbol of particular Data frames; the Data frames of interest are identified by their MAC header Address 1 field when it contains a group address previously registered with the MAC. The last symbol is observed[22] on the WM by STAs within a BSS while the delay between the

[22] The synchronization indication (observed time) within the BSS varies slightly due to propagation.

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observation and the delivery of the indication is known within a MAC by design (and communicated to the application by implementation dependent means). The common reference point in time provided by the end of last symbol indication is the essential building block upon which a variety of application-dependent timer synchronization methods might be based.

4.5.8 Radio measurement service

The Radio measurement service provides the following:

- The ability to request and report radio measurements in supported channels.
- The ability to perform radio measurements in supported channels.
- An interface for upper layer applications to retrieve radio measurements using MLME primitives and/or MIB access.
- Information about neighbor APs.

4.5.9 Interworking with external networks

4.5.9.1 General

The interworking service allows non-AP STAs to access services provided by an external network according to the subscription or other characteristics of that external network. An IEEE 802.11 non-AP STA might have a subscription relationship with an external network, e.g., with an SSPN.

An overview of the interworking functions addressed in this standard is provided below:

- Network discovery and selection
  - Discovery of suitable networks through the advertisement of access network type, roaming consortium and venue information, via Management frames
  - Selection of a suitable IEEE 802.11 infrastructure using advertisement services (e.g., access network query protocol (ANQP) or an IEEE 802.21™ Information Server) in the BSS or in an external network reachable via the BSS.
  - Selection of an SSPN or external network with its corresponding IEEE 802.11 infrastructure
- Preassociation discovery (PAD)
  - Discovery of services offered by a BSS or an external network reachable via that BSS
- Emergency services
  - Emergency Call and Network Alert support at the link level
- QoS mapping distribution
- SSPN interface service between the AP and the SSPN

The generic advertisement service (GAS), described in 4.5.10, provides both support for a STA's network discovery and selection, and support for a conduit for communication by a non-AP STA with other information resources in a network before joining the wireless LAN.

The interworking service supports emergency services by providing methods for users to access emergency services via the IEEE 802.11 infrastructure, advertising that emergency services are supported (see 11.22.6) and identifying that a traffic stream is used for emergency services.

The interworking service provides QoS mapping for SSPNs and other external networks. Since each SSPN or other external network might have its own layer-3 end-to-end packet marking practice (e.g., differentiated services code point (DSCP) usage conventions), a means to remap the layer-3 service levels to a common over-the-air service level is necessary. The QoS Map service provides STAs a mapping of network-layer QoS packet marking to over-the-air QoS frame marking (i.e., user priority).

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The SSPN Interface service supports service provisioning and transfer of user permissions from the SSPN to the AP. The method and protocol by which these permissions are transferred from the SSPN are outside the scope of this standard.

4.5.9.2 Preassociation discovery (PAD)

4.5.9.2.1 Introduction

PAD is an interworking function provided by a BSS to allow a non-AP and non-PCP STA, prior to association, to discover information concerning services that might be available to the STA when it is associated with the BSS. PAD provides a method for the STA to gather information to aid in the decision to select a BSS with which to become a member.

4.5.9.2.2 Architecture

Figure 4-19 and Figure 4-20 show the functional flow of MAC messaging and service information between a service information client (SIC) and a service information registry (SIR). These entities are described in 4.5.9.2.3, 4.5.9.2.4, and 4.5.9.2.5. The active components within the architecture differ depending upon whether unsolicited or solicited PAD is being used.

NOTE—A SIR can be either co-located with the AP or outside the AP. An SIR can only be co-located with a PCP. The communications between the SIR and the AP, together with the SIR and the ANQP server are out of the scope of this standard.

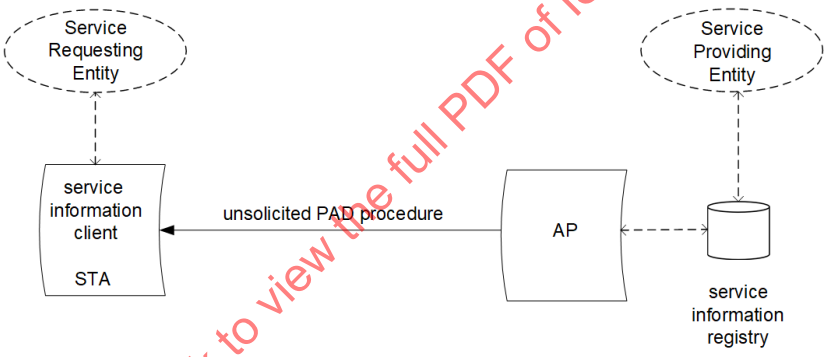

Figure 4-19—Unsolicited PAD architecture

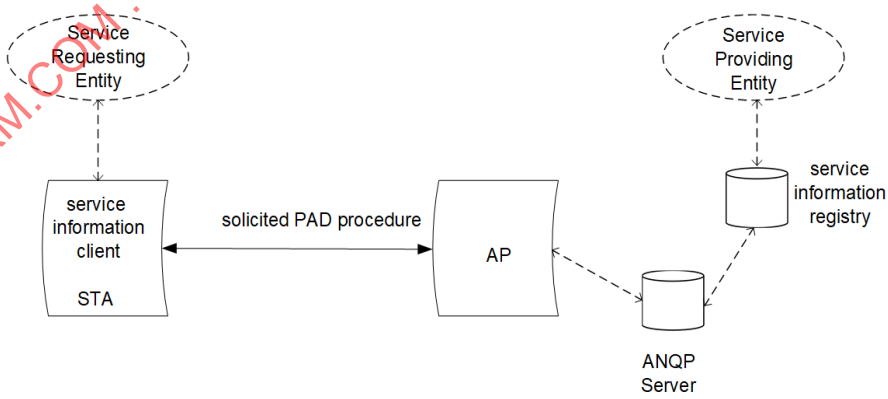

Figure 4-20—Solicited PAD architecture

The unsolicited PAD procedure is described in 11.23.2 and solicited PAD procedure is described in 11.23.3.

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4.5.9.2.3 Service information entities

The SIC and SIR are used to exchange PAD service information. The PAD procedures operate between the SIC and SIR.

4.5.9.2.4 Service information registry (SIR)

The SIR caches information about services that might be reachable via the BSS and therefore might be available to the STA once the STA is associated with that BSS. How the SIR obtains the information about services is outside the scope of this standard.

There is typically one SIR assigned to each ESS. It can be addressed by each AP and each service within that ESS. It includes supporting service discovery requests and responses from the BSS.

The SIR communicates with the ANQP server to respond to ANQP requests.

4.5.9.2.5 Service information client (SIC)

The SIC initiates service discovery. The SIC exchanges service discovery requests and responses between the SME and applications.

The SME determines whether to use unsolicited PAD or solicited PAD procedures. The SME also composes ANQP requests for solicited PAD procedures.

4.5.10 Generic advertisement service (GAS)

GAS provides functionality that enables STAs to discover the availability of information related to desired network services, e.g., information about services such as provided in an IBSS, local access services, available subscription service providers (SSPs) and/or SSPNs or other external networks. GAS uses a generic container to advertise network services information over an IEEE 802.11 network. Public Action frames are used to transport this information.

While the specification of network services information is outside the scope of this standard, in an infrastructure BSS there is a need for STAs to query for information on network services provided by SSPNs or other external networks beyond an AP, before they associate with the wireless LAN. The exchange of information can also be performed after associating to the BSS.

In an IBSS/PBSS, GAS functionality enables a STA to access the availability and information related to desired services provided by other STAs in the IBSS/PBSS. Exchange of information using GAS can be performed either prior to joining an IBSS/PBSS or after joining the IBSS/PBSS.

There are a number of reasons why providing information to a STA in a preassociated state is beneficial:

— It supports more informed decision making about an IEEE 802.11 infrastructure BSS or PBSS of which to become a member. This is generally more efficient than requiring a non-AP and non-PCP STA to associate with an AP or PCP before discovering the information and then deciding whether to stay associated.
— It is possible for the non-AP and non-PCP STA to query multiple networks in parallel.
— The non-AP STA can discover information about APs that are not part of the same administrative group as the AP with which it is associated, supporting the selection of an AP belonging to a different IEEE 802.11 infrastructure that has an appropriate SSP roaming agreement in place.

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4.6 Multiple logical address spaces

Just as the IEEE 802.11 architecture allows for the possibility that the WM, DSM, and an integrated non-IEEE-802.11 LAN might all be different physical media, it also allows for the possibility that each of these components might be operating within different address spaces. IEEE Std 802.11 uses and specifies only the use of the WM address space.

Each IEEE 802.11 PHY operates in a single medium—the WM. The IEEE 802.11 MAC operates in a single address space. MAC addresses are used on the WM in the IEEE 802.11 architecture. Therefore, it is unnecessary for the standard to explicitly specify that its addresses are "WM addresses." This is assumed throughout this standard.

IEEE Std 802.11 has chosen to use the IEEE 802 48-bit address space (see 9.2.4.3.2). Thus IEEE 802.11 addresses are compatible with the address space used by the IEEE 802 LAN family.

The IEEE 802.11 choice of address space implies that for many instantiations of the IEEE 802.11 architecture, the non-IEEE-802.11 LAN MAC address space and the IEEE 802.11 MAC address space might be the same. In the situations where a DS that uses MAC-level IEEE 802 addressing is appropriate, all three of the logical address spaces used within a system could be identical. While this is a common case, it is not the only combination allowed by the architecture. The IEEE 802.11 architecture allows for all three logical address spaces to be distinct. In the GLK case, IEEE 802.1Q bridges are included in the network topology; therefore, the wired LAN MAC address space and IEEE 802.11 MAC address space are the same

A multiple address space example is one in which the DS implementation uses network layer addressing. In this case, the WM address space and the DS address space are different.

Note that IEEE 802.11 STAs within a single ESS share the same address space, fulfilling the transparency requirement from the definition of the DS. The DSS uses this same address space, even in the case where the DSM uses a different address space.

The ability of the architecture to handle multiple logical media and address spaces is key to the ability of IEEE Std 802.11 to be independent of the DS implementation and to interface cleanly with network layer mobility approaches. The implementation of the DS is unspecified and is beyond the scope of this standard.

4.7 Differences among ESS, PBSS, and IBSS LANs

In 4.3.2 the concept of the IBSS LAN was introduced, and in 4.3.3 the concept of the PBSS LAN was introduced. In an IBSS or PBSS, a STA communicates directly with one or more other STAs.

Consider the full IEEE 802.11 architecture as shown in Figure 4-21.

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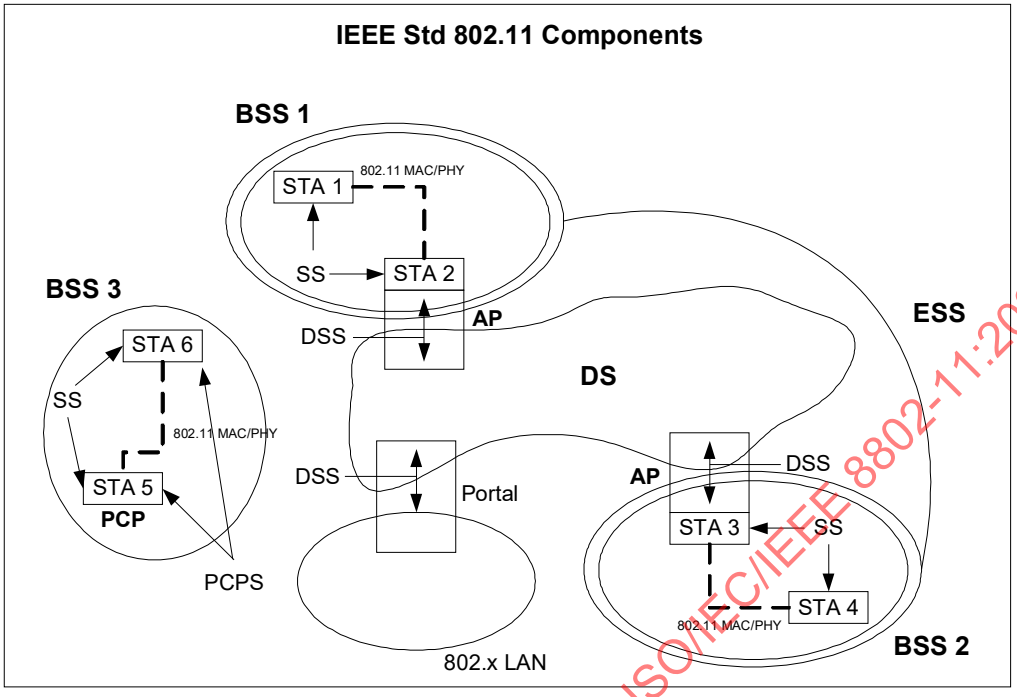

Figure 4-21—IEEE 802.11 architecture (again)

An IBSS consists of STAs that are directly connected. Thus there is (by definition) only one BSS. Further, because there is no physical DS, there is no portal, integrated non-IEEE-802.11 LAN, or DSS. The logical picture reduces to Figure 4-22.

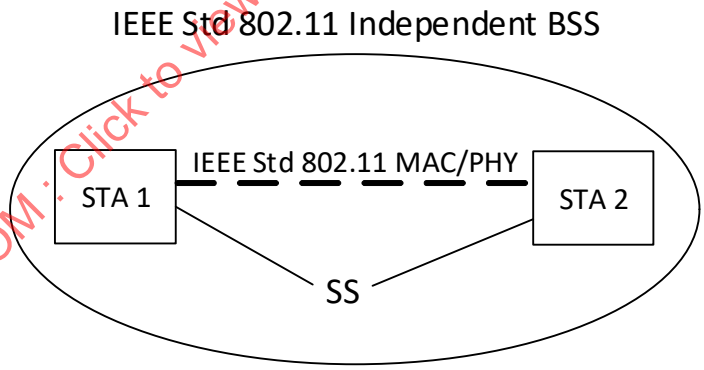

Figure 4-22—Logical architecture of an IBSS

An important difference between the IBSS and the PBSS is that, within the PBSS, Beacon frames are not transmitted by every STA and instead only a single STA, namely the PCP, is responsible for DMG Beacon frame transmission. Within the IBSS, all STAs are responsible for Beacon frame transmission. When compared to the infrastructure BSS, the PBSS does not provide certain DSSs as described in 4.4.3.

There can be more than one PBSS in the same BSA. One of the STAs within each PBSS assumes the role of the PCP. The logical picture of the PBSS reduces to Figure 4-23.

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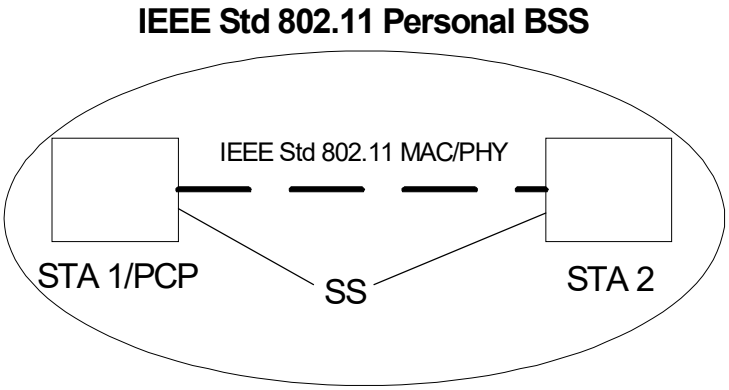

Figure 4-23—Logical architecture of a PBSS

Only the minimum two STAs are shown in Figure 4-22. An IBSS can have an arbitrary number of members. In an IBSS only Class 1 and Class 2 frames are allowed because there is no DS in an IBSS.

The services that apply to an IBSS are the SSs. A QoS IBSS supports operation under the HCF using TXOPs gained through the EDCA mechanism. The parameters that control differentiation of the delivery of MSDUs with different priority using EDCA are fixed. A QoS IBSS has no HC and does not support polled TXOP operation and setting up of TSPEC.

The services that apply to the PBSS are the SSs and the PCPSs as described in 4.4.3. A PBSS supports operation under the HCF using TXOPs gained through the EDCA mechanism. In a PBSS, the EDCA mechanism is used only within CBAPs. The parameters that control differentiation of traffic classes using EDCA can be configured by the PCP in a PBSS. The PCP of a PBSS has no HC, but can support TSPEC setup, DMG TSPEC setup, and service periods.

In an IBSS each STA enforces its own security policy. In an infrastructure BSS or a PBSS, an AP or a PCP, respectively, can enforce a uniform security policy across all STAs.

4.8 Differences between ESS and MBSS LANs

In 4.3.21, the concept of the MBSS LAN was introduced. It was noted that using the multi-hop capability it appears as if all mesh STAs are directly connected at the MAC layer even if the STAs are not within range of each other. This is different from an IBSS, where STAs cannot communicate if they are not within range of each other.

Unlike the IBSS, an MBSS might have access to the DS. An MBSS connects through one or more mesh gates to the DS. Since in an MBSS it appears as if all mesh STAs are directly connected at the MAC layer, the MBSS can be used as a DSM. APs, a portal, and mesh gates might use the MBSS as a DSM to provide the DSS. Thus, different infrastructure BSSs can unite over the MBSS to form an ESS for example.

An AP identifies the infrastructure BSS that it forms. This is different from the MBSS where no such central entity exists. Whereas infrastructure BSSs need the ESS and thus the DS to unite, the MBSS appears the same to an LLC layer without the need for access to a DS. However, if an MBSS has one or more mesh gates providing access to the DS, the MBSS might exist in disjointed areas and yet form a single network.

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4.9 Reference model

4.9.1 General

This standard presents the architectural view, emphasizing the separation of the system into two major parts: the MAC of the data link layer (DLL) and the PHY. These layers are intended to correspond closely to the lowest layers of the ISO/IEC basic reference model of Open Systems Interconnection (OSI) (ISO/IEC 7498-1:1994). The layers and sublayers described in this standard are shown in Figure 4-24.

There is an interface between the IEEE 802.1X Supplicant and Authenticator and the SME not shown in Figure 4-24. This interface is described in IEEE Std 802.1X-2010.

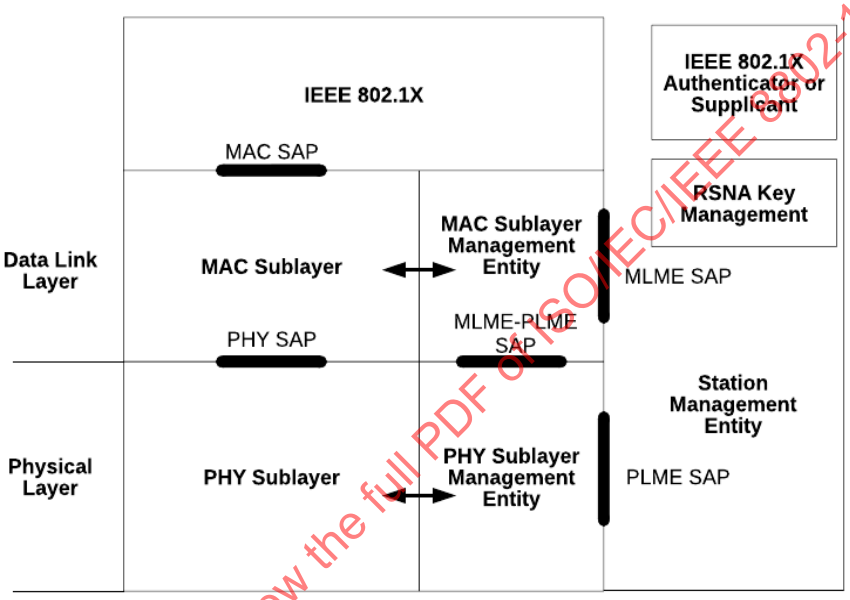

Figure 4-24—Portion of the ISO/IEC basic reference model covered in this standard

4.9.2 Interworking reference model

The MAC state generic convergence function (MSGCF) provides services to higher layer protocols based on MAC state machines and interactions between the layers.

Interworking functions might require correlating information from multiple management entities. It is the function of the MSGCF to correlate information for higher layer entities. The MSGCF observes the interactions between the MLME and SME, and between the PLME and SME. After correlation of lower-layer MLME and PLME events, the MSGCF might synthesize indications to higher layer entities.

Figure 4-25 shows an entity, the MSGCF, defined in 6.4, that has access to all management information through exposure to the MAC sublayer and PHY management entities, and provides management information to higher level entities, such as Mobility Managers, supporting heterogeneous medium mobility.

An example of how the MSGCF interfaces to these higher layer entities, is provided by the media independent service (MIS) interface, as defined in IEEE Std 802.21-2017.

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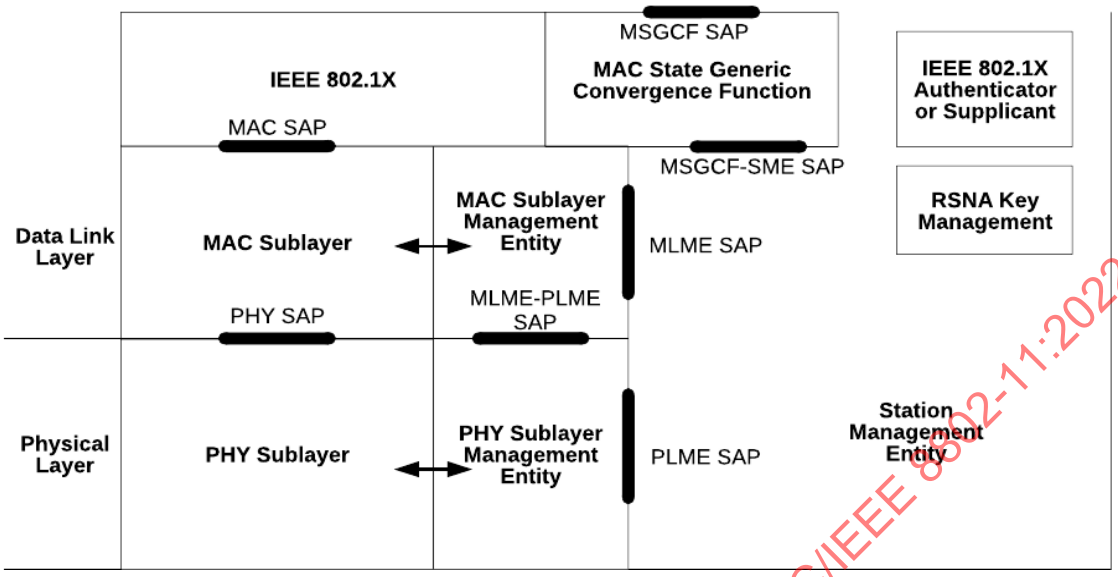

Figure 4-25—Interworking reference model

The MSGCF is designed to provide the status of the connection of a non-AP STA to a set of BSSs comprising a single ESS. Figure 4-26 illustrates the concept of an ESS link. This reflects the state of a connection to an ESS independent of any particular access point. In Figure 4-26, STA3 is associated with either AP1 or AP2. The state of the ESS link is up when STA3 is associated with any of the APs comprising an ESS.

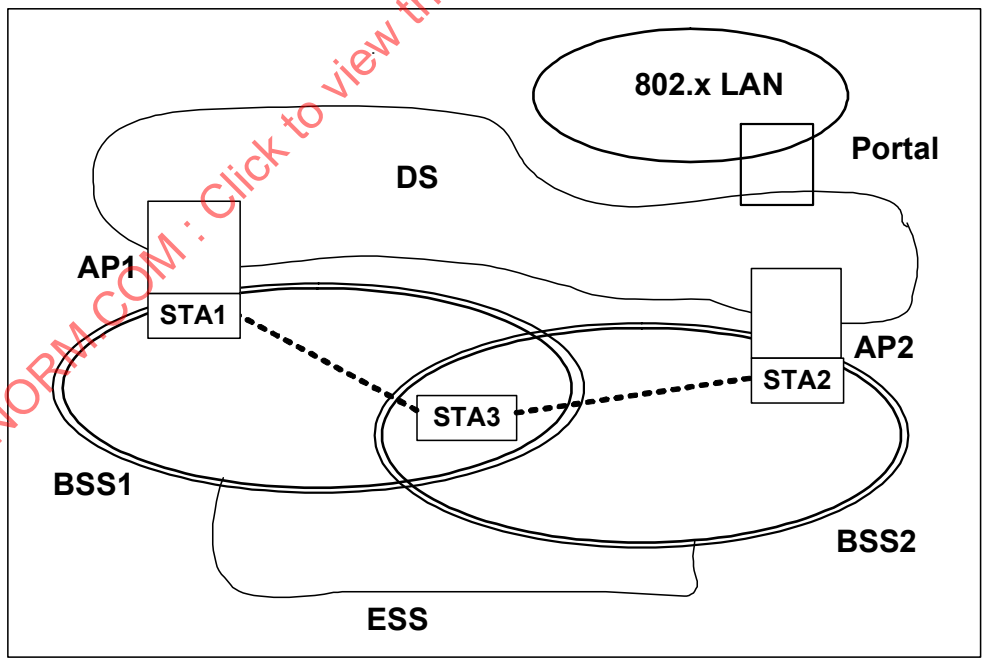

Figure 4-26—ESS link illustration

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4.9.3 Reference model for supporting multiple MAC sublayers

An MM-SME function interfaces with the SMEs of the coordinating STAs. STAs managed under the MM-SME share the same antennas and PHY and optionally unify power management. The reference model for supporting multiple MAC sublayers is shown in Figure 4-27.

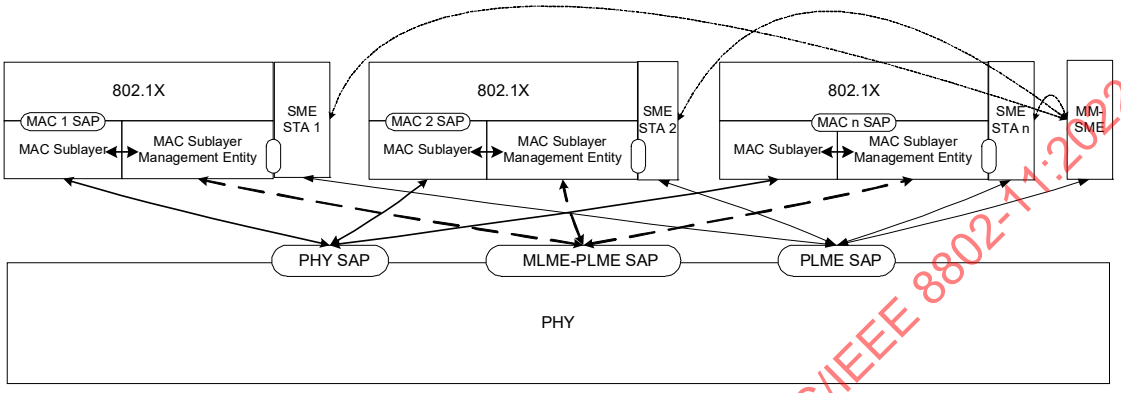

Figure 4-27—Reference model for supporting multiple MAC sublayers

An MM-SME coordinates the management of multiple MAC sublayers. Each MAC sublayer has a separate MAC SAP and MLME SAP. A MAC SAP together with its corresponding MLME SAP is identified by a MAC address.

Even when coordinated by an MM-SME, each MAC retains its single MAC address, and each STA contains a single MAC; therefore, the MM-SME coordinates multiple STAs as well as multiple MACs.

Multiple STAs coordinated by an MM-SME have a single PHY that is shared by the multiple MAC sublayers. Transmission attempts of different MAC sublayers can collide internally if the STAs share a single PHY, and a backoff procedure is invoked in this case. Since multiple STAs coordinated by the same MM-SME share the PHY, the STAs cannot directly exchange frames with each other.

NOTE—The multiple MAC reference model shown in Figure 4-27 defines how multiple STAs can share the same physical layer entity. If this model is used in conjunction with the reference model for multi-band operation (see 4.9.4), the multiple MAC reference model applies within each physical layer entity contained in the multi-band device, whereas the multi-band operation reference model applies to different physical layers.

The MM-SME accesses each of the MLME SAPs of the coordinated STAs separately to deliver MLME SAP primitives. STAs that are coordinated by the same MM-SME can establish a multiple MAC sublayers link (MMSL) with a peer STA. The set of all MMSLs between a pair of STAs creates an MMSL cluster.

An MM-SME controls the power management mode, DMG antenna configuration, and other parameters and states of the coordinated STAs to eliminate unnecessary duplication of functions. A change in the power management mode of the STAs coordinated by an MM-SME is signaled to a peer STA via any one of the STAs' MAC sublayer. Also, a beamforming link established between STAs can be used by all of the MAC sublayers of any of the STAs coordinated by the same MM-SME. For these purposes, a Multiple MAC Sublayers (MMS) element is used.

The MMS element contains multiple MAC addresses of the MACs coordinated by the same MM-SME. The element can be included in any frame that advertises the MM-SME capabilities, such as Probe Request and Probe Response frames and Information Request and Information Response frames, and the frames that establish communication agreements, such as Association, ADDTS Request, ADDTS Response, BlockAckReq, and BlockAck.

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4.9.4 Reference model for multi-band operation

The reference model of a device that is multi-band capable (see 11.31) and that supports transparent fast session transfer (FST) is shown in Figure 4-28. The reference model of a device that is multi-band capable and that supports nontransparent FST is shown in Figure 4-29.

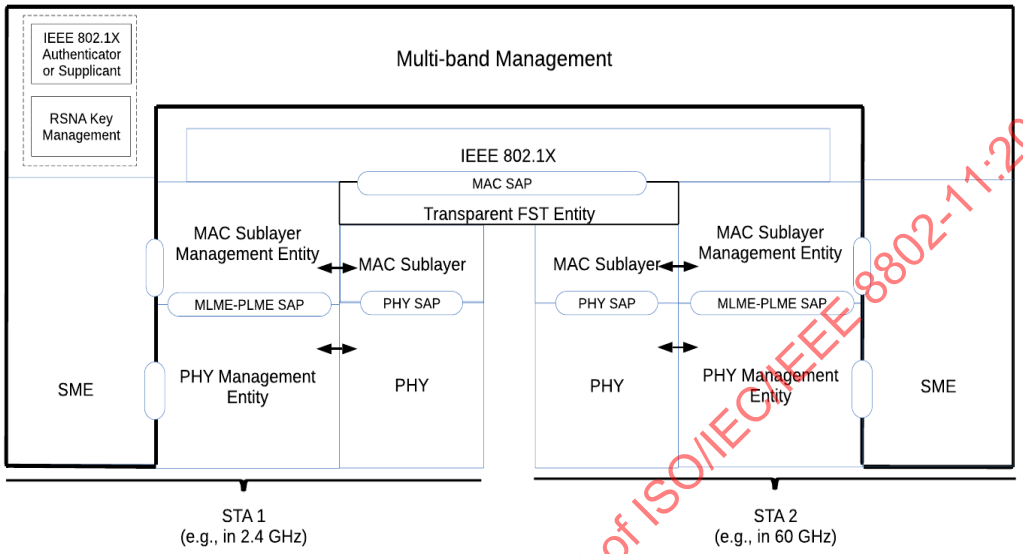

Figure 4-28—Reference model for a multi-band capable device (transparent FST)

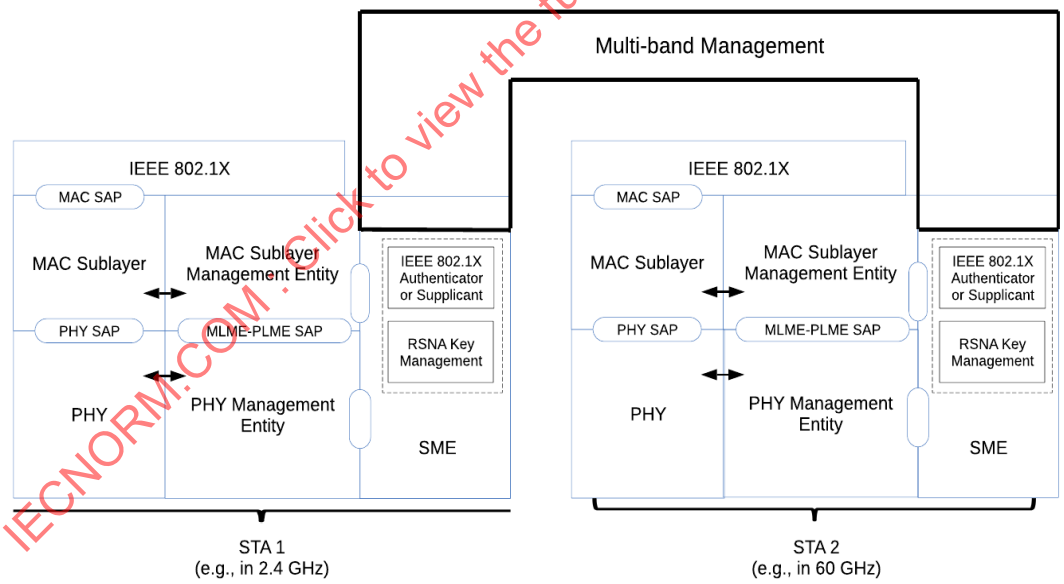

Figure 4-29—Reference model for a multi-band capable device (nontransparent FST)

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A multi-band capable device can manage operation over more than one frequency band/channel. The operation across the different frequency bands/channels can be simultaneous or nonsimultaneous.

A multi-band capable device can also support multiple MAC sublayers; in this case, it is coordinated by an MM-SME.

NOTE—For simplicity, Figure 4-28 and Figure 4-29 depict the reference model when there is a one-to-one mapping between PHYs and MACs. However, the reference model for a multi-band capable device can be applied in conjunction with the reference model for STAs that support multiple MAC sublayers (see 4.9.3).

When used in the context of FST, the term "session" refers to non-PHY state information that is kept in a pair of STAs that communicate directly (i.e., excludes forwarding) and that is available prior to and following a fast session transfer. This state information is different depending if transparent or nontransparent is used. For transparent FST, a shared multi-band management entity has access to the local information within each SME; and in this case the state information includes block ack agreements, TSs, association state, RSNA, security keys, sequence counter, and PN counter. For nontransparent FST, the function of the multi-band management entity is restricted to coordinating the setup and teardown of a fast session transfer with no access to other local information within each SME. Therefore, with nontransparent FST, any information local to an SME needs to be reestablished for the new band/channel, and this can be done either prior to or following the fast session transfer (see 11.31).

The SME of a multi-band capable device contains a multi-band management entity that is responsible for coordinating the setup, configuration, teardown, and transfer of FST sessions from a band/channel to another band/channel supported by the multi-band capable device. If using nontransparent FST, the multi-band management entity can employ a combination of the source and destination MAC addresses in both the old and new band/channel to configure the routing of MSDUs and MLME primitives within the STA. If using transparent FST, in addition to the MAC addresses, the multi-band management entity can employ the TID of an FST session for this routing.

The multi-band procedures (see 11.31) allow a pair of multi-band capable devices to discover, synchronize, (de)authenticate, (re)associate, disassociate, and manage resources with each other on any common band/channel that is supported by both STAs.

By using the on-channel tunneling (OCT) multi-band procedure described in 11.31.5, the SME of a multi-band capable device can instruct one of its MLMEs to use the OCT services provided by another MLME of the same multi-band capable device to communicate with a peer MLME of a peer multi-band capable device. This enables the SMEs of a pair of multi-band capable devices to provide a seamless FST, including performing (de)authentication and (re)association across bands/channels. The MLMEs that use the OCT services provided by another MLME within the same multi-band capable device to communicate are referred to as being *over-the-WM disabled* with respect to each other. Following a frame exchange on the new band/channel (e.g., after FST), two peer over-the-WM disabled MLMEs can become over-the-WM enabled with respect to each other.

As described in 5.1.5, a MAC address is not unique within the multi-band capable device when transparent FST is intended to be used. When transparent FST is used, a single MAC SAP at each peer is presented to the higher layers of that peer for all of the frequency bands/channels that are identified by the same MAC address at that peer. When nontransparent FST is used, different MAC SAPs are presented to higher layers since different MAC addresses are used prior to and following an FST. Therefore, when nontransparent FST is used, higher layers are responsible for managing the FST.

Each MAC SAP is controlled by a separate and independent RSNA key management entity and IEEE 802.1X Authenticator or Supplicant unless transparent FST is used, in which case the multi-band management entity is responsible for coordinating with each of the SMEs to ensure that a single RSNA key management entity and IEEE 802.1X Authenticator or Supplicant are shared among the MACs and that a single IEEE 802.1X entity is controlled.

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4.10 IEEE Std 802.11 and IEEE Std 802.1X-2010

4.10.1 General

An RSNA relies on IEEE Std 802.1X-2010 to provide authentication services and uses the IEEE 802.11 key management scheme defined in 12.7. The IEEE 802.1X access control mechanisms apply to the association between a STA and an AP and to the relationship between the IBSS STA and STA peer. The AP's SME performs the Authenticator and, optionally, the Supplicant and AS roles. In an infrastructure BSS, a non-AP STA's SME performs the Supplicant role. In an IBSS the SME takes on both the Supplicant and Authenticator roles and might take on the AS role.

4.10.2 IEEE 802.11 usage of IEEE Std 802.1X-2010

IEEE Std 802.11 depends upon IEEE Std 802.1X-2010 to control the flow of MAC service data units (MSDUs) between the DS and STAs by use of the IEEE 802.1X Controlled/Uncontrolled Port model. IEEE 802.1X EAPOL PDUs are transmitted in one or more IEEE 802.11 Data frames and passed via the IEEE 802.1X Uncontrolled Port. The IEEE 802.1X Controlled Port is blocked from passing general data traffic between two STAs until an IEEE 802.1X authentication procedure completes successfully over the IEEE 802.1X Uncontrolled Port. It is the responsibility of both the Supplicant and the Authenticator to implement port blocking. Each association between a pair of STAs creates a unique pair of IEEE 802.1X Ports, and authentication takes place relative to those ports alone.

IEEE Std 802.11 depends upon IEEE Std 802.1X-2010 and various IEEE 802.11 protocols and handshakes, described in Clause 12 and Clause 13, to establish and change cryptographic keys. Keys are established after authentication has completed. Keys might change for a variety of reasons, including expiration of an IEEE 802.1X authentication timer, key compromise, danger of compromise, or policy.

4.10.3 Infrastructure functional model overview

4.10.3.1 General

This subclause summarizes the system setup and operation of an RSN, in three cases: when a password or PSK is used during IEEE 802.11 authentication, when an IEEE 802.1X AS is used after Open System authentication, and when a PSK is used after Open System authentication. In an RSN, an AP includes an Authenticator, and each associated STA includes a Supplicant.

4.10.3.2 AKM operations with AS

The following AKM operations are carried out when an IEEE 802.1X AS is used:

a) Prior to any use of IEEE Std 802.1X-2010, IEEE Std 802.11 assumes that the Authenticator and AS have established a secure channel. The security of the channel between the Authenticator and the AS is outside the scope of this standard.

   Authentication credentials are distributed to the Supplicant and AS prior to association.

b) A STA discovers the AP's security policy through passively monitoring Beacon frames or through active probing (shown in Figure 4-30). If IEEE 802.1X authentication is used, the EAP authentication process starts when the Authenticator sends the EAP-Request (shown in Figure 4-31) or the Supplicant sends the EAPOL-Start frame. EAP messages pass between the Supplicant and AS via the Authenticator and Supplicant's Uncontrolled Ports. This is shown in Figure 4-31.

c) The Supplicant and AS authenticate each other and generate a PMK. The PMK is sent from the AS to the Authenticator over the secure channel. See Figure 4-31.

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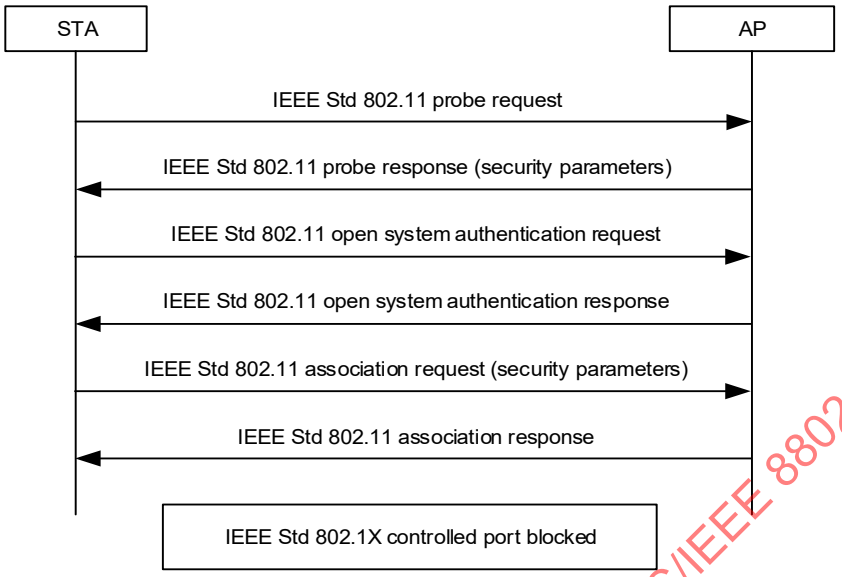

Figure 4-30—Establishing the IEEE 802.11 association

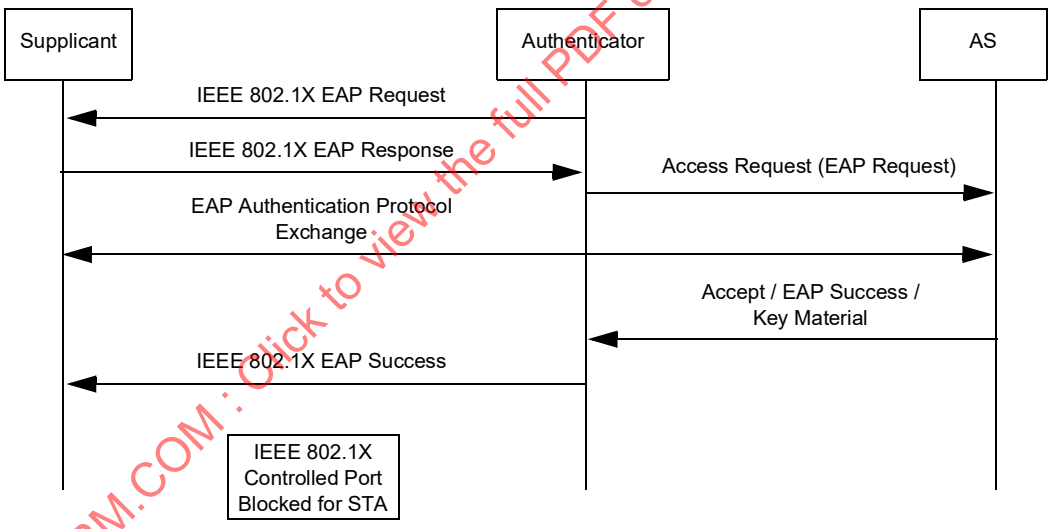

Figure 4-31—IEEE 802.1X EAP authentication

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A 4-way handshake or FT 4-way handshake utilizing EAPOL-Key frames is initiated by the Authenticator to do the following:

- Confirm that a live peer holds the PMK.
- Confirm that the PMK is current.
- In the case of fast BSS transition, derive PMK-R0s and PMK-R1s.
- Derive a fresh pairwise transient key (PTK) from the PMK or, in the case of fast BSS transition, from the PMK-R1.
- Install the pairwise encryption and integrity keys.

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— Transport the group temporal key (GTK) and GTK sequence number from Authenticator to Supplicant and install the GTK and GTK sequence number in the STA and, if not already installed, in the AP.
— If management frame protection is negotiated, transport the IGTK and the IGTK packet number (IPN) from the Authenticator to the Supplicant and install these values in the STA and, if not already installed, in the AP.
— If beacon protection is enabled, transport the BIGTK and the BIGTK packet number (BIPN) from the Authenticator to the Supplicant and install these values in the STA and, if not already installed, in the AP.
— Verify that the RSN capabilities negotiated are valid as defined in 9.4.2.24.4.
— Confirm the cipher suite selection.

Installing the PTK, and where applicable the GTK and, if management frame protection is negotiated, the IGTK, causes the MAC to encrypt and decrypt all subsequent MSDUs irrespective of their path through the controlled or uncontrolled ports. Installing the BIGTK when beacon protection is enabled causes the MAC to integrity protect at the AP or validate subsequent Beacon frames at the non-AP STA.

Upon successful completion of the 4-way handshake, the Authenticator and Supplicant have authenticated each other; and the IEEE 802.1X Controlled Ports are unblocked to permit general data traffic. See Figure 4-32.

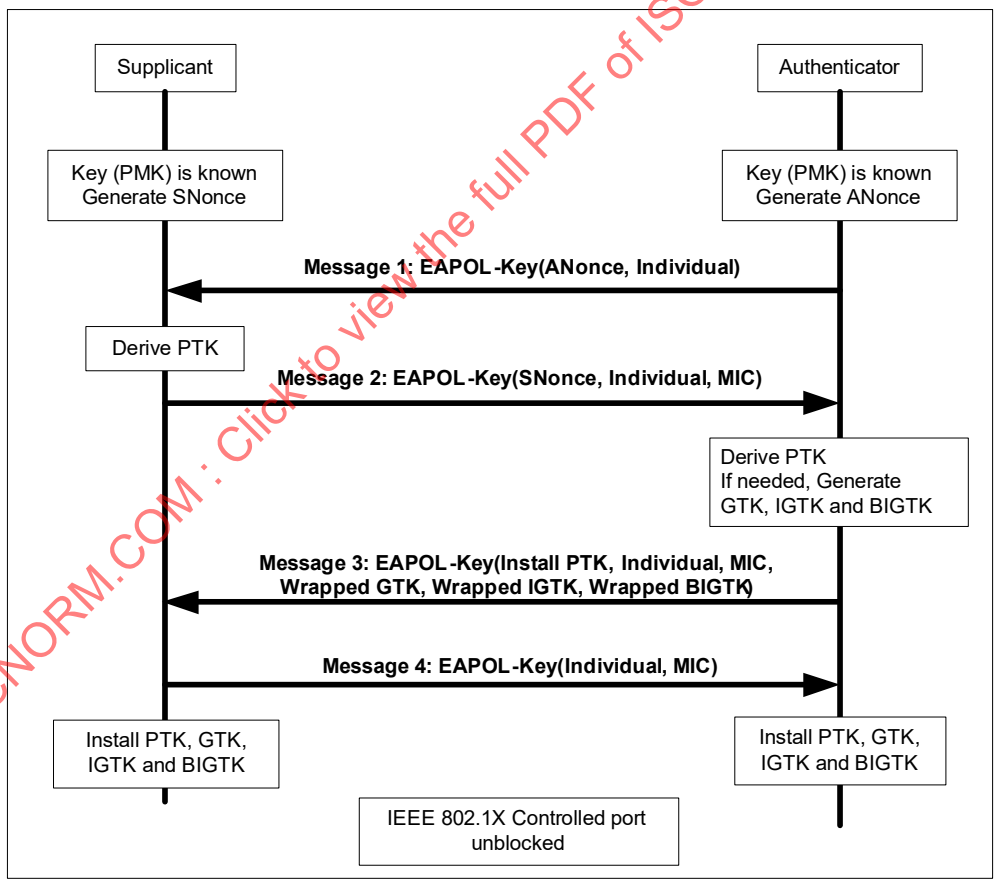

Figure 4-32—Establishing pairwise and group keys

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If the Authenticator later changes the GTK, it sends the new GTK and GTK sequence number to the Supplicant using the group key handshake to allow the Supplicant to continue to receive group addressed frames and, optionally, to transmit and receive individually addressed frames. EAPOL-Key frames are used to carry out this exchange. See Figure 4-33.

When management frame protection is negotiated, the Authenticator also uses the group key handshake with all associated STAs to change the IGTK, and BIGTK if beacon protection is enabled. The Authenticator encrypts the GTK, IGTK and BIGTK values in the EAPOL-Key frame as described in 12.7.

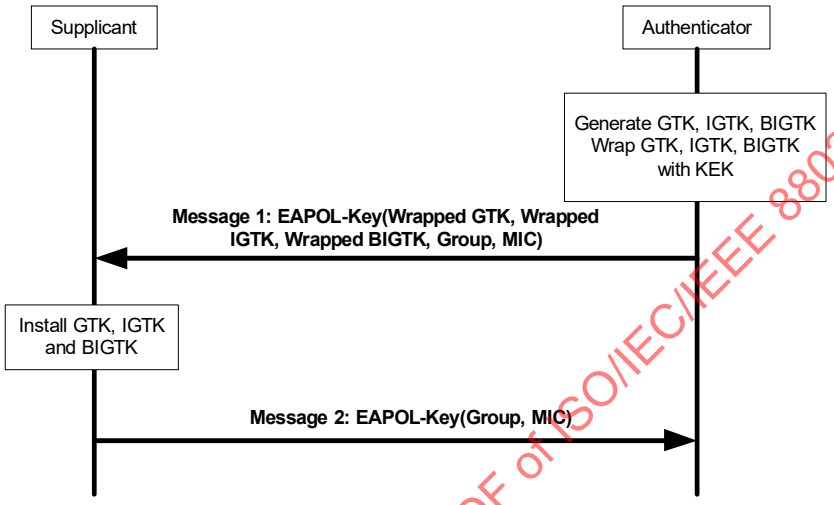

Figure 4-33—Delivery of subsequent group keys

4.10.3.3 AKM operations with a password or PSK

The following AKM operations are carried out when authentication is accomplished using a Password or PSK:

— A STA discovers the AP's security policy through passively monitoring the Beacon frames or through active probing. After discovery the STA performs SAE authentication using Authentication frames with the AP (see Figure 4-34).

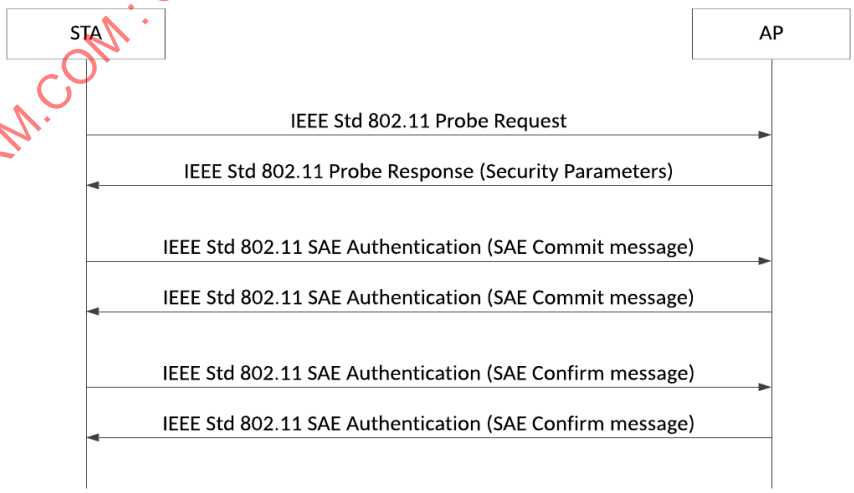

Figure 4-34—Example using SAE authentication

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— Upon the successful conclusion of SAE, both the STA and AP generate a PMK. The STA then associates to an AP and negotiates security policy. The AKM in the Association Request and Response frames is confirmed to be the AKM of SAE or of fast BSS transition.
— The PMK generated by SAE is used in a 4-way handshake using EAPOL-Key frames, just as with IEEE 802.1X authentication when an AS is present. See Figure 4-32.
— The GTK and GTK sequence number are sent from the Authenticator to the Supplicant just as in the AS case. See Figure 4-32 and Figure 4-33.

4.10.3.4 Alternate operations with PSK

The following AKM operations represent an alternate operation of using a PSK. This operation has security vulnerabilities if used with a low-entropy key and is recommended to be used only after taking that into account. When this operation is carried out, the PMK is a PSK:

— A STA discovers the AP's security policy through passively monitoring Beacon frames or through active probing (shown in Figure 4-30). A STA associates with an AP and negotiates a security policy. The PMK is the PSK.
— The 4-way handshake using EAPOL-Key frames is used, just as with IEEE 802.1X authentication, when an AS is present. See Figure 4-32.
— The GTK and GTK sequence number are sent from the Authenticator to the Supplicant just as in the AS case. See Figure 4-32 and Figure 4-33.
— If management frame protection is negotiated, the IGTK and IGTK packet number are sent from the Authenticator to the Supplicant just as in the AS case. If beacon protection is enabled, the BIGTK and BIPN are sent from the Authenticator to the Supplicant just as in the AS case. See Figure 4-32 and Figure 4-33.

4.10.3.5 Disassociation

Disassociation initiated by either STA in an RSNA causes the deletion of the PTKSA at both ends and the deletion of the GTKSA in a non-AP STA. The controlled and uncontrolled ports created for this association are also deleted.

4.10.3.6 AKM operations using FILS authentication

4.10.3.6.1 General

FILS authentication allows faster link setup to the network by performing authentication, association, and key confirmation using four frames—two Authentication frames, one (Re)Association Request frame, and one (Re)Association Response frame.

The following three FILS authentication methods are defined:

a) FILS Shared Key authentication performed without perfect forward security (PFS)
b) FILS Shared Key authentication performed with PFS
c) FILS Public Key authentication with PFS

FILS Shared Key authentication with and without PFS is described in 4.10.3.6.2.

FILS Public Key authentication exchange is described in 4.10.3.6.3.

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4.10.3.6.2 AKM operations using FILS Shared Key authentication

A non-AP STA and a trusted third party (TTP) using FILS Shared Key authentication verify mutual possession of a shared key (rRK) (as defined in IETF RFC 5295 and IETF RFC 6696) using Extensible Authentication Protocol (EAP) reauthentication protocol (EAP-RP) signaling. EAP-RP signaling is encapsulated using FILS wrapped data in an Authentication frame as shown in Figure 4-35. A valid rRK is derived using a prior full authentication using the full EAP as defined in 4.10.3.2. This rRK can be used for multiple runs of EAP-RP authentications as specified in IETF RFC 5295 and IETF RFC 6696.

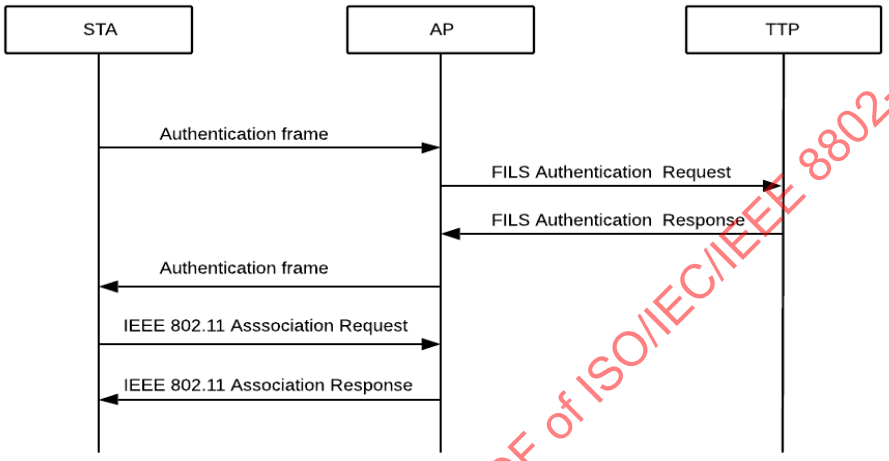

Figure 4-35—FILS authentication using TTP

4.10.3.6.3 AKM operations using FILS Public Key authentication

When using FILS Public Key authentication, it is assumed that both STAs using FILS have either:

— Obtained a public key certificate from a certificate authority (CA) and are capable of verifying each other's certificate during execution of FILS authentication procedures; or

— A priori knowledge of, and trust in, an uncertified public key.

The manner in which trust is obtained in certificates is outside the scope of this standard.

4.10.4 IBSS functional model description

4.10.4.1 General

This subclause summarizes the system setup and operation of an RSNA in an IBSS. An IBSS RSNA is specified in 12.6.11.

4.10.4.2 Key usage

In an IBSS the individually addressed Data frames between two STAs are protected with a pairwise key. The key is part of the PTK, which is derived during a 4-way handshake. In an IBSS the 4-way handshake can follow IEEE 802.11 authentication of one STA to another. Such authentication might be used by the peer to cause deletion of the PTKSA and Block the Controlled Port, resetting any previous handshake.

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In an IBSS group addressed Data frames are protected by a key, e.g., named B1, that is generated by the STA transmitting the group addressed frame. To allow other STAs to decrypt group addressed frames, B1 is sent to all of the other STAs in the IBSS. B1 is sent in an EAPOL-Key frame, encrypted under the EAPOL-Key encryption key (KEK) portion of the PTK, and protected from modification by the EAPOL-Key confirmation key (KCK) portion of the PTK.

In an IBSS the SME responds to Deauthentication frames from a STA by deleting the PTKSA associated with that STA.

4.10.4.3 Sample IBSS 4-way handshakes

In this example (see Figure 4-36), there are three STAs: S1, S2, S3. The group addressed frames sent by S1 are protected by B1; similarly B2 for S2, and B3 for S3.

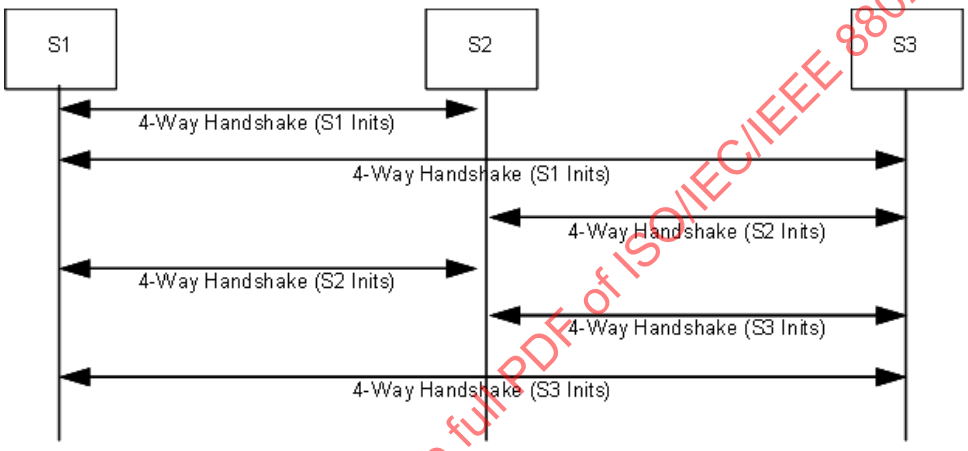

Figure 4-36—Sample 4-way handshakes in an IBSS

For STAs S2 and S3 to decrypt group addressed frames from S1, B1 is sent to S2 and S3. This is done using the 4-way handshake initially and using the group key handshake for GTK updates.

The 4-way handshake from S1 to S2 allows S1 to send group addressed frames to S2, but does not allow S2 to send group addressed frames to S1 because S2 has a different transmit GTK. Therefore, S2 needs to initiate a 4-way handshake to S1 to allow S1 to decrypt S2's group addressed frames. Similarly, S2 also needs to initiate a 4-way handshake to S3 to enable S3 to receive group addressed frames from S2.

In a similar manner S3 needs to complete the 4-way handshake with S1 and S2 to deliver B3 to S1 and S2.

In this example, there are six 4-way handshakes. In general, N Supplicants require $N(N–1)$ 4-way handshakes.

NOTE—In principle the KCK and KEK from a single 4-way handshake can be used for the group key handshake in both directions, but using two 4-way handshakes means the Authenticator key state machine does not need to be different between IBSS and ESS.

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The group key handshake can be used to send the GTKs to the correct STAs. The 4-way handshake is used to derive the pairwise key and to send the initial GTK. Because in an IBSS there are two 4-way handshakes between any two Supplicants and Authenticators, the pairwise key used between any two STAs is from the 4-way handshake initiated by the STA Authenticator with the higher MAC address (see 12.7.1 for the notion of address comparison). The KCK and KEK used for a group key handshake are the KCK and KEK derived by the 4-way handshake initiated by the same Authenticator that is initiating the group key handshake.

In an IBSS a secure link exists between two STAs when both 4-way handshakes have completed successfully. The Supplicant and Authenticator 4-way handshake state machines interact so the IEEE 802.1X variable portValid is not set to 1 until both 4-way handshakes complete.

If a fourth STA comes within range and its SME decides to initiate a security association with the three peers, its Authenticator initiates 4-way handshakes with each of the other three Supplicants. Similarly, the original three STA Authenticators in the IBSS need to initiate 4-way handshakes to the fourth STA Supplicant. A STA learns that a peer STA is RSNA-enabled and the peer's security policy (e.g., whether the Authentication and Key Management Protocol (AKMP) is SAE, PSK, or IEEE 802.1X authentication) from the Beacon or Probe Response frame. The initiation might start for a number of reasons:

a) The fourth STA receives a Beacon or Probe Response frame from a MAC address with which it has not completed a 4-way handshake.

b) An SME receives an MLME-PROTECTEDFRAMEDROPPED.indication primitive from a MAC address with which it has not completed a 4-way handshake. This could be a group addressed Data frame transmitted by any of the STAs. In order to set up a security association to the peer STA, an SME that does not know the security policy of the peer can send a Probe Request frame to the peer STA to find its security policy before setting up a security association to the peer STA.

c) An SME receives message 1 of the 4-way handshake sent to a STA because the initiator received a broadcast Data frame, Beacon frame, or Probe Response frame from that STA. In order to set up a security association to the peer STA, a STA that received a 4-way handshake but does not know the security policy of the peer can send a Probe Request frame to the peer STA to find its security policy before setting up a security association to the peer STA.

4.10.4.4 IBSS IEEE 802.1X example

When IEEE 802.1X authentication is used, each STA needs to include an IEEE 802.1X Authenticator and AS. A STA learns that a peer STA is RSNA-enabled and the peer's security policy (e.g., whether the AKMP is PSK or IEEE 802.1X authentication) from the Beacon or Probe Response frame.

Each Supplicant sends an EAPOL-Start frame to every other STA to which it intends to authenticate, and each STA's Authenticator responds with the identity of the credential it intends to use.

The EAPOL-Start and EAP-Request/Identity messages are initiated when a protected Data frame (indicated via an MLME-PROTECTEDFRAMEDROPPED.indication primitive), an IEEE 802.1X message, Beacon frame, or Probe Response frame is received from a MAC address with which the STA has not completed IEEE 802.1X authentication. In order to set up a security association to the peer STA, an SME that does not know the security policy of the peer can send a Probe Request frame to the peer STA to find its security policy before setting up a security association to the peer STA.

Although Figure 4-37 shows the two IEEE 802.1X exchanges serialized, they might occur interleaved.

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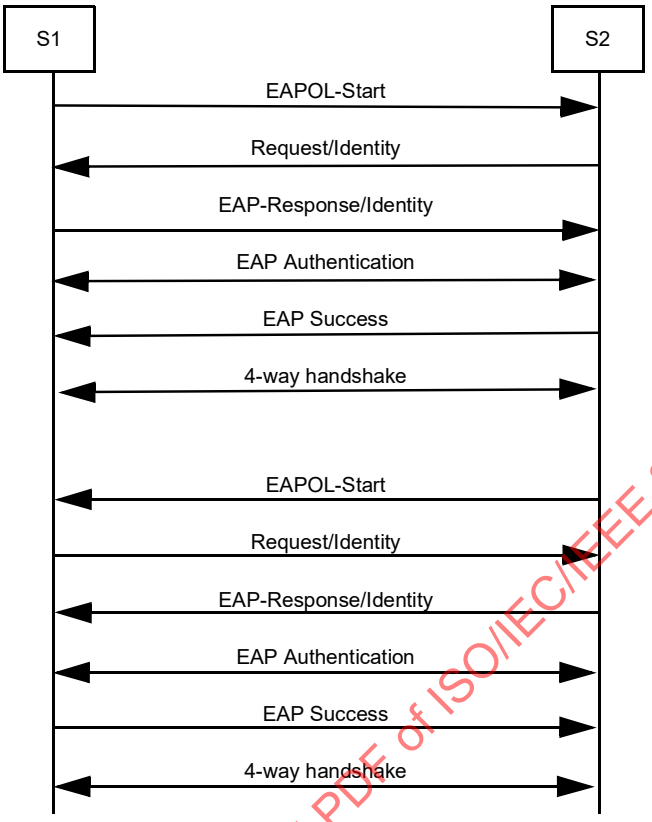

Figure 4-37—Example using IEEE 802.1X authentication

4.10.5 PBSS functional model description

This subclause summarizes the system setup and operation of an RSNA in a PBSS.

If a non-PCP STA chooses to associate with the PCP of the PBSS, the non-PCP STA establishes an RSNA with the PCP following the infrastructure functional model as specified in 4.10.3.

If a non-PCP STA wants to establish an RSNA with the PCP without association or if the non-PCP STA wants to establish an RSNA with another non-PCP STA, it can directly initiate an RSNA authentication with the peer STA, followed by a 4-way handshake. One difference between this model and the IBSS functional model is that only one RSNA authentication and one 4-way handshake are performed between two STAs. If both STAs initiate an RSNA setup at the same time, the RSNA setup initiated by the STA with the lower MAC address is carried through, while the RSNA setup initiated by the STA with the higher MAC address is terminated.

Figure 4-38 shows an example of the RSNA setup in a PBSS. An initiator STA discovers a peer STA's RSNA policies through the DMG Beacon frames from the peer STA if the peer STA is the PCP or through the Probe Response or Information Response frames from the peer STA. In this example, the initiator STA does not associate with the peer STA. The initiator STA performs RSNA authentication with the peer STA to derive a PMK. A 4-way handshake is then started to complete the RSNA setup.

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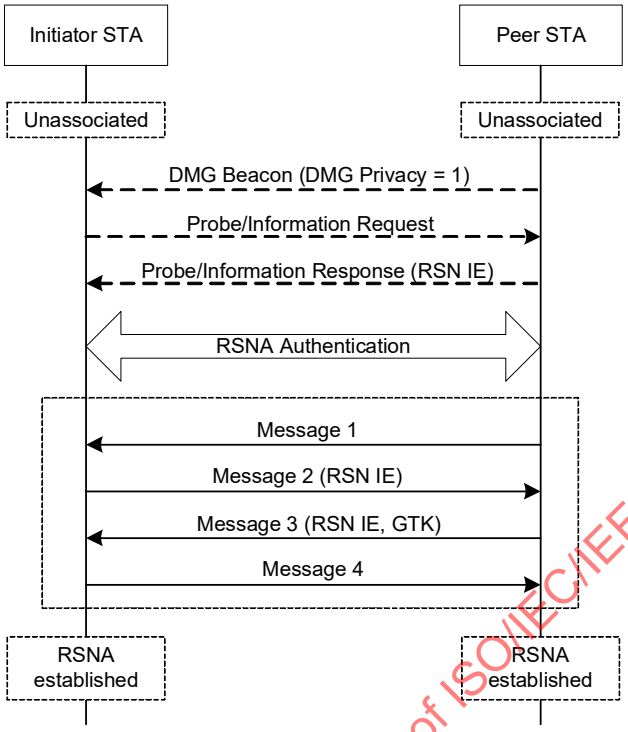

Figure 4-38—Example of RSNA setup in a PBSS

4.10.6 Authenticator-to-AS protocol

The Authenticator-to-AS authentication definition is out of the scope of this standard, but, to provide security assurances, the protocol needs to support the following functions:

a) Mutual authentication between the Authenticator and AS

b) A channel for the Supplicant and AS authentication

c) The ability to pass the generated key from the AS to the Authenticator in a manner that provides authentication of the key source, preserves integrity of the key transfer, and preserves data confidentiality of the key from all other parties

Suitable protocols include, but are not limited to, remote authentication dial-in user service (RADIUS) (IETF RFC 2865 [B33]) and Diameter (IETF RFC 3588 [B40]).

4.10.7 PMKSA caching

The Authenticator and Supplicant can cache PMKSAs, which include the IEEE 802.1X state. A PMKSA can be deleted from the cache for any reason and at any time.

A STA can supply a list of PMK identifiers in the (Re)Association Request frame or first FILS Authentication frame. Each key identifier names a PMKSA. The Authenticator can specify the selected PMK identifier in message 1 of the 4-way handshake or the second FILS Authentication frame. The selection of the key identifiers to be included by the STA and Authenticator is out of the scope of this standard.

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A FILS authentication exchange results in a PMKSA, which can be cached. A FILS STA can benefit from such caching, as a FILS STA performing subsequent authentications can supply a list of PMK identifiers in its initial Authentication frame. FILS APs that support PMK caching can identify themselves using a cache identifier. A FILS STA that has successfully established a PMKSA at an AP identifying a particular cache identifier can attempt to use PMK caching in a subsequent attempt with any AP that uses the same cache identifier.

4.10.8 Protection of group addressed robust Management frames

When management frame protection is negotiated, all group addressed robust Management frames are encapsulated using the procedures defined in 11.12. This service provides integrity protection of group addressed robust Management frames using BIP.

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5. MAC service definition

5.1 Overview of MAC services

5.1.1 Data service

5.1.1.1 General

This service provides peer LLC sublayer entities or IEEE 802.1Q bridge ports with the ability to exchange MSDUs. To support this service, the local MAC uses the underlying PHY-level services to transport an MSDU to a peer MAC entity, where it is delivered to the peer LLC sublayer or bridge port. Such asynchronous MSDU transport is performed on a connectionless basis. By default, MSDU transport is on a best-effort basis. However, the QoS facility uses a traffic identifier (TID) to specify differentiated services on a per-MSDU basis. The QoS facility also permits more synchronous behavior to be supported on a connection-oriented basis using TSPECs. There are no guarantees that the submitted MSDU will be delivered successfully. Group addressed transport is part of the data service provided by the MAC. Due to the characteristics of the WM, group addressed MSDUs might experience a lower QoS, compared to that of individually addressed MSDUs. All STAs support the data service, but only QoS STAs in a QoS BSS differentiate their MSDU delivery according to the designated traffic category or traffic stream (TS) of individual MSDUs. QoS STAs that support the QMF service differentiate their MMPDU delivery according to the MMPDU's access category. The access category of each MMPDU is designated by the transmitter's current QMF policy.

There are two service classes available in a QoS STA: QoSAck and QoSNoAck. The service classes are used to signal if the MSDU is to be transmitted with or without using the MAC-level acknowledgment.

In QoS STAs either associated in a BSS or having membership in an IBSS, the MAC uses a set of rules that tends to cause higher UP MSDUs in a BSS to be sent before lower UP MSDUs in the BSS. The MAC sublayer entities determine the UPs for MSDUs based on the TID values provided with those MSDUs. If a TSPEC has been provided for a TS, via the MAC sublayer management entity, the MAC attempts to deliver MSDUs belonging to that TS in accordance with the QoS parameter values contained in the TSPEC. In a BSS with some STAs supporting the QoS facility and others not supporting the QoS facility, in delivering an MSDU to a non-QoS STA, the QoS STA uses the access category (AC) corresponding to the UP of the MSDU.

5.1.1.2 Determination of UP

The QoS facility supports eight priority values, referred to as *UPs*. The values a UP may take are the integer values from 0 to 7 and are identical to the IEEE 802.1D™ priority tags. An MSDU with a particular UP is said to belong to a traffic category (TC) with that UP. The UP is provided with each MSDU at the medium access control service access point (MAC SAP) either directly, in the UP parameter, or indirectly, in a TSPEC or SCS Descriptor element designated by the UP parameter. For the transmission of an MSDU that was provided to the Internal Sublayer Service SAP associated with a general link, the UP is determined by the GLK convergence function based on the priority parameter of the MA_UNITDATA.request primitive. (See Annex R for recommended mapping guidelines.)

5.1.1.3 Interpretation of priority parameter in MAC service primitives

The value of the priority parameter in the MAC service primitives (see 5.2) may be a noninteger value of Contention or may be any integer value in the range 0 to 15.

When the priority parameter has an integer value, it is used in the TID subfields that appear in certain frames that are used to deliver and to control the delivery of QoS data across the WM.

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Priority parameter and TID subfield values 0 to 7 are interpreted as UPs for the MSDUs. Outgoing MSDUs with UP values 0 to 7 are handled by MAC entities at STAs in accordance with the UP.

Priority parameter and TID subfield values 8 to 15 specify TIDs that are also TS identifiers (TSIDs) and select the TSPEC for the TS designated by the TID. Outgoing MSDUs with priority parameter values 8 to 15 are handled by MAC entities at STAs in accordance with the UP value determined from the UP subfield as well as other parameter values in the selected TSPEC. When an MSDU arrives with a priority value between 8 and 15 and for which there is no TSPEC defined, then the MSDU shall be sent with priority parameter set to 0.

The noninteger value of the priority parameter is allowed at all non-QoS STAs. The integer values of the priority parameter (i.e., TID) are supported only at QoS STAs that are in a QoS BSS. A range of 0 to 15 is supported by QoS STAs associated in a QoS BSS; whereas a range of 0 to 7 is supported by QoS STAs that are members of a QoS IBSS. If a QoS STA is associated in a non-QoS BSS, the STA is functioning as a non-QoS STA, so the priority value is always Contention.

At QoS STAs associated in a QoS BSS, MSDUs with a priority of Contention are considered equivalent to MSDUs with TID 0. At STAs associated in a non-QoS BSS, all MSDUs with an integer priority are considered equivalent to MSDUs with a priority of Contention.

The received individually addressed frames at a QoS STA may be as follows:

a) Non-QoS subtypes, in which case the STA shall assign to them a priority of Contention.
b) QoS subtypes, in which case the STA shall infer the UP value from the TID in the QoS Control field directly for TID values between 0 and 7. For TID values between 8 and 15 the STA shall extract the UP value in the UP subfield of the TS Info field in the associated TSPEC or from the UP field in the associated TCLAS (traffic classification) element, as applicable.

QoS APs deliver the UP with the received MSDUs to the DS or bridge port.

5.1.1.4 Interpretation of service class parameter in MAC service primitives in a STA

In QoS STAs, the value of the service class parameter in the MAC service primitive (see 5.2) may be a noninteger value of QoSAck or QoSNoAck.

When an MSDU is received from the MAC SAP with one of the following service class indications, and the recipient STA is a QoS STA:

— QoSAck, the MSDU is transmitted using one or more QoS Data frame(s) with an ack policy other than No Ack.
— QoSNoAck, the MSDU is transmitted using one or more QoS Data frame(s) with an ack policy of No Ack.

When an MSDU is received from the MAC SAP and the recipient STA is not a QoS STA, the MSDU is transmitted using one or more non-QoS Data frame(s).

When a QoS Data frame is received from another STA, the service class parameter in the MA-UNITDATA.indication primitive is set to

— QoSAck, if the frame is a QoS Data frame with an ack policy other than No Ack; this includes when the frame was delivered via the DMS or the GCR block ack retransmission policy.
— QoSNoAck, if the frame is a QoS Data frame with an ack policy of No Ack. This service class is also used when the DA parameter is a group address unless the frame was delivered via DMS or the GCR block ack retransmission policy.

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When a non-QoS Data frame is received at a QoS STA, the service class parameter in the MA-UNITDATA.indication primitive is set to

— QoSAck, if the frame is an individually addressed frame and is acknowledged by the STA.
— QoSNoAck, if the frame is a group addressed frame and is not acknowledged by the STA.

In non-QoS STAs, the value of the service class parameter in invoked MAC service primitives (see 5.2) is ignored. The value of the service class parameter in generated MAC service primitives is set to ReorderableGroupAddressed.

5.1.2 Security services

Security services in IEEE Std 802.11 are provided by the authentication service and the CCMP, GCMP, and BIP. The scope of the security services provided is limited to station-to-station data and robust Management frame transmissions. When CCMP or GCMP is used, the data confidentiality service is provided for Data frames and individually addressed robust Management frames. For the purposes of this standard, CCMP, GCMP, and BIP are viewed as logical services located within the MAC sublayer as shown in the reference model, Figure 4-24 (in 4.9). Actual implementations of CCMP, GCMP, and BIP are transparent to the LLC sublayer and other layers above the MAC sublayer.

The security services provided by CCMP and GCMP in IEEE Std 802.11 are as follows:

a) Data Confidentiality;
b) Authentication; and
c) Access control in conjunction with layer management.

BIP provides message integrity and access control for group addressed robust Management frames.

During the authentication exchange, both parties exchange authentication information as described in Clause 12 and Clause 13.

The MAC sublayer security services provided by CCMP, GCMP, and BIP rely on information from non MAC sublayer management or system entities. Management entities communicate information to CCMP, GCMP, and BIP through a set of MAC sublayer management entity (MLME) interfaces and MIB attributes; in particular, the decision tree for CCMP, GCMP, and BIP is driven by MIB attributes.

WEP is obsolete. The WEP algorithm is unsuitable for the purposes of this standard.

The use of TKIP is deprecated. The TKIP algorithm is unsuitable for the purposes of this standard.

A STA that has associated with management frame protection enabled shall not use pairwise cipher suite selectors WEP-40, WEP-104, TKIP, or “Use group cipher suite.”

A mesh STA with dot11MeshSecurityActivated equal to true shall not use the pairwise cipher suite selectors WEP-40, WEP-104, or TKIP.

An S1G STA shall not use the pairwise cipher suite selectors WEP-40, WEP-104, TKIP, or “Use group cipher suite”.

5.1.3 MSDU ordering

The services provided by the MAC sublayer permit, and might in certain cases require, the reordering of MSDUs.

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In a non-QoS STA, the MAC does not intentionally reorder MSDUs except as might be necessary to improve the likelihood of successful delivery based on the current operational ("power management," FMS, DMS) mode of the designated recipient STA(s). The sole effect of this reordering (if any), for the set of MSDUs received at the MAC service interface of any single STA, is a change in the delivery order of group addressed MSDUs, relative to individually addressed MSDUs, originating from a single source STA address.

The MSDUs are reordered, not only to improve the likelihood of successful delivery based on the current operational mode of the designated recipient STA(s), but also to honor the priority parameters, specified in the MA-UNITDATA.request primitive, of the individual MSDUs. The effects of this reordering (if any), for the set of MSDUs received at the MAC service interface of any single STA, are:

a) A change in the delivery order of group addressed MSDUs, relative to individually addressed MSDUs, and
b) The reordering of MSDUs with different TID values, originating from a single source STA address.

There shall be no reordering of individually addressed MSDUs with the same TID value and addressed to the same destination.

STAs operating in a non-QoS BSS shall follow the reordering rules as defined for a non-QoS STA.

In order for the MAC to operate properly, this standard assumes that the DS meets the MSDU ("object") reordering requirements of IEEE Std 802.1AC-2012 [B17].

Operational restrictions that provide the appropriate ordering of MSDUs are specified in 10.7.

When MSDU or A-MSDU reordering is performed, the information in the MAC service tuple(s) for the MSDU(s) shall be maintained and reordered as a unit.

5.1.4 MSDU format

Logical Link Control (LLC) sublayer entities use the MAC sublayer service to exchange PDUs with peer LLC sublayer entities. These PDUs are termed MAC sublayer SDUs (MSDUs) when sent to the MAC sublayer. There are two LLC sublayer protocols used (see IEEE Std 802): LLC Protocol Discrimination (LPD) (see ISO/IEC 8802-2:1998) and Ethertype Protocol Discrimination (EPD) (see IEEE Std 802.3-2018). MSDUs are formatted in accordance with LPD or with EPD, as determined by the first condition below that is true. After a true condition has been found, subsequent conditions are ignored.

a) In the 5.9 GHz band in the United States (see E.2.3) use EPD.
b) For OCB communications outside of the 5.9 GHz bands, use LPD.
c) Within Data frames with RAs that are individual addresses, if both the transmitter and receiver are EPD STAs, use EPD.
d) Within Data frames with RAs that are individual addresses, if either the transmitter or the receiver are not EPD STAs, use LPD.
e) If the transmitting AP accepts association only from an EPD STA, use EPD.
f) If the transmitting mesh STA peers only with an EPD mesh STA, use EPD.
g) For all other cases, use LPD.

When LPD is used, in order to achieve interoperability, implementers are recommended to apply the procedures described in ISO/IEC Technical Report 11802-5:1997 (previously known as IEEE Std 802.1H, 1997 Edition [B19]), along with a selective translation table (STT) that handles a few specific network protocols, with specific attention to the operations required when passing MSDUs to or from LANs or operating system components that use the Ethernet frame format (EPD). Note that such translations might be required in a STA.

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5.1.5 MAC data service architecture

5.1.5.1 General

The MAC data plane architecture (i.e., processes that involve transport of all or part of an MSDU) is shown in Figure 5-1 when transparent FST is not being used and shown in Figure 5-2 when transparent FST is being used.

The dotted line box labeled “Role-specific behaviors” is replaced by one of several options, depending on the role of the STA. See the following subclauses

During transmission, an MSDU goes through the processes shown in the left-hand side of Figure 5-1. When transparent FST is used, an MSDU first goes, as shown in Figure 5-2, through an additional transparent FST entity that contains a demultiplexing process that forwards the MSDU down to the selected TX MSDU Rate Limiting process and from there to MAC data plane processing as described in the previous sentence. IEEE Std 802.1X-2010 may block the MSDU at the Controlled Port before the preceding processing occurs. Otherwise, at some point, the Data frames that contain all or part of the MSDU are queued per AC/TS.

During reception, a received Data frame goes through the processes shown in the right-hand side of of Figure 5-1. Then, one or more MSDUs are delivered to the MAC SAP or, via the DSAF, to either the DS or an IEEE 802.1Q bridge port. When transparent FST is used, MSDUs originating from different PHY SAPs go, as shown in Figure 5-2, through a final step of a transparent FST entity that contains a multiplexing process before delivering the MSDU. The IEEE 802.1X Controlled/Uncontrolled Ports discard any received MSDU if the Controlled Port is not enabled and if the MSDU does not represent an IEEE 802.1X frame.

NOTE—Many of the processes shown in Figure 5-1 also apply to MMPDU flows for the MAC control plane architecture, and the processes shown at the bottom also apply to Control and Extension frames.

When transparent FST is used, the same security keys, sequence counter, and PN counter are used by the MAC data plane to encrypt the MPDU prior to and following an FST, and the same security keys are used to check the integrity and perform the protection of MSDUs. When nontransparent FST is used, independent RSNAs, security keys, sequence counters, and PN counters have to be established for each MAC data plane to be used prior to and following an FST. When transparent FST is used, a single MAC SAP at each peer is presented to the higher layers of that peer for all of the frequency bands/channels that are identified by the same MAC address at that peer. When nontransparent FST is used, different MAC SAPs are presented to higher layers since different MAC addresses are used prior to and following an FST.

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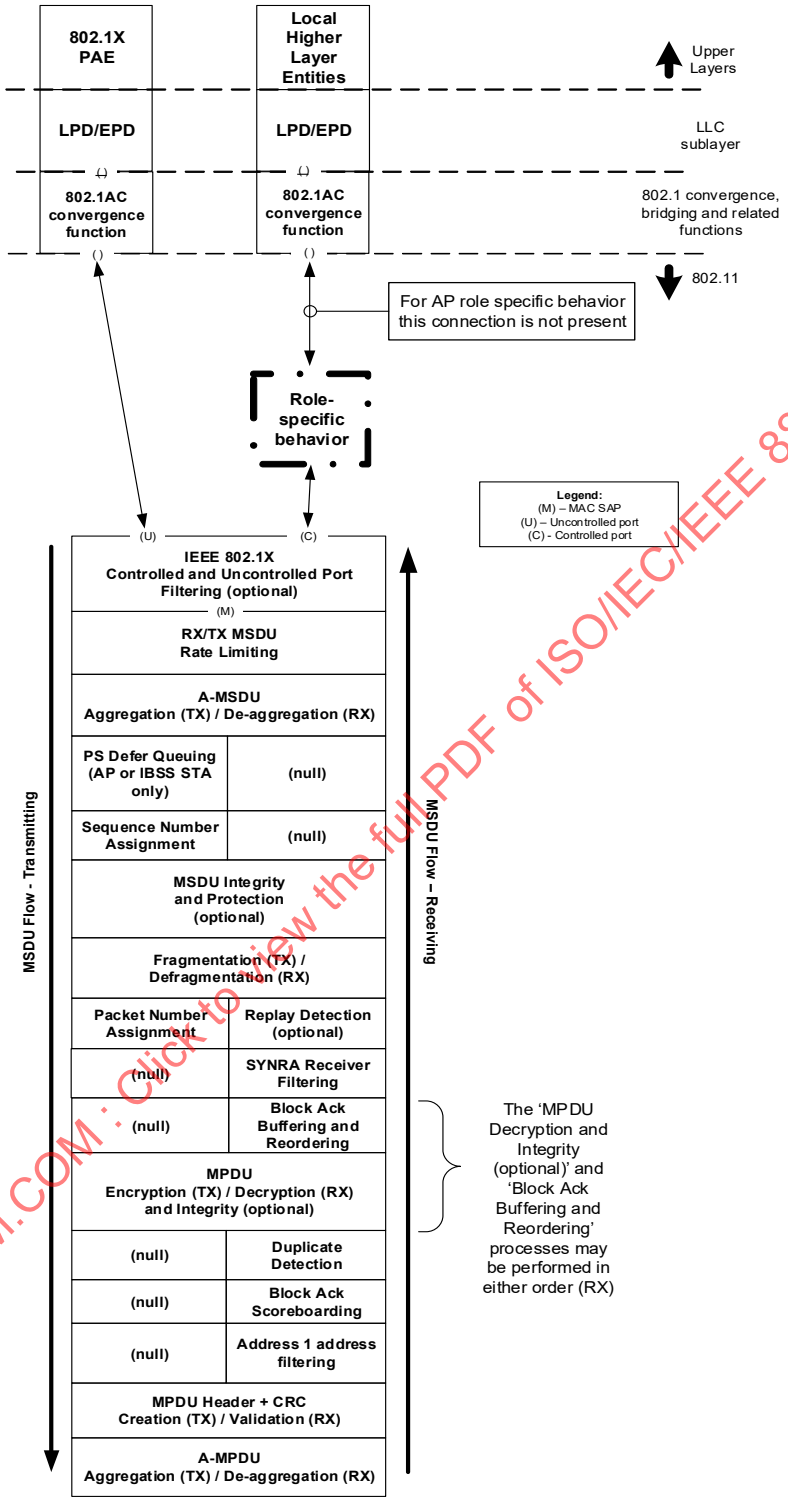

Figure 5-1—MAC data plane architecture

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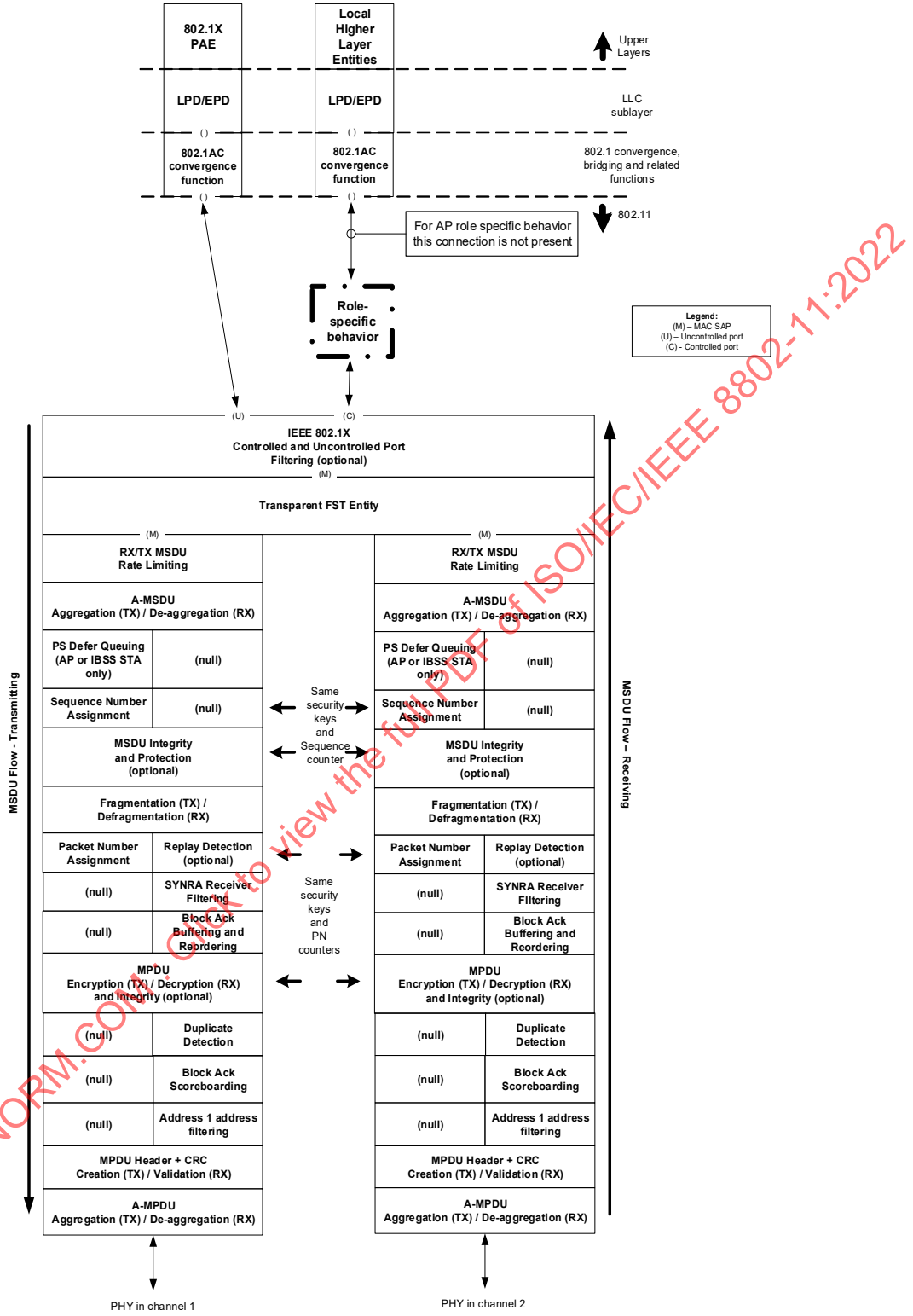

Figure 5-2—MAC data plane architecture (transparent FST)

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5.1.5.2 Non-GLK non-AP STA role

The MAC data plane architecture of a non-GLK non-AP STA is completed by replacing the role-specific behavior block with that shown in Figure 5-3. The function of this block in a non-AP STA is to perform destination address filtering as described in 10.2.7.

NOTE—In implementations, the DA address filtering function may be done "lower in the stack." It is shown in the role-specific behavior block location for simplicity, and any implementation choice needs to provide equivalent behavior.

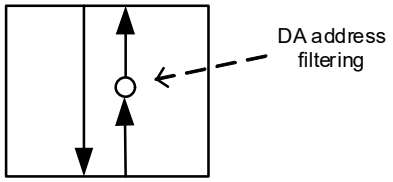

Figure 5-3—Role-specific behavior block for a non-GLK non-AP STA

5.1.5.3 Non-GLK AP role

In a non-GLK AP, the MAC data plane architecture includes distribution system access in its role-specific behavior block, as shown in Figure 5-4. This block provides access to the DS for associated non-AP STAs as described in 4.5.2.1.

NOTE—This behavior block indicates that there is no access through the controlled port to or from the local upper-layers (the LLC sublayer) at an AP. Any such access is logically achieved in the architecture via transition of the DS and Portal to an integrated LAN. In actual implementations, this is likely to be optimized, and Data frames appear to be delivered directly to one or more local LLC sublayer entities on the same physical device as the AP. Such optimization is effectively distributing the functions of the DS and Portal, and it is the responsibility of the implementation to ensure the logical behavior of these entities is maintained.

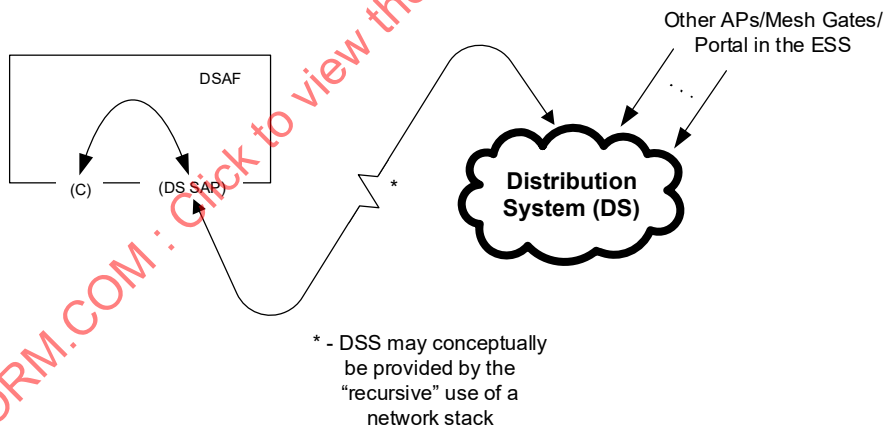

Figure 5-4—Role-specific behavior block for a non-GLK AP

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5.1.5.4 Non-GLK mesh STA role

The MAC data plane architecture of a mesh STA is completed by replacing the role-specific behavior block with that shown in Figure 5-5. The function of this block in a mesh STA is described in 10.38. This role is not applicable when transparent FST is used, and does not apply to Figure 5-2.

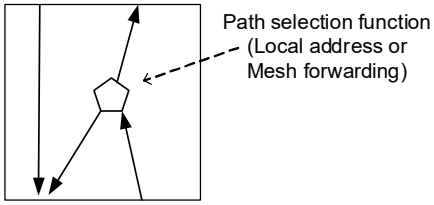

Figure 5-5—Role-specific behavior block for mesh STA

5.1.5.5 Mesh gate role

The MAC data plane architecture of a mesh gate is completed by replacing the role-specific behavior block with that shown in Figure 5-6. The function of this block in a mesh gate is described in 14.11. This role is not applicable when transparent FST is used and does not apply to Figure 5-2.

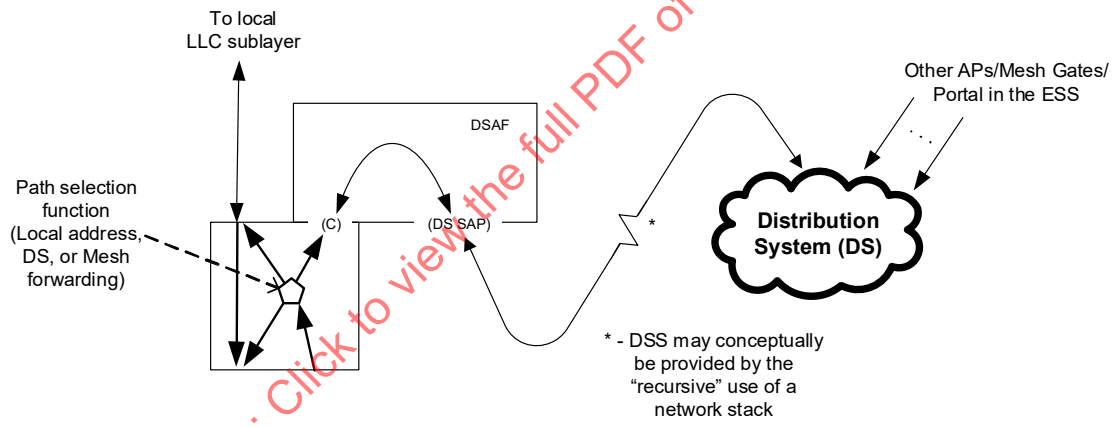

Figure 5-6—Role-specific behavior block for mesh gate

5.1.5.6 S1G relay

An S1G relay comprises a relay AP, a relay STA and a relay function (see Figure 5-7).

A relay STA is a non-AP STA associated to a root AP or the relay AP of another relay. A relay AP is an AP that offers the relay function to its associated non-AP STAs, and provides access to the DS indirectly through the relay STA’s path to the root AP. The relay function performs local reception or selective forwarding of MSDUs between the relay STA and relay AP, based on the destination address, as described in 10.54.

The MAC data plane architecture of an S1G relay is shown in Figure 5-7.

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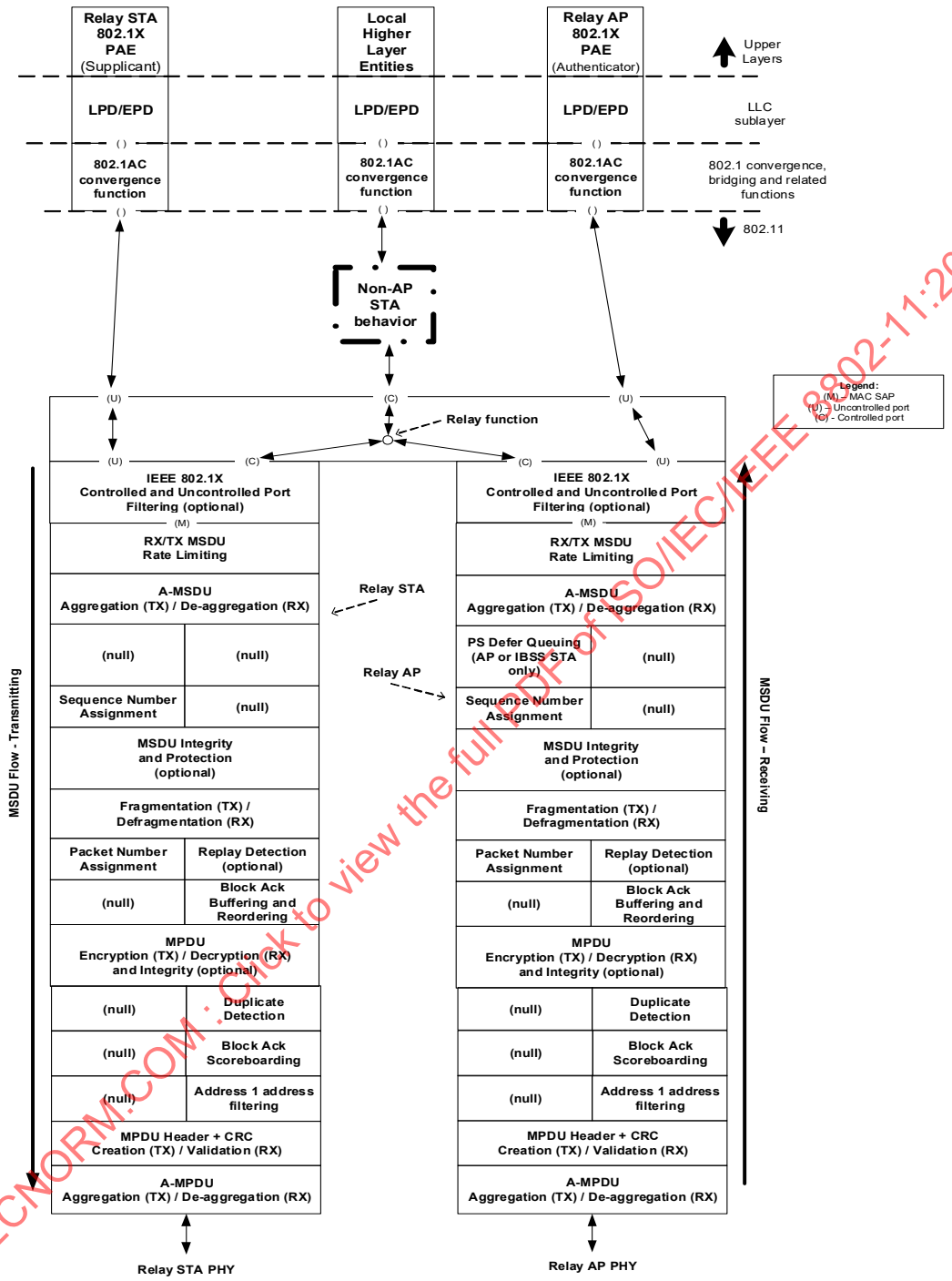

Figure 5-7—S1G relay data plane architecture

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5.1.5.7 GLK STA role

In a GLK STA's MAC data plane architecture, the role-specific behavior block is as shown in Figure 5-8. The MAC service interface to this block includes a station vector, to provide the selective delivery service to a GLK convergence function. This block performs destination address filtering, as described in 10.2.7, and provides access to the GLK convergence function and ultimately to the bridge ports.

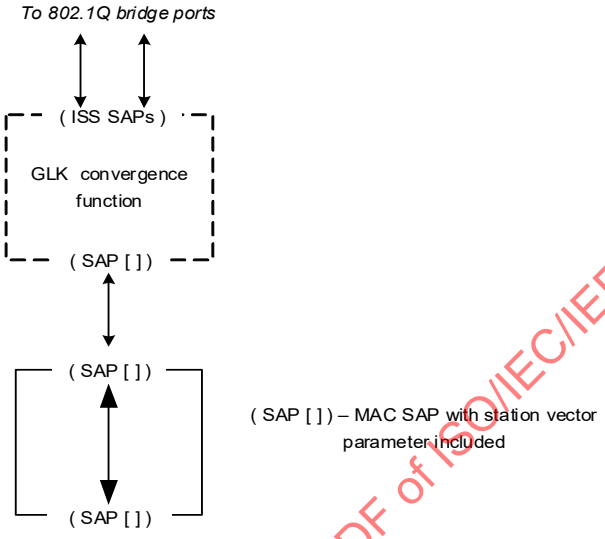

Figure 5-8—Role-specific behavior block for a GLK STA

5.1.5.8 GLK AP role

A GLK AP that supports only general links (dot11GLKRequired is true) has the same general architectural structure as described in 5.1.5.7 for a general GLK STA.

A GLK AP that supports both general links and non-GLK links provides access between the bridge ports and general links, and between the DS and non-GLK links. The DSAF behavior of such an AP is extended by adding a switching function to direct received MSDUs to either the DS or toward a bridge port, as appropriate, as shown in Figure 5-9.

5.1.5.9 GLK mesh STA role

The only type of mesh STA that has explicit support for GLK is the GLK mesh STA, which is the equivalent of a mesh gate, except it is attached to a bridge rather than a DS. Other mesh STA types implicitly may support general links with the role specific structure shown in 5.1.5.4.

The MAC data plane architecture of a GLK mesh STA, like that for a non-GLK mesh STA, is completed by replacing the role-specific behavior block with that shown in Figure 5-10. In a GLK mesh STA, the function of this block is described in 10.38, to provide access to bridge ports, through provision of the station vector parameter, rather than access to only the local DA like a non-GLK mesh STA.

This role is not applicable when transparent FST is used and does not apply to Figure 5-2.

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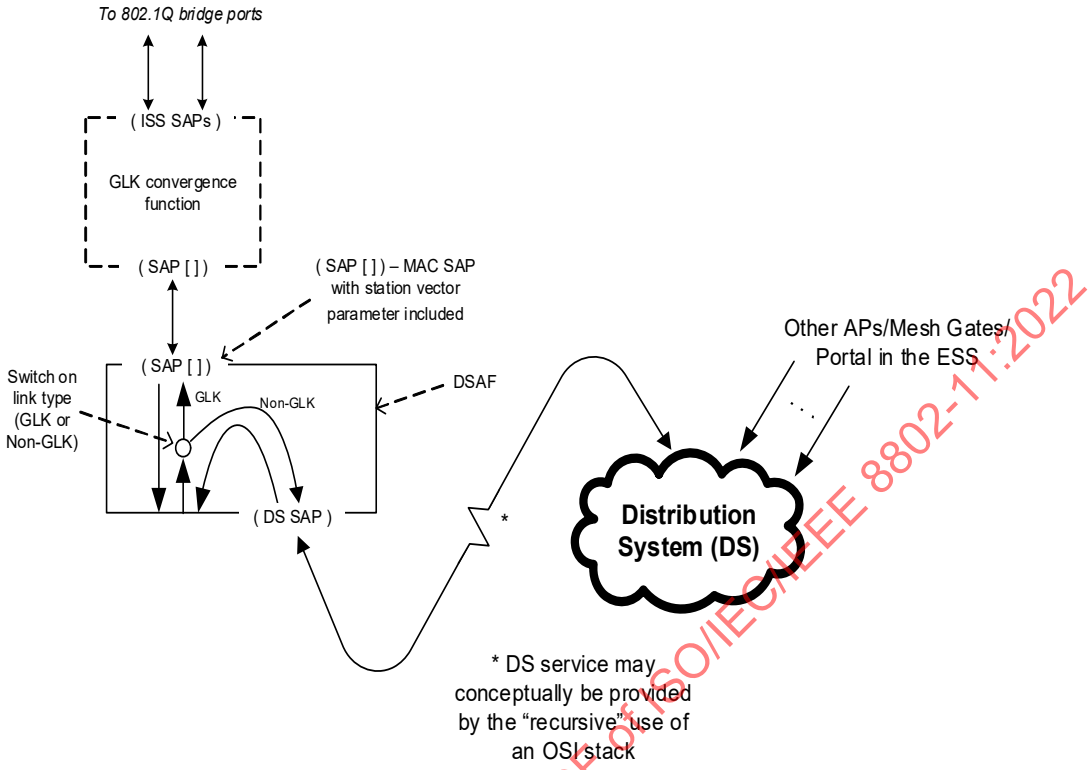

Figure 5-9—Role-specific behavior block for a mixed-mode GLK AP

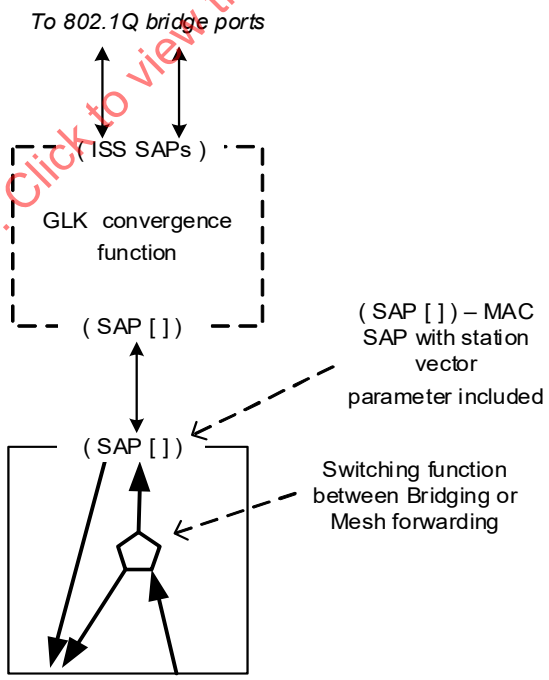

Figure 5-10—Role-specific behavior block for a GLK mesh STA

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5.2 MAC data service specification

5.2.1 General

The IEEE 802.11 MAC supports the following service primitives as defined in ISO/IEC 8802-2:1998:

— MA-UNITDATA.request
— MA-UNITDATA.indication
— MA-UNITDATA-STATUS.indication

IEEE Std 802.11 places restrictions and semantics on the parameter values for these primitives, as described in 5.2.3 to 5.2.5.

5.2.2 GLK MAC data service specification

A GLK STA coordinates with the GLK convergence function to create a virtual point-to-point LAN for each general link to an associated or peered GLK STA. This point-to-point LAN is presented by the convergence function as a unique Internal Sublayer Service SAP, which is ultimately mapped to an IEEE 802.1Q bridge port. Each such SAP is identified by a locally unique service_access_point_identifier (as defined in IEEE Std 802.1Q), generated by the STA and the convergence function.

In a GLK STA the MAC data plane architecture's MAC service uses the two parameters, a set of service_access_point_identifiers and an MSDU format indicator.

When GLK is in use, the MAC service primitives presented require the presence of the parameter station vector on request and supply a non-null value for this parameter on indication. In an MA-UNITDATA.request primitive, this parameter is a set of service_access_point_identifiers specifying the one or more general links that are to be used for this request. In an MA-UNITDATA.indication primitive, it is a vector of exactly one service_access_point_identifier specifying the general link that carried this MSDU.

When GLK is in use, the MAC service primitives make use of the MSDU format parameter. In an MA-UNITDATA.request primitive, this parameter indicates whether the supplied MSDU is in EPD or LPD format. If the format is inappropriate for the transmission that carries this MSDU as described in 5.1.4, the STA converts the format before transmission. In an MA-UNITDATA.indication primitive, this parameter indicates the format of the received MSDU, which is determined as described in 5.1.4. The MAC service user uses this information to parse the MSDU correctly.

5.2.3 MA-UNITDATA.request

5.2.3.1 Function

This primitive requests a transfer of an MSDU from a local LLC sublayer entity to a single peer LLC sublayer entity or bridge port, or multiple peer LLC sublayer entities or bridge port in the case of group addresses.

5.2.3.2 Semantics of the service primitive

The parameters of the primitive are as follows:

MA-UNITDATA.request(
source address,
destination address,
routing information,
data,
priority,
drop eligible,

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service class,
station vector,
MSDU format
)

The source address (SA) parameter specifies an individual MAC sublayer address of the sublayer entity from which the MSDU is being transferred.

The destination address (DA) parameter specifies either an individual or a group MAC sublayer entity address.

The routing information parameter specifies the route for the data transfer (a null value indicates source routing is not to be used). For IEEE Std 802.11, the routing information parameter shall be null.

The data parameter specifies the MSDU to be transmitted by the MAC sublayer entity. The length of the MSDU shall be less than or equal to the value shown in Table 9-25.

The priority parameter specifies the requested priority of the data unit transfer. The allowed values of priority are described in 5.1.1.3.

NOTE—For a GLK STA, the bridge port provides the priority. That priority might have been derived from a priority tag in the frame arriving on another port of the bridge or from the configuration of that port if the frame arrived there untagged.

The drop eligible parameter is a Boolean that indicates whether this MSDU can be discarded in preference to other MSDUs when there are insufficient resources in a STA. If drop eligible is true, the MSDU can be discarded in preference to other MSDUs for which drop eligible is false.

The service class parameter specifies the requested service class of the data unit transfer. The allowed values of service class are described in 5.1.1.4 and 5.1.3.

The station vector parameter is a set of service_access_point_identifiers (see 5.2.2) and is not null when dot11GLKImplemented is true and is null or not present otherwise. It indicates the set of virtual point-to-point LANs for these data transfers, which are mapped to the set of general links over which the MSDU is transferred.

The MSDU format parameter indicates whether the supplied MSDU is in EPD or LPD format.

5.2.3.3 When generated

This primitive is generated by the LLC sublayer entity when an MSDU is to be transferred to a peer LLC sublayer entity or entities or to a peer bridge or bridges.

5.2.3.4 Effect of receipt

On receipt of this primitive, the MAC sublayer entity determines whether it is able to fulfill the request according to the requested parameters. A request that cannot be fulfilled according to the requested parameters is discarded, and this action is indicated to the LLC sublayer entity using an MA-UNITDATA-STATUS.indication primitive that describes why the MAC was unable to fulfill the request. If the request can be fulfilled according to the requested parameters, the MAC sublayer entity properly formats a frame and passes it to the lower layers for transfer to a peer MAC sublayer entity or entities (see 5.1.4), and indicates this action to the LLC sublayer entity or bridge port using an MA-UNITDATA-STATUS.indication primitive with transmission status set to Successful.

At an AP for which dot11SSPNInterfaceActivated is true, upon receipt of an MA-UNITDATA.request primitive having a destination address that is an individual address and a priority of Contention, the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in

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dot11NonAPStationMaxAuthBestEffortRate in the dot11InterworkingEntry identified by the destination MAC address of the frame to be transmitted. The specific mechanism to perform rate limiting is outside the scope of this standard.

— If the rate limiting mechanism does not discard the frame, then dot11NonAPStationBestEffortMSDUCount shall be incremented by 1 and dot11NonAPStationBestEffortOctetCount shall be incremented by the number of octets in the MSDU.

— If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedBestEffortMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedBestEffortOctetCount shall be incremented by the number of octets in the MSDU.

At an AP for which dot11SSPNInterfaceActivated is true, upon receipt of an MA-UNITDATA.request primitive having a destination address that is an individual address for which the priority is an integer in the range 0 to 7, then the AP's MAC sublayer shall derive the access category from the priority using the mapping in Table 10-1. The AP's MAC sublayer shall retrieve the MIB attributes listed below from the dot11InterworkingEntry identified by the destination MAC address of the frame to be transmitted and perform the following operations:

— If the access category is AC_VO, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthVoiceRate; the specific mechanism to perform rate limiting is outside the scope of this standard. If the rate limiting mechanism does not discard the frame, then dot11NonAPStationVoiceMSDUCount shall be incremented by 1 and dot11NonAPStationVoiceOctetCount shall be incremented by the number of octets in the MSDU. If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedVoiceMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedVoiceOctetCount shall be incremented by the number of octets in the MSDU.

— If the access category is AC_VI, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthVideoRate; the specific mechanism to perform rate limiting is outside the scope of this standard. If the rate-limiting mechanism does not discard the frame, then dot11NonAPStationVideoMSDUCount shall be incremented by 1 and dot11NonAPStationVideoOctetCount shall be incremented by the number of octets in the MSDU. If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedVideoMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedVideoOctetCount shall be incremented by the number of octets in the MSDU.

— If the access category is AC_BE, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthBestEffortRate; the specific mechanism to perform rate limiting is outside the scope of this standard. If the rate-limiting mechanism does not discard the frame, then dot11NonAPStationBestEffortMSDUCount shall be incremented by 1 and dot11NonAPStationBestEffortOctetCount shall be incremented by the number of octets in the MSDU. If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedBestEffortMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedBestEffortOctetCount shall be incremented by the number of octets in the MSDU.

— If the access category is AC_BK, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthBackgroundRate; the specific mechanism to perform rate limiting is outside the scope of this standard. If the rate-limiting mechanism does not discard the frame, then dot11NonAPStationBackgroundMSDUCount shall be incremented by 1 and dot11NonAPStationBackgroundOctetCount shall be incremented by the number of octets in the MSDU. If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedBackgroundMSDUCount shall be incremented by 1 and

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dot11NonAPStationDroppedBackgroundOctetCount shall be incremented by the number of octets in the MSDU.

At an AP for which dot11SSPNInterfaceActivated is true, upon receipt of an MA-UNITDATA.request primitive having a destination address that is an individual address whose priority is an integer in the range 8 to 15, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationAuthMaxHCCAHEMMRate; the specific mechanism to perform rate limiting is outside the scope of this standard.

— If the rate-limiting mechanism does not discard the frame, then dot11NonAPStationHCCAHEMMMSDUCount shall be incremented by 1, and dot11NonAPStationHCCAHEMMOctetCount shall be incremented by the number of octets in the MSDU.

— If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedHCCAHEMMMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedHCCAHEMMOctetCount shall be incremented by the number of octets in the MSDU.

5.2.4 MA-UNITDATA.indication

5.2.4.1 Function

This primitive defines the transfer of an MSDU from the MAC sublayer entity to the LLC sublayer entity or bridge port, or entities or bridge ports in the case of group addresses. In the absence of error, the contents of the data parameter are logically complete and unchanged relative to the data parameter in the associated MA-UNITDATA.request primitive.

5.2.4.2 Semantics of the service primitive

The parameters of the primitive are as follows:

```
MA-UNITDATA.indication(
                        source address,
                        destination address,
                        routing information,
                        data,
                        reception status,
                        priority,
                        drop eligible,
                        service class,
                        station vector,
                        MSDU format
                        )
```

The SA parameter is an individual address as specified by the SA field of the incoming frame.

The DA parameter is either an individual or a group address as specified by the DA field of the incoming frame.

The routing information parameter specifies the route that was used for the data transfer. The MAC sublayer entity shall set this field to null.

The data parameter specifies the MSDU as received by the local MAC entity.

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The reception status parameter indicates the success or failure of the received frame. The MAC always reports "success" because all failures of reception are discarded without generating MA-UNITDATA.indication primitive.

The drop eligible parameter is a Boolean that indicates whether the received MSDU was designated as drop eligible in the DEI subfield of the HT variant HT Control field of the incoming frame, if present. If no HT variant HT Control field was present, the parameter value is false.

The priority parameter specifies the receive processing priority that was used for the data unit transfer. The allowed values of priority are described in 5.1.1.3.

The service class parameter specifies the receive service class that was used for the data unit transfer. The allowed values of service class are described in 5.1.1.4 and 5.1.3.

The station vector parameter is a set of service_access_point_identifiers (see 5.2.2) and is not null when dot11GLKImplemented is true. It indicates only the single virtual point-to-point LAN for this data transfer, which is mapped from the general link over which the MSDU was received.

The MSDU format parameter indicates if the received MSDU is in EPD or LPD format.

5.2.4.3 When generated

The MA-UNITDATA.indication primitive is passed from the MAC sublayer entity to the LLC sublayer entity or entities to, or bridge port or ports, indicate the arrival of a frame at the local MAC sublayer entity. Frames are reported only if they are validly formatted at the MAC sublayer, received without error, received with valid (or null) security and integrity information, and their destination address designates the local MAC sublayer entity. The MA-UNITDATA.indication primitive might also be passed from the MAC sublayer entity, in coordination with the MAC sublayer management entity, to the LLC sublayer entity to indicate the arrival of a FILS higher layer protocol (HLP) Container element.

5.2.4.4 Effect of receipt

The effect of receipt of this primitive by the LLC sublayer or bridge port is dependent on the content of the MSDU.

At an AP for which dot11SSPNInterfaceActivated is true, upon receipt of a frame with the Type subfield equal to Data having a group DA, the AP's MAC sublayer shall discard the frame if dot11NonAPStationAuthSourceMulticast is false in the dot11InterworkingEntry identified by the source MAC address of the received frame. If dot11NonAPStationAuthSourceMulticast is true, the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationAuthMaxSourceMulticastRate in the dot11InterworkingEntry identified by the source MAC address of the received frame. The specific mechanism to perform rate limiting is outside the scope of this standard.

— If the rate limiting mechanism does not discard the frame, then dot11NonAPStationMulticastMSDUCount shall be incremented by 1 and dot11NonAPStationMulticastOctetCount shall be incremented by the number of octets in the MSDU.

— If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedMulticastMSDUCount. shall be incremented by 1 and dot11NonAPStationDroppedMulticastOctetCount. shall be incremented by the number of octets in the MSDU.

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At an AP for which dot11SSPNInterfaceActivated is true, upon receipt of an individually addressed frame with the Type subfield equal to Data and a priority of Contention, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthBestEffortRate in the dot11InterworkingEntry identified by the source MAC address of the received frame. The specific mechanism to perform rate limiting is outside the scope of this standard.

— If the rate limiting mechanism does not discard the frame, then dot11NonAPStationBestEffortMSDUCount shall be incremented by 1 and dot11NonAPStationBestEffortOctetCount shall be incremented by the number of octets in the MSDU.

— If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedBestEffortMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedBestEffortOctetCount shall be incremented by the number of octets in the MSDU.

At an AP for which dot11SSPNInterfaceActivated is true, upon receipt of an individually addressed frame with the Type subfield equal to Data, for which the priority is an integer in the range 0 to 7, then the AP's MAC sublayer shall derive the access category from the priority using the mapping in Table 10-1. The AP's MAC sublayer shall retrieve the MIB attributes from the dot11InterworkingEntry identified by the source MAC address of the received frame and perform the following operations:

— If the access category is AC_VO, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthVoiceRate; the specific mechanism to perform rate limiting is outside the scope of this standard. If the rate-limiting mechanism does not discard the frame, then dot11NonAPStationVoiceMSDUCount shall be incremented by 1 and dot11NonAPStationVoiceOctetCount shall be incremented by the number of octets in the MSDU. If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedVoiceMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedVoiceOctetCount shall be incremented by the number of octets in the MSDU.

— If the access category is AC_VI, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthVideoRate; the specific mechanism to perform rate limiting is outside the scope of this standard. If the rate-limiting mechanism does not discard the frame, then dot11NonAPStationVideoMSDUCount shall be incremented by 1 and dot11NonAPStationVideoOctetCount shall be incremented by the number of octets in the MSDU. If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedVideoMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedVideoOctetCount shall be incremented by the number of octets in the MSDU.

— If the access category is AC_BE, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthBestEffortRate; the specific mechanism to perform rate limiting is outside the scope of this standard. If the rate-limiting mechanism does not discard the frame, then dot11NonAPStationBestEffortMSDUCount shall be incremented by 1 and dot11NonAPStationBestEffortOctetCount shall be incremented by the number of octets in the MSDU. If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedBestEffortMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedBestEffortOctetCount shall be incremented by the number of octets in the MSDU.

— If the access category is AC_BK, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthBackgroundRate; the specific mechanism to perform rate limiting is outside the scope of this standard. If the rate-limiting mechanism does not discard the frame, then dot11NonAPStationBackgroundMSDUCount shall be incremented by 1 and dot11NonAPStationBackgroundOctetCount shall be incremented by the number of octets in the MSDU. If the rate limiting mechanism discards the frame, then

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dot11NonAPStationDroppedBackgroundMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedBackgroundOctetCount shall be incremented by the number of octets in the MSDU.

At an AP for which dot11SSPNInterfaceActivated is true, upon receipt of an individually addressed frame with the Type subfield equal to Data for which the priority is an integer in the range 8 to 15, the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationAuthMaxHCCAHEMMRate; the specific mechanism to perform rate limiting is outside the scope of this standard.

— If the rate-limiting mechanism does not discard the frame, then dot11NonAPStationHCCAHEMMMSDUCount shall be incremented by 1, and dot11NonAPStationHCCAHEMMOctetCount shall be incremented by the number of octets in the MSDU.

— If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedHCCAHEMMMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedHCCAHEMMOctetCount shall be incremented by the number of octets in the MSDU.

5.2.5 MA-UNITDATA-STATUS.indication

5.2.5.1 Function

This primitive has local significance and provides the LLC sublayer or bridge port with status information for the corresponding preceding MA-UNITDATA.request primitive.

5.2.5.2 Semantics of the service primitive

The parameters of the primitive are as follows:

```
MA-UNITDATA-STATUS.indication(
                                source address,
                                destination address,
                                transmission status,
                                provided priority,
                                provided service class
                                )
```

The SA parameter is an individual MAC sublayer entity address as specified in the associated MA-UNITDATA.request primitive.

The DA parameter is either an individual or group MAC sublayer entity address as specified in the associated MA-UNITDATA.request primitive.

The transmission status parameter is used to pass status information back to the local requesting LLC sublayer entity or bridge port. IEEE Std 802.11 specifies the following values for transmission status:

a) Successful.
b) Undeliverable (excessive data length).
c) Undeliverable (non-null source routing).
d) Undeliverable: unsupported priority (for priorities other than Contention at a non-QoS STA; or for priorities other than Contention, or an integer in the range 0 to 15 at a QoS STA).
e) Undeliverable: unsupported service class (for service classes other than ReorderableGroupAddressed for non-QoS STAs and service classes other than QoSAck or QoSNoAck for QoS STAs).

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f) Unavailable priority (for an integer in the range 1 to 15 at a STA that is associated in a non-QoS BSS, or an integer in the range 8 to 15 at an IBSS STA, in which case the MSDU is transmitted with a provided priority of Contention).

g) Undeliverable: unavailable service class.

h) Undeliverable (no BSS available).

i) Undeliverable (cannot encrypt with a null key).

j) In a STA in which dot11RejectUnadmittedTraffic is true, Undeliverable: unadmitted traffic (for a requested priority in the range 0 to 7 because there is no admitted TS for this priority and admission control is required for the AC).

k) In an AP in which dot11SSPNInterfaceActivated is true, Undeliverable (violation of limit specified by dot11NonAPStationMaxAuthVoiceRate in the dot11InterworkingTable for the non-AP STA identified by the destination address of the MA-UNITDATA.request primitive).

l) In an AP in which dot11SSPNInterfaceActivated is true, Undeliverable (violation of limit specified by dot11NonAPStationMaxAuthVideoRate in the dot11InterworkingTable for the non-AP STA identified by the destination address of the MA-UNITDATA.request primitive).

m) In an AP in which dot11SSPNInterfaceActivated is true, Undeliverable (violation of limit specified by dot11NonAPStationMaxAuthBestEffortRate in the dot11InterworkingTable for the non-AP STA identified by the destination address of the MA-UNITDATA.request primitive).

n) In an AP in which dot11SSPNInterfaceActivated is true, Undeliverable (violation of limit specified by dot11NonAPStationAuthMaxBackgroundRate in the dot11InterworkingTable for the non-AP STA identified by the destination address of the MA-UNITDATA.request primitive).

o) In an AP in which dot11SSPNInterfaceActivated is true, Undeliverable (violation of limit specified by dot11NonAPStationAuthMaxHCCAHEMMRate in the dot11InterworkingTable for the non-AP STA identified by the destination address of the MA-UNITDATA.request primitive).

If the transmission status parameter is Successful, the provided priority parameter specifies the priority used for the associated data unit transfer (Contention or an integer in the range 0 to 15); otherwise the provided priority parameter is not present.

If the transmission status parameter is Successful, the provided service class parameter specifies the class of service for the associated data unit transfer; otherwise the provided service class parameter is not present. In non-QoS STAs, the value of this parameter is ReorderableGroupAddressed. In QoS STAs, it is QoSAck or QoSNoAck.

5.2.5.3 When generated

The MA-UNITDATA-STATUS.indication primitive is passed from the MAC sublayer entity to the LLC sublayer entity or bridge port to indicate the status of the service provided for the corresponding MA-UNITDATA.request primitive.

5.2.5.4 Effect of receipt

The effect of receipt of this primitive by the LLC sublayer or bridge port is dependent upon the type of operation employed by the LLC sublayer entity or bridge port.

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6. Layer management

6.1 Overview of management model

Both the MAC sublayer and PHY conceptually include management entities, called *MLME* and *PLME*, respectively. These entities provide the layer management service interfaces through which layer management functions are invoked.

In order to provide correct MAC operation, an SME is present within each STA. The SME is a layer-independent entity that resides in a separate management plane or resides "off to the side." Some of the functions of the SME are specified in this standard. Typically this entity is responsible for such functions as the gathering of layer-dependent status from the various layer management entities (LMEs), and similarly setting the value of layer-specific parameters. The SME typically performs such functions on behalf of general system management entities and would implement standard management protocols. Figure 4-24 (in 4.9) depicts the relationship among management entities.

The various entities within this model interact in various ways. Certain of these interactions are defined explicitly within this standard, via a SAP across which defined primitives are exchanged. This definition includes the GET and SET operations between MLME, PLME and SME as well as other individually defined service primitives, represented as double arrows within Figure 6-1. Other interactions are not defined explicitly within this standard, such as the interfaces between the MAC and MLME and between the PLME and PHY; the specific manner in which these MAC and PHY LMEs are integrated into the overall MAC sublayer and PHY is not specified within this standard. A STA includes only one instance of a PHY entity.

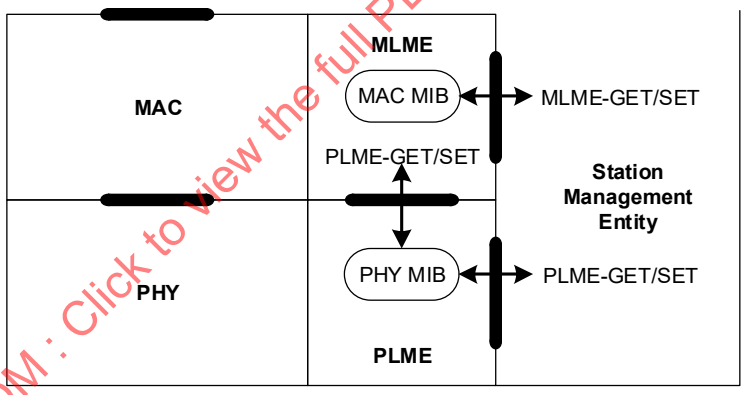

Figure 6-1—GET and SET operations

The management SAPs within this model are the following:

— SME-MLME SAP
— SME-PLME SAP
— MLME-PLME SAP

The latter two SAPs support identical primitives, and in fact might be viewed as a single SAP (called the *PLME SAP*) that is used either directly by MLME or by SME. In this fashion, the model reflects what is anticipated to be a common implementation approach in which PLME functions are controlled by the MLME (on behalf of SME).

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6.2 Generic management primitives

The management information specific to each layer is represented as a MIB for that layer. The MLME and PLME are viewed as "containing" the MIB for that layer. The generic model of MIB-related management primitives exchanged across the management SAPs is to allow the SAP user-entity to either GET the value of a MIB attribute, or to SET the value of a MIB attribute. The invocation of a SET.request primitive might require that the layer entity perform certain defined actions.

Figure 6-1 depicts these generic primitives.

The GET and SET primitives are represented as REQUESTs with associated CONFIRM primitives. These primitives are prefixed by MLME or PLME depending upon whether the MAC sublayer or PHY management SAP is involved. In the following, XX denotes MLME or PLME:

XX-GET.request(MIBattribute)
: Requests the value of the given MIBattribute.

XX-GET.confirm(status, MIBattribute, MIBattributevalue)
: Returns the appropriate MIB attribute value if status = "success," otherwise returns an error indication in the Status field. Possible error status values include "invalid MIB attribute" and "attempt to get write-only MIB attribute."

XX-SET.request(MIBattribute, MIBattributevalue)
: Requests that the indicated MIB attribute be set to the given value. If this MIBattribute implies a specific action, then this requests that the action be performed.

XX-SET.confirm(status, MIBattribute)
: If status = "success," this confirms that the indicated MIB attribute was set to the requested value; otherwise it returns an error condition in status field. If this MIBattribute implies a specific action, then this confirms that the action was performed. Possible error status values include "invalid MIB attribute" and "attempt to set read-only MIB attribute."

Additionally, there are certain requests that can be invoked across a given SAP that do not involve the setting or getting of a specific MIB attribute. One of these is supported by each SAP, as follows:

— XX-RESET.request: where XX is MLME or PLME as appropriate

This service is used to initialize the management entities, the MIBs, and the datapath entities. It might include a list of attributes for items to be initialized to nondefault values.

Other SAP-specific primitives are identified in 6.3.

6.3 MLME SAP interface

6.3.1 Introduction

The services provided by the MLME to the SME are specified in this subclause. These services are described in an abstract way (following the model described in ITU-T Recommendation X.210 [B56]) and do not imply any particular implementation or exposed interface. MLME SAP primitives are of the general form ACTION.request primitive followed by ACTION.confirm primitive (for an exchange initiated by the SAP client) and ACTION.indication primitive followed by ACTION.response primitive (for an exchange initiated by the MLME). The SME uses the services provided by the MLME through the MLME SAP.

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6.3.2 Power management

6.3.2.1 Introduction

This mechanism supports the process of establishment and maintenance of the power management mode of a STA.

6.3.2.2 MLME-POWERMGT.request

6.3.2.2.1 Function

This primitive requests a change in the power management mode.

6.3.2.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-POWERMGT.request(
                        PowerManagementMode,
                        ReceiveDTIMs,
                        ReceiveTIMs
                        )
```

Name	Type	Valid range	Description
PowerManagementMode	Enumeration	ACTIVE, POWER_SAVE	An enumerated type that describes the requested power management mode of the STA.
ReceiveDTIMs	Boolean	true, false	Non-DMG BSS: When true, this parameter causes the STA to awaken to receive all DTIM frames. When false, the STA is not required to awaken for every DTIM Beacon frame. DMG BSS: Not applicable
ReceiveTIMs	Boolean	true, false	The parameter is present if dot11S1GOptionImplemented is true; otherwise not present. This parameter is set to the boolean complement of dot11NonTIMModeActivated. When true, this parameter causes the S1G STA to awaken to receive a Beacon frame, as determined by the STA's ListenInterval and the ReceiveDTIMs parameter. When this parameter is false, the S1G STA transmits at least one frame every listen interval without receiving a Beacon frame.

6.3.2.2.3 When generated

This primitive is generated by the SME to implement the power saving strategy of an implementation.

6.3.2.2.4 Effect of receipt

This request sets the STA's power management parameters. The MLME subsequently issues an MLME-POWERMGT.confirm primitive that reflects the results of the power management change request.

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6.3.2.3 MLME-POWERMGT.confirm

6.3.2.3.1 Function

This primitive confirms the change in power management mode.

6.3.2.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-POWERMGT.confirm(
ResultCode
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, NOT_SUPPORTED	Indicates the result of the MLME-POWERMGT.request primitive.

6.3.2.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-POWERMGT.request primitive to establish a new power management mode. It is not generated until the change has completed as defined in 11.2.3.

6.3.2.3.4 Effect of receipt

The SME is notified of the change of power management mode.

6.3.3 Scan

6.3.3.1 Introduction

This mechanism supports the process of determining the characteristics of the available BSSs.

6.3.3.2 MLME-SCAN.request

6.3.3.2.1 Function

This primitive requests a survey of potential BSSs that the STA can later elect to try to join.

6.3.3.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-SCAN.request(
BSSType,
BSSID,
SSID,
ScanType,
ActiveScanType,
ProbeDelay,
ChannelList,
MinChannelTime,
MaxChannelTime,
RequestInformation,

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SSID List,
ChannelUsage,
AccessNetworkType,
HESSID,
MeshID,
DiscoveryMode,
FILSRequestParameters,
ReportingOption,
APConfigurationSequenceNumber,
S1GRelayDiscovery,
PV1ProbeResponseOption,
S1GCapabilities,
ChangeSequence,
ELOperation,
MaxAwayDuration,
Multi-band local,
Multi-band peer,
GeneralLinkType,
OperationalRateSet,
HT Capabilities,
VHT Capabilities,
VendorSpecificInfo
)

Name	Type	Valid range	Description
BSSType	Enumeration	INFRASTRUCTURE, PERSONAL, INDEPENDENT, MESH, ANY_BSS	Determines whether infrastructure BSS, PBSS, IBSS, MBSS, or all, are included in the scan.
BSSID	MAC address	Any valid individual address, or broadcast address	Identifies a specific or wildcard BSSID.
SSID	Octet string	0–32 octets	Specifies the desired SSID or the wildcard SSID.
ScanType	Enumeration	ACTIVE, PASSIVE	Indicates either active or passive scanning.
ActiveScanType	Enumeration	FRAME, NDP	Indicates active scanning type by the transmission of either Probe Request frames or NDP Probe Request frames. This parameter is optionally present if dot11S1GOptionImplemented is true and if ScanType is ACTIVE; otherwise not present.
ProbeDelay	Integer	N/A	Delay (in microseconds) to be used prior to transmitting a Probe frame during active scanning.
ChannelList	Set of integers	Each channel is selected from the valid channel range for the appropriate PHY and carrier set.	Specifies a list of channels that are examined when scanning for a BSS. If the Multi-band local and Multi-band peer parameters are present in the primitive, the ChannelList parameter specifies the channels used by the TR-MLME and the Multi-band peer parameter contains the channels to be scanned (see 11.31.5).
MinChannelTime	Integer	N/A	The minimum time (in TU) to spend on each channel when scanning.

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Name	Type	Valid range	Description
MaxChannelTime	Integer	≥ MinChannelTime	The maximum time (in TU) to spend on each channel when scanning.
RequestInformation	A list of element identifiers	As defined in 9.4.2.9 and 9.4.2.10.	This parameter is optionally present if dot11RadioMeasurementActivated is true and is placed in a Probe Request frame to request that the responding STA include the requested information in the Probe Response frame.
SSID List	A set of SSID element	As defined in 9.4.2.2.	One or more SSID elements that are optionally present when dot11SSIDListActivated is true.
ChannelUsage	A set of Channel Usage element	As defined in 9.4.2.85	Specifies request types for the Channel Usage request.
AccessNetworkType	As defined in Table 9-236	0 to 15	Specifies the target specific access network type or the wildcard access network type. This field is present when dot11InterworkingServiceActivated is true.
HESSID	MAC address	Any valid individual address or the broadcast address	Specifies the target specific HESSID network identifier or the wildcard network identifier. This field is present when dot11InterworkingServiceActivated is true.
Mesh ID	Octet string	0–32 octets	Present only if BSSType = MESH or BSSType = ANY_BSS. Specifies the target Mesh ID or wildcard Mesh ID.
DiscoveryMode	Integer	0–1	Indicates, if equal to 1, that a DMG Beacon frame is transmitted during active scanning with the Discovery Mode field set to 1 and, if equal to 0, that a DMG Beacon frame is not transmitted during active scanning. Present only when dot11DMGOptionImplemented is true.
FILSRequestParameters	As defined in 9.4.2.177	As defined in 9.4.2.177	Used in determining whether to transmit a Probe Response frame. This parameter is optionally present if dot11FILSActivated is true; otherwise not present.
ReportingOption	Enumeration	IMMEDIATE, CHANNEL_SPECIFIC, AT_END	Indicates the result reporting mode as described in 11.1.4. This parameter is optionally present if dot11FILSActivated is true; otherwise not present.
APConfigurationSequenceNumber	Integer	As defined in 9.4.2.181	Indicates the configuration sequence number for the static information fields and elements as described in 11.1.4.3.11. This parameter is optionally present if dot11FILSActivated is true and BSSID is an individual MAC address; otherwise not present.
S1GRelayDiscovery	S1G Relay Discovery element	As defined in 9.4.2.207	Indicates link budget information and QoS requirements for relay discovery. This element is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
PV1ProbeResponseOption	PV1 Probe Response Option element	As defined in 9.4.2.209	Indicates which optional information is requested to be included in the PV1 Probe Response frame. This element is optionally present if dot11PV1ProbeResponseOptionImplemented is true; otherwise not present.

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Name	Type	Valid range	Description
S1GCapabilities	S1G Capabilities element	As defined in 9.4.2.200	Indicates S1G capabilities of an S1G STA. The S1G Capabilities element is present if dot11S1GOptionImplemented is true; otherwise not present.
ChangeSequence	Change Sequence element	As defined in 9.4.2.198	Specifies the parameters within the Change Sequence element that are supported by the MAC entity. The parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.
ELOperation	EL Operation element	As defined in 9.4.2.210	Specifies the parameters within the EL Operation element that are supported by the MAC entity. The parameter is present if dot11S1GELOperationActivated is true; otherwise not present.
MaxAwayDuration	Integer	0–65 535	Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA. The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present.
Multi-band local	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise.
Multi-band peer	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. The parameter is present if OCT is being used and is absent otherwise.
GeneralLinkType	Enumeration	GLK_SUPPORTED, GLK_UNSPECIFIED	This parameter is present if dot11GLKImplemented is true. If GLK_SUPPORTED, a BSS in which the AP supports GLK is requested. If GLK_UNSPECIFIED, the GLK nature of the BSS is ignored.
OperationalRateSet	Non-DMG BSS: Set of integers DMG BSS: Set of numbers	Non-DMG BSS: a value in dot11SupportedDataRatesRxTable, for each member of the set DMG BSS: 0-12, 9.1, 12.1-12.6, or 25-31, for each member of the set	Non-DMG BSS: The set of data rates (in units of 500 kb/s) that the STA is able to use for communication within the BSS. The STA is able to receive at each of the data rates listed in the set. This set is a superset of the rates contained in the BSSBasicRateSet parameter of the SelectedBSS parameter. DMG BSS: The set of MCS indexes that the STA uses for communication within the BSS. Present only if ScanType = ACTIVE.
HT Capabilities	As defined in frame format HT Capabilities element	As defined in 9.4.2.55; the HT-MCSs in the element are present in dot11SupportedHTMCSRxTable and the highest supported data rate in the element does not exceed dot11HighestSupportedDataRate	Specifies the parameters in the HT Capabilities element that are supported by the STA. The parameter is present if dot11HighThroughputOptionImplemented is true; otherwise, this parameter is not present. Present only if ScanType = ACTIVE.

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Name	Type	Valid range	Description
VHT Capabilities	As defined in VHT Capabilities element	As defined in 9.4.2.157; the VHT-MCSs in the element are present in dot11VHTRxVHTMCSMap/ dot11VHTTxVHTMCSMap and the highest supported rates in the element do not exceed dot11VHTRxHighestDataRateSupported/ dot11VHTTxHighestDataRateSupported	Specifies the parameters in the VHT Capabilities element that are supported by the STA. The parameter is present if dot11VHTOptionImplemented is true and not present otherwise. Present only if ScanType = ACTIVE.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.3.2.3 When generated

This primitive is generated by the SME for a STA to determine if there are other BSSs that it can join.

6.3.3.2.4 Effect of receipt

This request initiates the scan process when the current frame exchange sequence is completed.

6.3.3.3 MLME-SCAN.confirm

6.3.3.3.1 Function

This primitive returns the descriptions of the set of BSSs detected by the scan process. Multiple MLME-SCAN.confirm primitives can be issued when the value of the ReportingOption parameter in the MLME-SCAN.request primitive is CHANNEL_SPECIFIC or IMMEDIATE. When the value of the ReportingOption parameter is AT_END, or the ReportingOption parameter is not present, a single MLME-SCAN.confirm primitive is issued.

6.3.3.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-SCAN.confirm(
BSSDescriptionSet,
BSSDescriptionFromMeasurementPilotSet,
BSSDescriptionFromFDSet,
ResultCode,
Multi-band local,
Multi-band peer,
ScannedChannelList,
VendorSpecificInfo
)

Name	Type	Valid range	Description
BSSDescriptionSet	Set of BSSDescriptions	N/A	The BSSDescriptionSet is returned to indicate the results of the scan request. It is a set containing zero or more instances of a BSSDescription.

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Name	Type	Valid range	Description
BSSDescriptionFromMeasurementPilotSet	Set of BSSDescriptionFromMeasurementPilots	N/A	The BSSDescriptionFromMeasurementPilotSet is returned to indicate the results of the scan request derived from Measurement Pilot frames. It is a set containing zero or more instances of a BSSDescriptionFromMeasurementPilot. Present if dot11RMMeasurementPilotActivated is nonzero; otherwise not present.
BSSDescriptionFromFDSet	Set of BSSDescriptionFromFDs	N/A	The BSSDescriptionFromFDSet is returned to indicate the results of the scan request derived from FILS Discovery frames. It is a set containing zero or more instances of a BSSDescriptionFromFD. Present if dot11FILSActivated is true; otherwise not present.
ResultCode	Enumeration	SUCCESS, INTERMEDIATE_SCAN_RESULT, NOT_SUPPORTED, PARTIAL_SCAN	Indicates the result of the MLME-SCAN.confirm primitive. The INTERMEDIATE_SCAN_RESULT is used to report the discovered BSSs when the value of the ReportingOption parameter in the MLME-SCAN.request primitive is CHANNEL_SPECIFIC or IMMEDIATE and is valid if dot11FILSActivated is true. The PARTIAL_SCAN is used to report that not all channels have been scanned as specified in the ChannelList parameter, if present, of the corresponding MLME-SCAN.request primitive. The ScannedChannelList parameter contains the list of scanned channels.
Multi-band local	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise.
Multi-band peer	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. The parameter is present if OCT is being used and is absent otherwise.
ScannedChannelList	Each channel is selected from the valid channel range for the appropriate PHY and carrier set	Each channel is selected from the valid channel range for the appropriate PHY and carrier set	This parameter is valid only if the ResultCode parameter has a value of PARTIAL_SCAN, and specifies a list of channels that were scanned. This list of channels is a subset of the channels present in the ChannelList parameter of the corresponding MLME-SCAN.request primitive.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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Each BSSDescription consists of the parameters shown in the following table, in which the term *peer STA* refers to the STA transmitting the Beacon frame, S1G Beacon frame, Probe Response frame, or PV1 Probe Response frame from which the BSSDescription was determined and the term *local STA* refers to the STA performing the scan, and in which the "IBSS adoption" column indicates whether

a) This parameter is adopted by a STA that is joining an IBSS.

b) This parameter is adopted by a STA that is a member of an IBSS that receives a beacon or S1G beacon from a STA that is a member of the same IBSS and that has a timestamp value that is greater than the local TSF value (see 11.1.5).

Name	Type	Valid range	Description	IBSS adoption
BSSID	MAC address	N/A	The BSSID of the found BSS or the MAC address of the found mesh STA.	Adopt
SSID	Octet string	0–32 octets	The SSID of the found BSS.	Adopt
BSSType	Enumeration	INFRASTRUCTURE, PERSONAL, INDEPENDENT, MESH	The type of the found BSS.	Adopt
Beacon Period	Integer	N/A	The beacon period (in TU) of the found BSS if the BSSType is not MESH, or of the found mesh STA if the BSSType = MESH.	Adopt
DTIM Period	Integer	As defined in 9.4.2.5	The DTIM period (in beacon periods) of the BSS if the BSSType is not MESH, or of the mesh STA if the BSSType = MESH.	Adopt
Timestamp	Integer	N/A	The timestamp of the received frame (Probe Response/ Beacon or PV1 Probe Response/S1G Beacon) from the found BSS. When a PV1 Probe Response or an S1G Beacon frame is received, the timestamp is reconstructed as described in 11.1.3.10.3. If the Multi-band local and Multi-band peer parameters are present in the MLME-SCAN.confirm primitive, the Timestamp parameter is reserved.	Adopt
Local Time	Integer	N/A	The value of the local STA's TSF timer at the start of reception of the first octet of the timestamp field of the received frame (Probe Response or Beacon) from the found BSS.	Do not adopt

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Name	Type	Valid range	Description	IBSS adoption
PHY Parameter Set	As defined in frame format or according to the relevant PHY clause.	As defined in frame format or according to the relevant PHY clause.	The parameter sets relevant to the PHY from the received Beacon or Probe Response frame. If no PHY Parameter Set element is present in the received frame, this parameter contains the channel number on which the frame was received. Valid channel numbers are defined in the relevant PHY clause.	Adopt
IBSS Parameter Set	IBSS Parameter Set element	As defined in 9.4.2.6	The parameter set for the IBSS, if found BSS is an IBSS.	Adopt
CapabilityInformation	Capability Information field	As defined in 9.4.1.4	The advertised capabilities of the BSS.	Do not adopt
BSSBasicRateSet	Set of integers	Non-DMG BSS: 1–127 excluding values from Table 9-93, for each member of the set	Non-DMG BSS: The set of data rates (in units of 500 kb/s) that all STAs in the BSS are able to use for communication. All STAs in the BSS are able to receive and transmit at each of the data rates listed in the set. DMG BSS: Empty.	Adopt
OperationalRateSet	Non-DMG BSS: Set of integers DMG BSS: Set of numbers	Non-DMG BSS: 1–127 excluding values from Table 9-93, for each member of the set DMG BSS: 0–12, 9.1, 12.1–12.6, or 25–31, for each member of the set	Non-DMG BSS: The set of data rates (in units of 500 kb/s) that the peer STA is able to use for communication within the BSS. The peer STA is able to receive at each of the data rates listed in the set. This set is a superset of the rates contained in the BSSBasicRateSet parameter. DMG BSS: The set of MCS indexes that the peer STA uses for communication within the BSS.	Do not adopt
Country	As defined in the Country element	As defined in the Country element	The information required to identify the regulatory domain in which the peer STA is located and to configure its PHY for operation in that regulatory domain. Present if TPC functionality is required, as specified in 11.7, or dot11MultiDomainCapability Activated is true or dot11RadioMeasurementActivated is true; otherwise not present.	Adopt

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Name	Type	Valid range	Description	IBSS adoption
IBSS DFS Recovery Interval	Integer	1–255	The time interval that is used for DFS recovery. Present if DFS functionality is required, as specified in 11.8 and BSSType = INDEPENDENT; otherwise not present.	Adopt
RSN	RSNE	As defined in 9.4.2.24	A description of the cipher suites and AKM suites supported in the BSS.	Do not adopt
Load	BSS Load element	As defined in 9.4.2.27	The values from the BSS Load element if such an element was present in the Probe Response or Beacon frame, else null.	Do not adopt
EDCAParameterSet	EDCA Parameter Set element	As defined in 9.4.2.28	The values from the EDCA Parameter Set element if such an element was present in the Probe Response or Beacon frame, else null.	Adopt
QoSCapability	QoS Capability element	As defined in 9.4.2.34	The values from the QoS Capability element if such an element was present in the Probe Response or Beacon frame, else null.	Adopt
AP Channel Report	Set of AP Channel Report elements	As defined in 9.4.2.35	The values from the AP Channel Report element(s) if present in the Probe Response or Beacon frame, else null.	Adopt
BSS Average Access Delay	BSS Average Access Delay element	As defined in 9.4.2.38	The values from the BSS Average Access Delay element if such an element was present in Probe Response or Beacon frame, else null.	Adopt
Antenna	Antenna element	As defined in 9.4.2.39	The values from the Antenna element if such an element was present in the Probe Response or Beacon frame, else null.	Adopt
BSS Available Admission Capacity	BSS Available Admission Capacity element	As defined in 9.4.2.42	The values from the BSS Available Admission Capacity element if such an element was present in the Probe Response or Beacon frame, else null.	Adopt
BSS AC Access Delay	BSS AC Access Delay element	As defined in 9.4.2.43	The values from the BSS AC Access Delay element if such an element was present in the Probe Response or Beacon frame, else null.	Adopt
Measurement Pilot Transmission Information	Measurement Pilot Transmission element	As defined in 9.4.2.41	The values from the Measurement Pilot Transmission element if such an element was present in the Probe Response or Beacon frame, else null.	Adopt
Multiple BSSID	As defined in Multiple BSSID element	As defined in 9.4.2.45	The values from the Multiple BSSID element if such an element was present in the Probe Response or Beacon frame, else null.	Do not adopt

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Name	Type	Valid range	Description	IBSS adoption
RM Enabled Capabilities	RM Enabled Capabilities element	As defined in 9.4.2.44	The values from the RM Enabled Capabilities element if such an element was present in the Probe Response or Beacon frame, else null.	Adopt
RCPIMeasurement	Integer	As defined in 9.4.2.37	The RCPI of the received frame.	Adopt
RSNIMeasurement	Integer	As defined in 9.4.2.40	The RSNI of the received frame.	Adopt
Requested elements	Set of elements	As defined in 9.4.1.35	Elements requested by the Request element or Extended Request element of the Probe Request frame.	Adopt
DSERegisteredLocation	DSE Registered Location element	As defined in 9.4.2.51	The information from the DSE Registered Location element, if such a field is present in the Probe Response or Beacon frame, else null. Present if DSE functionality is required, as specified in 11.11, or dot11LCIDSERequired is true; otherwise not present.	Adopt
HT Capabilities	As defined in frame format	As defined in 9.4.2.55	The values from the HT Capabilities element if such an element was present in the Probe Response or Beacon frame, else null. The parameter is optionally present if dot11HighThroughputOptionImplemented is true; otherwise not present.	Do not adopt
HT Operation	As defined in frame format	As defined in 9.4.2.56	The values from the HT Operation element if such an element was present in the Probe Response or Beacon frame, else null. The parameter is optionally present if dot11HighThroughputOptionImplemented is true; otherwise not present.	Adopt
BSSMembershipSelectorSet	Set of integers	A value from Table 9-93 for each member of the set	The set of features that are supported by all STAs joining this BSS.	Adopt
Extended Capabilities	As defined in frame format	As defined in 9.4.2.26	Specifies the parameters within the Extended Capabilities element that are supported by the MAC entity.	Do not adopt
20/40 BSS Coexistence	As defined in frame format	As defined in 9.4.2.59	Specifies the parameters within the 20/40 BSS Coexistence element that are indicated by the MAC entity. The parameter is present if dot112040BSSCoexistence-ManagementSupport is true.	Do not adopt

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Name	Type	Valid range	Description	IBSS adoption
Overlapping BSS Scan Parameters	As defined in frame format	As defined in 9.4.2.58	Specifies the parameters within the Overlapping BSS Scan Parameters element that are indicated by the MAC entity. This parameter is optionally present if dot11FortyMHzOptionImplemented is true and is not present if dot11FortyMHzOptionImplemented is false.	Adopt
FMSDescriptor	FMS Descriptor element	As defined in 9.4.2.74	The values from the FMS Descriptor element if such an element was present in the Probe Response or Beacon frame, else null.	Do not adopt
QoSTrafficCapability	QoS Traffic Capability element	As defined in 9.4.2.77	The values from the QoS Traffic Capability element if such an element was present in the Probe Response or Beacon frame, else null.	Do not adopt
ChannelUsage	A set of Channel Usage element	As defined in 9.4.2.85	Specifies parameters for the Channel Usage.	Do not adopt
TimeAdvertisement	Time Advertisement element	As defined in 9.4.2.60	The values from the Time Advertisement element if such an element was present in the Probe Response or Beacon frame, else null.	Do not adopt
TimeZone	Time Zone element	As defined in 9.4.2.86	The values from the Time Zone element if such an element was present in the Probe Response or Beacon frame, else null.	Do not adopt
MeshID	Mesh ID element	As defined in 9.4.2.98	The value of MeshID element if such element was present in the Probe Response or Beacon frame, else null.	Do not adopt
MeshConfiguration	Mesh Configuration element	As defined in 9.4.2.97	The values from the Mesh Configuration element if such an element was present in the Probe Response or Beacon frame, else null.	Do not adopt
Mesh Awake Window	Mesh Awake Window element	As defined in 9.4.2.103	The values from the Mesh Awake Window element if such an element was present in the Probe Response or Beacon frame, else null.	Do not adopt
BeaconTiming	Beacon Timing element	As defined in 9.4.2.104	The values from the Beacon Timing element if such an element was present in the Probe Response or Beacon frame, else null.	Do not adopt
MCCAOP Advertisement Overview	MCCAOP Advertisement Overview element	As defined in frame format	The values from the Beacon Timing element if such an element was present in the Probe Response or Beacon frame, else null.	Do not adopt

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Name	Type	Valid range	Description	IBSS adoption
MCCAOP Advertisement	MCCAOP Advertisement	As defined in frame format	The values from the Beacon Timing element if such an element was present in the Probe Response or Beacon frame, else null.	Do not adopt
QMFPolicy	QMF Policy element	As defined in 9.4.2.119	The values from the QMF Policy element if such an element was present in the Probe Response or Beacon frame, else null.	Do not adopt
QLoad Report	As defined in frame format	As defined in 9.4.2.122	The values from the QLoad Report element if such an element was present in the Probe Response frame, else null.	Do not adopt.
Sector Sweep	As defined in frame format	As defined in 9.3.4.2	The values from the Sector Sweep field from the DMG Beacon frame, else null. The parameter is present only if dot11DMGOptionImplemented is true.	Adopt
Beacon Interval Control	As defined in frame format	As defined in 9.3.4.2	The values from the Beacon Interval Control field from the DMG Beacon frame, else null. The parameter is present only if dot11DMGOptionImplemented is true.	Adopt
DMG Parameters	As defined in frame format	As defined in 9.3.4.2	The values from the DMG Parameters field from the DMG Beacon frame, else null. The parameter is present only if dot11DMGOptionImplemented is true.	Adopt
Clustering Control	As defined in frame format	As defined in 9.3.4.2	The values from the Clustering Control field from the DMG Beacon frame, else null. The parameter is present only if dot11DMGOptionImplemented is true.	Do not adopt
DMG Capabilities	As defined in frame format	As defined in 9.4.2.127	The values from the DMG Capabilities element if such an element was present in the Probe Response or DMG Beacon frame, else null. The parameter is optionally present if dot11DMGOptionImplemented is true.	Do not adopt

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Name	Type	Valid range	Description	IBSS adoption
DMG Operation	As defined in frame format	As defined in 9.4.2.127	The values from the DMG Operation element if such an element was present in the Probe Response or DMG Beacon frame, else null. The parameter is optionally present if dot11DMGOptionImplemented is true.	Adopt
Extended Schedule	As defined in frame format	As defined in 9.4.2.131	The values from the Extended Schedule element if such an element was present in the Probe Response or DMG Beacon frame, else null. The parameter is optionally present if dot11DMGOptionImplemented is true.	Adopt
Next DMG ATI	As defined in frame format	As defined in 9.4.2.135	The values from the Next DMG ATI element if such an element was present in the Probe Response or DMG Beacon frame, else null. The parameter is optionally present if dot11DMGOptionImplemented is true.	Adopt
DMG BSS Parameter Change	As defined in frame format	As defined in 9.4.2.126	The values from the DMG BSS Parameter Change element if such an element was present in the Probe Response or DMG Beacon frame, else null. The parameter is optionally present if dot11DMGOptionImplemented is true.	Adopt
Multi-band	As defined in frame format	As defined in 9.4.2.138	The values from the Multi-band element if such an element was present in the Probe Response or DMG Beacon frame, else null. The Multi-band element is optionally present if dot11MultibandImplemented is true.	Adopt
DMG Wakeup Schedule	As defined in frame format	As defined in 9.4.2.130	The values from the DMG Wakeup Schedule element if such an element was present in the Probe Response or DMG Beacon frame, else null. The parameter is optionally present if dot11DMGOptionImplemented is true.	Adopt

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Name	Type	Valid range	Description	IBSS adoption
Antenna Sector ID Pattern	As defined in frame format	As defined in 9.4.2.156	The values from the Antenna Sector ID Pattern element if such an element was present in the Probe Response or DMG Beacon frame, else null. The parameter is optionally present if dot11DMGOptionImplemented is true.	Adopt
Relay Capabilities	As defined in frame format	As defined in 9.4.2.147	The values from the Relay Capabilities element if such an element was present in the Probe Response or DMG Beacon frame, else null. The parameter is optionally present if dot11RelayActivated is true.	Do not adopt
VHT Capabilities	As defined in frame format	As defined in 9.4.2.157	The values from the VHT Capabilities element. The parameter is present if dot11VHTOptionImplemented is true and a VHT Capabilities element was present in the Probe Response or Beacon frame from which the BSSDescription was determined. The parameter is not present otherwise.	Do not adopt
VHT Operation	As defined in frame format	As defined in 9.4.2.158	The values from the VHT Operation element. The parameter is present if dot11VHTOptionImplemented is true and a VHT Operation element was present in the Probe Response or Beacon frame from which the BSSDescription was determined. The parameter is not present otherwise.	Adopt
TVHT Operation	As defined in frame format	As defined in 9.4.2.171	The values from the TVHT Operation element if such an element was present in the Probe Response or Beacon frame; otherwise, null. The parameter is optionally present if dot11TVHTOptionImplemented is true.	Adopt
CAG Number	As defined in 9.4.2.176	As defined in 9.4.2.176	One or more Common Advertisement Group (CAG) tuples. Each CAG Tuple describes the CAG Version, Scope, and partial advertisement protocol ID. This parameter is optionally present when dot11FILSActivated is true; otherwise not present.	Do not adopt.

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Name	Type	Valid range	Description	IBSS adoption
DILS	As defined in 9.4.2.186	As defined in 9.4.2.186	The values from the DILS element. It is optionally present when dot11FILSActivated is true and if such an element was present in the Probe Response or Beacon frame; otherwise not present.	Do not adopt
Compressed SSID	Integer	N/A	The Compressed SSID of the received frame (PV1 Probe Response or S1G Beacon) from the found BSS. This parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.	Adopt
Next TBTT	Integer	N/A	Highest 3 octets of the 4 least significant octets of the next TBTT. This parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.	Adopt
S1G Relay Discovery	As defined in frame format	As defined in 9.4.2.207	The values from the S1G Relay Discovery element if such an element was present in the Probe Response, PV1 Probe Response, or S1G Beacon frame. More description is provided in 10.54.6.	Do not adopt
RPS	RPS element	As defined in 9.4.2.191	The parameter set for group-based restricted medium access, if such element was present in the S1G Beacon, PV1 Probe Response, or Probe Response frame, else null. The support of the feature is described on RAW-based medium access 10.23.5.	Do not adopt
Page Slice	Page Slice element	As defined in 9.4.2.192	The set of page slices present in DTIM interval, if such element was present in the S1G Beacon, or Probe Response, or PV1 Probe Response frame, else null. The support of the feature is described 10.51.	Do not adopt
S1G Capabilities	As defined in frame format	As defined in 9.4.2.200	The values from the S1G Capabilities element. The parameter is present if dot11S1GOptionImplemented is true and an S1G Capabilities element was present in the S1G Beacon, or Probe Response, or PV1 Probe Response frame from which the BSSDescription was determined; otherwise not present.	Adopt

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Name	Type	Valid range	Description	IBSS adoption
TSF Timer Accuracy	TSF Timer Accuracy element	As defined in 9.4.2.203	The values from the TSF Timer Accuracy element if such an element was present in the Probe Response, PV1 Probe Response, or S1G Beacon frame, else null. The parameter is optionally present if dot11TSFTimerAccuracyImplemented is true; otherwise not present.	Adopt
Change Sequence	As defined in frame format	As defined in 9.4.2.198	A Change Sequence element indicates the change of system information within a BSS. The support of the feature is described 10.46.2.	Do not adopt
S1GRelay	As defined in frame format	As defined in 9.4.2.204	The S1G Relay element is present in the S1G Beacon frame if dot11RelayAPOperationActivated is true or if dot11RelayAPImplemented is true; otherwise not present. The S1G Relay element is optionally present in Probe Response, or PV1 Probe Response, if dot11RelayAPImplemented is true. More description is provided in 10.54.	Do not adopt
S1GOperation	As defined in frame format	As defined in 9.4.2.212	The values from the S1G Operation element if such an element was present in the Probe Response, PV1 Probe Response, or S1G Beacon frame, else null. The parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.	Adopt
ShortBeaconPeriod	As defined in frame format	As defined in 9.4.2.197	The short beacon period, in TUs, of the found BSS if the Short Beacon Interval element was present in the Probe Response, PV1 Probe Response, or S1G Beacon frame, else null. The parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.	Adopt
ShortBeaconDTIM Period	As defined in frame format	As defined in 9.4.2.5	The values from the TIM element if such an element was present in the S1G Beacon frame, else null. The parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.	Adopt

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Name	Type	Valid range	Description	IBSS adoption
MaxAwayDuration	Integer	0–65 535	Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA. The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present.	Do not adopt
CDMG Capabilities	CDMG Capabilities element	As defined in 9.4.2.219	Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present.	Do not adopt
CMMG Capabilities	CMMG Capabilities element	As defined in 9.4.2.229	Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present.	Do not adopt
CMMG Operation	CMMG Operation element	As defined in 9.4.2.230	Specifies the parameters within the CMMG Operation element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present.	Do not adopt
ServiceHint	Service Hint element	As defined in 9.4.2.237	Provides an indication of the services advertised in Beacon frames and Probe Response frames. The values from the Service Hint element, if such an element was present in the Beacon or Probe Response frame; else null.	Do not adopt
ServiceHash	Service Hash element	As defined in 9.4.2.238	Specifies services advertised in Beacon and Probe Response frames. The values from the Service Hash element, if such an element was present in the Beacon or Probe Response frame; else null.	Do not adopt

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Each BSSDescriptionFromMeasurementPilot consists of the following parameters, in which the term *peer STA* refers to the STA transmitting the Measurement Pilot frame from which the BSSDescription was determined and the term *local STA* refers to the STA performing the scan:

Name	Type	Valid range	Description
BSSID	MAC address	N/A	The BSSID of the found BSS.
BSS Type	Enumeration	INFRASTRUCTURE	The type of the found BSS.
Local Time	Integer	N/A	The value of the local STA's TSF timer at the start of reception of the first octet of the timestamp field of the received frame from the found BSS.
Condensed Capability Information	Condensed Capability Information field	As defined in 9.6.7.3	The advertised condensed capabilities of the BSS.
Condensed Country String	Condensed Country String field	As defined in 9.6.7.3	Together with the Operating Class, the information required to identify the regulatory domain in which the peer STA is located and to configure its PHY for operation in that regulatory domain.
Operating Class	Operating Class field	The field is defined in 9.6.7.3, valid values for the field are defined in Annex E.	Together with the Condensed Country String, the information required to identify the regulatory domain in which the peer STA is located and to configure its PHY for operation in that regulatory domain.
Channel	Channel field	The field is defined in 9.6.7.3, valid values for the field are defined in Annex E.	The operating channel of the BSS indicated in the received frame.
Measurement Pilot Interval	Measurement Pilot Interval field	As defined in 9.6.7.3	The measurement pilot interval of the BSS indicated in the received frame.
Multiple BSSID element	Multiple BSSID element	As defined in 9.4.2.45	Indicates that the BSS is within a multiple BSSID set (see 11.10.14). The range of BSSIDs is determined by the BSSID and Multiple BSSID element.
PHY Type	Integer	As defined in Annex C	The dot11PHYType of the received frame.
RCPIMeasurement	Integer	As defined in 9.4.2.37	The RCPI of the received frame.
RSNIMeasurement	Integer	As defined in 9.4.2.40	The RSNI of the received frame.

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The BSSDescriptionFromFDSet parameter is present if dot11FILSActivated is true; otherwise, it is not present. Each BSSDescriptionFromFD consists of the parameters shown in the following table:

Name	Type	Valid range	Description
BSSID	MAC address	N/A	The BSSID of the found BSS.
SSID	Octet String	As defined in 9.4.2.2	The SSID of the found BSS. This parameter is present if the Short SSID Indicator field in the received FILS Discovery frame is equal to 0.
Short SSID	Integer	As defined in the 9.4.2.170	The short SSID of the found BSS. This parameter is present if the Short SSID Indicator field in the received FILS Discovery frame is equal to 1.
FD Capability	As defined in 9.6.7.36	As defined in 9.6.7.36	The FD Capability contains the capabilities and operational indications of the BSS. This parameter is optional.
Operating class	Integer	As defined in 9.4.1.36	The operating class of the advertised BSS.
Access Network Options	As defined in 9.4.2.91	As defined in 9.4.2.91	The advertised access network options of the BSS. This parameter is optional.
Primary Channel	Integer	1–255	The Primary Channel of the advertised BSS. The Primary Channel is defined within the indicated Operating Class as shown in Annex E. This parameter is optional.
FD RSN Information	As defined in 9.6.7.36	As defined in 9.6.7.36	The information for robust security network. This parameter is optional.
Channel Center Frequency Segment 1	Integer	1–255	The channel frequency index of the 80 MHz channel of frequency segment 1 when the BSS operates on an 80+80 MHz operating channel width. This parameter is optional.
AP-CSN	Integer	As defined in 9.4.2.181	The value of the Configuration Sequence Number in the found BSS. This parameter is optional.
AP's next TBTT Offset	Integer	As defined in 9.6.7.36	The information of next target beacon transmission time of the found BSS. This parameter is optional.
Reduced Neighbor Report	As defined in 9.4.2.170	As defined in 9.4.2.170	The information of the Reduced Neighbor Information field of the received FILS Discovery frame. This parameter is optional.
FILS Indication	As defined in 9.4.2.182	As defined in 9.4.2.182	The information related to FILS authentication and upper layer set up capabilities of the found AP. This parameter is optional.

6.3.3.3.3 When generated

This primitive is generated by the MLME to report the operating environment of the STA. It is issued after receiving an MLME-SCAN.request primitive or, if dot11FILSActivated is true, after receiving an MLME-SCAN-STOP.request primitive following an MLME-SCAN.request primitive.

6.3.3.3.4 Effect of receipt

The SME is notified of the results of the scan procedure. If dot11FILSActivated is true, these results might be intermediate results, according to the value of ResultCode.

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6.3.3.4 MLME-SCAN-STOP.request

6.3.3.4.1 Function

This primitive terminates any ongoing scan.

6.3.3.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-SCAN-STOP.request(
Multi-band local,
Multi-band peer
)

Name	Type	Valid range	Description
Multi-band local	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dotMultibandImplemented is true and is absent otherwise.
Multi-band peer	Multi-band elemen	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. The parameter is present if OCT is being used and is absent otherwise.

6.3.3.4.3 When generated

This primitive is generated by the SME in order to stop all ongoing active or passive scan processes in the STA.

6.3.3.4.4 Effect of receipt

This request terminates all ongoing scan procedures.

6.3.4 Synchronization

6.3.4.1 Introduction

This mechanism supports the process of selection of a peer in the authentication process.

6.3.4.2 MLME-JOIN.request

6.3.4.2.1 Function

This primitive requests synchronization with a BSS, of which type is infrastructure or independent.

6.3.4.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-JOIN.request(
SelectedBSS,
JoinFailureTimeout,
NAVSyncDelay,

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OperationalRateSet,
Capability Information,
HT Capabilities,
VHT Capabilities,
DMG Capabilities,
S1G Capabilities,
Extended Capabilities,
20/40 BSS Coexistence,
InterworkingInfo,
AdvertisementProtocolInfo,
VendorSpecificInfo
)

Name	Type	Valid range	Description
SelectedBSS	BSSDescription	N/A	The BSSDescription of the BSS to join. The SelectedBSS is a member of the set of descriptions that was returned as a result of an MLME-SCAN.request primitive.
JoinFailureTimeout	Integer	≥ 1	The time limit, in units of beacon intervals, after which the join procedure is terminated.
NAVSyncDelay	Integer	N/A	Delay (in microseconds) to be used prior to transmitting when changing from doze to awake state, if no frame is detected by which the network allocation vector (NAV) can be set.
OperationalRateSet	Non-DMG BSS: Set of integers DMG BSS: Set of numbers	Non-DMG BSS: a value in dot11SupportedDataRatesRxTable, for each member of the set DMG BSS: 0-12, 9.1, 12.1-12.6, or 25-31, for each member of the set	Non-DMG BSS: The set of data rates (in units of 500 kb/s) that the STA is able to use for communication within the BSS. The STA is able to receive at each of the data rates listed in the set. This set is a superset of the rates contained in the BSSBasicRateSet parameter of the SelectedBSS parameter. DMG BSS: The set of MCS indexes that the STA uses for communication within the BSS.
CapabilityInformation	Capability Information field	As defined in 9.4.1.4	Specifies the parameters in the Capability Information field that are supported by the STA.
HT Capabilities	As defined in frame format HT Capabilities element	As defined in 9.4.2.55; the HT-MCSs in the element are present in dot11SupportedHTMCSRxTable and the highest supported data rate in the element does not exceed dot11HighestSupportedDataRate	Specifies the parameters in the HT Capabilities element that are supported by the STA. The parameter is present if dot11HighThroughputOptionImplemented is true; otherwise, this parameter is not present.

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Name	Type	Valid range	Description
VHT Capabilities	As defined in VHT Capabilities element	As defined in 9.4.2.157; the VHT-MCSs in the element are present in dot11VHTRxVHTMCSMap/ dot11VHTTxVHTMCSMap and the highest supported rates in the element do not exceed dot11VHTRxHighestDataRateSupported/ dot11VHTTxHighestDataRateSupported	Specifies the parameters in the VHT Capabilities element that are supported by the STA. The parameter is present if dot11VHTOptionImplemented is true and not present otherwise.
DMG Capabilities	DMG Capabilities element	As defined in 9.4.2.127	Specifies the parameters within the DMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11DMGOptionImplemented is true and is absent otherwise.
S1G Capabilities	As defined in frame format	As defined in 9.4.2.200	Specifies the parameters in the S1G Capabilities element that are supported by the STA. The parameter is present if dot11S1GOptionImplemented is true; otherwise not present.
Extended Capabilities	As defined in frame format	As defined in 9.4.2.26	Specifies the parameters within the Extended Capabilities element that are supported by the MAC entity.
20/40 BSS Coexistence	As defined in frame format	As defined in 9.4.2.59	Specifies the parameters within the 20/40 BSS Coexistence element that are indicated by the MAC entity. The parameter is present if dot112040BSSCoexistence-ManagementSupport is true.
InterworkingInfo	As defined in frame format	As defined in Interworking element in 9.4.2.91	Specifies the Interworking capabilities of STA. This field is present when dot11InterworkingServiceActivated is true.
AdvertisementProtocolInfo	Integer or Sequence of integers	As defined in Advertisement Protocol element in Table 9-237	Identifies zero or more advertisement protocols and advertisement control to be used in the BSSs. This field is present when dot11InterworkingServiceActivated is true.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.4.2.3 When generated

This primitive is generated by the SME for a STA to establish synchronization with a BSS.

6.3.4.2.4 Effect of receipt

This primitive initiates a synchronization procedure once the current frame exchange sequence is complete. The MLME synchronizes its timing with the specified BSS based on the information provided in the SelectedBSS parameter. The MLME subsequently issues an MLME-JOIN.confirm primitive that reflects the results.

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If the MLME of a non-DMG STA receives an MLME-JOIN.request primitive with the SelectedBSS parameter containing a BSSBasicRateSet parameter that contains any unsupported rates, the MLME response in the resulting MLME-JOIN.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of an HT STA receives an MLME-JOIN.request primitive with the SelectedBSS parameter containing a Basic HT-MCS Set field in the HT Operation parameter that contains any unsupported MCSs, the MLME response in the resulting MLME-JOIN.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of a VHT STA receives an MLME-JOIN.request primitive with a SelectedBSS parameter containing a Basic VHT-MCS And NSS Set field in the VHT Operation parameter that contains any unsupported <VHT-MCS, NSS> tuple, the MLME response in the resulting MLME-JOIN.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of a DMG STA receives an MLME-JOIN.request primitive with the SelectedBSS parameter containing a BSSBasicRateSet parameter that is not empty, or with the OperationalRateSet parameter containing any unsupported MCSs, the MLME response in the resulting MLME-JOIN.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of an S1G STA receives an MLME-JOIN.request primitive with a SelectedBSS parameter containing a Basic S1G-MCS and NSS Set field in the S1GOperation parameter that contains any unsupported <S1G-MCS, NSS> tuple, the MLME response in the resulting MLME-JOIN.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

6.3.4.3 MLME-JOIN.confirm

6.3.4.3.1 Function

This primitive confirms synchronization with a BSS.

6.3.4.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-JOIN.confirm(
ResultCode,
VendorSpecificInfo
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, JOIN_FAILURE_TIMEOUT	Indicates the result of the MLME-JOIN.request primitive.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.4.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-JOIN.request primitive to establish synchronization with a BSS.

6.3.4.3.4 Effect of receipt

The SME is notified of the results of the synchronization procedure.

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6.3.5 Authenticate

6.3.5.1 Introduction

This mechanism supports the process of establishing an authentication relationship with a peer MAC entity.

6.3.5.2 MLME-AUTHENTICATE.request

6.3.5.2.1 Function

This primitive requests authentication with a specified peer MAC entity.

6.3.5.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-AUTHENTICATE.request(
PeerSTAAddress,
AuthenticationType,
AuthenticateFailureTimeout,
Content of FT Authentication elements,
Content of SAE Authentication frame,
Multi-band local,
Multi-band peer,
Content of FILS Authentication frame,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the authentication process.
AuthenticationType	Enumeration	OPEN_SYSTEM, SHARED_KEY, FAST_BSS_TRANSITION, SAE, FILS_SHARED_KEY WITHOUT_PFS, FILS_SHARED KEY_WITH_PFS, FILS_PUBLIC_KEY	Specifies the type of authentication algorithm to use during the authentication process.
AuthenticateFailureTimeout	Integer	≥ 1	Specifies a time limit (in TU) after which the authentication procedure is terminated.
Content of FT Authentication elements	Sequence of elements	As defined in 13.8	The set of elements to be included in the first message of the FT authentication sequence, as described in 13.8.2. Present if dot11FastBSSTransitionActivated is true; otherwise not present.
Content of SAE Authentication frame	Sequence of elements and fields	As defined in 9.4.1.37, 9.4.1.38, 9.4.1.39, 9.4.1.40, 9.4.1.41, and 9.4.1.42	The set of elements and fields to be included in the SAE Commit message or SAE Confirm message. Present if AuthenticationType indicates SAE authentication; otherwise not present.

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Name	Type	Valid range	Description
Multi-band local	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise.
Multi-band peer	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. This parameter is present if OCT is being used and is absent otherwise.
Content of FILS Authentication frame	Sequence of elements and fields	As defined in 9.4.1.42, 9.4.1.40, 9.4.2.24, 9.4.2.179, 9.4.2.187, and 9.4.2.189	The set of elements and fields to be included in the first message of the FILS authentication sequence, as described in 12.11. Present if AuthenticationType indicates FILS SHARED KEY WITHOUT PFS, FILS SHARED KEY WITH PFS, or FILS PUBLIC KEY; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.5.2.3 When generated

This primitive is generated by the SME for a STA to establish authentication with a specified peer MAC entity in order to permit Class 2 frames, or mesh peering Management frames for AMPE utilizing SAE authentication, to be exchanged between the two STAs. During the authentication procedure, the SME might generate additional MLME-AUTHENTICATE.request primitives.

If dot11S1GCentralizedAuthenticationControlActivated is true and a STA's MAC variable AuthenticationRequestTransmission is false, then the STA shall not invoke this primitive.

6.3.5.2.4 Effect of receipt

This primitive initiates an authentication procedure. In the case that a response is received from the responder STA, the MLME subsequently issues an MLME-AUTHENTICATE.confirm primitive that reflects the results.

6.3.5.3 MLME-AUTHENTICATE.confirm

6.3.5.3.1 Function

This primitive reports the results of an authentication attempt with a specified peer MAC entity.

6.3.5.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-AUTHENTICATE.confirm(
PeerSTAAddress,
AuthenticationType,
ResultCode,
Content of FT Authentication elements,
Content of SAE Authentication frame,
Multi-band local,

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Multi-band peer,
Content of FILS Authentication frame,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the authentication process was attempted. This value matches the peerSTAAddress parameter specified in the corresponding MLME-AUTHENTICATE.request primitive.
AuthenticationType	Enumeration	OPEN_SYSTEM, SHARED_KEY FAST_BSS_TRANSITION, SAE, FILS_SHARED KEY_WITHOUT_PFS, FILS_SHARED_KEY_WI TH_PFS, FILS_PUBLIC_KEY	Specifies the type of authentication algorithm that was used during the authentication process. This value matches the AuthenticationType parameter specified in the corresponding MLME-AUTHENTICATE.request primitive.
ResultCode	Enumeration	SUCCESS, REFUSED, ANTI_CLOGGING_TOKE N_REQUIRED, FINITE_CYCLIC_GROUP _NOT_SUPPORTED, AUTHENTICATION_REJ ECTED, AUTH_FAILURE_TIMEO UT	Indicates the result of the MLME-AUTHENTICATE.request primitive.
Content of FT Authentication elements	Sequence of elements	As defined in 13.8	The set of elements included in the second message of the FT authentication sequence, as described in 13.8.3. Present if dot11FastBSSTransitionActivated is true; otherwise not present.
Content of SAE Authentication frame	Sequence of elements	As defined in 9.4.1.37, 9.4.1.38, 9.4.1.39, 9.4.1.40, 9.4.1.41, and 9.4.1.42	The set of elements to be included in the SAE Commit message or SAE Confirm message. Present if AuthenticationType indicates SAE authentication; otherwise not present.
Multi-band local	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that identify the local MAC entity. This parameter is present if OCT is being used and is absent otherwise.
Multi-band peer	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are supported by the peer MAC entity. This parameter is present if OCT is being used and is absent otherwise.
Content of FILS Authentication frame	Sequence of elements and fields	As defined in 9.4.1.42, 9.4.1.40, 9.4.2.24, 9.4.2.175, 9.4.2.179, 9.4.2.187, and 9.4.2.189	The set of elements and fields included in the second message of the FILS authentication sequence, as described in 12.11. Present if AuthenticationType indicates FILS SHARED KEY WITHOUT PFS, FILS SHARED KEY WITH PFS, or FILS PUBLIC KEY; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.5.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-AUTHENTICATE.request primitive to authenticate with a specified peer MAC entity.

6.3.5.3.4 Effect of receipt

The SME is notified of the results of the authentication procedure.

6.3.5.4 MLME-AUTHENTICATE.indication

6.3.5.4.1 Function

This primitive indicates receipt of a request from a specific peer MAC entity to establish an authentication relationship with the STA processing this primitive.

6.3.5.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-AUTHENTICATE.indication(
PeerSTAAddress,
AuthenticationType,
Content of FT Authentication elements,
Content of SAE Authentication frame,
Multi-band local,
Multi-band peer,
Content of FILS Authentication frame,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the authentication relationship was established.
AuthenticationType	Enumeration	OPEN_SYSTEM, SHARED_KEY, FAST_BSS_TRANSITION, SAE, FILS_SHARED_KEY_WITHOUT_PFS, FILS_SHARED_KEY_WITH_PFS, FILS_PUBLIC_KEY	Specifies the type of authentication algorithm that was used during the authentication process.
Content of FT Authentication elements	Sequence of elements	As defined in 13.8	The set of elements included in the first message of the FT authentication sequence, as described in 13.8.2. Present if dot11FastBSSTransitionActivated is true; otherwise not present.
Content of SAE Authentication frame	Sequence of elements	As defined in 9.4.1.37, 9.4.1.38, 9.4.1.39, 9.4.1.40, 9.4.1.41, and 9.4.1.42	The set of elements to be included in the SAE Commit message or SAE Confirm message. Present if AuthenticationType indicates SAE authentication; otherwise not present.

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Name	Type	Valid range	Description
Multi-band local	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that identify and are supported by the local MAC entity. This parameter is present if OCT is being used and is absent otherwise.
Multi-band peer	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that identify and are supported by the peer MAC entity. This parameter is present if OCT is being used and is absent otherwise.
Content of FILS Authentication frame	Sequence of elements and fields	As defined in 9.4.1.42, 9.4.1.40, 9.4.2.24, 9.4.2.175, 9.4.2.179, 9.4.2.187, and 9.4.2.189	The set of elements and fields included in the first message of the FILS authentication sequence, as described in 12.11. Present if AuthenticationType indicates FILS SHARED KEY WITHOUT PFS, FILS SHARED KEY WITH PFS, or FILS PUBLIC KEY; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.5.4.3 When generated

This primitive is generated by the MLME as a result of the receipt of an authentication request from a specific peer MAC entity.

6.3.5.4.4 Effect of receipt

The SME is notified of the receipt of the authentication request.

6.3.5.5 MLME-AUTHENTICATE.response

6.3.5.5.1 Function

This primitive is used to send a response to a specific peer MAC entity that requested authentication with the STA that issued this primitive.

6.3.5.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-AUTHENTICATE.response(
PeerSTAAddress,
ResultCode,
Content of FT Authentication elements,
Content of SAE Authentication frame,
Multi-band local,
Multi-band peer,
Content of FILS Authentication frame,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity from which the authentication request was received.
ResultCode	Enumeration	SUCCESS, REFUSED, ANTI_CLOGGING_TOKEN_REQUIRED, FINITE_CYCLIC_GROUP_NOT_SUPPORTED, AUTHENTICATION_REJECTED	Indicates the result response to the authentication request from the peer MAC entity.
Content of FT Authentication elements	Sequence of elements	As defined in 13.8	The set of elements to be included in the second message of the FT authentication sequence, as described in 13.8.3. Present if dot11FastBSSTransitionActivated is true; otherwise not present.
Content of SAE Authentication frame	Sequence of elements	As defined in 9.4.1.37, 9.4.1.38, 9.4.1.39, 9.4.1.40, 9.4.1.41, and 9.4.1.42	The set of elements to be included in the SAE Commit message or SAE Confirm message. Present if the AuthenticationType of the MLME-AUTHENTICATE.indication primitive that generated this response indicated SAE authentication; otherwise not present.
Multi-band local	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise.
Multi-band peer	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. This parameter is present if OCT is being used and is absent otherwise.
Content of FILS Authentication frame	Sequence of elements and fields	As defined in 9.4.1.42, 9.4.1.40, 9.4.2.24, 9.4.2.179, 9.4.2.187, and 9.4.2.189	The set of elements and fields to be included in the second message of the FILS authentication sequence, as described in 12.11. Present if AuthenticationType indicates FILS SHARED KEY WITHOUT PFS, FILS SHARED KEY WITH PFS, or FILS PUBLIC KEY; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.5.5.3 When generated

This primitive is generated by the SME of a STA as a response to an MLME-AUTHENTICATE.indication primitive.

6.3.5.5.4 Effect of receipt

This primitive initiates transmission of a response to the specific peer MAC entity that requested authentication.

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6.3.6 Deauthenticate

6.3.6.1 Introduction

This mechanism supports the process of invalidating an authentication relationship with a peer MAC entity.

6.3.6.2 MLME-DEAUTHENTICATE.request

6.3.6.2.1 Function

This primitive requests that the authentication relationship with a specified peer MAC entity be invalidated.

6.3.6.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DEAUTHENTICATE.request(
PeerSTAAddress,
ReasonCode,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the deauthentication process.
ReasonCode	Reason Code field	As defined in 9.4.1.7	Specifies the reason for initiating the deauthentication procedure.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.6.2.3 When generated

This primitive is generated by the SME for a STA to invalidate authentication with a specified peer MAC entity in order to prevent the exchange of Class 2 frames, or mesh peering Management frames for AMPE utilizing SAE authentication, between the two STAs. During the deauthentication procedure, the SME might generate additional MLME-DEAUTHENTICATE.request primitives.

6.3.6.2.4 Effect of receipt

This primitive initiates a deauthentication procedure. The MLME subsequently issues an MLME-DEAUTHENTICATE.confirm primitive that reflects the results.

6.3.6.3 MLME-DEAUTHENTICATE.confirm

6.3.6.3.1 Function

This primitive reports the results of a deauthentication attempt with a specified peer MAC entity.

6.3.6.3.2 Semantics of the service primitive

The primitive parameter is as follows:

MLME-DEAUTHENTICATE.confirm(
PeerSTAAddress
)

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the deauthentication process was attempted.

6.3.6.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-DEAUTHENTICATE.request primitive to invalidate the authentication relationship with a specified peer MAC entity.

6.3.6.3.4 Effect of receipt

The SME is notified of the results of the deauthentication procedure.

6.3.6.4 MLME-DEAUTHENTICATE.indication

6.3.6.4.1 Function

This primitive reports the invalidation of an authentication relationship with a specific peer MAC entity.

6.3.6.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DEAUTHENTICATE.indication(
                                PeerSTAAddress,
                                ReasonCode,
                                VendorSpecificInfo
                                )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the authentication relationship was invalidated.
ReasonCode	Reason Code field	As defined in 9.4.1.7	Specifies the reason the deauthentication procedure was initiated.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.6.4.3 When generated

This primitive is generated by the MLME as a result of the invalidation of an authentication relationship with a specific peer MAC entity.

6.3.6.4.4 Effect of receipt

The SME is notified of the invalidation of the specific authentication relationship.

6.3.7 Associate

6.3.7.1 Introduction

The following primitives describe how a STA becomes associated with an AP.

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6.3.7.2 MLME-ASSOCIATE.request

6.3.7.2.1 Function

This primitive requests association with a specified peer MAC entity that is within an AP.

6.3.7.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ASSOCIATE.request(
PeerSTAAddress,
BSSMaxIdlePeriod,
ListenInterval,
Supported Channels,
RSN,
QoSCapability,
Content of FT Authentication elements,
SupportedOperatingClasses,
SM Power Save,
QoSTrafficCapability,
TIMBroadcastRequest,
EmergencyServices,
Multi-band local,
Multi-band peer,
MMS,
FILSHLPContainer,
FILSIPAddressAssignment,
AID Request,
TWT,
MaxAwayDuration,
S1GRelayActivation,
ReachableAddress,
CDMG Capabilities,
CMMG Capabilities,
GLK-GCR Parameter Set,
MSCS Descriptor,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the association process.
BSSMaxIdlePeriod	BSS Max Idle Period element	As defined in 9.4.2.78	Indicates the preferred BSS max idle period parameters. This parameter is optionally present if dot11WirelessManagementImplemented and dot11BSSMaxIdlePeriodIndicationByNonAPSTA are true, or if dot11S1GOptionImplemented is true; otherwise not present.
ListenInterval	Integer	≥ 0	Specifies how often the STA awakens and listens for the next Beacon frame, if it enters power save mode.

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Name	Type	Valid range	Description
Supported Channels	As defined in the Supported Channels element	As defined in the Supported Channels element	The list of channels in which the STA is capable of operating. Present if DFS functionality is required, as specified in 11.8; otherwise not present.
RSN	RSNE	As defined in 9.4.2.24	A description of the cipher suites and AKM suites selected by the STA.
QoSCapability	QoS Capability element	As defined in 9.4.2.34	Specifies the parameters within the QoS Capability element that are supported by the MAC entity. The parameter is present if dot11QosOptionImplemented is true; otherwise not present.
Content of FT Authentication elements	Sequence of elements	As defined in 13.4	The set of elements to be included in the initial mobility domain association request, as described in 13.4. Present if dot11FastBSSTransitionActivated is true; otherwise not present.
SupportedOperating Classes	As defined in the Supported Operating Classes element	As defined in 9.4.2.53	Specifies the supported operating classes of the STA. This parameter is present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true; otherwise not present.
SM Power Save	Integer	As defined in Table 9-184	Indicates the spatial multiplexing power save mode that is in operation immediately after association.
QoS Traffic Capability	As defined in the QoS Traffic Capability element	As defined in 9.4.2.77	Specifies the QoS Traffic Capability flags of the non-AP STA. This parameter is optionally present if dot11ACStationCountActivated is true and is not present otherwise.
TIMBroadcastRequest	As defined in the TIM Broadcast Request element	As defined in 9.4.2.82	Specifies the proposed service parameters for TIM Broadcast. This parameter is optionally present if dot11TIMBroadcastActivated is true and is not present otherwise.
EmergencyServices	Boolean	true, false	Specifies that the non-AP STA intends to associate for the purpose of unauthenticated access to emergency services. The parameter is optionally present if dot11InterworkingServiceActivated is true and is not present otherwise.
Multi-band local	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise.
Multi-band peer	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. The parameter is present if OCT is being used and is absent otherwise.
MMS	Multiple MAC Sublayers element	As defined in 9.4.2.152	Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity. The parameter is present if dot11MultipleMACActivated is true and is absent otherwise.

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Name	Type	Valid range	Description
FILSHLPContainer	As defined in 9.4.2.183	As defined in 9.4.2.183	A set of elements containing encapsulated data of higher layer protocol frames (e.g., DHCP message) that is transported in FILS association. The parameter is optionally present if dot11FILSActivated is true; otherwise not present.
FILSIPAddressAssignment	As defined in 9.4.2.184	As defined in 9.4.2.184	An explicit request for an IP address. The request is either for a new IP address or for a specified IP address. The parameter is optionally present if dot11FILSActivated is true; otherwise not present.
AID Request	AID Request element	As defined in 9.4.2.193	Indicates the device characteristic of the non-AP STA requesting AID assignment. This parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.
TWT	TWT element	As defined in 9.4.2.199	Specifies the parameters in the TWT element. This parameter is optionally present if dot11TWTOptionActivated is true; otherwise not present.
MaxAwayDuration	Integer	0–65 535	Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA. The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present.
S1GRelayActivation	S1G Relay Activation element	As defined in 9.4.2.206	Indicates if the STA with dot11RelaySTAImplemented equal to true requests to operate as a relay (in a request) and the AP with dot11RelayAPImplemented equal to true requests/confirms operation as a relay. The parameter is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
ReachableAddress	Reachable Address element	As defined in 9.4.2.205	The Reachable Address element is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
CDMG Capabilities	CDMG Capabilities element	As defined in 9.4.2.219	Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present.
CMMG Capabilities	CMMG Capabilities element	As defined in 9.4.2.229	Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present.
GLK-GCR Parameter Set	GLK-GCR Parameter Set element	As defined in 9.4.2.234	This parameter is present if dot11GLKGCRImplemented is true and not present otherwise. Specifies the GLK-GCR capabilities supported by the STA.

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Name	Type	Valid range	Description
MSCS Descriptor	As defined in the MSCS Descriptor element	As defined in 9.4.2.243	The parameters used to classify streams using the procedures defined in 11.25.3. Optionally present if dot11MSCSActivated is true; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

Additional parameters needed to perform the association procedure are not included in the primitive parameter list since the MLME already has that data (maintained as internal state).

6.3.7.2.3 When generated

This primitive is generated by the SME when a STA wishes to establish association with an AP or PCP.

6.3.7.2.4 Effect of receipt

This primitive initiates an association procedure. In the case that a response is received from the responder STA, the MLME subsequently issues an MLME-ASSOCIATE.confirm primitive that reflects the results.

6.3.7.3 MLME-ASSOCIATE.confirm

6.3.7.3.1 Function

This primitive reports the results of an association attempt with a specified peer MAC entity that is in an AP or PCP.

6.3.7.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ASSOCIATE.confirm(
ResultCode,
CapabilityInformation,
AssociationID,
EDCAParameterSet,
RCPI of Request,
RSNI of Request,
RCPI of Response,
RSNI of Response,
RMEnabledCapabilities,
Content of FT Authentication elements,
SupportedOperatingClasses,
Extended Capabilities,
20/40 BSS Coexistence,
TimeoutInterval,
BSSMaxIdlePeriod,
TIMBroadcastResponse,
QosMapSet,
QMFPolicy,
DMG Capabilities,
Multi-band local,
Multi-band peer,
MMS,

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FILSHLPContainer,
FILSIPAddressAssignment,
KeyDelivery,
S1G Sector Operation,
S1G Capabilities,
AID Response,
TSF Timer Accuracy,
TWT,
Sectorized Group ID List,
MaxAwayDuration,
S1GRelayActivation,
S1GOperation,
SSTOperation,
S1GRelay,
HeaderCompression,
CDMG Capabilities,
CMMG Capabilities,
GLK-GCR Parameter Set,
MSCS Descriptor,
VendorSpecificInfo
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, REFUSED_REASON_UNSPECIFIED, REFUSED_NOT_AUTHENTICATED, REFUSED_CAPABILITIES_MISMATCH, REFUSED_EXTERNAL_REASON, REFUSED_AP_OUT_OF_MEMORY, REFUSED_BASIC_RATES_MISMATCH, REJECTED_EMERGENCY_SERVICES_NOT_SUPPORTED, REFUSED_TEMPORARILY	Indicates the result of the MLME-ASSOCIATE.request primitive.
Capability-Information	Capability Information field	As defined in 9.4.1.4	Specifies the operational capabilities advertised by the AP or PCP.
AssociationID	Integer	Non-DMG: 1–2007 DMG: 1–254	If the association request result was SUCCESS, then AssociationID specifies the association ID value assigned by the AP or PCP. This parameter is not present if dot11S1GOptionImplemented is true.
EDCAParameter Set	EDCA Parameter Set element	As defined in 9.4.2.28	Specifies the EDCA parameter set that the STA should use. The parameter is present if dot11QosOptionImplemented is true; otherwise not present.

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Name	Type	Valid range	Description
RCPI of Request	Integer	As defined in 9.4.2.37	Indicates the RCPI value contained in the received Association Response frame. This value represents the RCPI that the AP or PCP measured at the time it received the corresponding Association Request frame. The element is optionally present if dot11RMRCPIMeasurementActivated is true; otherwise not present.
RSNI of Request	Integer	As defined in 9.4.2.40	Indicates the RSNI value contained in the received Association Response frame. This value represents the RSNI that the AP or PCP measured at the time it received the corresponding Association Request frame. The element is optionally present if dot11RMRSNIMeasurementActivated is true; otherwise not present.
RCPI of Response	Integer	As defined in 9.4.2.37	The RCPI value represents the measured RCPI of the corresponding Association Response frame. The element is optionally present if dot11RMRCPIMeasurementActivated is true; otherwise not present.
RSNI of Response	Integer	As defined in 9.4.2.40	RSNI at the time the corresponding Association Response frame was receive. The element is optionally present if dot11RMRSNIMeasurementActivated is true; otherwise not present.
RMEnabledCapabilities	RM Enabled Capabilities element	As defined in 9.4.2.44	Specifies the RM enabled capabilities advertised by the AP or PCP. The element is present if dot11RadioMeasurementActivated is true; otherwise not present.
Content of FT Authentication elements	Sequence of elements	As defined in 13.4	The set of elements included in the initial mobility domain association response, as described in 13.4. Present if dot11FastBSSTransitionActivated is true; otherwise not present.
SupportedOperatingClasses	As defined in the Supported Operating Classes element	As defined in 9.4.2.53	Indicates the supported operating classes of the AP or PCP. This parameter is optionally present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true; otherwise not present.
Extended Capabilities	As defined in frame format	As defined in 9.4.2.26	Specifies the parameters within the Extended Capabilities element that are supported by the MAC entity.

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Name	Type	Valid range	Description
20/40 BSS Coexistence	As defined in frame format	As defined in 9.4.2.59	Specifies the parameters within the 20/40 BSS Coexistence element that are indicated by the MAC entity. The parameter is present if dot112040BSSCoexistence-ManagementSupport is true.
TimeoutInterval	Timeout Interval element, as defined in frame format	As defined in 9.4.2.48	This parameter is present when ResultCode is REFUSED_TEMPORARILY.
BSSMaxIdlePeriod	As defined in BSS Max Idle Period element	As defined in 9.4.2.78	Indicates the BSS max idle period parameters of the AP or PCP. This parameter is present if dot11WirelessManagementImplemented is true and is not present otherwise.
TIMBroadcastResponse	As defined in TIM Broadcast Response element	As defined in 9.4.2.83	Specifies the service parameters for TIM Broadcast. This parameter is optionally present if dot11TIMBroadcastActivated is true and the TIM Broadcast Request element is present in the corresponding Association Request frame; this parameter is not present otherwise.
QoSMapSet	As defined in frame format	As defined in 9.4.2.94	Specifies the QoS Map the non-AP and non-PCP STA should use.
QMFPolicy	QMF Policy element	As defined in 9.4.2.119	The values from the QMF Policy element if such an element was present in the Association Response frame; otherwise, null.
DMG Capabilities	DMG Capabilities element	As defined in 9.4.2.127	Specifies the parameters within the DMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11DMGOptionImplemented is true and is absent otherwise.
Multi-band local	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that identify and are supported by the local MAC entity. The parameter is present if OCT is being used and is absent otherwise.
Multi-band peer	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that identify and are supported by the peer MAC entity. This parameter is present if OCT is being used and is absent otherwise.
MMS	Multiple MAC Sublayers element	As defined in 9.4.2.152	Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity. The parameter is present if dot11MultipleMACActivated is true and is absent otherwise.

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Name	Type	Valid range	Description
FILSHLPContainer	As defined in 9.4.2.183	As defined in 9.4.2.183	A set of elements containing encapsulated data of higher layer protocol (HLP) frames (e.g., DHCP message) that is transported in FILS association. The parameter is optionally present if dot11FILSActivated is true; otherwise not present.
FILSIPAddressAssignment	As defined in 9.4.2.184	As defined in 9.4.2.184	The IP address of a network layer entity associated with the STA. The parameter is optionally present if dot11FILSActivated is true; otherwise not present.
KeyDelivery	As defined in 9.4.2.185	As defined in 9.4.2.185	The KDE(s) and the Key RSC. The parameter is present if dot11FILSActivated is true; otherwise not present.
S1G Sector Operation	S1G Sector Operation element	As defined in 9.4.2.195	Specifies the sectorization scheme, period, subperiod sector intervals, and sector training.
S1G Capabilities	As defined in frame format	As defined in 9.4.2.200	Specifies the parameters in the S1G Capabilities element that are supported by the AP. The parameter is present if dot11S1GOptionImplemented is true and the S1G Capabilities element is present in the Association Response frame received from the AP; otherwise not present.
AID Response	AID Response element	As defined in 9.4.2.194	Parameters describing an AID assignment. This parameter is present if dot11S1GOptionImplemented is true; otherwise not present.
TSF Timer Accuracy	TSF Timer Accuracy element	As defined in 9.4.2.203	Indicates the information about the TSF timer accuracy. The parameter is optionally present if dot11TSFTimerAccuracyImplemented is true; otherwise not present.
TWT	TWT element	As defined in 9.4.2.199	Specifies the parameters in the TWT element. This parameter is optionally present if dot11TWTOptionActivated is true; otherwise not present.
Sectorized Group ID List	Sectorized Group ID List element	As defined in 9.4.2.211	Specifies the parameters in the Sectorized Group ID List element. This parameter is optionally present if dot11S1GSectorizationActivated is true; otherwise not present.

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Name	Type	Valid range	Description
MaxAwayDuration	Integer	0–65 535	Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA. The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present.
S1GRelayActivation	S1G Relay Activation element	As defined in 9.4.2.206	Indicates if the STA with dot11RelaySTAImplemented equal to true requests to operate as a relay (in a request) and the AP with dot11RelayAPImplemented equal to true requests/confirms operation as a relay. The parameter is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
S1GOperation	S1G Operation element	As defined in 9.4.2.212	The S1G Operation element is present if dot11S1GOptionImplemented is true; otherwise not present.
SSTOperation	SST Operation element	As defined in 9.4.2.214	The SST Operation element is optionally present if dot11SelectiveSubchannelTransmissionPermitted is true; otherwise not present.
S1GRelay	S1G Relay element	As defined in 9.4.2.204	Indicates the support of the relay operation by the STA transmitting the element.
HeaderCompression	Header Compression element	As defined in 9.4.2.213	The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true; otherwise not present.
CDMG Capabilities	CDMG Capabilities element	As defined in 9.4.2.219	Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present.
CMMG Capabilities	CMMG Capabilities element	As defined in 9.4.2.229	Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present.

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Name	Type	Valid range	Description
GLK-GCR Parameter Set	GLK-GCR Parameter Set element	As defined in 9.4.2.234	Specifies the values from the GLK-GCR Parameter Set element if such an element was present in the Association Response frame, otherwise null.
MSCS Descriptor	As defined in the MSCS Descriptor element	As defined in 9.4.2.243	The parameters used to classify streams using the procedures defined in 11.25.3. Optionally present if dot11MSCSActivated is true; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.7.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-ASSOCIATE.request primitive or receipt of an Association Response frame from the peer MAC entity to associate with a specified peer MAC entity that is in an AP or PCP.

6.3.7.3.4 Effect of receipt

The SME is notified of the results of the association procedure.

6.3.7.4 MLME-ASSOCIATE.indication

6.3.7.4.1 Function

This primitive indicates that a specific peer MAC entity is requesting association with the local MAC entity, which is in an AP or PCP.

6.3.7.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ASSOCIATE.indication(
PeerSTAAddress,
CapabilityInformation,
BSSMaxIdlePeriod,
ListenInterval,
SSID,
OperationalRateSet,
BSSMembershipSelectorSet,
RSN,
QoSCapability,
RCPI,
RSNI,
RMEnabledCapabilities,
Content of FT Authentication elements,
SupportedOperatingClasses,
DSERegisteredLocation,
HT Capabilities,
Extended Capabilities,
20/40 BSS Coexistence,
QoSTrafficCapability,
TIMBroadcastRequest,

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EmergencyServices,
DMG Capabilities,
Multi-band local,
Multi-band peer,
MMS,
VHT Capabilities,
FILSHLPContainer,
FILSIPAddressAssignment,
AID Request,
S1G Capabilities,
TWT,
MaxAwayDuration,
S1GRelayActivation,
ReachableAddress,
CDMG Capabilities,
CMMG Capabilities,
GLK-GCR Parameter Set,
MSCS Descriptor,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity from which the association was received.
Capability-Information	Capability Information field	As defined in 9.4.1.4	Specifies the operational capability definitions provided by the peer MAC entity as part of the association request.
BSSMaxIdlePeriod	BSS Max Idle Period element	As defined in 9.4.2.78	Indicates the preferred BSS max idle period parameters. This parameter is optionally present if dot11WirelessManagementImplemented and dot11BSSMaxIdlePeriodIndicationByNonAP STA are true, or if dot11S1GOptionImplemented is true; otherwise not present.
ListenInterval	Integer	≥ 0	Specifies the listen interval provided by the peer MAC entity as part of the association request.
SSID	Octet string	0–32 octets	Specifies the SSID provided by the peer MAC entity as part of the association request.
OperationalRateSet	Non-DMG BSS: Set of integers DMG BSS: Set of numbers	Non-DMG BSS: 1-127 excluding values from Table 9-93 for each member of the set DMG BSS: 0-12, 9.1, 12.1-12.6, or 25-31, for each member of the set	The set of data rates (in units of 500 kb/s) that the STA that is requesting association is able to use for communication within the BSS. The STA is able to receive at each of the data rates listed in the set. This set is a superset of the rates contained in the BSSBasicRateSet parameter. DMG BSS: The set of MCS indexes that the AP or PCP uses for communication within the BSS.
BSSMembershipSelectorSet	Set of integers	A value from Table 9-93, for each member of the set	The set of features that the STA that is requesting association is able to use for communication
RSN	RSNE	As defined in 9.4.2.24	A description of the cipher suites and AKM suites selected by the STA.

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Name	Type	Valid range	Description
QoSCapability	QoS Capability element	As defined in 9.4.2.34	Specifies the parameters within the QoSCapability that are supported by the peer MAC entity. The parameter is optionally present if dot11QosOptionImplemented is true; otherwise not present.
RCPI	Integer	As defined in 9.4.2.37	The RCPI value represents the measured RCPI of the corresponding Association Request frame. The element is optionally present if dot11RMRCPIMeasurementActivated is true; otherwise not present.
RSNI	Integer	As defined in 9.4.2.40	The RSNI value represents the measured RSNI at the time the corresponding Association Request frame was received. The element is optionally present if dot11RMRSNIMeasurementActivated is true; otherwise not present.
RMEnabledCapabilities	RM Enabled Capabilities element	As defined in 9.4.2.44	Specifies the RM enabled capabilities advertised by the AP or PCP. The element is present if dot11RadioMeasurementActivated is true; otherwise not present.
Content of FT Authentication elements	Sequence of elements	As defined in 13.4	The set of elements included in the initial mobility domain association, as described in 13.4. Present if dot11FastBSSTransitionActivated is true; otherwise not present.
SupportedOperatingClasses	As defined in the Supported Operating Classes element	As defined in 9.4.2.53	Indicates the supported operating classes of the STA. This parameter is optionally present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true; otherwise not present.
DSERegisteredLocation	As defined in the DSE Registered Location element	As defined in 9.4.2.51	Indicates the DSE registered location including the dependent enablement identifier assigned by the enabling STA. This parameter is optionally present if dot11LCIDSERequired is true; otherwise not present.
HT Capabilities	As defined in frame format	As defined in 9.4.2.55	Specifies the parameters within the HT Capabilities element that are supported by the MAC entity. The parameter is optionally present if dot11HighThroughputOptionImplemented is true; otherwise not present.
Extended Capabilities	As defined in frame format	As defined in 9.4.2.26	Specifies the parameters within the Extended Capabilities element that are supported by the MAC entity.
20/40 BSS Coexistence	As defined in frame format	As defined in 9.4.2.59	Specifies the parameters within the 20/40 BSS Coexistence element that are indicated by the MAC entity. The parameter is present if dot112040BSSCoexistenceManagementSupport is true.
QoS Traffic Capability	As defined in the QoS Traffic Capability element	As defined in 9.4.2.77	Specifies the QoS Traffic Capability flags of the non-AP and non-PCP STA. This parameter is optionally present if dot11ACStationCountActivated is true and is not present otherwise.
TIMBroadcastRequest	As defined in TIM Broadcast Request element	As defined in 9.4.2.82	Specifies the proposed service parameters for TIM Broadcast. This parameter is optionally present if dot11TIMBroadcastActivated is true and is not present otherwise.

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Name	Type	Valid range	Description
EmergencyServices	Boolean	true, false	Specifies the setting of the UESA field received from the non-AP and non-PCP STA, if an Interworking element was present in the Association Request frame. The parameter is present if dot11InterworkingServiceActivated is true; otherwise not present.
DMG Capabilities	DMG Capabilities element	As defined in 9.4.2.127	Specifies the parameters within the DMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11DMGOptionImplemented is true and is absent otherwise.
Multi-band local	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that identify and are supported by the local MAC entity. The parameter is present if OCT is being used and is absent otherwise.
Multi-band peer	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that identify and are supported by the peer MAC entity. This parameter is present if OCT is being used and is absent otherwise.
MMS	Multiple MAC Sublayers element	As defined in 9.4.2.152	Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity. The parameter is present if dot11MultipleMACActivated is true and is absent otherwise.
VHT Capabilities	As defined in VHT Capabilities element	As defined in 9.4.2.157	Specifies the parameters in the VHT Capabilities element that are supported by the STA. The parameter is present if dot11VHTOptionImplemented is true and the VHT Capabilities element is present in the Association Request frame received from the STA. The parameter is not present otherwise.
FILSHLPContainer	As defined in 9.4.2.183	As defined in 9.4.2.183	A set of elements containing encapsulated data of higher layer protocol frames (e.g., DHCP message) that is transported in FILS association. The parameter is optionally present if dot11FILSActivated is true; otherwise not present.
FILSIPAddressAssignment	As defined in 9.4.2.184	As defined in 9.4.2.184	An explicit request for an IP address. The request is for a new IP address or a specified IP address. The parameter is optionally present if dot11FILSActivated is true; otherwise not present.
AID Request	AID Request element	As defined in 9.4.2.193	Indicates the device characteristic of the non-AP STA requesting AID assignment. This parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.
S1G Capabilities	As defined in frame format	As defined in 9.4.2.200	Specifies the parameters in the S1G Capabilities element that are supported by the STA. The parameter is present if dot11S1GOptionImplemented is true and the S1G Capabilities element is present in the Association Request frame received from the STA; otherwise not present.
TWT	TWT element	As defined in 9.4.2.199	Specifies the parameters in the TWT element. This parameter is optionally present if dot11TWTOptionActivated is true; otherwise not present.

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Name	Type	Valid range	Description
MaxAwayDuration	Integer	0–65 535	Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA. The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present.
S1GRelayActivation	S1G Relay Activation element	As defined in 9.4.2.206	Indicates if the STA with dot11RelaySTAImplemented equal to true requests to operate as a relay (in a request) and the AP with dot11RelayAPImplemented equal to true requests/confirms operation as a relay. The parameter is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
ReachableAddress	Reachable Address element	As defined in 9.4.2.205	The Reachable Address element is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
CDMG Capabilities	CDMG Capabilities element	As defined in 9.4.2.219.	Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present.
CMMG Capabilities	CMMG Capabilities element	As defined in 9.4.2.229.	Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present.
GLK-GCR Parameter Set	GLK-GCR Parameter Set element	As defined in 9.4.2.234	Specifies the values from the GLK-GCR Parameter Set element if such an element was present in the Association Request frame, otherwise not present.
MSCS Descriptor	As defined in the MSCS Descriptor element	As defined in 9.4.2.243	The parameters used to classify streams using the procedures defined in 11.25.3. Optionally present if dot11MSCSActivated is true; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.7.4.3 When generated

This primitive is generated by the MLME as a result of the receipt of an association request from a specific peer MAC entity.

6.3.7.4.4 Effect of receipt

The SME is notified of the receipt of the association request.

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6.3.7.5 MLME-ASSOCIATE.response

6.3.7.5.1 Function

This primitive is used to send a response to a specific peer MAC entity that requested an association with the STA that issued this primitive, which is in an AP or PCP.

6.3.7.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ASSOCIATE.response(
PeerSTAAddress,
ResultCode,
AssociationID,
RCPI,
RSNI,
RMEnabledCapabilities,
Content of FT Authentication elements,
SupportedOperatingClasses,
TimeoutInterval,
BSSMaxIdlePeriod,
TIMBroadcastResponse,
QoSMapSet,
Multi-band local,
Multi-band peer,
MMS,
FILSHLPContainer,
FILSIPAddressAssignment,
KeyDelivery,
S1G Sector Operation,
S1G Capabilities,
AID Response,
TSF Timer Accuracy,
TWT,
Sectorized Group ID List,
MaxAwayDuration,
S1GRelay,
S1GRelayActivation,
S1GOperation,
HeaderCompression,
SSTOperation,
CDMG Capabilities,
CMMG Capabilities,
GLK-GCR Parameter Set,
MSCS Descriptor,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity from which the association request was received.

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Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, REFUSED_REASON_UNSPECIFIED, REFUSED_CAPABILITIES_MISMATCH, REFUSED_EXTERNAL_REASON, REFUSED_AP_OUT_OF_MEMORY, REFUSED_BASIC_RATES_MISMATCH, REJECTED_EMERGENCY_SERVICES_NOT_SUPPORTED, REFUSED_TEMPORARILY, GLK_NOT_AUTHORIZED	Indicates the result response to the association request from the peer MAC entity.
AssociationID	Integer	Non-DMG: 1–2007 DMG: 1–254	If the association request result was SUCCESS and dot11S1GOptionImplemented is not true, then AssociationID specifies the association ID value assigned to the peer MAC entity by the AP or PCP; otherwise not present.
RCPI	Integer	As defined in 9.4.2.37	The RCPI value represents the measured RCPI of the corresponding Association Request frame. The element is optionally present if dot11RMRCPIMeasurementActivated is true; otherwise not present.
RSNI	Integer	As defined in 9.4.2.40	The RSNI value represents the measured RSNI at the time the corresponding Association Request frame was received. The element is optionally present if dot11RMRSNIMeasurementActivated is true; otherwise not present.
RMEnabledCapabilities	RM Enabled Capabilities element	As defined in 9.4.2.44	Specifies the RM enabled capabilities advertised by the AP or PCP. The element is present if dot11RadioMeasurementActivated is true; otherwise not present.
Content of FT Authentication elements	Sequence of elements	As defined in 13.4	The set of elements to be included in the initial mobility domain association response, as described in 13.4. Present if dot11FastBSSTransitionActivated is true; otherwise not present.
SupportedOperatingClasses	As defined in the Supported Operating Classes element	As defined in 9.4.2.53	Specifies the supported operating classes of the AP or PCP. This parameter is present if dot11ExtendedChannelSwitchActivated ot dot11OperatingClassesRequired is true; otherwise not present.
TimeoutInterval	Timeout Interval element, as defined in frame format	As defined in 9.4.2.48	This parameter is present when ResultCode is REFUSED_TEMPORARILY.

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Name	Type	Valid range	Description
BSSMaxIdlePeriod	BSS Max Idle Period element	As defined in 9.4.2.78	Indicates the BSS max idle period parameters of the AP or PCP. This parameter is present if dot11WirelessManagementImplemented is true or dot11S1GOptionImplemented is true; otherwise not present.(
TIMBroadcastResponse	As defined in TIM Broadcast Response element	As defined in 9.4.2.83	Specifies the service parameters for TIM Broadcast. This parameter is optionally present if dot11TIMBroadcastActivated is true and the TIM Broadcast Request element is present in the corresponding Association Request frame; this parameter is not present otherwise.
QoSMapSet	As defined in frame format	As defined in 9.4.2.94	Specifies the QoS Map the non-AP and non-PCP STA should use.
Multi-band local	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise.
Multi-band peer	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. The parameter is present if OCT is being used and is absent otherwise.
MMS	Multiple MAC Sublayers element	As defined in 9.4.2.152	Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity, and negotiated for the association. The parameter is present if dot11MultipleMACActivated is true and is absent otherwise.
FILSHLPContainer	As defined in 9.4.2.183	As defined in 9.4.2.183	A set of elements containing encapsulated data of higher layer protocol frames (e.g., a DHCP message) transported in FILS association. The parameter is optionally present if dot11FILSActivated is true; otherwise not present.
FILSIPAddressAssignment	As defined in 9.4.2.184	As defined in 9.4.2.184	The IP address of a network layer entity associated with the STA. The parameter is optionally present if dot11FILSActivated is true; otherwise not present
KeyDelivery	As defined in 9.4.2.185	As defined in 9.4.2.185	KDE(s) and the current Key RSC. The parameter is present if dot11FILSActivated is true; otherwise not present.
S1G Sector Operation	S1G Sector Operation element	As defined in 9.4.2.195	Specifies the sectorization scheme, period, subperiod sector intervals, and sector training.
S1G Capabilities	As defined in frame format	As defined in 9.4.2.200	Specifies the parameters in the S1G Capabilities element that are supported by the AP. The parameter is present if dot11S1GOptionImplemented is true and the S1G Capabilities element is present in the Association Response frame received from the AP; otherwise not present.
AID Response	AID Response element	As defined in 9.4.2.194	Parameters describing an AID assignment. This parameter is present if dot11S1GOptionImplemented is true; otherwise not present.

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Name	Type	Valid range	Description
TSF Timer Accuracy	TSF Timer Accuracy element	As defined in 9.4.2.203	Indicates the information about the TSF timer accuracy. The parameter is optionally present if dot11TSFTimerAccuracyImplemented is true; otherwise not present.
TWT	TWT element	As defined in 9.4.2.199	Specifies the parameters in the TWT element. This parameter is optionally present if dot11TWTOptionActivated is true; otherwise not present.
Sectorized Group ID List	Sectorized Group ID List element	As defined in 9.4.2.211	Specifies the parameters in the Sectorized Group ID List element. This parameter is optionally present if dot11S1GSectorizationActivated is true; otherwise not present.
MaxAwayDuration	Integer	0–65 535	Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA. The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present.
S1GRelay	S1G Relay element	As defined in 9.4.2.204	Indicates the support of the relay operation by the STA transmitting the element.
S1GRelayActivation	S1G Relay Activation element	As defined in 9.4.2.206	Indicates if the STA with dot11RelaySTAImplemented equal to true requests to operate as a relay (in a request) and the AP with dot11RelayAPImplemented equal to true requests/confirms operation as a relay. The parameter is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
S1GOperation	S1G Operation element	As defined in 9.4.2.212	The S1G Operation element is present if dot11S1GOptionImplemented is true; otherwise not present.
HeaderCompression	Header Compression element	As defined in 9.4.2.213	The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true; otherwise not present.
SSTOperation	SST Operation element	As defined in 9.4.2.214	The SST Operation element is optionally present if dot11SelectiveSubchannelTransmissionPermitted is true; otherwise not present.
CDMG Capabilities	CDMG Capabilities element	As defined in 9.4.2.219.	Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present.
CMMG Capabilities	CMMG Capabilities element	As defined in 9.4.2.229.	Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present.

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Name	Type	Valid range	Description
GLK-GCR Parameter Set	GLK-GCR Parameter Set element	As defined in 9.4.2.234	This parameter is present only if the AP selects GLK-GCR for groupcast (either unsolicited retry or block ack) over the general link. Describes the parameters that define how GLK-GCR operates.
MSCS Descriptor	As defined in the MSCS Descriptor element	As defined in 9.4.2.243	The parameters used to classify streams using the procedures defined in 11.25.3. Optionally present if dot11MSCSActivated is true; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

Additional parameters needed to perform the association response procedure are not included in the primitive parameter list since the MLME already has that data (maintained as internal state).

6.3.7.5.3 When generated

This primitive is generated by the SME of a STA that is in an AP or PCP as a response to an MLME-ASSOCIATE.indication primitive.

6.3.7.5.4 Effect of receipt

This primitive initiates transmission of an AssociationResponse to the specific peer MAC entity that requested association.

6.3.8 Reassociate

6.3.8.1 Introduction

The following primitives describe how a STA becomes associated with another AP or PCP.

6.3.8.2 MLME-REASSOCIATE.request

6.3.8.2.1 Function

This primitive requests a change in association to a specified new peer MAC entity that is in an AP or PCP.

6.3.8.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-REASSOCIATE.request(
NewPCPorAPAddress,
BSSMaxIdlePeriod,
ListenInterval,
Supported Channels
RSN,
QoSCapability,
Content of FT Authentication elements,
SupportedOperatingClasses,
SM Power Save,
QoSTrafficCapability,
TIMBroadcastRequest,
FMSRequest,
DMSRequest,

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EmergencyServices,
Multi-band local,
Multi-band peer,
MMS,
FILSHLPContainer,
FILSIPAddressAssignment,
AID Request,
TWT,
Sectorized Group ID List,
MaxAwayDuration,
S1GRelayActivation,
ELOperation,
S1GRelay,
HeaderCompression,
ReachableAddress,
S1GOperation,
SSTOperation,
CDMG Capabilities,
CMMG Capabilities,
GLK-GCR Parameter Set,
MSCS Descriptor,
VendorSpecificInfo
)

Name	Type	Valid range	Description
NewPCPorAPAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the reassociation process.
BSSMaxIdlePeriod	BSS Max Idle Period element	As defined in 9.4.2.78	Indicates the preferred BSS max idle period parameters. This parameter is optionally present if dot11WirelessManagementImplemented and dot11BSSMaxIdlePeriodIndicationByNonAPSTA are true, or if dot11S1GOptionImplemented is true; otherwise not present.
ListenInterval	Integer	≥ 0	Specifies how often the STA awakens and listens for the next Beacon frame, if it enters power save mode.
Supported Channels	As defined in the Supported Channels element	As defined in the Supported Channels element	The list of channels in which the STA is capable of operating. Present if DFS functionality is required, as specified in 11.8; otherwise not present.
RSN	RSNE	As defined in 9.4.2.24	A description of the cipher suites and AKM suites selected by the STA.
QoSCapability	QoS Capability element	As defined in 9.4.2.34	Specifies the parameters within the QoS Capability element that are supported by the MAC entity. The parameter is present if dot11QosOptionImplemented is true; otherwise not present.
Content of FT Authentication elements	Sequence of elements	As defined in 13.8	The set of elements to be included in the third message of the FT authentication sequence, as described in 13.8.4. Present if dot11FastBSSTransitionActivated is true; otherwise not present.

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Name	Type	Valid range	Description
SupportedOperating Classes	As defined in the Supported Operating Classes element	As defined in 9.4.2.53	Specifies the supported operating classes of the STA. This parameter is present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true; otherwise not present.
SM Power Save	Integer	As defined in Table 9-184	Indicates the spatial multiplexing power save mode that is in operation immediately after reassociation.
QoS Traffic Capability	As defined in the QoS Traffic Capability element	As defined in 9.4.2.77	Specifies the QoS Traffic Capability flags of the non-AP and non-PCP STA. This parameter is optionally present if dot11ACStationCountActivated is true and is not present otherwise.
TIMBroadcastRequest	As defined in TIM Broadcast Request element	As defined in 9.4.2.82	Specifies the proposed service parameters for TIM Broadcast. This parameter is optionally present if dot11TIMBroadcastActivated is true and is not present otherwise.
FMSRequest	As defined in FMS Request element	As defined in 9.4.2.75	Specifies the proposed multicast parameters for FMS Request. This parameter is optionally present if dot11FMSActivated is true and is not present otherwise.
DMSRequest	Sequence of DMS Request elements	As defined in 9.4.2.87	Specifies the proposed multicast parameters for DMS Request. This parameter is optionally present if dot11DMSActivated is true and is not present otherwise.
EmergencyServices	Boolean	true, false	Specifies that the non-AP and non-PCP STA intends to reassociate for the purpose of unauthenticated access to emergency services. The parameter shall be present only if dot11InterworkingServiceActivated is true.
Multi-band local	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise.
Multi-band peer	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. The parameter is present if OCT is being used and is absent otherwise.
MMS	Multiple MAC Sublayers element	As defined in 9.4.2.152	Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity. The parameter is present if dot11MultipleMACActivated is true and is absent otherwise.
FILSHLPContainer	As defined in 9.4.2.183	As defined in 9.4.2.183	A set of elements containing encapsulated data of higher layer protocol frames (e.g., a DHCP message) that is transported in FILS association. The parameter is optionally present if dot11FILSActivated is true; otherwise not present.

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Name	Type	Valid range	Description
FILSIPAddressAssignment	As defined in 9.4.2.184	As defined in 9.4.2.184	An explicit request for an IP address. The request may be for a new IP address or a specified IP address. The parameter is optionally present if dot11FILSActivated is true; otherwise not present.
AID Request	AID Request element	As defined in 9.4.2.193	Indicates the device characteristic of the non-AP STA requesting AID assignment. This parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.
TWT	TWT element	As defined in 9.4.2.199	Specifies the parameters in the TWT element. This parameter is optionally present if dot11TWTOptionActivated is true; otherwise not present.
Sectorized Group ID List	Sectorized Group ID List element	As defined in 9.4.2.211	Specifies the parameters in the Sectorized Group ID List element. This parameter is optionally present if dot11S1GSectorizationActivated is true; otherwise not present.
MaxAwayDuration	Integer	0–65 535	Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA. The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present.
S1GRelayActivation	S1G Relay Activation element	As defined in 9.4.2.206	Indicates if the STA with dot11RelaySTAImplemented equal to true requests to operate as a relay (in a request) and the AP with dot11RelayAPImplemented equal to true requests/confirms operation as a relay. The parameter is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
ELOperation	EL Operation element	As defined in 9.4.2.210	The EL Operation element is optionally present if dot11S1GELOperationActivated is true; otherwise not present.
S1GRelay	S1G Relay element	As defined in 9.4.2.204	Specifies the parameters within the S1G Relay element that are supported by the MAC entity. The parameter is present if dot11RelaySTAImplemented is true; otherwise not present.
HeaderCompression	Header Compression element	As defined in 9.4.2.213	The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true; otherwise not present.
ReachableAddress	Reachable Address element	As defined in 9.4.2.205	The Reachable Address element is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
S1GOperation	S1G Operation element	As defined in 9.4.2.212	The S1G Operation element is present if dot11S1GOptionImplemented is true; otherwise not present.
SSTOperation	SST Operation element	As defined in 9.4.2.214	The SST Operation element is optionally present if dot11SelectiveSubchannelTransmissionPermitted is true; otherwise not present.

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Name	Type	Valid range	Description
CDMG Capabilities	CDMG Capabilities element	As defined in 9.4.2.219	Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present.
CMMG Capabilities	CMMG Capabilities element	As defined in 9.4.2.229	Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present.
GLK-GCR Parameter Set	GLK-GCR Parameter Set element	As defined in 9.4.2.234	This parameter is present if dot11GLKGCRImplemented is true and not present otherwise. Specifies the GLK-GCR capabilities supported by the STA.
MSCS Descriptor	As defined in the MSCS Descriptor element	As defined in 9.4.2.243	The parameters used to classify streams using the procedures defined in 11.25.3. Optionally present if dot11MSCSActivated is true; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

Additional parameters needed to perform the reassociation procedure are not included in the primitive parameter list since the MLME already has that data (maintained as internal state).

6.3.8.2.3 When generated

This primitive is generated by the SME for a STA to change association to a specified new peer MAC entity that is in an AP or PCP.

6.3.8.2.4 Effect of receipt

This primitive initiates a reassociation procedure. In the case that a response is received from the responder STA, the MLME subsequently issues an MLME-REASSOCIATE.confirm primitive that reflects the results.

6.3.8.3 MLME-REASSOCIATE.confirm

6.3.8.3.1 Function

This primitive reports the results of a reassociation attempt with a specified peer MAC entity that is in an AP or PCP.

6.3.8.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-REASSOCIATE.confirm(
ResultCode,
CapabilityInformation,
AssociationID,
EDCAParameterSet,
RCPI of Request,
RSNI of Request,
RCPI of Response,
RSNI of Response,

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RMEnabledCapabilities,
Content of FT Authentication elements,
SupportedOperatingClasses,
Extended Capabilities,
20/40 BSS Coexistence,
TimeoutInterval,
BSSMaxIdlePeriod,
TIMBroadcastResponse,
FMSResponse,
DMSResponse,
QoSMapSet,
QMFPolicy,
DMG Capabilities,
Multi-band local,
Multi-band peer,
MMS,
FILSHLPContainer,
FILSIPAddressAssignment,
KeyDelivery,
S1G Sector Operation,
S1G Capabilities,
AID Response,
TSF Timer Accuracy,
TWT,
MaxAwayDuration,
S1GRelayActivation,
ELOperation,
S1GRelay,
HeaderCompression,
S1GOperation,
SectorizedGroupIDList,
SSTOperation,
CDMG Capabilities,
CMMG Capabilities,
GLK-GCR Parameter Set,
MSCS Descriptor,
VendorSpecificInfo
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, REFUSED_REASON_UNSPECIFIED, REFUSED_NOT_AUTHENTICATED, REFUSED_CAPABILITIES_MISMATCH, REFUSED_EXTERNAL_REASON, REFUSED_AP_OUT_OF_MEMORY, REFUSED_BASIC_RATES_MISMATCH, REJECTED_EMERGENCY_SERVICES_NOT_SUPPORTED, REFUSED_TEMPORARILY	Indicates the result of the MLME-REASSOCIATE.request primitive.

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Name	Type	Valid range	Description
Capability-Information	Capability Information field	As defined in 9.4.1.4	Specifies the operational capabilities advertised by the AP or PCP.
AssociationID	Integer	Non-DMG: 1–2007 DMG: 1–254	If the association request result was SUCCESS, then AssociationID specifies the association ID value assigned by the AP or PCP. This parameter is not present if dot11S1GOptionImplemented is true.
EDCAParameterSet	EDCA Parameter Set element	As defined in 9.4.2.28	Specifies the EDCA parameter set that the STA should use. The parameter is present if dot11QosOptionImplemented is true; otherwise not present.
RCPI of Request	Integer	As defined in 9.4.2.37	Indicates the RCPI value contained in the received Reassociation Response frame. This value represents the RCPI that the AP or PCP measured at the time it received the corresponding Reassociation Request frame. The element is optionally present if dot11RMRCPIMeasurementActivated is true; otherwise not present.
RSNI of Request	Integer	As defined in 9.4.2.40	Indicates the RSNI value contained in the received Reassociation Response frame. This value represents the RSNI that the AP or PCP measured at the time it received the corresponding Reassociation Request frame. The element is optionally present if dot11RMRSNIMeasurementActivated is true; otherwise not present.
RCPI of Response	Integer	As defined in 9.4.2.37	The RCPI value represents the measured RCPI of the corresponding Reassociation Response frame. The element is optionally present if dot11RMRCPIMeasurementActivated is true; otherwise not present.
RSNI of Response	Integer	As defined in 9.4.2.40	RSNI at the time the corresponding Reassociation Response frame was received. The element is optionally present if dot11RMRSNIMeasurementActivated is true; otherwise not present.
RMEnabledCapabilities	RM Enabled Capabilities element	As defined in 9.4.2.44	Specifies the RM enabled capabilities advertised by the AP or PCP. The element is present if dot11RadioMeasurementActivated is true; otherwise not present.
Content of FT Authentication elements	Sequence of elements	As defined in 13.8	The set of elements included in the fourth message of the FT authentication sequence, as described in 13.8.5. This includes an optional response to a resource request (RIC). Present if dot11FastBSSTransitionActivated is true; otherwise not present.

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Name	Type	Valid range	Description
SupportedOperating Classes	As defined in the Supported Operating Classes element	As defined in 9.4.2.53	Indicates the supported operating classes of the AP or PCP. This parameter is optionally present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true; otherwise not present.
Extended Capabilities	As defined in frame format	As defined in 9.4.2.26	Specifies the parameters within the Extended Capabilities element that are supported by the MAC entity.
20/40 BSS Coexistence	As defined in frame format	As defined in 9.4.2.59	Specifies the parameters within the 20/40 BSS Coexistence element that are indicated by the MAC entity. The parameter is present if dot112040BSSCoexistenceManagement Support is true.
TimeoutInterval	Timeout Interval element, as defined in frame format	As defined in 9.4.2.48	This parameter is present when ResultCode is REFUSED_TEMPORARILY.
BSSMaxIdlePeriod	BSS Max Idle Period element	As defined in 9.4.2.78	Indicates the BSS max idle period parameters of the AP or PCP. This parameter is present if dot11WirelessManagementImplemented is true or dot11S1GOptionImplemented is true; otherwise not present.
TIMBroadcastResp onse	As defined in TIM Broadcast Response element	As defined in 9.4.2.83	Specifies the service parameters for TIM Broadcast. This parameter is optionally present if dot11TIMBroadcastActivated is true and the TIM Broadcast Request element is present in the corresponding Association Request frame; this parameter is not present otherwise.
FMSResponse	As defined in FMS Response element	As defined in 9.4.2.76	Specifies the multicast parameters for FMS Response. This parameter is optionally present if dot11FMSActivated is true and the FMS Request element is present in the corresponding Association Request frame; this parameter is not present otherwise.
DMSResponse	Sequence of DMS Response elements	As defined in 9.4.2.88	Specifies the multicast parameters for DMS Response. This parameter is optionally present if dot11DMSActivated is true and the DMS Request element is present in the corresponding Association Request frame; this parameter is not present otherwise.
QoSMapSet	As defined in frame format	As defined in 9.4.2.94	Specifies the QoS Map the non-AP and non-PCP STA should use.
QMFPolicy	QMF Policy element	As defined in 9.4.2.119	Describes the QMF policy of the AP. This parameter is present when dot11QMFActivated is true and is not present otherwise.
DMG Capabilities	DMG Capabilities element	As defined in 9.4.2.127	Specifies the parameters within the DMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11DMGOptionImplemented is true and is absent otherwise.

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Name	Type	Valid range	Description
Multi-band local	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that identify and are supported by the local MAC entity. The parameter is present if OCT is being used and is absent otherwise.
Multi-band peer	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that identify and are supported by the peer MAC entity. This parameter is present if OCT is being used and is absent otherwise.
MMS	Multiple MAC Sublayers element	As defined in 9.4.2.152	Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity. The parameter is present if dot11MultipleMACActivated is true and is absent otherwise.
FILSHLPContainer	As defined in 9.4.2.183	As defined in 9.4.2.183	A set of elements containing encapsulated data of higher layer protocol frames (e.g., a DHCP message) that is transported in FILS association. The parameter is present if dot11FILSActivated is true; otherwise not present.
FILSIPAddressAssignment	As defined in 9.4.2.184	As defined in 9.4.2.184	The IP address assigned to the STA for higher layer communication. The parameter is present if dot11FILSActivated is true; otherwise not present.
KeyDelivery	As defined in 9.4.2.185	As defined in 9.4.2.185	KDE(s) and the current Key RSC. The parameter is present if dot11FILSActivated is true; otherwise not present.
S1G Sector Operation	S1G Sector Operation element	As defined in 9.4.2.195	Specifies the sectorization scheme, period, subperiod sector intervals, sector training.
S1G Capabilities	As defined in frame format	As defined in 9.4.2.200	Specifies the parameters in the S1G Capabilities element that are supported by the AP. The parameter is present if dot11S1GOptionImplemented is true and the S1G Capabilities element is present in the (Re)Association Response frame received from the AP; otherwise not present.
AID Response	AID Response element	As defined in 9.4.2.194	Parameters describing an AID assignment. This parameter is present if dot11S1GOptionImplemented is true; otherwise not present.
TSF Timer Accuracy	TSF Timer Accuracy element	As defined in 9.4.2.203	Indicates the information about the TSF Timer Accuracy. The parameter is optionally present if dot11TSFTimerAccuracyImplemented is true; otherwise not present.
TWT	TWT element	As defined in 9.4.2.199	Specifies the parameters in the TWT element. This parameter is optionally present if dot11TWTOptionActivated is true; otherwise not present.

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Name	Type	Valid range	Description
MaxAwayDuration	Integer	0–65 535	Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA. The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present.
S1GRelayActivation	S1G Relay Activation element	As defined in 9.4.2.206	Indicates if the STA with dot11RelaySTAImplemented equal to true requests to operate as a relay (in a request) and the AP with dot11RelayAPImplemented equal to true requests/confirms operation as a relay. The parameter is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
ELOperation	EL Operation element	As defined in 9.4.2.210	The EL Operation element is optionally present if dot11S1GELOperationActivated is true; otherwise not present.
S1GRelay	S1G Relay element	As defined in 9.4.2.204	Specifies the parameters within the S1G Relay element that are supported by the MAC entity. The parameter is present if dot11RelaySTAImplemented is true; otherwise not present.
HeaderCompression	Header Compression element	As defined in 9.4.2.213	The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true; otherwise not present.
S1GOperation	S1G Operation element	As defined in 9.4.2.212	The S1G Operation element is present if dot11S1GOptionImplemented is true; otherwise not present.
SectorizedGroupID List	Sectorized Group ID List element	As defined in 9.4.2.211	Specifies the parameters in the Sectorized Group ID List element. This parameter is optionally present if dot11S1GSectorizationActivated is true; otherwise not present.
SSTOperation	SST Operation element	As defined in 9.4.2.214	The SST Operation element is optionally present if dot11SelectiveSubchannelTransmissionPermitted is true; otherwise not present.
CDMG Capabilities	CDMG Capabilities element	As defined in 9.4.2.219	Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present.
CMMG Capabilities	CMMG Capabilities element	As defined in 9.4.2.229	Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present.
GLK-GCR Parameter Set	GLK-GCR Parameter Set element	As defined in 9.4.2.234	Specifies the values from the GLK-GCR Parameter Set element if such an element was present in the Reassociation Response frame, otherwise not present.

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Name	Type	Valid range	Description
MSCS Descriptor	As defined in the MSCS Descriptor element	As defined in 9.4.2.243	The parameters used to classify streams using the procedures defined in 11.25.3. Optionally present if dot11MSCSActivated is true; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.8.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-REASSOCIATE.request primitive to reassociate with a specified peer MAC entity that is in an AP or PCP.

6.3.8.3.4 Effect of receipt

The SME is notified of the results of the reassociation procedure.

6.3.8.4 MLME-REASSOCIATE.indication

6.3.8.4.1 Function

This primitive indicates that a specific peer MAC entity is requesting reassociation with the local MAC entity, which is in an AP or PCP.

6.3.8.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-REASSOCIATE.indication(
PeerSTAAddress,
CurrentAPAddress,
CapabilityInformation,
BSSMaxIdlePeriod,
ListenInterval,
SSID,
OperationalRateSet,
BSSMembershipSelectorSet,
RSN,
QoSCapability,
RCPI,
RSNI,
RMEnabledCapabilities,
Content of FT Authentication elements,
SupportedOperatingClasses,
DSERegisteredLocation,
HT Capabilities,
Extended Capabilities,
20/40 BSS Coexistence,
QoSTrafficCapability,
TIMBroadcastRequest,
FMSRequest,
DMSRequest,
EmergencyServices,
DMG Capabilities,

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Multi-band local,
Multi-band peer,
MMS,
VHT Capabilities,
FILSHLPContainer,
FILSIPAddressAssignment,
AID Request,
S1G Capabilities,
TWT,
Sectorized Group ID List,
MaxAwayDuration,
S1GRelayActivaton,
ELOperation,
S1GRelay,
HeaderCompression,
ReachableAddress,
S1GOperation,
SSTOperation,
CDMG Capabilities,
CMMG Capabilities,
GLK-GCR Parameter Set,
MSCS Descriptor,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity from which the reassociation request was received.
CurrentAPAddress	MAC address	Any valid individual MAC address	Specifies the address of the AP or PCP with which the peer STA is currently associated.
Capability-Information	Capability Information field	As defined in 9.4.1.4	Specifies the operational capability definitions provided by the peer MAC entity as part of the reassociation request.
BSSMaxIdlePeriod	BSS Max Idle Period element	As defined in 9.4.2.78	Indicates the preferred BSS max idle period parameters. This parameter is optionally present if dot11WirelessManagementImplemented and dot11BSSMaxIdlePeriodIndicationByNonAPSTA are true, or if dot11S1GOptionImplemented is true; otherwise not present.
ListenInterval	Integer	≥ 0	Specifies the listen interval provided by the peer MAC entity as part of the reassociation request.
SSID	Octet string	0–32 octets	Specifies the desired SSID provided by the peer MAC entity as part of the reassociation request.

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Name	Type	Valid range	Description
OperationalRateSet	Non-DMG BSS: Set of integers DMG BSS: Set of numbers	Non-DMG BSS: 1–127 excluding values from Table 9-93 for each member of the set DMG BSS: 0–12, 9.1, 12.1–12.6, or 25–31, for each member of the set	The set of data rates (in units of 500 kb/s) that the STA that is requesting association is able to use for communication within the BSS. The STA is able to receive at each of the data rates listed in the set. This set is a superset of the rates contained in the BSSBasicRateSet parameter. DMG BSS: The set of MCS indexes that the AP or PCP uses for communication within the BSS.
BSSMembershipSelectorSet	Set of integers	A value from Table 9-93, for each member of the set	The set of features that the STA that is requesting association is able to use for communication.
RSN	RSNE	As defined in 9.4.2.24	A description of the cipher suites and AKM suites selected by the STA.
QoSCapability	QoS Capability element	As defined in 9.4.2.34	Specifies the parameters within the QoS Capability that are supported by the peer MAC entity. The parameter is present if dot11QosOptionImplemented is true; otherwise not present.
RCPI	Integer	As defined in 9.4.2.37	The RCPI value represents the measured RCPI of the corresponding Reassociation Request frame. The element is optionally present if dot11RMRCPIMeasurementActivated is true; otherwise not present.
RSNI	Integer	As defined in 9.4.2.40	The RSNI value represents the measured RSNI at the time the corresponding Reassociation Request frame was received. The element is optionally present if dot11RMRSNIMeasurementActivated is true; otherwise not present.
RMEnabledCapabilities	RM Enabled Capabilities element	As defined in 9.4.2.44	Specifies the RM enabled capabilities advertised by the AP or PCP. The element is present if dot11RadioMeasurementActivated is true; otherwise not present.
Content of FT Authentication elements	Sequence of elements	As defined in 13.8	The set of elements included in the third message of the FT authentication sequence, as described in 13.8.4. Present if dot11FastBSSTransitionActivated is true; otherwise not present.
SupportedOperatingClasses	As defined in the Supported Operating Classes element	As defined in 9.4.2.53	Indicates the supported operating classes of the STA. This parameter is optionally present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true; otherwise not present.
DSERegisteredLocation	As defined in the DSE Registered Location element	As defined in 9.4.2.51	Indicates the DSE registered location including the dependent enablement identifier assigned by the enabling STA. This parameter is optionally present if dot11LCIDSERequired is true; otherwise not present.

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Name	Type	Valid range	Description
HT Capabilities	As defined in frame format	As defined in 9.4.2.55	Specifies the parameters within the HT Capabilities element that are supported by the MAC entity. The parameter is optionally present if dot11HighThroughputOptionImplemented is true.
Extended Capabilities	As defined in frame format	As defined in 9.4.2.26	Specifies the parameters within the Extended Capabilities element that are supported by the MAC entity.
20/40 BSS Coexistence	As defined in frame format	As defined in 9.4.2.59	Specifies the parameters within the 20/40 BSS Coexistence element that are indicated by the MAC entity. The parameter is present if dot112040BSSCoexistenceManagementSupport is true.
QoS Traffic Capability	As defined in the QoS Traffic Capability element	As defined in 9.4.2.77	Specifies the QoS Traffic Capability flags of the non-AP and non-PCP STA. This parameter is optionally present if dot11ACStationCountActivated is true and is not present otherwise.
TIMBroadcastRequest	As defined in TIM Broadcast Request element	As defined in 9.4.2.82	Specifies the proposed service parameters for TIM Broadcast. This parameter is optionally present if dot11TIMBroadcastActivated is true and is not present otherwise.
FMSRequest	As defined in FMS Request element	As defined in 9.4.2.75	Specifies the proposed multicast parameters for FMS Request. This parameter is optionally present if dot11FMSActivated is true and is not present otherwise.
DMSRequest	Sequence of DMS Request elements	As defined in 9.4.2.87	Specifies the proposed multicast parameters for DMS Request. This parameter is optionally present if dot11DMSActivated is true and is not present otherwise.
EmergencyServices	Boolean	true, false	Specifies the setting of the UESA field received from the non-AP and non-PCP STA, if an Interworking element was present in the Reassociation Request frame. The parameter is present if dot11InterworkingServiceActivated is true; otherwise not present.
DMG Capabilities	DMG Capabilities element	As defined in 9.4.2.127	Specifies the parameters within the DMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11DMGOptionImplemented is true and is absent otherwise.
Multi-band local	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that identify the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise.
Multi-band peer	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are supported by the peer MAC entity. This parameter is present if OCT is being used and is absent otherwise.

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Name	Type	Valid range	Description
MMS	Multiple MAC Sublayers element	As defined in 9.4.2.152	Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity. The parameter is present if dot11MultipleMACActivated is true and is absent otherwise.
VHT Capabilities	As defined in VHT Capabilities element	As defined in 9.4.2.157	Specifies the parameters in the VHT Capabilities element that are supported by the STA. The parameter is present if dot11VHTOptionImplemented is true and the VHT Capabilities element is present in the Reassociation Request frame received from the STA. The parameter is not present otherwise.
FILSHLPContainer	As defined in 9.4.2.183	As defined in 9.4.2.183	A set of elements containing encapsulated data of higher layer protocol frames (e.g., a DHCP message) that is transported in FILS reassociation. The parameter is optionally present if dot11FILSActivated is true; otherwise not present.
FILSIPAddressAssignment	As defined in 9.4.2.184	As defined in 9.4.2.184	An explicit request for an IP address. The request may be for a new IP address or a specified IP address. The parameter is optionally present if dot11FILSActivated is true; otherwise not present.
AID Request	AID Request element	As defined in 9.4.2.193	Indicates the device characteristic of the non-AP STA requesting AID assignment. This parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.
S1G Capabilities	As defined in frame format	As defined in 9.4.2.200	Specifies the parameters in the S1G Capabilities element that are supported by the STA. The parameter is present if dot11S1GOptionImplemented is true and the S1G Capabilities element is present in the Reassociation Request frame received from the STA; otherwise not present.
TWT	TWT element	As defined in 9.4.2.199	Specifies the parameters in the TWT element. This parameter is optionally present if dot11TWTOptionActivated is true; otherwise not present.
Sectorized Group ID List	Sectorized Group ID List element	As defined in 9.4.2.211	Specifies the parameters in the Sectorized Group ID List element. This parameter is optionally present if dot11S1GSectorizationActivated is true; otherwise not present.
MaxAwayDuration	Integer	0–65 535	Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA. The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present.

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Name	Type	Valid range	Description
S1GRelayActivation	S1G Relay Activation element	As defined in 9.4.2.206	Indicates if the STA with dot11RelaySTAImplemented equal to true requests to operate as a relay (in a request) and the AP with dot11RelayAPImplemented equal to true requests/confirms operation as a relay. The parameter is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
ELOperation	EL Operation element	As defined in 9.4.2.210	The EL Operation element is optionally present if dot11S1GELOperationActivated is true; otherwise not present.
S1GRelay	S1G Relay element	As defined in 9.4.2.204	Specifies the parameters within the S1G Relay element that are supported by the MAC entity. The parameter is present if dot11RelaySTAImplemented is true; otherwise not present.
HeaderCompression	Header Compression element	As defined in 9.4.2.213	The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true; otherwise not present.
ReachableAddress	Reachable Address element	As defined in 9.4.2.205	The Reachable Address element is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
S1GOperation	S1G Operation element	As defined in 9.4.2.212	The S1G Operation element is present if dot11S1GOptionImplemented is true; otherwise not present.
SSTOperation	SST Operation element	As defined in 9.4.2.214	The SST Operation element is optionally present if dot11SelectiveSubchannelTransmissionPermitted is true; otherwise not present.
CDMG Capabilities	CDMG Capabilities element	As defined in 9.4.2.219	Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present.
CMMG Capabilities	CMMG Capabilities element	As defined in 9.4.2.229	Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present.
GLK-GCR Parameter Set	GLK-GCR Parameter Set element	As defined in 9.4.2.234	The GLK-GCR Parameter Set element from the received Reassociation Request frame.
MSCS Descriptor	As defined in the MSCS Descriptor element	As defined in 9.4.2.243	The parameters used to classify streams using the procedures defined in 11.25.3. Optionally present if dot11MSCSActivated is true; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.8.4.3 When generated

This primitive is generated by the MLME as a result of the establishment of a reassociation with a specific peer MAC entity that resulted from a reassociation procedure that was initiated by that specific peer MAC entity.

6.3.8.4.4 Effect of receipt

The SME is notified of the establishment of the reassociation.

6.3.8.5 MLME-REASSOCIATE.response

6.3.8.5.1 Function

This primitive is used to send a response to a specific peer MAC entity that requested a reassociation with the STA that issued this primitive, which is in an AP or PCP.

6.3.8.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-REASSOCIATE.response(
PeerSTAAddress,
ResultCode,
AssociationID,
RCPI,
RSNI,
RMEnabledCapabilities,
Content of FT Authentication elements,
SupportedOperatingClasses,
TimeoutInterval,
BSSMaxIdlePeriod,
TIMBroadcastResponse,
FMSResponse,
DMSResponse,
QoSMapSet,
Multi-band local,
Multi-band peer,
MMS,
FILSHLPContainer,
FILSIPAddressAssignment,
KeyDelivery,
S1G Sector Operation,
S1G Capabilities,
AID Response,
TSF Timer Accuracy,
TWT,
Sectorized Group ID List,
MaxAwayDuration,
S1GRelay,
S1GRelayActivation,
S1GOperation,
HeaderCompression,
SSTOperation,
CDMG Capabilities,

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CMMG Capabilities,
GLK-GCR Parameter Set,
MSCS Descriptor,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity from which the reassociation request was received.
ResultCode	Enumeration	SUCCESS, REFUSED_REASON_UNSPECIFIED, REFUSED_CAPABILITIES_MISMATCH, REFUSED_EXTERNAL_REASON, REFUSED_AP_OUT_OF_MEMORY, REFUSED_BASIC_RATES_MISMATCH, REJECTED_EMERGENCY_SERVICES_NOT_SUPPORTED, REFUSED_TEMPORARILY	Indicates the result response to the reassociation request from the peer MAC entity.
AssociationID	Integer	Non-DMG: 1–2007 DMG: 1–254	If the reassociation request result was SUCCESS, then AssociationID specifies the association ID value assigned to the peer MAC entity by the AP or PCP. This parameter is not present if dot11S1GOptionImplemented is true.
RCPI	Integer	As defined in 9.4.2.37	The RCPI value represents the measured RCPI of the corresponding Reassociation Request frame. The element is optionally present if dot11RMRCPIMeasurementActivated is true; otherwise not present.
RSNI	Integer	As defined in 9.4.2.40	The RSNI value represents the measured RSNI at the time the corresponding Reassociation Request frame was received. The element is optionally present if dot11RMRSNIMeasurementActivated is true; otherwise not present.
RMEnabledCapabilities	RM Enabled Capabilities element	As defined in 9.4.2.44	Specifies the RM enabled capabilities advertised by the AP or PCP. The element is present if dot11RadioMeasurementActivated is true; otherwise not present.
Content of FT Authentication elements	Sequence of elements	As defined in 13.8	The set of elements to be included in the fourth message of the FT authentication sequence, as described in 13.8.5. This includes an optional response to a resource request (RIC). Present if dot11FastBSSTransitionActivated is true; otherwise not present.

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Name	Type	Valid range	Description
SupportedOperating Classes	As defined in the Supported Operating Classes element	As defined in 9.4.2.53	Specifies the supported operating classes of the AP or PCP. This parameter is present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true; otherwise not present.
TimeoutInterval	Timeout Interval element, as defined in frame format	As defined in 9.4.2.48	This parameter is present when ResultCode is REFUSED_TEMPORARILY.
BSSMaxIdlePeriod	BSS Max Idle Period element	As defined in 9.4.2.78	Indicates the BSS max idle period parameters of the AP or PCP. This parameter is present if dot11WirelessManagementImplemented is true or dot11S1GOptionImplemented is true; otherwise not present.
TIMBroadcastResp onse	As defined in TIM Broadcast Response element	As defined in 9.4.2.83	Specifies the service parameters for TIM Broadcast. This parameter is optionally present if dot11TIMBroadcastActivated is true and the TIM Broadcast Request element is present in the corresponding Association Request frame; this parameter is not present otherwise.
FMSResponse	As defined in FMS Response element	As defined in 9.4.2.76	Specifies the multicast parameters for FMS Response. This parameter is optionally present if dot11FMSActivated is true and the FMS Request element is present in the corresponding Association Request frame; this parameter is not present otherwise.
DMSResponse	Sequence of DMS Response elements	As defined in 9.4.2.88	Specifies the multicast parameters for DMS Response. This parameter is optionally present if dot11DMSActivated is true and the DMS Request element is present in the corresponding Association Request frame; this parameter is not present otherwise.
QoSMapSet	As defined in frame format	As defined in 9.4.2.94	Specifies the QoS Map the non-AP and non-PCP STA should use.
Multi-band local	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise.
Multi-band peer	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. The parameter is present if OCT is being used and is absent otherwise.
MMS	Multiple MAC Sublayers element	As defined in 9.4.2.152	Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity, and negotiated for the association. The parameter is present if dot11MultipleMACActivated is true and is absent otherwise.

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Name	Type	Valid range	Description
FILSHLPContainer	As defined in 9.4.2.183	As defined in 9.4.2.183	A set of elements containing encapsulated data of higher layer protocol frames (e.g., a DHCP message) that is transported in FILS reassociation. The parameter is optionally present if dot11FILSActivated is true; otherwise not present.
FILSIPAddressAssignment	As defined in 9.4.2.184	As defined in 9.4.2.184	The IP address of a network layer entity associated with the STA. The parameter is optionally present if dot11FILSActivated is true; otherwise not present.
KeyDelivery	As defined in 9.4.2.185	As defined in 9.4.2.185	KDE(s) and the current Key RSC. The parameter is present if dot11FILSActivated is true; otherwise not present.
S1G Sector Operation	S1G Sector Operation element	As defined in 9.4.2.195	Specifies the sectorization scheme, period, subperiod sector intervals, and sector training.
S1G Capabilities	As defined in frame format	As defined in 9.4.2.200	Specifies the parameters in the S1G Capabilities element that are supported by the STA. The parameter is present if dot11S1GOptionImplemented is true; otherwise not present.
AID Response	AID Response element	As defined in 9.4.2.194	Parameters describing an AID assignment. This parameter is present if dot11S1GOptionImplemented is true; otherwise not present.
TSF Timer Accuracy	TSF Timer Accuracy element	As defined in 9.4.2.203	Indicates the information about the TSF timer accuracy. The parameter is optionally present if dot11TSFTimerAccuracyImplemented is true; otherwise not present.
TWT	TWT element	As defined in 9.4.2.199	Specifies the parameters in the TWT element. This parameter is optionally present if dot11TWTOptionActivated is true; otherwise not present.
Sectorized Group ID List	Sectorized Group ID List element	As defined in 9.4.2.211	Specifies the parameters in the Sectorized Group ID List element. This parameter is optionally present if dot11S1GSectorizationActivated is true; otherwise not present.
MaxAwayDuration	Integer	0–65 535	Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA. The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present.
S1GRelay	S1G Relay element	As defined in 9.4.2.204	Indicates the support of the relay operation by the STA transmitting the element.

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Name	Type	Valid range	Description
S1GRelayActivation	S1G Relay Activation element	As defined in 9.4.2.206	Indicates if the STA with dot11RelaySTAImplemented equal to true requests to operate as a relay (in a request) and the AP with dot11RelayAPImplemented equal to true requests/confirms operation as a relay. The parameter is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
S1GOperation	S1G Operation element	As defined in 9.4.2.212	Provides additional information for operating the S1G BSS. The parameter is present if dot11S1GOptionImplemented is true; otherwise not present.
HeaderCompression	Header Compression element	As defined in 9.4.2.213	The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true; otherwise not present.
SSTOperation	SST Operation element	As defined in 9.4.2.214	The SST Operation element is optionally present if dot11SelectiveSubchannelTransmissionPermitted is true; otherwise not present.
CDMG Capabilities	CDMG Capabilities element	As defined in 9.4.2.219	Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present.
CMMG Capabilities	CMMG Capabilities element	As defined in 9.4.2.229	Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present.
GLK-GCR Parameter Set	GLK-GCR Parameter Set element	As defined in 9.4.2.234	This parameter is present only if the AP selects GLK-GCR for groupcast (either unsolicited retry or block ack) over the general link. Describes the parameters that define how GLK-GCR operates.
MSCS Descriptor	As defined in the MSCS Descriptor element	As defined in 9.4.2.243	The parameters used to classify streams using the procedures defined in 11.25.3. Optionally present if dot11MSCSActivated is true; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

Additional parameters needed to perform the reassociation response procedure are not included in the primitive parameter list since the MLME already has that data (maintained as internal state).

6.3.8.5.3 When generated

This primitive is generated by the SME of a STA that is in an AP or PCP as a response to an MLME-REASSOCIATE.indication primitive.

6.3.8.5.4 Effect of receipt

This primitive initiates transmission of a response to the specific peer MAC entity that requested reassociation.

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6.3.9 Disassociate

6.3.9.1 MLME-DISASSOCIATE.request

6.3.9.1.1 Function

This primitive requests disassociation with a specified peer MAC entity.

6.3.9.1.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DISASSOCIATE.request(
PeerSTAAddress,
ReasonCode,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the disassociation process.
ReasonCode	Reason Code field	As defined in 9.4.1.7	Specifies the reason for initiating the disassociation procedure.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.9.1.3 When generated

This primitive is generated by the SME for a STA to disassociate from a STA with which it has an association.

6.3.9.1.4 Effect of receipt

This primitive initiates a disassociation procedure. The MLME subsequently issues an MLME-DISASSOCIATE.confirm primitive that reflects the results.

6.3.9.2 MLME-DISASSOCIATE.confirm

6.3.9.2.1 Function

This primitive reports the results of a disassociation procedure with a specific peer MAC entity.

6.3.9.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DISASSOCIATE.confirm()

6.3.9.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-DISASSOCIATE.request primitive to disassociate with a specified peer MAC entity.

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6.3.9.2.4 Effect of receipt

The SME is notified of the results of the disassociation procedure.

6.3.9.3 MLME-DISASSOCIATE.indication

6.3.9.3.1 Function

This primitive reports disassociation with a specific peer MAC entity.

6.3.9.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DISASSOCIATE.indication(
PeerSTAAddress,
ReasonCode,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the association relationship was invalidated.
ReasonCode	Reason Code field	As defined in 9.4.1.7	Specifies the reason the disassociation procedure was initiated.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.9.3.3 When generated

This primitive is generated by the MLME as a result of the invalidation of an association relationship with a specific peer MAC entity.

6.3.9.3.4 Effect of receipt

The SME is notified of the invalidation of the specific association relationship.

6.3.10 Reset

6.3.10.1 Introduction

This mechanism supports the process of resetting the MAC.

6.3.10.2 MLME-RESET.request

6.3.10.2.1 Function

This primitive requests that the MAC entity be reset.

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6.3.10.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-RESET.request(
STAAddress,
SetDefaultMIB
)

Name	Type	Valid range	Description
STAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address that is to be used by the MAC entity that is being reset. This value can be used to provide a locally administered STA address.
SetDefaultMIB	Boolean	true, false	If true, all MIB attributes are set to their default values. The default values are implementation dependent. If false, the MAC is reset, but all MIB attributes retain the values that were in place prior to the generation of the MLME-RESET.request primitive.

6.3.10.2.3 When generated

This primitive is generated by the SME to reset the MAC to initial conditions. The MLME-RESET.request primitive shall be used prior to use of the MLME-START.request primitive. The MLME-RESET.request primitive shall be used prior to the first use of the MLME-JOIN.request primitive, or any time a STA's state is to be reinitialized.

6.3.10.2.4 Effect of receipt

This primitive sets the MAC to initial conditions, clearing all MAC variables to the default values. MIB attributes can be reset to their implementation dependent default values by setting the SetDefaultMIB flag to true.

If dot11OCBActivated is true and if the SetDefaultMIB parameter is false, MAC operation shall resume in less than 2 TU after the STAAddress parameter is changed.

6.3.11 Start

6.3.11.1 Introduction

This mechanism supports the process of starting a new BSS or becoming a member of an MBSS.

6.3.11.2 MLME-START.request

6.3.11.2.1 Function

This primitive requests that the MAC entity start a new BSS or become a member of an MBSS.

6.3.11.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-START.request(
SSID,
BSSType,
BeaconPeriod,

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DTIMPeriod,
PHY parameter set,
IBSS parameter set,
NAVSyncDelay,
CapabilityInformation,
BSSBasicRateSet,
OperationalRateSet,
Country,
IBSS DFS Recovery Interval,
EDCAParameterSet,
DSERegisteredLocation,
HT Capabilities,
HT Operation,
BSSMembershipSelectorSet,
Extended Capabilities,
20/40 BSS Coexistence,
Overlapping BSS Scan Parameters,
MultipleBSSID,
InterworkingInfo,
AdvertisementProtocolInfo,
RoamingConsortiumInfo,
Mesh ID,
Mesh Configuration,
QMFPolicy,
DMG Capabilities,
Multi-band,
MMS,
DMG Operation,
Clustering Control,
CBAP Only,
PCP Association Ready,
VHT Capabilities,
VHT Operation,
Known OUIs,
S1G Capabilities,
S1GOperation,
ShortBeaconPeriod,
ShortBeaconDTIMPeriod,
CDMG Capabilities,
CMMG Capabilities,
CMMG Operation,
ServiceHint,
ServiceHash,
VendorSpecificInfo
)

Name	Type	Valid range	Description
SSID	Octet string	0–32 octets	The SSID of the BSS.
BSSType	Enumeration	INFRASTRUCTURE, INDEPENDENT, MESH, PERSONAL	The type of the BSS.
Beacon Period	Integer	≥ 1	The beacon period (in TU) of the BSS if the BSSType is not MESH, or of the mesh STA if the BSSType is MESH.

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Name	Type	Valid range	Description
DTIM Period	Integer	As defined in 9.4.2.5	The DTIM Period (in beacon periods) of the BSS if the BSSType is not MESH, or of the mesh STA if the BSSType is MESH.
PHY parameter sets	DSSS Parameter Set element	As defined in 9.4.2.4	The parameter sets relevant to the PHY.
IBSS parameter set	IBSS Parameter Set element	As defined in 9.4.2.6	The parameter set for the IBSS, if BSS is an IBSS.
NAVSyncDelay	Integer	N/A	Delay (in microseconds) to be used, while the STA is a member of this BSS, prior to transmitting when changing from doze to awake state, if no frame is detected by which the NAV can be set.
CapabilityInformation	Capability Information field	As defined in 9.4.1.4	The STA capabilities to be advertised for the BSS.
BSSBasicRateSet	Set of integers	Non-DMG BSS: a value in both dot11SupportedDataRatesRxTable and dot11SupportedDataRatesTxTable for each member of the set	Non-DMG BSS: The set of data rates (in units of 500 kb/s) that all STAs in the BSS are able to use for communication. All STAs in the BSS, including the STA that is starting the BSS, are able to receive and transmit at each of the data rates listed in the set. DMG BSS: Empty.
OperationalRateSet	Non-DMG BSS: Set of integers DMG BSS: Set of numbers	Non-DMG BSS: a value in dot11SupportedDataRatesRxTable for each member of the set DMG BSS: 0-12, 9.1, 12.1-12.6, or 25-31, for each member of the set	Non-DMG BSS: The set of data rates (in units of 500 kb/s) that the STA is able to use for communication within the BSS. The STA is able to receive at each of the data rates listed in the set. This set is a superset of the rates contained in the BSSBasicRateSet parameter. DMG BSS: The set of MCS indexes that the STA uses for communication within the BSS.
Country	As defined in the Country element	As defined in the Country element	The information required to identify the regulatory domain in which the STA is located and to configure its PHY for operation in that regulatory domain. Present if TPC functionality is required, as specified in 11.7 or dot11MultiDomainCapabilityActivated is true; otherwise not present.
IBSS DFS Recovery Interval	Integer	1–255	The time interval that is used for DFS recovery. Present if DFS functionality is required, as specified in 11.8 and BSSType = INDEPENDENT; otherwise not present.
EDCAParameterSet (QoS only)	EDCA Parameter Set element	As defined in 9.4.2.28	The initial EDCA parameter set values to be used in the BSS. The parameter is present if dot11QosOptionImplemented is true and dot11MeshActivated is true; otherwise not present.
DSERegisteredLocation	As defined in the DSE Registered Location element	As defined in 9.4.2.51	The information for the DSE Registered Location element. The parameter is present if dot11LCIDSERequired is true.

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Name	Type	Valid range	Description
HT Capabilities	As defined in frame format HT Capabilities element	As defined in 9.4.2.55; the HT-MCSs in the element are present in dot11SupportedHTMCSRxTable and the highest supported data rate in the element does not exceed dot11HighestSupportedDataRate	The STA's HT capabilities to be advertised for the BSS. The parameter is present if dot11HighThroughputOptionImplemented is true; otherwise, this parameter is not present.
HT Operation	As defined in frame format HT Operation element	As defined in 9.4.2.56; the HT-MCSs in the element are present in both dot11SupportedHTMCSRxTable and dot11SupportedHTMCSTxTable	Provides additional information for operating the HT BSS. The parameter is present if dot11HighThroughputOptionImplemented is true; otherwise, this parameter is not present.
BSSMembershipSelectorSet	Set of integers	A value from Table 9-93 for each member of the set	The set of features that are supported by all STAs in the BSS, including the STA that is starting the BSS.
Extended Capabilities	As defined in frame format	As defined in 9.4.2.26	Specifies the parameters within the Extended Capabilities element to be advertised for the BSS.
20/40 BSS Coexistence	As defined in frame format	As defined in 9.4.2.59	Specifies the parameters within the 20/40 BSS Coexistence element that are indicated by the MAC entity. The parameter is present if dot112040BSSCoexistence-ManagementSupport is true.
Overlapping BSS Scan Parameters	As defined in frame format	As defined in 9.4.2.58	Specifies the parameters within the Overlapping BSS Scan Parameters element that are indicated by the MAC entity. This parameter is optionally present if dot11FortyMHzOptionImplemented is true; otherwise, it is not present.
MultipleBSSID	As defined in Multiple BSSID element in 9.4.2.45	As defined in Multiple BSSID element in 9.4.2.45	This element is optionally present when dot11RMMeasurementPilotActivated is a value between 2 and 7 and the AP is a member of a multiple BSSID set (see 11.10.14) with two or more members, or if dot11MultiBSSIDImplemented is true. This element is present when dot11FILSActivated is true and the AP is a member of a Multiple BSSID Set with two or more members.
InterworkingInfo	As defined in frame format	As defined in Interworking element in 9.4.2.91	Specifies the Interworking capabilities of STA. This field is present when dot11InterworkingServiceActivated is true.
AdvertisementProtocolInfo	Integer or Sequence of integers	As defined in Advertisement Protocol element in Table 9-237	Identifies zero or more advertisement protocols and advertisement control to be used in the BSSs. This field is present when dot11InterworkingServiceActivated is true.
RoamingConsortiumInfo	As defined in frame format	As defined in roaming consortium element in 9.4.2.95	Specifies identifying information for SSPs whose security credentials can be used to authenticate with the AP. This field is optionally present when dot11InterworkingServiceActivated is true.

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Name	Type	Valid range	Description
Mesh ID	Octet string	0–32 octets	The value of MeshID. This element is present if the BSSType = MESH; otherwise not present.
Mesh Configuration	As defined in frame format	As defined in 9.4.2.97	Specifies the configuration of the mesh STA. This element is present if the BSSType = MESH; otherwise not present.
QMFPolicy	QMF Policy element	As defined in 9.4.2.119	This element is present when dot11QMFActivated is true and BSSType = INFRASTRUCTURE or MESH, and it is not present otherwise. The element is provided by the SME to signal to the MLME the QMF policy to be used for this BSS.
DMG Capabilities	DMG Capabilities element	As defined in 9.4.2.127	Specifies the parameters within the DMG Capabilities element to be advertised for the BSS. The parameter is present if dot11DMGOptionImplemented is true and is absent otherwise.
Multi-band	Multi-band element	As defined in 9.4.2.138	Specifies the parameters within the Multi-band element that are supported by the MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise.
MMS	Multiple MAC Sublayers element	As defined in 9.4.2.152	Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity. The parameter is present if dot11MultipleMACActivated is true and is absent otherwise.
DMG Operation	DMG Operation element	As defined in 9.4.2.127	Provides additional information for operating the DMG BSS. The parameter is present if dot11DMGOptionImplemented is true and is absent otherwise.
Clustering Control	Clustering Control field	As defined in 9.3.4.2	Specifies the parameters within the Clustering Control field that are supported by the MAC entity. The parameter is present if dot11ClusteringActivated is true and is absent otherwise.
CBAP Only	Integer	0 or 1	Specifies the setting of the CBAP Only field as defined in 9.3.4.2
PCP Association Ready	Integer	0 or 1	Specifies the setting of the PCP Association Ready field as defined in 9.3.4.2
VHT Capabilities	As defined in VHT Capabilities element	As defined in 9.4.2.157; the VHT-MCSs in the element are present in dot11VHTRxVHTMCSMap/ dot11VHTTxVHTMCSMap and the highest supported data rates in the element do not exceed dot11VHTRxHighestDataRateSupported/ dot11VHTTxHighestDataRateSupported	Specifies the parameters in the VHT Capabilities element to be advertised for the BSS. The parameter is present if dot11VHTOptionImplemented is true and not present otherwise.

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Name	Type	Valid range	Description
VHT Operation	As defined in VHT Operation element	As defined in 9.4.2.158; the VHT-MCSs in the element are present in both dot11VHTRxVHTMCSMap and dot11VHTTxVHTMCSMap	Provides additional information for operating the VHT BSS. The parameter is present if dot11VHTOptionImplemented is true and not present otherwise.
Known OUIs	A set of OUIs, each of which is defined in 9.4.1.31	N/A	Zero or more OUIs that specify the OUIs considered known by the AP, in the context of determining if it should respond to certain Probe Request frames, as defined in 11.1.4.3.4.
S1G Capabilities	As defined in frame format	As defined in 9.4.2.200	Specifies the parameters in the S1G Capabilities element to be advertised for the BSS. The parameter is present if dot11S1GOptionImplemented is true; otherwise not present.
S1GOperation	As defined in frame format	As defined in 9.4.2.212	Provides additional information for operating the S1G BSS. The parameter is present if dot11S1GOptionImplemented is true; otherwise not present.
ShortBeaconPeriod	As defined in frame format	As defined in 9.4.2.197	Provides the short beacon period of the S1G BSS. The parameter is present if dot11ShortBeaconInterval is true; otherwise not present.
ShortBeaconDTIMPeriod	As defined in frame format	As defined in 9.4.2.5	Provides the DTIM period (in short beacon periods) of the S1G BSS. The parameter is present if dot11ShortBeaconInterval is true; otherwise not present.
CDMG Capabilities	CDMG Capabilities element	As defined in 9.4.2.219	Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CDMGOptionImplemented is true.
CMMG Capabilities	CMMG Capabilities element	As defined in 9.4.2.229	Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true and is absent otherwise.
CMMG Operation	CMMG Operation element	As defined in 9.4.2.230.	Specifies the parameters within the CMMG Operation element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present.
ServiceHint	Service Hint element	As defined in 9.4.2.237	Provides an indication of the services advertised in Beacon and Probe Response frames. The element is optionally present if dot11UnsolicitedPADActivated is true and absent otherwise.
ServiceHash	Service Hash element	As defined in 9.4.2.238	Specifies services advertised in Beacon and Probe Response frames. The element is optionally present if dot11UnsolicitedPADActivated is true and absent otherwise.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.11.2.3 When generated

This primitive is generated by the SME to start an infrastructure BSS (with the MAC entity within an AP), an IBSS (with the MAC entity acting as the first STA in the IBSS), or an MBSS (with the MAC entity acting as the first mesh STA in the MBSS) or to become a member of an existing MBSS or a PBSS (with the MAC entity within a PCP). In an MBSS, this primitive starts the process of mesh beaconing.

The MLME-START.request primitive in an MBSS shall be generated before any synchronization or mesh peering have been attempted.

The MLME-START.request primitive shall not be used after successful use of the MLME-START.request primitive or successful use of the MLME-JOIN.request primitive without generating an intervening MLME-RESET.request primitive.

6.3.11.2.4 Effect of receipt

This primitive initiates the BSS initialization procedure once the current frame exchange sequence is complete. The MLME subsequently issues an MLME-START.confirm primitive that reflects the results of the creation procedure.

If the MLME of a non-DMG STA receives an MLME-START.request primitive with a BSSBasicRateSet parameter containing any unsupported rates, the MLME response in the resulting MLME-START.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of an HT STA receives an MLME-START.request primitive with the Basic HT-MCS Set field of the HT Operation parameter containing any unsupported MCSs, the MLME response in the resulting MLME-START.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of a VHT STA receives an MLME-START.request primitive with a Basic VHT-MCS And NSS Set field in the VHT Operation parameter containing any unsupported <VHT-MCS, NSS> tuple, the MLME response in the resulting MLME-START.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of a CMMG STA receives an MLME-START.request primitive with a Basic CMMG-MCS and NSS Set field in the CMMG Operation parameter containing any unsupported <CMMG-MCS, NSS> tuple, the MLME response in the resulting MLME-START.confirm primitive contains a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of a DMG STA receives an MLME-START.request primitive with a BSSBasicRateSet parameter containing any rates, or with the OperationalRateSet parameter containing any unsupported MCSs, the MLME response in the resulting MLME-START.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of an S1G STA receives an MLME-START.request primitive with a Basic S1G-MCS and NSS Set field in the S1GOperation parameter containing any unsupported <S1G-MCS, NSS> tuple, the MLME response in the resulting MLME-START.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

6.3.11.3 MLME-START.confirm

6.3.11.3.1 Function

This primitive reports the results of a BSS creation procedure or a procedure to become a member of an MBSS.

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6.3.11.3.2 Semantics of the service primitive

The primitive parameter is as follows:

MLME-START.confirm(
ResultCode
)

Name	Type	Valid range	resetDescription
ResultCode	Enumeration	SUCCESS, BSS_ALREADY_STARTED_OR_JOINED, RESET_REQUIRED_BEFORE_ START, NOT_SUPPORTED	Indicates the result of the MLME-START.request primitive.

6.3.11.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-START.request primitive to create a new BSS or to become a member of an MBSS.

6.3.11.3.4 Effect of receipt

The SME is notified of the results of the BSS creation procedure or a procedure to become a member of an MBSS.

6.3.12 Stop

6.3.12.1 General

This mechanism supports the process of terminating an existing BSS.

6.3.12.2 MLME-STOP.request

6.3.12.2.1 Function

This primitive requests that the MAC entity stop a BSS previously started by using an MLME-START.request primitive

6.3.12.2.2 Semantics of the service primitive

The primitive parameter is as follows:

MLME-STOP.request(
SSID
)

Name	Type	Valid range	Description
SSID	Octet string	0–32 octets	The SSID of the BSS to be stopped.

6.3.12.2.3 When generated

This primitive is generated by the SME to terminate an infrastructure BSS (with the MAC entity within an AP) or a PBSS (with the MAC entity within the PCP). The MLME-STOP.request primitive shall be generated only after successful use of an MLME-START.confirm primitive.

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The MLME-STOP termination procedure does not reset the MAC to initial conditions. An MLME-RESET.request primitive shall be issued prior to use of the MLME-START.request primitive and subsequent to the use of an MLME-STOP.request primitive.

The SME should notify associated non-AP STAs of imminent infrastructure BSS termination before issuing the MLME-STOP.request primitive. This can be done with the BSS transition management procedure, using the Termination information.

6.3.12.2.4 Effect of receipt

This primitive initiates the termination of the BSS. All services provided by the AP to an infrastructure BSS, including Beacon and Probe Response frame transmissions and access to the DS, are stopped by the termination. All STAs in an infrastructure BSS are deauthenticated by the termination. In a PBSS, all of the services provided by the PCP, including DMG Beacon frames, are stopped by the termination. All of the STAs in a PBSS have their RSNA unestablished by the termination.

6.3.13 Protocol layer model for spectrum management and radio measurement

The layer management extensions for measurement, TPC, and channel switching assume a certain partition of functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 6-2).

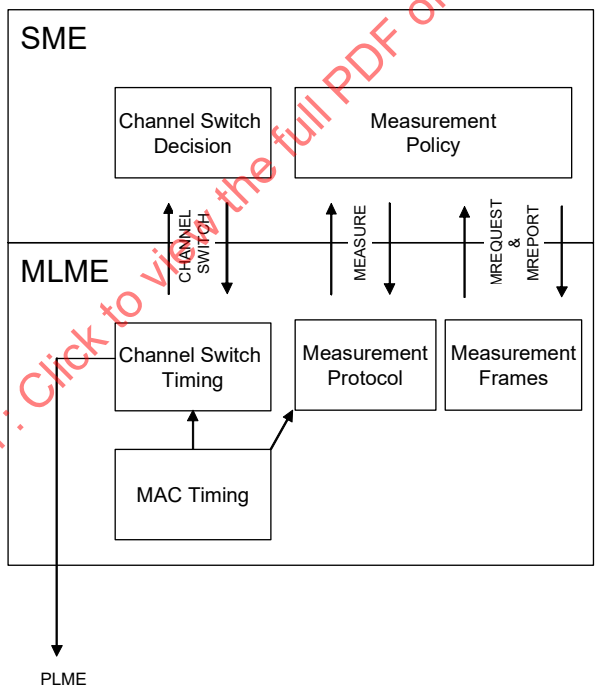

Figure 6-2—Layer management model

The diagrams within this subclause further illustrate the protocol layer model adopted. Figure 6-3 and Figure 6-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 6-5 illustrates the TPC adaptation process. Lastly, Figure 6-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.

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Note that these diagrams are intended as examples and do not depict all possible protocol scenarios, e.g., a measurement request may result in more than one Spectrum or Radio Measurement Report frame as described in 11.8.7 and 11.10.

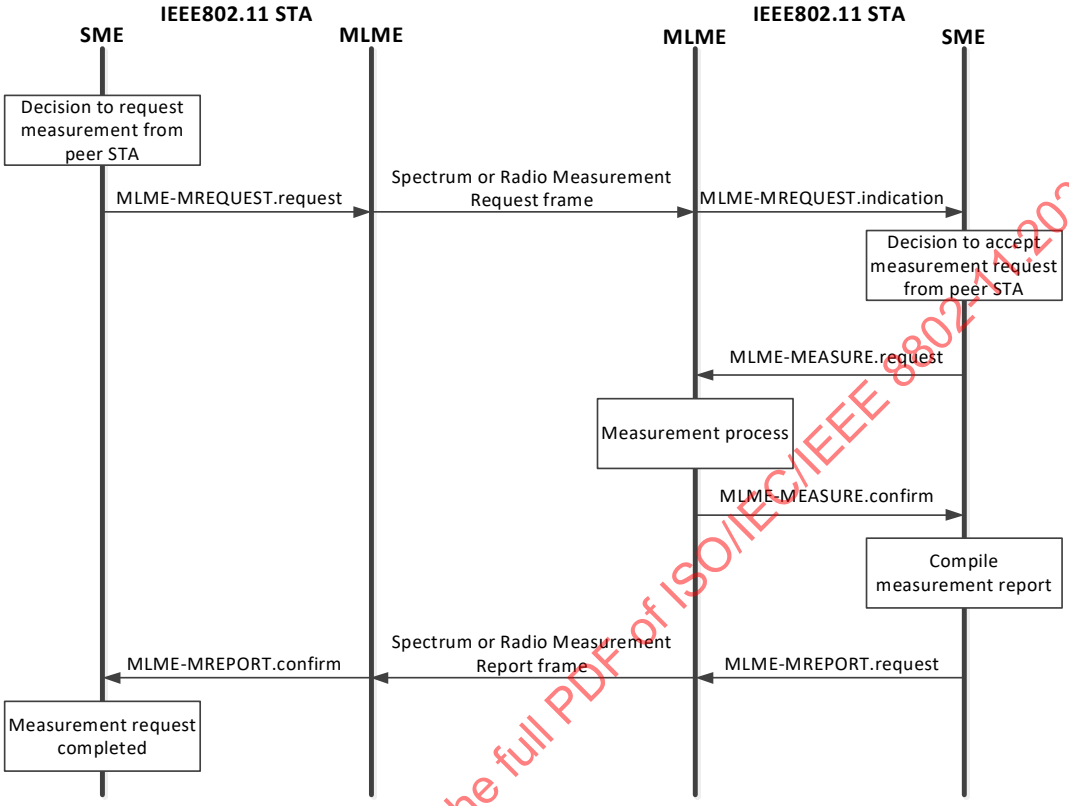

Figure 6-3—Measurement request—accepted

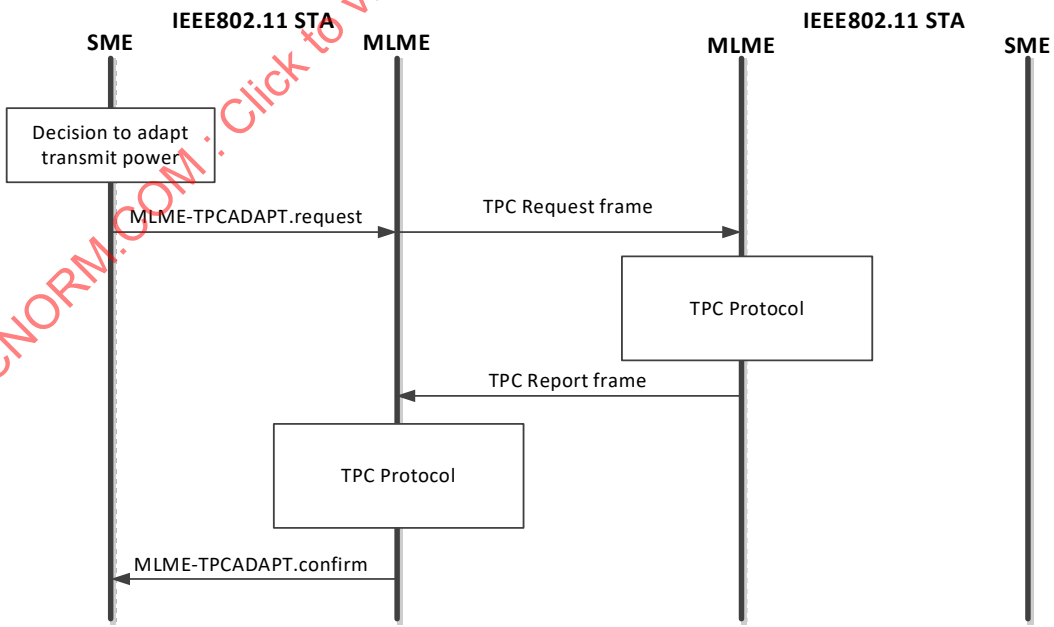

Figure 6-5—TPC adaptation

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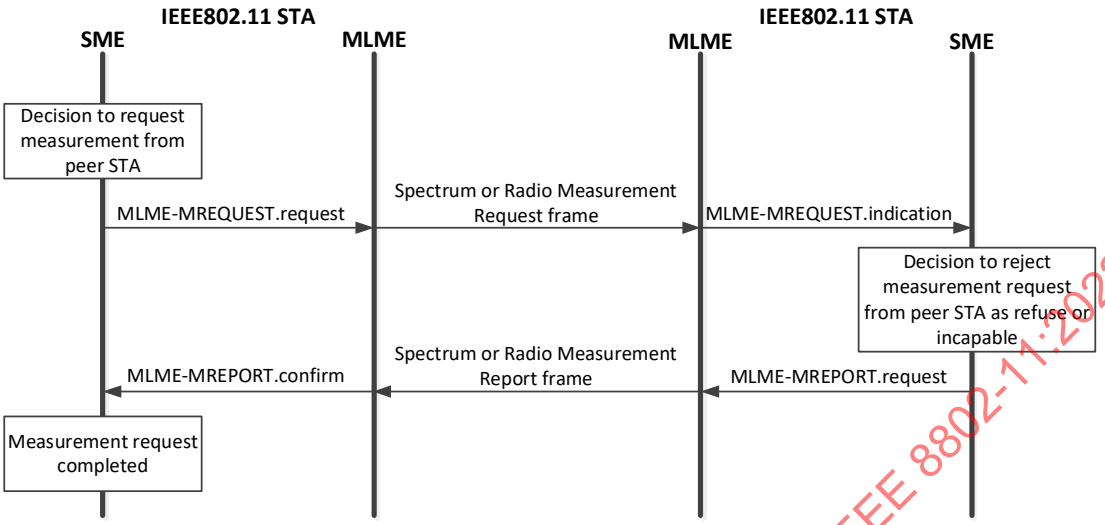

Figure 6-4—Measurement request—rejected

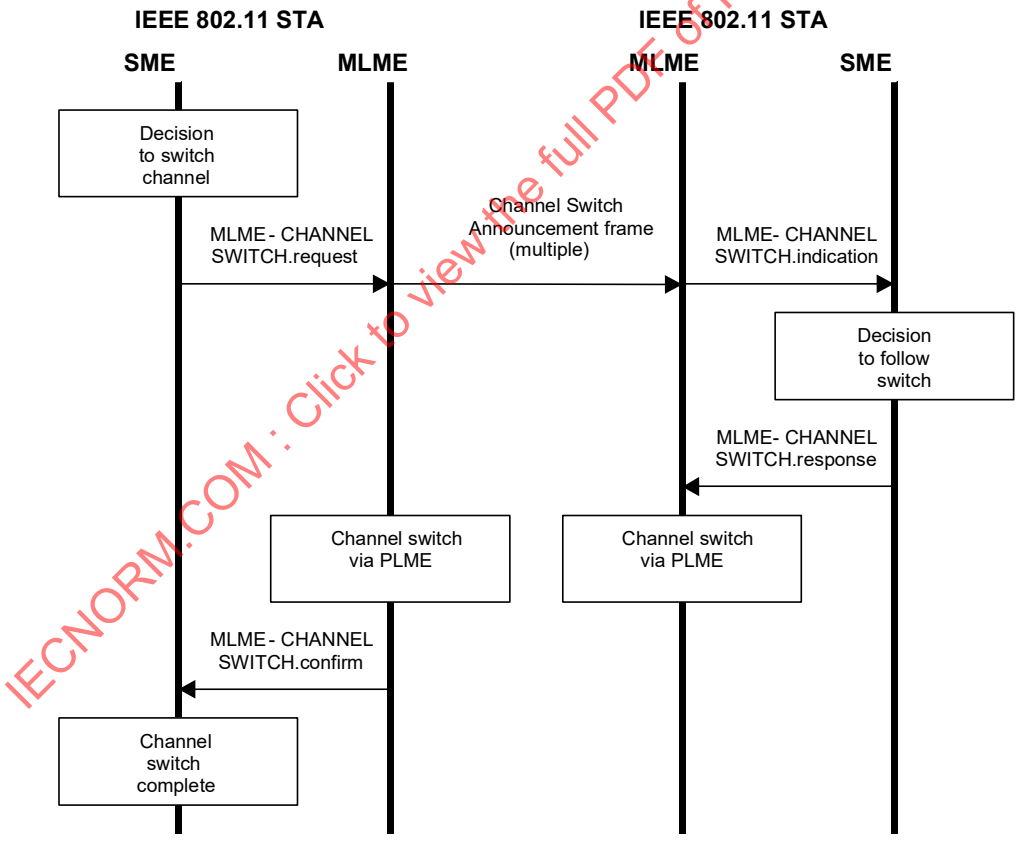

Figure 6-6—Channel switching

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6.3.14 Measurement request

6.3.14.1 Introduction

This set of primitives supports the signaling of measurement requests between peer SMEs.

6.3.14.2 MLME-MREQUEST.request

6.3.14.2.1 Function

This primitive requests the transmission of a measurement request to a peer entity.

6.3.14.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MREQUEST.request(
Peer MAC Address,
Dialog Token,
Measurement Request Set,
Number of Repetitions,
Measurement Category,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual or group MAC address	The address of the peer MAC entity to which the measurement request is transmitted.
Dialog Token	Integer	1–255	The dialog token to identify the measurement transaction.
Measurement Request Set	Set of measurement requests, each as defined in the Measurement Request element format	Set of measurement requests, each as defined in 9.4.2.20	A set of measurement requests, each containing a measurement token, measurement request mode, measurement type, and measurement request.
Number of Repetitions	Integer	0–65 535	The number of times the Measurement Request Set is to be repeated. The parameter is present if Measurement Category is Radio Measurement and dot11RadioMeasurementActivated is true; otherwise not present.
Measurement Category	Enumeration	SPECTRUM MANAGEMENT, or RADIO MEASUREMENT	Indicates whether the contents of the Measurement Report Set parameter is a set of Spectrum Management requests or a set of Radio Measurement requests. The parameter is present if dot11RadioMeasurementActivated is true; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.14.2.3 When generated

This primitive is generated by the SME to request that a Spectrum or Radio Measurement Request frame be sent to a peer entity to initiate one or more measurements.

6.3.14.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Spectrum or Radio Measurement Request frame containing the set of Measurement Request elements specified. This frame is then scheduled for transmission.

6.3.14.3 MLME-MREQUEST.indication

6.3.14.3.1 Function

This primitive indicates that a Spectrum or Radio Measurement Request frame has been received requesting the measurement of one or more channels.

6.3.14.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MREQUEST.indication(
Peer MAC Address,
Dialog Token,
Measurement Request Set,
Number of Repetitions,
Measurement Category,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the measurement request was received.
Dialog Token	Integer	1–255	The dialog token to identify the measurement transaction.
Measurement Request Set	Set of measurement requests, each as defined in the Measurement Request element format	Set of measurement requests, each as defined in 9.4.2.20	A set of measurement requests, each containing a Measurement Token, Measurement Request Mode, Measurement Type, and Measurement Request.
Number of Repetitions	Integer	0–65 535	The number of times the Measurement Request Set is to be repeated. The parameter is present if Measurement Category is Radio Measurement and dot11RadioMeasurementActivated is true; otherwise not present.
Measurement Category	Enumeration	SPECTRUM MANAGEMENT, or RADIO MEASUREMENT	Indicates whether the contents of the Measurement Report Set parameter is a set of Spectrum Management requests or a set of Radio Measurement requests. The parameter is present if dot11RadioMeasurementActivated is true; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.14.3.3 When generated

This primitive is generated by the MLME when a Spectrum or Radio Measurement Request frame is received.

6.3.14.3.4 Effect of receipt

On receipt of this primitive, the SME either rejects the request or commences the requested measurements.

6.3.15 Channel measurement

6.3.15.1 Introduction

This set of primitives supports the requesting and reporting of measurement data.

6.3.15.2 MLME-MEASURE.request

6.3.15.2.1 Function

This primitive is generated by the SME to request that the MLME initiate specified measurements.

6.3.15.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MEASURE.request(
Dialog Token,
Measurement Request Set
)

Name	Type	Valid range	Description
Dialog Token	Integer	0–255	The dialog token to identify the measurement transaction.
Measurement Request Set	Set of measurement requests, each as defined in the Measurement Request element	Set of measurement requests, each as defined in 9.4.2.20	A set of measurement requests, each containing a Measurement Token, Measurement Request Mode, Measurement Type, and Measurement Request.

6.3.15.2.3 When generated

This primitive is generated by the SME to request that the MLME initiate the specified measurements.

6.3.15.2.4 Effect of receipt

On receipt of this primitive, the MLME commences the measurement process.

6.3.15.3 MLME-MEASURE.confirm

6.3.15.3.1 Function

This primitive reports the result of a measurement.

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6.3.15.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MEASURE.confirm(
Dialog Token,
Measurement Report Set,
)

Name	Type	Valid range	Description
Dialog Token	Integer	0–255	The dialog token to identify the measurement transaction.
Measurement Report Set	Set of measurement reports, each as defined in the Measurement Report element	Set of measurement reports, each as defined in 9.4.2.21	A set of measurement reports, each containing a Measurement Token, Measurement Report Mode, Measurement Type, and Measurement Report.

6.3.15.3.3 When generated

This primitive is generated by the MLME to report the results when a measurement set completes.

6.3.15.3.4 Effect of receipt

On receipt of this primitive, the SME evaluates the result code and, if appropriate, stores the channel measurements pending communication to the requesting entity or for local use.

6.3.16 Measurement report

6.3.16.1 Introduction

This set of primitives supports the signaling of measurement reports.

6.3.16.2 MLME-MREPORT.request

6.3.16.2.1 Function

This primitive supports the signaling of measurement reports between peer SMEs.

6.3.16.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MREPORT.request(
Peer MAC Address,
Dialog Token,
Measurement Report Set,
Measurement Category,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the measurement report is sent.
Dialog Token	Integer	0–255	The dialog token to identify the measurement transaction. Set to 0 for an autonomous report.
Measurement Report Set	Set of measurement reports, each as defined in the Measurement Report element format	Set of measurement reports, each as defined in 9.4.2.21	A set of measurement reports, each containing a Measurement Token, Measurement Report Mode, Measurement Type, and Measurement Report.
Measurement Category	Enumeration	SPECTRUM MANAGEMENT, or RADIO MEASUREMENT	Indicates whether the Measurement Report Set is a set of Spectrum Management or Radio Measurement reports. The parameter is present if dot11RadioMeasurementActivated is true; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.16.2.3 When generated

This primitive is generated by the SME to request that a frame be sent to a peer entity to report the results of measuring one or more channels.

6.3.16.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Spectrum or Radio Measurement Report frame containing the set of measurement reports. This frame is then scheduled for transmission.

6.3.16.3 MLME-MREPORT.indication

6.3.16.3.1 Function

This primitive indicates that a Spectrum or Radio Measurement Report frame has been received from a peer entity. This management report is either a response to an earlier measurement request (e.g., MLME-MREQUEST.request primitive) or an autonomous report.

6.3.16.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MREPORT.indication(
Peer MAC Address,
Dialog Token,
Measurement Report Set,
Measurement Category,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the Spectrum or Radio Measurement Report frame was received.
Dialog Token	Integer	0–255	The dialog token to identify the measurement transaction. Set to 0 for an autonomous report.
Measurement Report Set	Set of measurement reports, each as defined in the Measurement Report element format	Set of measurement reports, each as defined in 9.4.2.21	A set of measurement reports, each containing a Measurement Token, Measurement Report Mode, Measurement Type, and Measurement Report.
Measurement Category	Enumeration	SPECTRUM MANAGEMENT, or RADIO MEASUREMENT	Indicates whether the Measurement Report Set is a set of Spectrum Management or Radio Measurement reports. The parameter is present if dot11RadioMeasurementActivated is true; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.16.3.3 When generated

This primitive is generated by the MLME when a Spectrum or Radio Measurement Report frame is received.

6.3.16.3.4 Effect of receipt

On receipt of this primitive, measurement data might be available for SME processes, such as channel selection.

6.3.17 Channel switch

6.3.17.1 MLME-CHANNELSWITCH.request

6.3.17.1.1 Function

This primitive requests a switch to a new operating channel.

6.3.17.1.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-CHANNELSWITCH.request(
Mode,
Channel Number,
Secondary Channel Offset,
Channel Switch Count,
Mesh Channel Switch Parameters,
Wide Bandwidth Channel Switch,
New Transmit Power Envelope,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
Mode	Integer	0, 1	Channel switch mode, as defined for the Channel Switch Announcement element.
Channel Number	Integer	As defined in 17.3.8.4.3	Specifies the new channel number.
Secondary Channel Offset	Integer	As in Table 9-96	Specifies the position of secondary channel in relation to the primary channel. The parameter is present if dot11FortyMHzOperationImplemented is true; otherwise, the parameter is not present.
Channel Switch Count	As defined in 9.4.2.18	As defined in 9.4.2.18	Specifies the time period until the channel switch event, as described in 9.4.2.18.
Mesh Channel Switch Parameters	As defined in 9.4.2.102	As defined in 9.4.2.102	Specifies MBSS Channel Switch Parameters used by a mesh STA. This parameter is present if dot11MeshActivated is true; otherwise, the parameter is not present.
Wide Bandwidth Channel Switch	As defined in 9.4.2.160	As defined in 9.4.2.160	Specifies channel parameters used when switching to a channel width wider than 40 MHz. The parameter is present if dot11VHTOptionImplemented is true and switching to a channel width wider than 40 MHz; otherwise, the parameter is not present.
New Transmit Power Envelope	Set of New Transmit Power Envelope elements	N/A	Specifies power parameters used for the BSS after the channel switch. Optionally present if dot11VHTOptionImplemented is true.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.17.1.3 When generated

This primitive is generated by the SME to schedule a channel switch and announce this switch to peer entities in the BSS.

6.3.17.1.4 Effect of receipt

On receipt of this primitive, the MLME schedules the channel switch event and announces this switch to other STAs in the BSS using the Channel Switch Announcement frame or element. The MLME sets the timing of the frame transmission taking into account the activation delay.

6.3.17.2 MLME-CHANNELSWITCH.confirm

6.3.17.2.1 Function

This primitive reports the result of a request to switch channel.

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6.3.17.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-CHANNELSWITCH.confirm(
ResultCode,
VendorSpecificInfo
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, UNSPECIFIED_FAILURE	Reports the result of a channel switch request.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.17.2.3 When generated

This primitive is generated by the MLME when a channel switch request completes. Possible unspecified failure causes include an inability to schedule a channel switch announcement.

6.3.17.2.4 Effect of receipt

The SME is notified of the results of the channel switching procedure.

6.3.17.3 MLME-CHANNELSWITCH.indication

6.3.17.3.1 Function

This primitive indicates that a channel switch announcement has been received from a peer entity.

6.3.17.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-CHANNELSWITCH.indication(
Peer MAC Address,
Mode,
Channel Number,
Secondary Channel Offset,
Channel Switch Count,
Mesh Channel Switch Parameters,
Wide Bandwidth Channel Switch,
New Transmit Power Envelope,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the Channel Switch Announcement frame was received.
Mode	Integer	0, 1	Channel switch mode, as defined for the Channel Switch Announcement element.
Channel Number	Integer	As defined in 17.3.8.4.3	Specifies the new channel number.

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Name	Type	Valid range	Description
Secondary Channel Offset	Integer	As in Table 9-96	Specifies the position of secondary channel in relation to the primary channel. The parameter is optionally present if dot11FortyMHzOperationImplemented is true; otherwise not present.
Channel Switch Count	As defined in 9.4.2.18	As defined in 9.4.2.18	Specifies the time period until the channel switch event, as described in 9.4.2.18.
Mesh Channel Switch Parameters	As defined in 9.4.2.102	As defined in 9.4.2.102	Specifies MBSS Channel Switch Parameters used by a mesh STA. This parameter is present if dot11MeshActivated is true; otherwise, the parameter is not present.
Wide Bandwidth Channel Switch	As defined in 9.4.2.160	As defined in 9.4.2.160	Specifies channel parameters used when switching to a channel width wider than 40 MHz. The parameter is present if dot11VHTOptionImplemented is true and switching to a channel width wider than 40 MHz; otherwise, the parameter is not present.
New Transmit Power Envelope	Set of New Transmit Power Envelope elements	N/A	Specifies power parameters used for the BSS after the channel switch. Optionally present if dot11VHTOptionImplemented is true.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.17.3.3 When generated

This primitive is generated by the MLME when a Channel Switch Announcement frame is received.

6.3.17.3.4 Effect of receipt

On receipt of this primitive, the SME decides whether to accept the switch.

6.3.17.4 MLME-CHANNELSWITCH.response

6.3.17.4.1 Function

This primitive is used to schedule an accepted channel switch.

6.3.17.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-CHANNELSWITCH.response(
Mode,
Channel Number,
Secondary Channel Offset,
Channel Switch Count,
Mesh Channel Switch Parameters,
Wide Bandwidth Channel Switch,
New Transmit Power Envelope,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
Mode	Integer	0, 1	Channel switch mode, as defined for the Channel Switch Announcement element.
Channel Number	Integer	As defined in 17.3.8.4.3	Specifies the new channel number.
Secondary Channel Offset	Integer	As in Table 9-96	Specifies the position of secondary channel in relation to the primary channel. The parameter is optionally present if dot11FortyMHzOperationImplemented is true; otherwise not present.
Channel Switch Count	As defined in 9.4.2.18	As defined in 9.4.2.18	Specifies the time period until the channel switch event, as described in 9.4.2.18.
Mesh Channel Switch Parameters	As defined in 9.4.2.102	As defined in 9.4.2.102	Specifies MBSS Channel Switch Parameters used by a mesh STA. This parameter is present if dot11MeshActivated is true; otherwise, the parameter is not present.
Wide Bandwidth Channel Switch	As defined in 9.4.2.160	As defined in 9.4.2.160	Specifies channel parameters used when switching to a channel width wider than 40 MHz. The parameter is present if dot11VHTOptionImplemented is true and switching to a channel width wider than 40 MHz; otherwise, the parameter is not present.
New Transmit Power Envelope	Set of New Transmit Power Envelope elements	N/A	Specifies power parameters used for the BSS after the channel switch. Optionally present if dot11VHTOptionImplemented is true.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.17.4.3 When generated

This primitive is generated by the SME to schedule an accepted channel switch request.

6.3.17.4.4 Effect of receipt

On receipt of this primitive, the MLME schedules the channel switch.

6.3.18 TPC request

6.3.18.1 Introduction

This set of primitives supports the adaptation of transmit power between peer entities as described in 11.7.7.

6.3.18.2 MLME-TPCADAPT.request

6.3.18.2.1 Function

This primitive supports the adaptation of transmit power between peer entities as specified in 11.7.7.

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6.3.18.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TPCADAPT.request(
Peer MAC Address,
Dialog Token,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual or group MAC address	The address of the peer MAC entity to which the TPC request is sent.
Dialog Token	Integer	1–255	The dialog token to identify the TPC transaction.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.18.2.3 When generated

This primitive is generated by the SME to request that a TPC Request frame be sent to a peer entity to request that entity to report transmit power and link margin information.

6.3.18.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TPC Request frame. This frame is then scheduled for transmission.

6.3.18.3 MLME-TPCADAPT.confirm

6.3.18.3.1 Function

This primitive reports the result of the TPC adaptation procedure.

6.3.18.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TPCADAPT.confirm(
ResultCode
Transmit Power,
Link Margin,
Rate,
VendorSpecificInfo
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, UNSPECIFIED_FAILURE	Reports the outcome of a request to send a TPC Request frame.
Transmit Power	Integer	–127 to 127	Value of the Transmit Power field of the TPC Report element of the TPC Report frame.
Link Margin	Integer	–127 to 127	Value of the Link Margin field of the TPC Report element of the TPC Report frame.

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Name	Type	Valid range	Description
Rate	Integer	As defined in 9.4.2.3	The rate at which the TPC Request frame was sent.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.18.3.3 When generated

This primitive is generated by the MLME when the TPC adaptation procedure completes.

6.3.18.3.4 Effect of receipt

The SME is notified of the results of the TPC adaptation procedure.

6.3.19 SetKeys

6.3.19.1 MLME-SETKEYS.request

6.3.19.1.1 Function

This primitive causes the keys identified in the parameters of the primitive to be set in the MAC and enabled for use.

6.3.19.1.2 Semantics of the service primitive

The primitive parameter is as follows:

MLME-SETKEYS.request(
Keylist
)

Name	Type	Valid range	Description
Keylist	A set of SetKeyDescriptors	N/A	The list of keys to be used by the MAC.

Each SetKeyDescriptor consists of the following parameters:

Name	Type	Valid range	Description
Key	Bit string	N/A	The temporal key value
Length	Integer	N/A	The number of bits in the Key to be used.
Key ID	Integer	0–3 shall be used with WEP, TKIP, CCMP, and GCMP; 4–5 with BIP for IGTK; 6-7 with BIP for BIGTK; and 8–4095 are reserved	Key identifier
Key Type	Enumeration	Group, Pairwise, PeerKey, IGTK, BIGTK	Defines whether this key is a group key, pairwise key, PeerKey, integrity group key, or beacon protection key.

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Name	Type	Valid range	Description
Address	MAC address	Any valid individual MAC address	This parameter is valid only when the Key Type value is Pairwise, when the Key Type value is Group and the STA is in IBSS, or when the Key Type value is PeerKey.
Receive Sequence Count	8 octets	N/A	Value to which the RSC(s) is initialized. This parameter is valid only when the Key Type is Group, IGTK, or BIGTK.

6.3.19.1.3 When generated

This primitive is generated by the SME at any time when one or more keys are to be set in the MAC.

6.3.19.1.4 Effect of receipt

When the Key Type is Group, IGTK, or BIGTK, and the key matches the GTK, IGTK, or BIGTK, if any, installed as a result of EAPOL-Key frames (see 12.7.7.4) or exiting WNM sleep mode (see 11.2.3.16.1) receipt of this primitive shall have no effect. Otherwise, receipt of this primitive causes the MAC to apply the keys as follows, subject to the MLME-SETPROTECTION.request primitive:

— The MAC uses the key information (as defined by the Key Type, Key ID, and Address parameters) for the transmission of subsequent frames to which the key applies (as defined by the Key Type, Key ID and Address parameters).

— The MAC installs the key with the associated Key ID such that received frames for that cipher, of the appropriate type, and containing the matching Key ID are processed using that key and its associated state information, subject to validation based on the Receive Sequence Count, if applicable.

— When the Key, Address, Key Type, and Key ID parameters identify a new key to be set, the MAC initializes the transmitter TSC/PN/IPN/BIPN counter to 0. When the Key, Address, Key Type, and Key ID parameters identify an existing key, the MAC shall not change the current transmitter TSC/PN/IPN/BIPN counter or the receiver replay counter values associated with that key.

6.3.20 DeleteKeys

6.3.20.1 MLME-DELETEKEYS.request

6.3.20.1.1 Function

This primitive causes the keys identified in the parameters of the primitive to be deleted from the MAC and thus disabled for use.

6.3.20.1.2 Semantics of the service primitive

The primitive parameter is as follows:

MLME-DELETEKEYS.request(
Keylist
)

Name	Type	Valid range	Description
Keylist	A set of DeleteKeyDescriptors	N/A	The list of keys to be deleted from the MAC.

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Each DeleteKeyDescriptor consists of the following parameters:

Name	Type	Valid range	Description
Key ID	Integer	0–3 shall be used with WEP, TKIP, CCMP, and GCMP; 4–5 with BIP for IGTK; 6-7 with BIP for BIGTK; and 8–4095 are reserved	Key identifier.
Key Type	Enumeration	Group, Pairwise, PeerKey, IGTK, BIGTK	Defines whether this key is a group key, pairwise key, PeerKey, integrity group key, or beacon protection key.
Address	MAC address	Any valid individual MAC address	This parameter is valid only when the Key Type value is Pairwise, or when the Key Type value is Group and is from an IBSS STA, or when the Key Type value is PeerKey.

6.3.20.1.3 When generated

This primitive is generated by the SME at any time when keys for a security association are to be deleted in the MAC.

6.3.20.1.4 Effect of receipt

Receipt of this primitive causes the MAC to delete all the temporal keys identified by each DeleteKeyDescriptor in the Keylist (as defined by the Key Type, Key ID and Address parameters), and to cease using them.

6.3.21 MIC (michael) failure event

6.3.21.1 MLME-MICHAELMICFAILURE.indication

6.3.21.1.1 Function

This primitive reports that a MIC failure event was detected.

6.3.21.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MICHAELMICFAILURE.indication (
                                    Count,
                                    Address,
                                    Key Type,
                                    Key ID,
                                    TSC
                                    )
```

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Name	Type	Valid range	Description
Count	Integer	1 or 2	The current number of MIC failure events.
Address	MAC address	Any valid individual MAC address	The source MAC address of the frame.
Key Type	Enumeration	Group, Pairwise, PeerKey	The key type that the received frame used.
Key ID	Integer	0–3	Key identifier.
TSC	6 octets	N/A	The TSC value of the frame that generated the MIC failure.

6.3.21.1.3 When generated

This primitive is generated by the MAC when it has detected a MIC failure.

6.3.21.1.4 Effect of receipt

The SME is notified that the MAC has detected a MIC failure; see 12.5.2.4.

6.3.22 EAPOL

6.3.22.1 MLME-EAPOL.request

6.3.22.1.1 Function

This primitive is generated by the SME when the SME has an EAPOL-Key frame to send.

6.3.22.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-EAPOL.request (
                    Source Address,
                    Destination Address,
                    Data
                    )
```

Name	Type	Valid range	Description
Source Address	MAC address	N/A	The MAC sublayer address from which the EAPOL PDU is being sent.
Destination Address	MAC address	N/A	The MAC sublayer entity address to which the EAPOL PDU is being sent.
Data	EAPOL PDU (as defined in Clause 11 of IEEE Std 802.1X-2010)	N/A	The EAPOL PDU to be transmitted.

6.3.22.1.3 When generated

This primitive is generated by the SME when the SME has a EAPOL-Key frame to send.

6.3.22.1.4 Effect of receipt

The MAC sends this EAPOL-Key frame.

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6.3.22.2 MLME-EAPOL.confirm

6.3.22.2.1 Function

This primitive indicates that this EAPOL-Key frame has been transmitted by the MAC.

6.3.22.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EAPOL.confirm (
ResultCode
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, TRANSMISSION_FAILURE	Indicates whether the EAPOL-Key frame has been transmitted to the target STA.

6.3.22.2.3 When generated

This primitive is generated by the MAC as a result of an MLME-EAPOL.request primitive being generated to send an EAPOL-Key frame.

6.3.22.2.4 Effect of receipt

The SME is always notified whether this EAPOL-Key frame has been transmitted to the IEEE 802.11 MAC.

This primitive communicates that the frame has been transmitted; see the procedures in 12.5.2.4.1.

6.3.23 SetProtection

6.3.23.1 MLME-SETPROTECTION.request

6.3.23.1.1 Function

This primitive indicates whether protection is required for frames sent to and received from the indicated MAC address.

6.3.23.1.2 Semantics of the service primitive

The primitive parameter is as follows:

MLME-SETPROTECTION.request(
Protectlist
)

Name	Type	Valid range	Description
Protectlist	A set of ProtectDescriptors	N/A	The list of how each key is being used currently.

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Each ProtectDescriptor consists of the following parameters:

Name	Type	Valid range	Description
Address	MAC address	Any valid individual MAC address	This parameter is valid only when the Key Type value is Pairwise or when the Key Type value is Group and is from an IBSS STA or PeerKey.
ProtectType	Enumeration	None, Rx, Tx, Rx_Tx	The protection value for this MAC.
Key Type	Enumeration	Group, Pairwise, PeerKey, IGTK, BIGTK	Defines whether this key is a group key, pairwise key, PeerKey, integrity group key, or beacon protection key.

6.3.23.1.3 When generated

This primitive is generated by the SME when protection is required for frames sent to and received from the indicated MAC address.

6.3.23.1.4 Effect of receipt

Receipt of this primitive causes the MAC to set the protection and to protect Data frames as indicated in the ProtectType parameter of the Protectlist parameter:

— None: Specifies that Data frames to and from the MAC address are not protected.
— Rx: Specifies that Data frames from the MAC address are protected (i.e., any Data frames without protection received from the MAC address are discarded) but Data frames to the MAC address are not protected.
— Tx: Specifies that Data frames to the MAC address are protected but Data frames from the MAC address are not protected.
— Rx_Tx: Specifies that Data frames to and from the MAC address are protected.

Once Data frames are protected to and/or from the specified MAC address, the MLME-SETPROTECTION.request primitive is used to reset the prior setting. Invocation of the MLME-SETPROTECTION.request primitive with a ProtectType of None deletes a protection state.

6.3.24 MLME-PROTECTEDFRAMEDROPPED

6.3.24.1 MLME-PROTECTEDFRAMEDROPPED.indication

6.3.24.1.1 Function

This primitive notifies the SME that a frame has been dropped because a temporal key was unavailable.

6.3.24.1.2 Semantics of the service primitive

This primitive has two parameters, the MAC addresses of the two STAs.

The primitive parameters are as follows:

```
MLME-PROTECTEDFRAMEDROPPED.indication (
                                        Address1,
                                        Address2
                                        )
```

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Name	Type	Valid range	Description
Address1	MAC address	Any valid individual MAC address	MAC address of TA.
Address2	MAC address	Any valid individual MAC address	MAC address of RA.

6.3.24.1.3 When generated

This primitive is generated by the MAC when a frame is dropped because no temporal key is available for the frame.

6.3.24.1.4 Effect of receipt

The SME is notified that a frame was dropped. The SME can use this information in an IBSS to initiate a security association to the peer STA.

6.3.25 TS management interface

6.3.25.1 General

This mechanism supports the process of adding, modifying, or deleting a TS in a BSS using the procedures defined in 11.4.

The primitives used for this mechanism are called *TS Management primitives*, which include MLME-ADDTS.xxx, MLME-DELTS.xxx, and MLME-ADDTSRESERVE.xxx primitives, where xxx denotes request, confirm, indication, or response. Each primitive contains parameters that correspond to a QoS Action frame. Requests and responses might cause the transmission of the corresponding QoS Action frames. Confirms and indications are issued upon the receipt of the appropriate QoS Action frame.

Table 6-1 defines which primitives are supported by which type of STA.

Table 6-1—Supported TS management primitives

Primitive	Request	Confirm	Indication	Response
ADDTS (in the context of establishing a TS)	DMG STA CMMG STA non-AP QoS STA	DMG STA CMMG STA non-AP QoS STA	DMG STA CMMG STA HC	DMG STA CMMG STA HC
ADDTS (in the context of requesting an allocation)	Non-AP and non-PCP DMG STA CMMG STA	Non-AP and non-PCP DMG STA CMMG STA	DMG AP or PCP CMMG AP or PCP	DMG AP or PCP CMMG AP or PCP
DELTS	DMG STA CMMG STA non-AP QoS STA HC	DMG STA CMMG STA non-AP QoS STA HC	DMG STA CMMG STA non-AP QoS STA HC	—
ADDTSRESERVE	HC	HC	non-AP QoS STA	non-AP QoS STA

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6.3.25.2 MLME-ADDTS.request

6.3.25.2.1 Function

This primitive requests addition (or modification) of a TS. It requests the HC or PCP to admit the new or changed TS.

6.3.25.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ADDTS.request (
DialogToken,
TSPEC,
TCLAS,
TCLASProcessing,
U-APSD Coexistence,
EBR,
IntraAccessCategoryPriority,
HigherLayerStreamID,
STAAddress,
DMG TSPEC,
CMMG TSPEC,
Multi-band,
U-PID,
MMS,
VendorSpecificInfo
)

Name	Type	Valid range	Description
DialogToken	Integer	0–127	Identifies the ADDTS transaction.
TSPEC	As defined in TSPEC element with the exception of the surplus bandwidth allowance, minimum PHY rate, and maximum and minimum SIs, which are optionally specified	As defined in 9.4.2.29 with the exception of the surplus bandwidth allowance, minimum PHY rate, and maximum and minimum SIs, which are optionally specified	Specifies the TSID, traffic characteristics, and QoS requirements of the TS of concern.
TCLAS	TCLAS element	As defined in 9.4.2.30	Zero or more TCLAS elements. Specifies the rules and parameters by which an MSDU may be classified to the specified TS.
TCLASProcessing	TCLAS Processing element	As defined in 9.4.2.32	Specifies how the TCLAS elements are to be processed when there are multiple TCLAS elements.
U-APSD Coexistence	U-APSD Coexistence element	As defined in 9.4.2.90.	Indicates the coexistence parameters for requested transmission during a U-APSD service period.

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Name	Type	Valid range	Description
EBR	Expedited Bandwidth Request element	As defined in 9.4.2.93	Specifies the precedence level of the TS request. This element is optionally present when dot11EBRActivated is true.
IntraAccessCategoryPriority	Intra-Access Category Priority element	As defined in 9.4.2.120	Specifies the intra-AC priorities the STA should use.
HigherLayerStreamID	Higher Layer Stream ID element	As defined in 9.4.2.124	Identifies the higher layer stream.
STAAddress	MAC address		Specifies the MAC address of the peer STA for a PTP TSPEC.
DMG TSPEC	DMG TSPEC element	As defined in 9.4.2.133	Specifies the characteristics and QoS (scheduling) requirements of the DMG allocation request.
CMMG TSPEC	CMMG TSPEC element	As defined in 9.4.2.134.	Specifies the characteristics and QoS scheduling requirements of the CMMG allocation request.
Multi-band	Multi-band element	As defined in 9.4.2.138	Specifies the frequency band and channel number where the TSID is to be established. The parameter is absent if the TSID is intended to be established on the same frequency band and channel where the ADDTS Request frame is transmitted.
U-PID	U-PID element	As defined in 9.4.2.153	This parameter is optionally present and specifies the parameters of the LLC for the purpose of (de)multiplexing of frames associated with the TSID.
MMS	Multiple MAC Sublayers element	As defined in 9.4.2.152	This parameter is optionally present and specifies the parameters of an MMSL cluster establishment.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.25.2.3 When generated

This primitive is generated by the SME to request the addition of a new (or modification of an existing) TS in order to support parameterized QoS transport of the MSDUs belonging to this TS when a higher layer protocol or mechanism signals the STA to initiate such an addition (or modification).

6.3.25.2.4 Effect of receipt

The STA operates according to the procedures defined in 11.4.

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6.3.25.3 MLME-ADDTS.confirm

6.3.25.3.1 Function

This primitive reports the results of a TS addition (or modification) attempt.

6.3.25.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ADDTS.confirm(
ResultCode,
DialogToken,
TSDelay,
TSPEC,
Schedule,
TCLAS,
TCLASProcessing,
EBR,
HigherLayerStreamID,
STAAddress,
DMG TSPEC,
CMMG TSPEC,
Multi-band,
U-PID,
MMS,
VendorSpecificInfo
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, REJECTED_WITH_SUGGESTED_CHANGES, REJECTED_FOR_DELAY_PERIOD, REJECTED_WITH_SUGGESTED_BSS_TRANSITION, REQUESTED_TCLAS_NOT_SUPPORTED, TCLAS_RESOURCES_EXHAUSTED, REJECTED_HOME_WITH_SUGGESTED_CHANGES, REJECTED_FOR_SSP_PERMISSIONS, SUCCESS_STA_IN_PS_MODE, REJECT_U-PID_SETTING	Indicates the results of the corresponding MLME-ADDTS.request primitive.
DialogToken	Integer	As defined in the corresponding MLME-ADDTS.request primitive	Identifies the ADDTS transaction.
TSDelay	Integer	≥ 0	When the result code is REJECTED_FOR_DELAY_PERIOD, provides the amount of time a STA should wait before attempting another ADDTS Request frame.
TSPEC	TSPEC element	As defined in 9.4.2.29	Specifies the TS information, traffic characteristics, and QoS requirements of the TS.

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Name	Type	Valid range	Description
Schedule	Schedule element	As defined in 9.4.2.33	Specifies the schedule information, service start time, SI, and the specification interval.
TCLAS	TCLAS element	As defined in 9.4.2.30	Zero or more TCLAS elements. Specifies the rules and parameters by which an MSDU may be classified to the specified TS.
TCLASProcessing	TCLAS Processing element	As defined in 9.4.2.32	Specifies how the TCLAS elements are to be processed when there are multiple TCLAS elements.
EBR	Expedited Bandwidth Request element	As defined in 9.4.2.93	Specifies the precedence level of the TS request. This element is optionally present when dot11EBRActivated is true.
HigherLayerStream ID	Higher Layer Stream ID element	As defined in 9.4.2.124	Identifies the higher layer stream.
STAAddress	MAC address		Specifies the MAC address of the peer STA for a PTP TSPEC.
DMG TSPEC	DMG TSPEC element	As defined in 9.4.2.133	Specifies the characteristics and QoS (scheduling) requirements of the DMG allocation request.
CMMG TSPEC	CMMG TSPEC element	As defined in 9.4.2.134.	Specifies the characteristics and QoS scheduling requirements of the CMMG allocation request.
Multi-band	Multi-band element	As defined in 9.4.2.138	Specifies the frequency band and channel number where the TSID is to be established. The parameter is absent if the TSID is intended to be established on the same frequency band and channel where the ADDTS Request frame is transmitted.
U-PID	U-PID element	As defined in 9.4.2.153	This parameter is optionally present and specifies the parameters of the LLC for the purpose of (de)multiplexing of frames associated with the TSID.
MMS	Multiple MAC Sublayers element	As defined in 9.4.2.152	This parameter is optionally present and specifies the parameters of an MMSL cluster establishment.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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For the ResultCode value of SUCCESS received by a non-DMG STA or a non-CMMG STA, the TSPEC and the optional TCLAS parameters describe the characteristics of the TS that has been created (or modified); and the specified (nonzero) parameters [with the exception of Service Start Time, Medium Time, and any possibly unspecified minimum set of parameters (see 10.23.4.3) in the TSPEC element in ADDTS Request frame] exactly match those of the matching MLME-ADDTS.request primitive.

For other values of ResultCode received by a non-DMG STA or a non-CMMG STA, no new TS has been created. In the case of REJECTED_WITH_ SUGGESTED_CHANGES, the TSPEC represents an alternative proposal by the HC based on information about the current status of the MAC entity. In the case of REJECTED_HOME_WITH_SUGGESTED_CHANGES, the TSPEC represents an alternative proposal by the HC based on information received from the SSPN interface. A TS is not created with this definition. If the suggested changes are acceptable to the STA, it is the responsibility of the STA to set up the TS with the suggested changes.

In the case of REJECTED_WITH_SUGGESTED_BSS_TRANSITION, non-AP STA should retry TS setup process with the newly associated AP once the transition is done.

If this is the result of a modification of an existing TS, the status of that TS remains unchanged.

For the ResultCode value of SUCCESS or SUCCESS_STA_IN_PS_MODE received by a DMG STA, the DMG TSPEC and the optional TCLAS parameters describe the characteristics of the allocation or TS that has been created (or modified); and the specified (nonzero) parameters [with the exception of Maximum Allocation in the DMG TSPEC in the ADDTS Request frame] exactly match those of the matching MLME-ADDTS.request primitive.

For other values of ResultCode received by a DMG STA, no new allocation or TS has been created. In the case of REJECTED_WITH_SUGGESTED_CHANGES or REJECT_U-PID_SETTING, then the DMG TSPEC, Multi-band, and U-PID parameters represent an alternative proposal by the peer STA. In such cases, an allocation or TS has not been created. If the suggested changes are acceptable to the STA, it is the responsibility of the STA to set up the allocation or TS with the suggested changes.

If this failure is the result of a modification of an existing allocation or TS, the status of that allocation or TS remains unchanged.

6.3.25.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-ADDTS.request primitive indicating the results of that request.

This primitive is generated when that MLME-ADDTS.request primitive is found to contain invalid parameters, when a timeout occurs, or when the STA receives a response in the form of an ADDTS Response frame in the corresponding QoS Action frame from the HC, DMG STA, or CMMG STA.

6.3.25.3.4 Effect of receipt

The SME is notified of the results of the TS addition (or modification) procedure.

The SME should operate according to the procedures defined in 11.4.

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6.3.25.4 MLME-ADDTS.indication

6.3.25.4.1 Function

This primitive reports to the DMG STA's SME, CMMG STA's SME, or the HC's SME the request for adding (or modifying) a TS.

6.3.25.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ADDTS.indication (
DialogToken,
STAAddress,
TSPEC,
TCLAS,
TCLASProcessing,
U-APSD Coexistence,
EBR,
IntraAccessCategoryPriority,
HigherLayerStreamID,
DMG TSPEC,
CMMG TSPEC,
Multi-band,
U-PID,
MMS,
VendorSpecificInfo
)

Name	Type	Valid range	Description
DialogToken	Integer	As defined in the received ADDTS Request frame	Identifies the ADDTS transaction.
STAAddress	MAC address		The MAC address of the STA that initiated the MLME-ADDTS.request primitive.
TSPEC	As defined in the TSPEC element, with the exception of the surplus bandwidth allowance, minimum PHY rate, and maximum and minimum SIs, which are optionally specified	As defined in 9.4.2.29 with the exception of the surplus bandwidth allowance, minimum PHY rate, and maximum and minimum SIs, which are optionally specified	Specifies the TSID, traffic characteristics, and QoS requirements of the TS.
TCLAS	TCLAS element	As defined in 9.4.2.30	Zero or more TCLAS elements. Specifies the rules and parameters by which an MSDU may be classified to the specified TS.
TCLASProcessing	TCLAS Processing element	As defined in 9.4.2.32	Specifies how the TCLAS elements are to be processed when there are multiple TCLAS elements.

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Name	Type	Valid range	Description
U-APSD Coexistence	U-APSD Coexistence element	As defined in 9.4.2.90	Indicates the coexistence parameters for requested transmission during a U-APSD service period.
EBR	Expedited Bandwidth Request element	As defined in 9.4.2.93	Specifies the precedence level of the TS request. This element is optionally present when dot11EBRActivated is true.
IntraAccessCategory Priority	Intra-Access Category Priority element	As defined in 9.4.2.120	Specifies the intra-AC priorities the STA should use.
HigherLayerStreamID	Higher Layer Stream ID element	As defined in 9.4.2.124	Identifies the higher layer stream.
DMG TSPEC	DMG TSPEC element	As defined in 9.4.2.133	Specifies the characteristics (scheduling) and QoS requirements of the DMG allocation request.
CMMG TSPEC	CMMG TSPEC element	As defined in 9.4.2.134.	Specifies the characteristics and QoS (scheduling) requirements of the CMMG allocation request.
Multi-band	Multi-band element	As defined in 9.4.2.138	Specifies the frequency band and channel number where the TSID is to be established. The parameter is absent if the TSID is intended to be established on the same frequency band and channel where the ADDTS Request frame is transmitted.
U-PID	U-PID element	As defined in 9.4.2.153	This parameter is optionally present and specifies the parameters of the LLC for the purpose of (de)multiplexing of frames associated with the TSID.
MMS	Multiple MAC Sublayers element	As defined in 9.4.2.152	This parameter is optionally present and specifies the parameters of an MMSL cluster establishment.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

The TCLAS is optional at the discretion of the STA that originated the request.

6.3.25.4.3 When generated

This primitive is generated by the MLME as a result of receipt of a request to add (or modify) a TS by a specified STA in the form of an ADDTS Request frame.

6.3.25.4.4 Effect of receipt

The SME is notified of the request for a TS addition (or modification) by a specified STA.

This primitive solicits an MLME-ADDTS.response primitive from the SME that reflects the results of admission control at the HC or DMT STA on the TS requested to be added (or modified).

The SME should operate according to the procedures defined in 11.4.

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The SME generates an MLME-ADDTS.response primitive within a dot11ADDTSResponseTimeout.

6.3.25.5 MLME-ADDTS.response

6.3.25.5.1 Function

This primitive responds to the request for a TS addition (or modification) by a specified STA's MAC entity.

6.3.25.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ADDTS.response(
ResultCode,
DialogToken,
STAAddress,
TSDelay,
TSPEC,
Schedule,
TCLAS,
TCLASProcessing,
EBR,
HigherLayerStreamID,
DMG TSPEC,
CMMG TSPEC,
Multi-band,
U-PID,
MMS,
VendorSpecificInfo
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, REJECTED_WITH_SUGGESTED_CHANGES, REJECTED_FOR_DELAY_PERIOD, REJECTED_WITH_SUGGESTED_BSS_TRANSITION, REQUESTED_TCLAS_NOT_SUPPORTED, TCLAS_RESOURCES_EXHAUSTED, REJECTED_HOME_WITH_SUGGESTED_CHANGES, REJECTED_FOR_SSP_PERMISSIONS, SUCCESS_STA_IN_PS_MODE, REJECT_U-PID_SETTING	Indicates the results of the corresponding MLME-ADDTS.indication primitive.
DialogToken	Integer	As defined in the corresponding MLME-ADDTS.indication	DialogToken of the matching MLME-ADDTS.indication primitive.
STAAddress	MAC address		The STA address of the matching MLME-ADDTS.indication primitive.

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Name	Type	Valid range	Description
TSDelay	Integer	≥ 0	When the result code is REJECTED_FOR_DELAY_PERIOD, provides the amount of time a STA should wait before attempting another ADDTS request.
TSPEC	TSPEC element	As defined in 9.4.2.29	Specifies the QoS parameters of the TS.
Schedule	Schedule element	As defined in 9.4.2.33	Specifies the schedule information, service start time, SI, and the specification interval.
TCLAS	TCLAS element	As defined in 9.4.2.30	Zero or more TCLAS elements. Specifies the rules and parameters by which an MSDU may be classified to the specified TS.
TCLASProcessing	TCLAS Processing element	As defined in 9.4.2.32	Specifies how the TCLAS elements are to be processed when there are multiple TCLAS elements.
EBR	Expedited Bandwidth Request element	As defined in 9.4.2.93	Specifies the precedence level of the TS request. This element is optionally present when dot11EBRActivated is true.
HigherLayerStream ID	Higher Layer Stream ID element	As defined in 9.4.2.124	Identifies the higher layer stream.
DMG TSPEC	DMG TSPEC element	As defined in 9.4.2.133	Specifies the characteristics (scheduling) and QoS requirements of the DMG allocation request.
CMMG TSPEC(	CMMG TSPEC element	As defined in 9.4.2.134.	Specifies the characteristics and QoS (scheduling) requirements of the CMMG allocation request.
Multi-band	Multi-band element	As defined in 9.4.2.138	Specifies the frequency band and channel number where the TSID is to be established. The parameter is absent if the TSID is intended to be established on the same frequency band and channel where the ADDTS Request frame is transmitted.
U-PID	U-PID element	As defined in 9.4.2.153	This parameter is optionally present and specifies the parameters of the LLC for the purpose of (de)multiplexing of frames associated with the TSID.
MMS	Multiple MAC Sublayers element	As defined in 9.4.2.152	This parameter is optionally present and specifies the parameters of an MMSL cluster establishment.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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The DialogToken and STAAddress parameters contain the values from the matching MLME-ADDTS.indication primitive.

If a non-DMG STA receives a result code of SUCCESS, the TSPEC and (optional) TCLAS parameters contain the values from the matching MLME-ADDTS-indication.

If a DMG STA receives a result code of SUCCESS or SUCCESS_STA_IN_PS_MODE, the DMG TSPEC and (optional) TCLAS parameters contain the values from the matching MLME-ADDTS.indication primitive.

If a non-DMG STA receives a result code of REJECTED_WITH_SUGGESTED_CHANGES or REJECTED_HOME_WITH_ SUGGESTED_CHANGES, the TSPEC and TCLAS parameters represent an alternative proposed TS either based on information local to the MAC entity or using additional information received across the SSPN interface. The TS, however, is not created. The TSID and direction values within the TSPEC are as in the matching MLME-ADDTS.indication primitive. The difference may lie in the QoS (e.g., minimum data rate, mean data rate, and delay bound) values, as a result of admission control performed at the SME of the HC on the TS requested to be added (or modified) by the STA. If sufficient bandwidth is not available, the QoS values may be reduced. In one extreme, the minimum data rate, mean data rate, and delay bound may be all set to 0, indicating that no QoS is to be provided to this TS.

If a DMG STA receives a result code of REJECTED_WITH_SUGGESTED_CHANGES or REJECT_U-PID_SETTING, then the DMG TSPEC, TCLAS, Multi-band, and U-PID parameters represent an alternative proposal for the allocation or TS. The allocation or TS, however, has not been created. The allocation ID value within the DMG TSPEC is as in the matching MLME-ADDTS.indication primitive. The difference might lie in the other parameter values, as a result of admission control performed at the SME of the peer STA on the allocation or TS requested to be added (or modified). If sufficient bandwidth is not available, the QoS values might be reduced.

If the result code is REJECTED_WITH_SUGGESTED_BSS_TRANSITION, the non-AP STA should initiate a transition query as defined in 11.21.7. Once the transition is completed, the STA should retry TS setup process, as defined in 11.4.4.

6.3.25.5.3 When generated

This primitive is generated by the SME at the HC or DMG STA as a result of an MLME-ADDTS.indication primitive to initiate addition (or modification) of a TS with a specified peer MAC entity or entities.

6.3.25.5.4 Effect of receipt

This primitive approves addition (or modification) of a TS requested by a specified STA's MAC entity, with or without altering the TSPEC.

This primitive causes the MAC entity at the HC or DMG STA to send an ADDTS Response frame to the requesting STA containing the specified parameters.

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6.3.25.6 MLME-DELTS.request

6.3.25.6.1 Function

This primitive requests deletion of a TS with a specified peer MAC.

This primitive may be generated by one of the following:

— DMG STA
— Non-AP STA
— PCP
— HC

6.3.25.6.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DELTS.request(
STAAddress1,
TSInfo,
ReasonCode,
STAAddress2,
DMG Allocation Info,
Multi-band,
VendorSpecificInfo
)

Name	Type	Valid range	Description
STAAddress1	MAC address		Specifies the MAC address of the STA that initiated this TS or MAC address of the STA to which the second DELTS frame is sent, as defined in 11.4.9.2. Present only at the HC and PCP.
TSInfo	TS Info field	As defined in 9.4.2.29	Specifies the TS to be deleted. Not present when DMG Allocation Info is present.
ReasonCode	Enumeration	STA_LEAVING, END_TS, UNKNOWN_TS, TIMEOUT, SERVICE_CHANGE_PRECLUDES_TS	Indicates the reason why the TS is being deleted.
STAAddress2	MAC address		Specifies the MAC address of the peer STA for the PTP TSPEC or MAC address of the STA to which the first DELTS frame is sent, as defined in 11.4.9.2.

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Name	Type	Valid range	Description
DMG Allocation Info	DMG Allocation Info field	As defined in 9.4.2.133	Specifies the DMG allocation to be deleted. Not present when TSInfo is present.
Multi-band	Multi-band element	As defined in 9.4.2.138	Specifies the frequency band and channel number where the TS is to be deleted. The parameter is absent if the TS is intended to be deleted on the same frequency band and channel where the DELTS is transmitted.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.25.6.3 When generated

This primitive is generated by the SME to initiate deletion of a TS when a higher layer protocol or mechanism signals the STA to initiate such a deletion.

6.3.25.6.4 Effect of receipt

This primitive initiates a TS deletion procedure.

This primitive causes the local MAC entity to send out a DELTS frame containing the specified parameters. If this primitive was generated at the HC, the frame is sent to the specified STA's MAC address. If this primitive was generated at the non-AP STA that is a non-DMG STA, the frame is sent to its HC. A DMG STA sends the frame to the specified STA's MAC address. In any of these cases, the DELTS frame does not solicit a response from the recipient frame other than an acknowledgment to receipt of the frame.

6.3.25.7 MLME-DELTS.indication

6.3.25.7.1 Function

This primitive reports the deletion of a TS by a specified peer MAC entity or deletion of the TS due to an inactivity timeout (HC or PCP only).

6.3.25.7.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DELTS.indication(
                        STAAddress,
                        TSInfo,
                        ReasonCode,
                        DMG Allocation Info,
                        Multi-band,
                        VendorSpecificInfo
                        )
```

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Name	Type	Valid range	Description
STAAddress	MAC address		Specifies the MAC address of the STA for which the TS is being deleted. Present only at the HC.
TSInfo	TS Info field	As defined in 9.4.2.29	Specifies the TS information of the TS of concern. Not present when DMG Allocation Info is present.
ReasonCode	Enumeration	STA_LEAVING, END_TS, UNKNOWN_TS, TIMEOUT, SERVICE_CHANGE_PRECLUDES_TS	Indicates the reason why the TS is being deleted.
DMG Allocation Info	DMG Allocation Info field	As defined in 9.4.2.133	Specifies the DMG allocation under consideration. Not present when TSInfo is present.
Multi-band	Multi-band element	As defined in 9.4.2.138	Specifies the frequency band and channel number for the TS under consideration. The parameter is absent if the TS is intended to be deleted on the same frequency band and channel where the DELTS is transmitted.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.25.7.3 When generated

This primitive is generated by the MLME when it receives a DELTS frame from the specified peer MAC entity.

This primitive may also be generated by the MLME at the DMG STA or HC as a result of inactivity of a particular TS. Inactivity results when a period equal to the inactivity interval in the TSPEC for the TS elapses

— Without arrival of an MSDU belonging to that TS at the MAC entity of the DMG STA or HC via an MA-UNITDATA.request primitive when the DMG STA or HC is the source STA of that TS or

— Without reception of an MSDU belonging to that TS by the MAC entity of the DMG STA or HC when the DMG STA or HC is not the source STA of that TS.

This primitive is generated after any other state concerning the TSID/direction within the MAC has been deleted.

6.3.25.7.4 Effect of receipt

The SME is notified of the initiation of a TS deletion by a specified peer MAC entity.

6.3.25.8 MLME-ADDTSRESERVE.request

6.3.25.8.1 Function

This primitive request is used by the SME at the AP to start the AP-initiated TS setup procedure.

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6.3.25.8.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-ADDTSRESERVE.request (
                                    TSPEC,
                                    HigherLayerStreamID,
                                    Schedule,
                                    VendorSpecificInfo
                                    )
```

Name	Type	Valid range	Description
TSPEC	TSPEC element	As defined in 9.4.2.29	Specifies the QoS parameters of the TS.
HigherLayerStreamID	Higher Layer Stream ID element	As defined in 9.4.2.124	Stream identifier assigned by a higher layer protocol.
Schedule	Schedule element	As defined in 9.4.2.33	Specifies the schedule information, service start time, SI, and the specification interval.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.25.8.3 When generated

This primitive is generated by the SME at the AP to start the AP-initiated TS setup procedure. If the parameter validation on the parameters used in this primitive succeeds, an ADDTS Reserve Request frame is transmitted from the AP to a non-AP STA.

6.3.25.8.4 Effect of receipt

The STA operates according to the procedures defined in 11.4.4.3.

6.3.25.9 MLME-ADDTSRESERVE.confirm

6.3.25.9.1 Function

This primitive is an indication to the SME that is generated by the MLME as a result of receiving an ADDTS Reserve Response frame from the non-AP STA to which the AP sent a corresponding ADDTS Reserve Request frame.

6.3.25.9.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-ADDTSRESERVE.confirm (
                                    ResultCode,
                                    HigherLayerStreamID,
                                    VendorSpecificInfo
                                    )
```

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Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, FAILURE	Indicates the results of the corresponding MLME-ADDTSRESERVE.request primitive.
HigherLayerStreamID	Higher Layer Stream ID element	As defined in 9.4.2.124	Stream identifier specified in the corresponding MLME-ADDTSRESERVE.request primitive.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.25.9.3 When generated

This primitive is generated by the MLME as a result of receiving an ADDTS Reserve Response frame from the non-AP STA to which the AP sent a corresponding ADDTS Reserve Request action.

6.3.25.9.4 Effect of receipt

The SME is notified of the results of the AP-initiated TS setup procedure.

6.3.25.10 MLME-ADDTSRESERVE.indication

6.3.25.10.1 Function

This primitive reports to the non-AP STA's SME the initiation of AP-initiated TS setup procedure.

6.3.25.10.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-ADDTSRESERVE.indication (
                                APAddress,
                                TSPEC,
                                Schedule,
                                HigherLayerStreamID,
                                VendorSpecificInfo
                                )
```

Name	Type	Valid range	Description
APAddress	MAC address	—	The MAC address of the AP initiating the TS setup procedure.
TSPEC	TSPEC element	As defined in 9.4.2.29	Specifies the QoS parameters of the TS.
Schedule	Schedule element	As defined in 9.4.2.33	Specifies the schedule information, service start time, SI, and the specification interval.
HigherLayerStreamID	Higher Layer Stream ID element	As defined in 9.4.2.124	Stream identifier in the received ADDTS Reserve Request frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.25.10.3 When generated

This primitive is generated by the MLME at the non-AP STA as a result of the receipt of an ADDTS Reserve Request frame from the AP to which the non-AP STA is associated.

6.3.25.10.4 Effect of receipt

The SME is notified of the receipt of the ADDTS Reserve Request frame from the AP. This primitive solicits the SME to participate in the AP-initiated TS setup procedure.

The SME should operate according to the procedures defined in 11.4.4.3.

6.3.25.11 MLME-ADDTSRESERVE.response

6.3.25.11.1 Function

This primitive is used by a non-AP STA to indicate to the HC the completion of an AP-initiated TS setup procedure.

6.3.25.11.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-ADDTSRESERVE.response (
                                HigherLayerStreamID,
                                ResultCode,
                                VendorSpecificInfo
                                )
```

Name	Type	Valid range	Description
HigherLayerStreamID	Higher Layer Stream ID element	As defined in 9.4.2.124	Stream identifier specified in the corresponding MLME-ADDTSRESERVE.indication primitive.
ResultCode	Enumeration	SUCCESS, FAILURE	Indicates the result of the AP-initiated TS setup procedure.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.25.11.3 When generated

This primitive is generated by the SME at the non-AP STA to indicate to an HC that the non-AP STA has setup a TS in response to a higher layer protocol.

6.3.25.11.4 Effect of receipt

The STA operates according to the procedures defined in 11.4.4.3.

6.3.26 Higher layer synchronization support

6.3.26.1 Introduction

This mechanism supports the process of synchronization among higher layer protocol entities residing within different wireless STAs. The actual synchronization mechanism in the higher layer is out of the scope

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of this standard. In principle, the MLME indicates the transmission/reception of frames with a specific group address in the Address 1 field of a Data frame.

6.3.26.2 MLME-HL-SYNC.request

6.3.26.2.1 Function

This primitive requests activation of the synchronization support mechanism.

6.3.26.2.2 Semantics of the service primitive

The primitive parameter is as follows:

MLME-HL-SYNC.request(
GroupAddress
)

Name	Type	Valid range	Description
GroupAddress	MAC address	A group MAC address	Specifies the group MAC address to which the synchronization frames are addressed. A synchronization frame is a Data frame with higher layer synchronization information.

6.3.26.2.3 When generated

This primitive is generated by the SME when a higher layer protocol initiates a synchronization process.

6.3.26.2.4 Effect of receipt

This request activates the synchronization support mechanism at the STA. The MLME issues an MLME-HL-SYNC.indication primitive when a higher layer synchronization frame, which is a Data frame with the specified group address in Address 1 field, is received or transmitted.

6.3.26.3 MLME-HL-SYNC.indication

6.3.26.3.1 Function

This primitive indicates the last symbol on air of a higher layer synchronization frame, whether transmitted or received by the MAC.

6.3.26.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-HL-SYNC.indication(
SourceAddress,
SequenceNumber
)

Name	Type	Valid range	Description
SourceAddress	MAC address	Any valid individual MAC address	Specifies the SA of the STA that transmitted the higher layer synchronization frame.
SequenceNumber	Integer	As defined in 9.2.4.4.2	Specifies the sequence number of the higher layer synchronization frame received or transmitted.

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6.3.26.3.3 When generated

This primitive is generated by the MLME when the reception or transmission of a higher layer synchronization frame is detected, as indicated by the PHY-RXEND.indication or PHY-TXEND.confirm primitives generated by the PHY. The higher layer synchronization frame is identified by the group MAC address registered by an earlier MLME-HL-SYNC.request primitive in the Address 1 field of a Data frame.

6.3.26.3.4 Effect of receipt

The SME is notified of the reception or transmission of a higher layer synchronization frame.

6.3.27 Block Ack

6.3.27.1 General

This mechanism supports the initiation (or modification) and termination of block ack.

The primitives used for this mechanism are called *block ack primitives*, which include MLME-ADDBA.xxx and MLME-DELBA.xxx primitives, where xxx denotes request, confirm, indication, or response. Each primitive contains parameters that correspond to a Block Ack Action frame body. Requests and responses might cause these frames to be sent. Confirms and indications are emitted when an appropriate Block Ack Action frame is received.

6.3.27.2 MLME-ADDBA.request

6.3.27.2.1 Function

This primitive requests the initiation (or modification) of block ack with a peer MAC entity.

6.3.27.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ADDBA.request(
PeerSTAAddress,
DialogToken,
TID,
BlockAckPolicy,
BufferSize,
BlockAckTimeout,
BlockAckStartingSequenceControl,
GCRGroupAddress,
Multi-band,
TCLAS,
ADDBA Extension,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	N/A	Specifies the address of the peer MAC entity with which to perform the block ack initiation (or modification).
DialogToken	Integer	0–255	Identifies the ADDBA transaction.
TID	Integer	0–15	Specifies the TID of the data.

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Name	Type	Valid range	Description
BlockAckPolicy	Enumeration	Immediate, HT-delayed	Specifies the block ack policy.
BufferSize	Integer	0–1023	Specifies the number of MPDUs that can be held in its buffer.
BlockAckTimeout	Integer	0–65 535	Specifies the number of TUs without a frame exchange between peers after which the block ack agreement is considered to be torn down.
BlockAckStartingSequenceControl	Block Ack Starting Sequence Control subfield	As defined in 9.3.1.7	Specifies the value of the Block Ack Starting Sequence Control subfield.
GCRGroupAddress	GCR Group Address element	As defined in 9.4.2.125	Specifies the group address for which a block ack agreement is requested. If the element is present, a GCR Group Address element is included in the transmitted ADDBA Request frame.
Multi-band	Multi-band element	As defined in 9.4.2.138	Specifies the frequency band and channel number where the block ack agreement is to be established. The parameter is absent if the block ack agreement is intended to be established on the same frequency band and channel where the ADDBA Request frame is transmitted.
TCLAS	TCLAS element	As defined in 9.4.2.30	Zero or more TCLAS elements. Specifies the rules and parameters by which an MSDU might be classified to the specified TID.
ADDBA Extension	ADDBA Extension element	As defined in 9.4.2.139	Specifies additional parameters associated with the block ack agreement.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.27.2.3 When generated

This primitive is generated by the SME to request initiation (or modification) of block ack with the specified peer MAC entity.

6.3.27.2.4 Effect of receipt

The STA sends the ADDBA Request frame to the specified peer MAC entity.

6.3.27.3 MLME-ADDBA.confirm

6.3.27.3.1 Function

The primitive reports the results of initiation (or modification) of the block ack attempt with the specified peer MAC entity.

6.3.27.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ADDBA.confirm(
PeerSTAAddress,
DialogToken,
TID,
ResultCode,
BlockAckPolicy,

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BufferSize,
BlockAckTimeout,
GCRGroupAddress,
Multi-band,
TCLAS,
ADDBA Extension,
OriginatorPreferredMCS,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	N/A	Specifies the address of the peer MAC entity with which the block ack initiation (or modification) was attempted. This value matches the PeerSTAAddress parameter specified in MLME-ADDBA.request primitive.
DialogToken	Integer	0–255	Identifies the ADDBA transaction. This value matches the DialogToken parameter specified in MLME-ADDBA.request primitive.
TID	Integer	0–15	Specifies the TID of the data. This value matches the TID specified in MLME-ADDBA.request primitive.
ResultCode	Enumeration	SUCCESS, REFUSED	Indicates the result of the corresponding MLME-ADDBA.request primitive.
BlockAckPolicy	Enumeration	Immediate, HT-delayed	Specifies the block ack policy.
BufferSize	Integer	0–1023	Specifies the maximum number of MPDUs in the block for the specified TID.
BlockAckTimeout	Integer	0–65 535	Specifies the number of TUs without a frame exchange between peers after which the block ack agreement is considered to be torn down.
GCRGroupAddress	GCR Group Address element	As defined in 9.4.2.125	Specifies the group address for which a block ack agreement was requested.
Multi-band	Multi-band element	As defined in 9.4.2.138	Specifies the frequency band and channel number where the block ack initiation was attempted. The parameter is absent if the block ack agreement is intended was attempted to be established on the same frequency band and channel where the ADDBA Request frame is transmitted.
TCLAS	TCLAS element	As defined in 9.4.2.30	Zero or more TCLAS elements. Specifies the rules and parameters by which an MSDU might be classified to the specified TID.
ADDBA Extension	ADDBA Extension element	As defined in 9.4.2.139	Specifies additional parameters associated with the block ack agreement.
OriginatorPreferred MCS	Integer	0–10, 15	Indicates preferred MCS used for eliciting A-MPDUs. This parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.27.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-ADDBA.request primitive to indicate the results of that request.

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6.3.27.3.4 Effect of receipt

The SME is notified of the results of the block ack initiation (or modification).

6.3.27.4 MLME-ADDBA.indication

6.3.27.4.1 Function

This primitive reports the initiation (or modification) of block ack by a peer MAC entity.

6.3.27.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ADDBA.indication(
PeerSTAAddress,
DialogToken,
TID,
BlockAckPolicy,
BufferSize,
BlockAckTimeout,
GCRGroupAddress,
Multi-band,
TCLAS,
ADDBA Extension,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	N/A	Specifies the address of the peer MAC entity that requested the block ack initiation (or modification).
DialogToken	Integer	0–255	Identifies the ADDBA transaction.
TID	Integer	0–15	Specifies the TID of the data.
BlockAckPolicy	Enumeration	Immediate, HT-delayed	Specifies the block ack policy.
BufferSize	Integer	0–1023	Specifies the number of MPDUs that can be held in peerSTAAddress buffer.
BlockAckTimeout	Integer	0–65 535	Specifies the number of TUs without a frame exchange between peers after which the block ack agreement is considered to be torn down.
GCRGroupAddress	GCR Group Address element	As defined in 9.4.2.125	Specifies the group address for which a block ack agreement is requested. This element is present if a GCR Group Address element was included in the transmitted ADDBA Request frame.
Multi-band	Multi-band element	As defined in 9.4.2.138	Specifies the frequency band and channel number where the block ack agreement is to be established. The parameter is absent if the block ack agreement is intended to be established on the same frequency band and channel where the ADDBA Request frame is transmitted.
TCLAS	TCLAS element	As defined in 9.4.2.30	Zero or more TCLAS elements. Specifies the rules and parameters by which an MSDU might be classified to the specified TID.

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Name	Type	Valid range	Description
ADDBA Extension	ADDBA Extension element	As defined in 9.4.2.139	Specifies additional parameters associated with the block ack agreement.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.27.4.3 When generated

This primitive is generated by the MLME as a result of receipt of a block ack initiation (or modification) by the specified peer MAC entity in the form of an ADDBA Request frame.

6.3.27.4.4 Effect of receipt

The SME is notified of the initiation (or modification) of the block ack by the specified peer MAC entity.

6.3.27.5 MLME-ADDBA.response

6.3.27.5.1 Function

The primitive responds to the initiation (or modification) by a specified peer MAC entity.

6.3.27.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-ADDBA.response(
                    PeerSTAAddress,
                    DialogToken,
                    TID,
                    ResultCode,
                    BlockAckPolicy,
                    BufferSize,
                    BlockAckTimeout,
                    GCRGroupAddress,
                    Multi-band,
                    TCLAS,
                    ADDBA Extension,
                    OriginatorPreferredMCS,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	N/A	Specifies the address of the peer MAC entity that attempted the block ack initiation (or modification). This value matches the PeerSTAAddress parameter specified in MLME-ADDBA.indication primitive.
DialogToken	Integer	0–255	Identifies the ADDBA transaction. This value matches the DialogToken parameter specified in MLME-ADDBA.indication primitive.
TID	Integer	0–15	Specifies the TID of the data. This value matches the TID specified in MLME-ADDBA.indication primitive.

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Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, REFUSED	Indicates the result of the corresponding MLME-ADDBA.indication primitive.
BlockAckPolicy	Enumeration	Immediate, HT-delayed	Specifies the block ack policy. Undefined when the result code is REFUSED.
BufferSize	Integer	0–1023	Specifies the maximum number of MPDUs in the block for the specified TID. Undefined when the result code is REFUSED.
BlockAckTimeout	Integer	0–65 535	Specifies the number of TUs without a frame exchange between peers after which the block ack agreement is considered to be torn down.
GCRGroupAddress	GCR Group Address element	As defined in 9.4.2.125	Specifies the group address for which a block ack agreement was requested.
Multi-band	Multi-band element	As defined in 9.4.2.138	Specifies the frequency band and channel number where the block ack agreement is intended to be established. The parameter is absent if the block ack agreement is intended to be established on the same frequency band and channel where the ADDBA Response frame is transmitted.
TCLAS	TCLAS element	As defined in 9.4.2.30	Zero or more TCLAS elements. Specifies the rules and parameters by which an MSDU might be classified to the specified TID.
ADDBA Extension	ADDBA Extension element	As defined in 9.4.2.139	Specifies additional parameters associated with the block ack agreement.
OriginatorPreferred MCS	Integer	0–10, 15	Indicates preferred MCS used for eliciting A-MPDUs. This parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.27.5.3 When generated

This primitive is generated by the MLME as a result of an MLME-ADDBA.indication primitive to initiate block ack by the specified peer MAC entity.

6.3.27.5.4 Effect of receipt

The primitive causes the MAC entity to send an ADDBA Response frame to the specified peer MAC entity.

6.3.27.6 MLME-DELBA.request

6.3.27.6.1 Function

This primitive requests the deletion of block ack with a peer MAC entity.

6.3.27.6.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DELBA.request(
PeerSTAAddress,
Direction,
TID,
ReasonCode,
Multi-band,

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TCLAS,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	N/A	Specifies the address of the peer MAC entity with which to perform the block ack deletion.
Direction	Enumeration	Originator, Recipient	Specifies if the MAC entity initiating the MLME-DELBA.request primitive is the originator or the recipient of the data stream that uses the block ack agreement.
TID	Integer	0–15	Specifies the TID of the MSDUs for which this block ack agreement has been set up.
ReasonCode	Enumeration	STA_LEAVING, END_BA, UNKNOWN_BA, TIMEOUT	Indicates the reason why the block ack agreement is being deleted.
Multi-band	Multi-band element	As defined in 9.4.2.138	Specifies the frequency band and channel number where the block ack agreement is to be deleted. The parameter is absent if the block ack agreement to be deleted is established on the same frequency band and channel where the DELBA frame is transmitted.
TCLAS	TCLAS element	As defined in 9.4.2.30	Zero or more TCLAS elements. Specifies the rules and parameters by which an MSDU might be classified to the specified TID.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.27.6.3 When generated

This primitive is generated by the SME to request deletion of block ack with the specified peer MAC entity.

6.3.27.6.4 Effect of receipt

The STA sends the DELBA frame to the specified peer MAC entity.

6.3.27.7 MLME-DELBA.indication

6.3.27.7.1 Function

This primitive reports the deletion of block ack by a peer MAC entity.

6.3.27.7.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DELBA.indication(
PeerSTAAddress,
Direction,
TID,
ReasonCode,
Multi-band,
TCLAS,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	N/A	Specifies the address of the peer MAC entity with which to perform the block ack deletion.
Direction	Enumeration	Originator, Recipient	Specifies if the MAC entity initiating the MLME-DELBA.request primitive is the originator or the recipient of the data stream that uses block ack.
TID	Integer	0–15	Specifies the TID of the MSDUs for which this block ack agreement has been set up.
ReasonCode	Enumeration	STA_LEAVING, END_BA, UNKNOWN_BA, TIMEOUT	Indicates the reason why the block ack agreement is being deleted.
Multi-band	Multi-band element	As defined in 9.4.2.138	Specifies the frequency band and channel number where block ack agreement is to be deleted. The parameter is absent if the block ack deletion refers to the same frequency band and channel where the DELBA frame is transmitted.
TCLAS	TCLAS element	As defined in 9.4.2.30	Zero or more TCLAS elements. Specifies the rules and parameters by which an MSDU might be classified to the specified TID.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.27.7.3 When generated

This primitive is generated by the MLME as a result of receipt of a block ack deletion by the specified peer MAC entity in the form of a DELBA frame.

6.3.27.7.4 Effect of receipt

The SME is notified of the deletion of the block ack by the specified peer MAC entity.

6.3.28 Schedule element management

6.3.28.1 Introduction

This subclause describes the management procedures associated with the QoS Schedule element.

MLME-SCHEDULE.request and MLME-SCHEDULE.indication primitives are defined.

6.3.28.2 MLME-SCHEDULE.request

6.3.28.2.1 Function

This primitive requests transmission of a Schedule frame. It is valid at the HC.

6.3.28.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SCHEDULE.request(
                        STAAddress,
                        Schedule,
                        VendorSpecificInfo
                        )
```

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Name	Type	Valid range	Description
STAAddress	MAC address	Any valid individual address	MAC address of the STA to which the Schedule frame shall be sent.
Schedule	Schedule element	As defined in 9.4.2.33	Specifies the schedule for the STA, including the SI (minimum and maximum), TXOP duration (minimum and maximum), and specification interval.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.28.2.3 When generated

This primitive is generated by the SME at the HC to send the schedule information, in the form of a Schedule frame, to a specified STA when the schedule information for the STA is changed.

6.3.28.2.4 Effect of receipt

This primitive causes the MAC entity at the HC to send a Schedule frame to the STA specified in the primitive containing the specified Schedule parameters.

6.3.28.3 MLME-SCHEDULE.indication

6.3.28.3.1 Function

This primitive reports the reception of a new schedule by the STA in the form of a Schedule frame.

6.3.28.3.2 Semantics of the service primitive

The primitive parameter is as follows:

```
MLME-SCHEDULE.indication(
                        Schedule,
                        VendorSpecificInfo
                        )
```

Name	Type	Valid range	Description
Schedule	Schedule element	As defined in 9.4.2.33	Specifies the schedule for the STA, including the SI (minimum and maximum), TXOP duration (minimum and maximum), and specification interval.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.28.3.3 When generated

This primitive is generated by the MLME as a result of receipt of a new schedule in the form of a Schedule frame.

6.3.28.3.4 Effect of receipt

The SME is notified of the receipt of QoS schedule in the form of a Schedule frame. The new Schedule parameters overwrite the previously stored values.

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6.3.29 Vendor-specific action

6.3.29.1 Introduction

This set of primitives supports the signaling of (Protected) Vendor Specific frames among peer SMEs.

6.3.29.2 MLME-VSPECIFIC.request

6.3.29.2.1 Function

This primitive requests transmission of a Vendor Specific frame.

6.3.29.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-VSPECIFIC.request(
PeerMACAddress,
Protected,
Organization Identifier,
VendorSpecificContent
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address or any valid group MAC address	The address of the peer MAC entity or group of entities to which the Vendor Specific frame is sent.
Protected	Boolean	true, false	Specifies whether the request is sent using a protected robust Management frame. If true, the request is sent using a Protected Vendor Specific frame. If false, the request is sent using a Vendor Specific frame.
Organization Identifier	As defined in 9.4.1.31	As defined in 9.4.1.31	A public value assigned by the IEEE to identify the organization that has defined the content of the particular vendor-specific action.
VendorSpecificContent	Determined by the entity to whom the Organization Identifier is registered	Determined by the entity to whom the Organization Identifier is registered	Vendor-specific content.

6.3.29.2.3 When generated

This primitive is generated by the SME to request that a Vendor Specific frame be sent.

6.3.29.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Vendor Specific frame containing the set of elements and vendor-specific fields. The STA then attempts to transmit the frame.

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6.3.29.3 MLME-VSPECIFIC.indication

6.3.29.3.1 Function

This primitive indicates that a Vendor Specific frame has been received from a peer entity.

6.3.29.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-VSPECIFIC.indication(
PeerMACAddress,
Protected,
Organization Identifier,
RCPI,
VendorSpecificContent
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the Vendor Specific frame was received.
Protected	Boolean	true, false	Specifies whether the request was received using a protected robust Management frame. If true, the request was received using a Protected Vendor Specific frame. If false, the request was received using a Vendor Specific frame.
Organization Identifier	As defined in 9.4.1.31	As defined in 9.4.1.31	A public value assigned by the IEEE to identify the organization that has defined the content of the particular vendor-specific action.
RCPI	As defined in 9.4.2.37	As defined in 9.4.2.37	Present when dot11OCBActivated is true. RCPI is the measured value of received channel power on the received Vendor Specific frame.
VendorSpecificContent	Determined by the entity to whom the Organization Identifier is registered	Determined by the entity to whom the Organization Identifier is registered	Vendor-specific content.

6.3.29.3.3 When generated

This primitive is generated by the MLME when a Vendor Specific frame is received.

6.3.29.3.4 Effect of receipt

On receipt of this primitive, the vendor specific content can be made available for SME processes.

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6.3.30 Neighbor report request

6.3.30.1 General

The following MLME primitives support the signaling of neighbor report requests.

6.3.30.2 MLME-NEIGHBORREPREQ.request

6.3.30.2.1 Function

This primitive requests that a Neighbor Report Request frame be sent to the AP with which the STA is associated. It is valid only at a radio measurement capable STA.

6.3.30.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-NEIGHBORREPREQ.request(
DialogToken,
SSID,
LCI requested,
LCI optional subelements,
Location Civic requested,
Civic Location Type,
Location Civic optional subelements,
VendorSpecificInfo
)

Name	Type	Valid range	Description
DialogToken	Integer	1–255	The dialog token to identify the neighbor report transaction.
SSID	As defined in the SSID element	As defined in the SSID element	Optional SSID element to request a list of neighbor reports for a specific SSID.
LCI requested	Boolean	true, false	Indicates whether an LCI Measurement Request field is to be included in the generated Neighbor Report Request frame.
LCI optional subelements	As defined in 9.4.2.20.10	As listed in Table 9-111	Optionally present if LCI requested is true. Zero or more subelements to include in the request.
Location Civic requested	Boolean	true, false	Indicates whether a Location Civic Measurement Request field is to be included in the generated Neighbor Report Request frame.
Civic Location Type	Enumeration	IETF_RFC_4776, VENDOR_SPECIFIC	Present if Location Civic requested is true. Indicates the format of the location information in the Location Civic optional subelements, if included.
Location Civic optional subelements	As defined in 9.4.2.20.14	As listed in Table 9-118	Optionally present if Location Civic requested is true. Zero or more subelements to include in the request.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.30.2.3 When generated

This primitive is generated by the SME to request that a Neighbor Report Request frame be sent to the AP with which the STA is associated to request a neighbor report.

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6.3.30.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Neighbor Report Request frame. The STA then attempts to transmit this to the AP with which it is associated.

6.3.30.3 MLME-NEIGHBORREPREQ.indication

6.3.30.3.1 Function

This primitive indicates that a Neighbor Report Request frame was received. It is valid only at a radio measurement capable AP.

6.3.30.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-NEIGHBORREPREQ.indication(
PeerSTAAddress,
DialogToken,
SSID,
LCI requested,
LCI optional subelements,
Location Civic requested,
Civic Location Type,
Location Civic optional subelements,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the STA's MAC entity from which a Neighbor Report Request frame was received.
DialogToken	Integer	1–255	The dialog token in the Neighbor Report Request frame that was received.
SSID	As defined in the SSID element	As defined in the SSID element	Optional SSID element to request a list of neighbor reports for a specific SSID.
LCI requested	Boolean	true, false	Indicates whether an LCI Measurement Request field is included in the received Neighbor Report Request frame.
LCI optional subelements	As defined in 9.4.2.20.10	As listed in Table 9-111	Optionally present if LCI requested is true. Zero or more subelements to include in the request.
Location Civic requested	Boolean	true, false	Indicates whether a Location Civic Measurement Request field is included in the received Neighbor Report Request frame.
Civic Location Type	Enumeration	IETF_RFC_4776, VENDOR_SPECIFIC	Present if Location Civic requested is true. Indicates the format of the location information in the Location Civic optional subelements, if included.
Location Civic optional subelements	As defined in 9.4.2.20.14	As listed in Table 9-118	Optionally present if Location Civic requested is true. Zero or more subelements to include in the request.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.30.3.3 When generated

This primitive is generated by the MLME when a Neighbor Report Request frame is received.

6.3.30.3.4 Effect of receipt

On receipt of this primitive, the SME operates according to the procedure in 11.10.10.3.

6.3.31 Neighbor report response

6.3.31.1 General

The following MLME primitives support the signaling of neighbor report responses.

6.3.31.2 MLME-NEIGHBORREPRESP.request

6.3.31.2.1 Function

This primitive requests that a neighbor report response be sent. This may be in response to an MLME-NEIGHBORREPREQ.indication primitive or an autonomous request. It is valid only at a radio measurement capable AP.

6.3.31.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-NEIGHBORREPRESP.request(
PeerSTAAddress,
DialogToken,
NeighborListSet,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the STA's MAC entity to which a Neighbor Report Response frame is to be sent.
DialogToken	Integer	0–255	The dialog token to identify the neighbor report transaction. Set to the value received in the corresponding MLME-NEIGHBORREPREQ.indication primitive or to 0 for an autonomous report.
NeighborListSet	Set of Neighbor Report elements each as defined in the Neighbor Report element format	As defined in 9.4.2.36	A set of Neighbor Report elements, each representing a neighboring AP being reported.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.31.2.3 When generated

This primitive is generated by the SME to request a neighbor report be sent. This may be in response to an earlier MLME-NEIGHBORREPREQ.indication primitive or a request to transmit an autonomous report.

6.3.31.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Neighbor Report Response frame. The STA then attempts to transmit this to the STA indicated by the PeerSTAAddress parameter.

6.3.31.3 MLME-NEIGHBORREPRESP.indication

6.3.31.3.1 Function

This primitive indicates that a neighbor report response has been received. This may be in response to an earlier neighbor report request (MLME-NEIGHBORREPREQ.request primitive) or an autonomous report. It is valid only at a radio measurement capable STA.

6.3.31.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-NEIGHBORREPRESP.indication(
PeerSTAAddress,
DialogToken,
NeighborListSet,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the AP from which the Neighbor Report Response frame was received.
DialogToken	Integer	0–255	The Dialog Token received in the Neighbor Report Response frame to identify the neighbor report transaction.
NeighborListSet	Set of Neighbor Report elements each as defined in the Neighbor Report element format	As defined in 9.4.2.36	A set of Neighbor Report elements derived from the MIB table dot11RMNeighborReportTable, each representing a neighboring AP being reported.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.31.3.3 When generated

This primitive is generated by the MLME when a Neighbor Report Response frame is received.

6.3.31.3.4 Effect of receipt

The SME is notified of the receipt of the neighbor report.

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6.3.32 Link Measure Request

6.3.32.1 General

The following primitives support the measurement of link path loss and the estimation of link margin between peer entities.

6.3.32.2 MLME-LINKMEASURE.request

6.3.32.2.1 Function

This primitive supports the measurement of link path loss and the estimation of link margin between peer entities.

NOTE—The layer management model used assumes that the handling of a received Link Measurement Request frame is entirely within the MLME. Correspondingly there are no MLME-SME primitives specified for the peer side of a link measurement request transaction.

6.3.32.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-LINKMEASURE.request(
PeerMACAddress,
DialogToken,
Transmit Power,
Max Transmit Power,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the Link Measure Request shall be sent.
DialogToken	Integer	1–255	The dialog token to identify the Link Measure transaction.
Transmit Power	Integer	As defined in 9.6.6.4	The transmit power to be used when transmitting the Link Measurement Request frame and included in the frame body. See 9.6.6.4.
Max Transmit Power	Integer	As defined in 9.6.6.4	The maximum transmit power to be used by the transmitting STA on its operating channel, as described in 9.4.1.20.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.32.2.3 When generated

This primitive is generated by the SME to request that a Link Measurement Request frame be sent to the peer entity to request that entity to report transmit power and link margin information.

6.3.32.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Link Measurement Request frame. The STA then attempts to transmit this to the STA indicated in the PeerMACAddress parameter.

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6.3.32.3 MLME-LINKMEASURE.confirm

6.3.32.3.1 Function

This primitive reports the result of a Link Measurement request.

6.3.32.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-LINKMEASURE.confirm(
ResultCode,
DialogToken,
TransmitPower,
LinkMargin,
RCPI of Request,
RSNI of Request,
RCPI of Report,
RSNI of Report,
Receive Antenna ID,
Transmit Antenna ID,
VendorSpecificInfo
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, UNSPECIFIED_FAILURE	Indicates the result of the corresponding MLME-LINKMEASURE.request primitive.
DialogToken	Integer	As defined in the corresponding MLME-LINK-MEASURE.request primitive	The dialog token to identify the link measurement transaction.
TransmitPower	As defined in the TPC Report element	As defined in the TPC Report element	The contents of the Transmit Power field of the received Link Measurement Report frame. Present if ResultCode = SUCCESS; otherwise not present.
LinkMargin	As defined in the TPC Report element	As defined in the TPC Report element	The contents of the Link Margin field of the received Link Measurement Report frame. Present if ResultCode = SUCCESS; otherwise not present.
RCPI of Request	Integer	As defined in 9.4.2.37	Indicates the RCPI value contained in the corresponding Link Measurement Report frame received at the requesting STA. Present if ResultCode = SUCCESS; otherwise not present.
RSNI of Request	Integer	As defined in 9.4.2.40	Indicates the RSNI value contained in the corresponding Link Measurement Report frame received at the requesting STA. Present if ResultCode = SUCCESS; otherwise not present
RCPI of Report	Integer	As defined in 9.4.2.37	The RCPI level of the corresponding Link Measurement Report frame received at the requesting STA. Present if ResultCode = SUCCESS; otherwise not present.

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Name	Type	Valid range	Description
RSNI of Report	Integer	As defined in 9.4.2.40	The RSNI of the corresponding Link Measurement Report frame received at the requesting STA. Present if ResultCode = SUCCESS; otherwise not present.
Receive Antenna ID	Integer	0–255	The antenna ID or DMG antenna ID corresponding to the antenna or DMG antenna on which the Link Measurement Request frame was received at the reporting STA. The antenna ID or DMG antenna ID is defined in 9.4.2.39.
Transmit Antenna ID	Integer	0–255	The antenna ID or DMG antenna ID corresponding to the antenna or DMG antenna used to transmit the Link Measurement Report frame. The antenna ID or DMG antenna ID is defined in 9.4.2.39.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.32.3.3 When generated

This primitive is generated by the MLME when a Link Measurement Report frame is received from the requested STA.

6.3.32.3.4 Effect of receipt

On receipt of this primitive, the SME evaluates the ResultCode and may use the reported data.

6.3.33 MLME SAP interface for resource request

6.3.33.1 MLME-RESOURCE-REQUEST.request

6.3.33.1.1 Function

This primitive is used to perform the over-the-air resource request of an FT resource request protocol. The over-the-air resource request is performed using Authentication frames, with an authentication algorithm number corresponding to FT authentication and an authentication algorithm sequence number of 3 or 4.

6.3.33.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-RESOURCE-REQUEST.request(
                                        PeerMACAddress,
                                        Contents of FT Authentication elements,
                                        VendorSpecificInfo
                                        )
```

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Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the AP that is the intended immediate recipient of the resource request.
Content of FT Authentication elements	Sequence of elements	As defined in 13.8	The set of elements to be included in the FT Confirm frame, as described in 13.8.4.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.33.1.3 When generated

This primitive is generated by the SME to send the third frame of the over-the-air FT resource request protocol. The third frame is an Authentication frame, with an number corresponding to FT authentication and an Authentication algorithm sequence number of 3.

6.3.33.1.4 Effect of receipt

Upon receipt of this primitive, the MLME constructs the appropriate Authentication frame and causes it to be transmitted to the peer MAC address.

6.3.33.2 MLME-RESOURCE-REQUEST.indication

6.3.33.2.1 Function

This primitive is used to enact the security and QoS resource request with a specified peer MAC entity.

6.3.33.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-RESOURCE-REQUEST.indication(
                                 PeerMACAddress,
                                 Content of FT Authentication elements,
                                 VendorSpecificInfo
                                 )
```

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA that was the sender of the resource request.
Content of FT Authentication elements	Sequence of elements	As defined in 13.8	The set of elements included in the FT Confirm frame, as described in 13.8.4.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.33.2.3 When generated

This primitive is generated by the MLME at an AP to indicate that the third frame of the over-the-air FT resource request protocol has been received. The third frame is an Authentication frame, with an authentication algorithm number corresponding to FT authentication and an authentication algorithm sequence number of 3.

6.3.33.2.4 Effect of receipt

Upon receipt of this primitive, the SME examines the Transition element and RSNE contents and responds to the peer MAC address using the MLME-RESOURCE-REQUEST.response primitive.

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6.3.33.3 MLME-RESOURCE-REQUEST.response

6.3.33.3.1 Function

This primitive is used to enact the security and QoS resource request protocol with a specified peer MAC entity.

6.3.33.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-RESOURCE-REQUEST.response(
PeerMACAddress,
Content of FT Authentication elements,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA that is the intended immediate recipient of the resource response.
Content of FT Authentication elements	Sequence of elements	As defined in 13.8	The set of elements to be included in the FT Ack frame, as described in 13.8.5. This includes an optional response to a resource request (RIC).
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.33.3.3 When generated

This primitive is generated by the SME at an AP to cause the transmission of the fourth frame in the over-the-air FT resource request protocol. The fourth frame is an Authentication frame, with an authentication algorithm number corresponding to FT authentication and an authentication algorithm sequence number of 4.

6.3.33.3.4 Effect of receipt

Upon receipt of this primitive, the MLME constructs the appropriate Authentication frame and causes it to be transmitted to the peer MAC address.

6.3.33.4 MLME-RESOURCE-REQUEST.confirm

6.3.33.4.1 Function

This primitive is used to enact the security and QoS resource request protocol with a specified peer MAC entity.

6.3.33.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-RESOURCE-REQUEST.confirm(
PeerMACAddress,
Content of FT Authentication elements,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the AP that was the sender of the resource response.
Content of FT Authentication elements	Sequence of elements	As defined in 13.8	The set of elements included in the FT Ack frame, as described in 13.8.5. This includes an optional response to a resource request (RIC).
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.33.4.3 When generated

This primitive is generated by the MLME on receipt of the fourth frame in the FT resource request protocol.

6.3.33.4.4 Effect of receipt

Upon receipt of this primitive, the SME examines the content of the message and completes its processing of the resource request.

6.3.33.5 MLME-RESOURCE-REQUEST-LOCAL.request

6.3.33.5.1 Function

This primitive is used to enact the over-the-DS FT resource request protocol for a specified peer MAC entity. The over-the-DS FT resource request protocol is performed by communication between the STA and the SME of the target AP, bypassing the MAC of the target AP. This MLME function is used to allow the MAC of the target AP to process the resource requests.

6.3.33.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-RESOURCE-REQUEST-LOCAL.request(
                                    MACAddress,
                                    Content of Resource Descriptor(s)
                                    )
```

Name	Type	Valid range	Description
MACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA that is making the resource request.
Content of Resource Descriptor(s)	Sequence of elements	As defined in 13.11.2	Specifies the resource(s) that are being requested.

6.3.33.5.3 When generated

This primitive is generated by the SME at a target AP upon receiving an over-the-DS resource request to request resources within the local MAC.

6.3.33.5.4 Effect of receipt

Upon receipt of this primitive, the MAC checks for resource availability and allocates resources as requested.

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6.3.33.6 MLME-RESOURCE-REQUEST-LOCAL.confirm

6.3.33.6.1 Function

This primitive is used to respond to a local resource request for resources from the SME.

6.3.33.6.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-RESOURCE-REQUEST-LOCAL.confirm(
MACAddress,
Content of Resource Descriptor(s),
ResultCode
)

Name	Type	Valid range	Description
MACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA that is making the resource request.
Content of Resource Descriptor(s)	Sequence of elements	As defined in 13.11.2	Specifies the resource(s) that were allocated or could have been allocated.
ResultCode	Enumeration	SUCCESS, REFUSED, UNSPECIFIED_FAILURE	Indicates the result of the outcome of a resource request.

6.3.33.6.3 When generated

This primitive is generated by the MAC in response to a local resource request for resources via MLME-RESOURCE-REQUEST-LOCAL.request primitive.

6.3.33.6.4 Effect of receipt

Upon receipt of this primitive, the SME prepares a success or failure response to be sent to the STA via the current AP.

6.3.34 MLME SAP interface for remote requests

6.3.34.1 MLME-REMOTE-REQUEST.request

6.3.34.1.1 Function

This primitive is used by the SME of a non-AP STA (to send over-the-DS requests) and the SME of an AP (to send over-the-DS responses) to request the MAC to send an FT Action frame.

6.3.34.1.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-REMOTE-REQUEST.request(
PeerMACAddress,
Content of FT Action Frame
)

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Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA that is the destination of the Action frame
Content of FT Action Frame	Sequence of octets	As defined in 9.6.8	The Action frame to send to the STA.

6.3.34.1.3 When generated

This primitive is generated by the SME to send an FT Action frame to a specific peer MAC entity.

6.3.34.1.4 Effect of receipt

Upon receipt of this primitive, the MAC forwards the Action frame to the STA identified in the Action frame.

6.3.34.2 MLME-REMOTE-REQUEST.indication

6.3.34.2.1 Function

This primitive is used by the MAC to indicate to the SME the reception of an FT Action frame.

6.3.34.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-REMOTE-REQUEST.indication(
                                    PeerMACAddress,
                                    Contents of FT Action Frame
                                    )
```

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA that issued the Action frame.
Content of FT Action Frame	Sequence of octets	As defined in 9.6.8	The Action frame received from the STA.

6.3.34.2.3 When generated

This primitive is generated by the MAC as a result of the receipt of an FT Action frame from a specific peer MAC entity.

6.3.34.2.4 Effect of receipt

Upon receipt of this primitive, the remote request broker (RRB) in the SME of the current AP forwards the Action frame to the target AP identified in the Action frame.

6.3.35 Extended channel switch announcement

6.3.35.1 General

The following MLME primitives support the signaling of extended channel switch announcement.

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6.3.35.2 MLME-EXTCHANNELSWITCH.request

6.3.35.2.1 Function

This primitive requests that a (Protected) Extended Channel Switch Announcement frame be sent by an AP or mesh STA.

6.3.35.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EXTCHANNELSWITCH.request(
Mode,
OperatingClass,
ChannelNumber,
ChannelSwitchCount,
Protected,
Mesh Channel Switch Parameters,
New Country,
Wide Bandwidth Channel Switch,
New Transmit Power Envelope,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Mode	Integer	0,1	Channel switch mode, as defined for the Extended Channel Switch Announcement element.
OperatingClass	Integer	As defined in Annex E	Specifies the new operating class.
ChannelNumber	Integer	As defined in Annex E	Specifies the new channel number.
ChannelSwitchCount	As defined in 9.4.2.52	As defined in 9.4.2.52	Specifies the time period until the channel switch event, as described in 9.4.2.52.
Protected	Boolean	true, false	Specifies whether the request is sent using a protected robust Management frame. If true, the request is sent using the Protected Extended Channel Switch Announcement frame. If false, the request is sent using the Extended Channel Switch Announcement frame.
Mesh Channel Switch Parameters	As defined in 9.4.2.102	As defined in 9.4.2.102	Specifies MBSS Channel Switch Parameters used by a mesh STA. This parameter is present if dot11MeshActivated is true; otherwise, the parameter is not present.
New Country	As defined in 9.4.2.8	As defined in 9.4.2.8	Specifies the country, operating class table and operating classes used for the BSS after the channel switch. Optionally present if dot11VHTOptionImplemented is true.
Wide Bandwidth Channel Switch	As defined in 9.4.2.160	As defined in 9.4.2.160	Specifies channel parameters used when switching to a channel width wider than 40 MHz. The parameter is present if dot11VHTOptionImplemented is true and switching to a channel width wider than 40 MHz; otherwise, the parameter is not present.

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Name	Type	Valid range	Description
New Transmit Power Envelope	Set of New Transmit Power Envelope elements	N/A	Specifies power parameters used for the BSS after the channel switch. Optionally present if dot11VHTOptionImplemented is true.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.35.2.3 When generated

This primitive is generated by the STA management entity (SME) to request that a (Protected) Extended Channel Switch Announcement frame be sent to a STA that is associated to the AP or to peer mesh STAs in the MBSS.

6.3.35.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs and transmits a (Protected) Extended Channel Switch Announcement frame.

6.3.35.3 MLME-EXTCHANNELSWITCH.confirm

6.3.35.3.1 Function

This primitive reports the result of a request to switch channel.

6.3.35.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EXTCHANNELSWITCH.confirm(
VendorSpecificInfo
)

Name	Type	Valid range	Description
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.35.3.3 When generated

This primitive is generated by the MLME when an extended channel switch request completes. Possible unspecified failure causes include an inability to schedule an extended channel switch announcement.

6.3.35.3.4 Effect of receipt

The SME is notified of the results of the extended channel switching procedure.

6.3.35.4 MLME-EXTCHANNELSWITCH.indication

6.3.35.4.1 Function

This primitive indicates that a (Protected) Extended Channel Switch Announcement frame was received from an AP or from a peer mesh STA.

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6.3.35.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EXTCHANNELSWITCH.indication(
Peer MAC Address,
Mode,
OperatingClass,
ChannelNumber,
ChannelSwitchCount,
Protected,
Mesh Channel Switch Parameters,
New Country,
Wide Bandwidth Channel Switch,
New Transmit Power Envelope,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the Extended Channel Switch Announcement frame was received.
Mode	Integer	0, 1	Channel switch mode, as defined for the Channel Switch Announcement element.
OperatingClass	Integer	As defined in Annex E	Specifies the new operating class.
ChannelNumber	Integer	As defined in Annex E	Specifies the new channel number.
ChannelSwitchCount	As defined in 9.4.2.52	As defined in 9.4.2.52	Specifies the time period until the channel switch event, as described in 9.4.2.52.
Protected	Boolean	true, false	Specifies whether the request was received using a protected robust Management frame. If true, the request was received using the Protected Extended Channel Switch Announcement frame. If false, the request was received using the Extended Channel Switch Announcement frame.
Mesh Channel Switch Parameters	As defined in 9.4.2.102	As defined in 9.4.2.102	Specifies MBSS Channel Switch Parameters used by a mesh STA. This parameter is present if dot11MeshActivated is true; otherwise, the parameter is not present.
New Country	As defined in 9.4.2.8	As defined in 9.4.2.8	Specifies the country, operating class table and operating classes used for the BSS after the channel switch. Optionally present if dot11VHTOptionImplemented is true.
Wide Bandwidth Channel Switch	As defined in 9.4.2.160	As defined in 9.4.2.160	Specifies channel parameters used when switching to a channel width wider than 40 MHz. The parameter is present if dot11VHTOptionImplemented is true and switching to a channel width wider than 40 MHz; otherwise, the parameter is not present.
New Transmit Power Envelope	Set of New Transmit Power Envelope elements	N/A	Specifies power parameters used for the BSS after the channel switch. Optionally present if dot11VHTOptionImplemented is true.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.35.4.3 When generated

This primitive is generated by the MLME when a (Protected) Extended Channel Switch Announcement frame is received.

6.3.35.4.4 Effect of receipt

On receipt of this primitive, the SME decides whether to accept the switch request.

6.3.35.5 MLME-EXTCHANNELSWITCH.response

6.3.35.5.1 Function

This primitive is used to schedule an accepted extended channel switch.

6.3.35.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EXTCHANNELSWITCH.response(
Mode,
OperatingClass,
ChannelNumber,
ChannelSwitchCount,
Mesh Channel Switch Parameters,
New Country,
Wide Bandwidth Channel Switch,
New Transmit Power Envelope,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Mode	Integer	0, 1	Channel switch mode, as defined for the Channel Switch Announcement element.
OperatingClass	Integer	As defined in Annex E	Specifies the new operating class.
ChannelNumber	Integer	As defined in Annex E	Specifies the new channel number.
ChannelSwitchCount	As defined in 9.4.2.52	As defined in 9.4.2.52	Specifies the time period until the channel switch event, as described in 9.4.2.52.
Mesh Channel Switch Parameters	As defined in 9.4.2.102	As defined in 9.4.2.102	Specifies MBSS Channel Switch Parameters used by a mesh STA. This parameter is present if dot11MeshActivated is true; otherwise, the parameter is not present.
New Country	As defined in 9.4.2.8	As defined in 9.4.2.8	Specifies the country, operating class table and operating classes used for the BSS after the channel switch. Optionally present if dot11VHTOptionImplemented is true.
Wide Bandwidth Channel Switch	As defined in 9.4.2.160	As defined in 9.4.2.160	Specifies channel parameters used when switching to a channel width wider than 40 MHz. The parameter is present if dot11VHTOptionImplemented is true and switching to a channel width wider than 40 MHz; otherwise, the parameter is not present.

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Name	Type	Valid range	Description
New Transmit Power Envelope	Set of New Transmit Power Envelope elements	N/A	Specifies power parameters used for the BSS after the channel switch. Optionally present if dot11VHTOptionImplemented is true.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.35.5.3 When generated

This primitive is generated by the SME to schedule an accepted extended channel switch request.

6.3.35.5.4 Effect of receipt

On receipt of this primitive, the MLME schedules the extended channel switch.

6.3.36 DSE power constraint announcement

6.3.36.1 General

The following MLME primitives support the signaling of DSE power constraint to dependent STAs.

6.3.36.2 MLME-DSETPC.request

6.3.36.2.1 Function

This primitive requests that a (Protected) DSE Power Constraint frame be sent by an enabling STA.

6.3.36.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DSETPC.request(
                    RequesterSTAAddress,
                    ResponderSTAAddress,
                    DSELocalPowerConstraint,
                    Protected,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
RequesterSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the MAC entity of the enabling STA.
ResponderSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the MAC entity that initiates the enablement process.
DSELocalPowerConstraint	Integer	0–255	Specifies the local power constraint, as described in the DSE Power Constraint frame (see 9.6.7.10).

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Name	Type	Valid range	Description
Protected	Boolean	true, false	Specifies whether the request is sent using a protected robust Management frame. If true, the request is sent using the Protected DSE Power Constraint frame. If false, the request is sent using the DSE Power Constraint frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.36.2.3 When generated

This primitive is generated by the SME to request that a (Protected) DSE Power Constraint Announcement frame be sent to a dependent STA.

6.3.36.2.4 Effect of receipt

Upon receipt of this primitive, the MLME constructs a (Protected) DSE Power Constraint Announcement frame. The enabling STA then schedules this frame for transmission.

6.3.36.3 MLME-DSETPC.confirm

6.3.36.3.1 Function

This primitive reports the results of a request to send a (Protected) DSE Power Constraint Announcement frame.

6.3.36.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DSETPC.confirm(
                    ResultCode,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, REFUSED	Indicates the result of MLME-DSETPC.request primitive.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.36.3.3 When generated

This primitive is generated by the MLME when a DSE power constraint announcement completes.

6.3.36.3.4 Effect of receipt

The SME is notified of the results of the DSE power constraint procedure.

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6.3.36.4 MLME-DSETPC.indication

6.3.36.4.1 Function

This primitive indicates that a DSE Power Constraint Announcement frame was received from an enabling STA.

6.3.36.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DSETPC.indication(
                        RequesterSTAAddress,
                        ResponderSTAAddress,
                        DSELocalPowerConstraint,
                        Protected,
                        VendorSpecificInfo
                        )
```

Name	Type	Valid range	Description
RequesterSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity that initiated the enablement process.
ResponderSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity that is the enabling STA.
DSELocalPowerConstraint	Integer	0–255	Specifies the local power constraint, as described in the DSE Power Constraint frame (see 9.6.7.10).
Protected	Boolean	true, false	Specifies whether the request was received using a protected robust Management frame. If true, the request was received using the Protected DSE Power Constraint frame. If false, the request was received using the DSE Power Constraint frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.36.4.3 When generated

This primitive is generated by the MLME when a (Protected) DSE Power Constraint Announcement frame is received.

6.3.36.4.4 Effect of receipt

On receipt of this primitive, the SME performs the DSE power constraint procedure (see 11.11.5).

6.3.36.5 MLME-DSETPC.response

6.3.36.5.1 Function

This primitive is used to report the result of the DSE power constraint procedure.

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6.3.36.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DSETPC.response(
RequesterSTAAddress,
ResponderSTAAddress,
ResultCode,
Protected,
VendorSpecificInfo
)

Name	Type	Valid range	Description
RequesterSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the MAC entity of the enabling STA.
ResponderSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity that initiates the enabling process.
ResultCode	Enumeration	SUCCESS, REFUSED	Reports the result of a DSE power constraint procedure.
Protected	Boolean	true, false	Specifies whether the response is sent using a protected robust Management frame. If true, the response is sent using the Protected DSE Power Constraint frame. If false, the response is sent using the DSE Power Constraint frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.36.5.3 When generated

This primitive is generated by the SME to schedule a response to DSE power constraint announcement.

6.3.36.5.4 Effect of receipt

On receipt of this primitive, the MLME schedules the transmission of a (Protected) DSE power constraint result to the enabling STA that sent the DSE power constraint announcement.

6.3.37 Enablement

6.3.37.1 General

This mechanism supports the process of establishing an enablement relationship with a peer MAC entity.

6.3.37.2 MLME-ENABLEMENT.request

6.3.37.2.1 Function

This primitive requests enablement with a specified peer MAC entity.

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6.3.37.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ENABLEMENT.request(
RequesterSTAAddress,
ResponderSTAAddress,
EnablementTimeLimit,
Protected,
VendorSpecificInfo
)

Name	Type	Valid range	Description
RequesterSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the MAC entity that initiates the enablement process.
ResponderSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the MAC entity of the enabling STA.
EnablementTimeLimit	Integer	> 0	Specifies a time limit (in TU) after which the enablement process is terminated.
Protected	Boolean	true, false	Specifies whether the request is sent using a protected robust Management frame. If true, the request is sent using the Protected DSE Enablement frame. If false, the request is sent using the DSE Enablement frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.37.2.3 When generated

This primitive is generated by the SME for a STA to establish enablement with a specified peer MAC entity. During the enablement procedure, the SME can generate additional MLME-ENABLEMENT.request primitives.

6.3.37.2.4 Effect of receipt

This primitive initiates an enablement procedure. In the case that a response is received from the responder STA, the MLME subsequently issues an MLME-ENABLEMENT.confirm primitive that reflects the results.

6.3.37.3 MLME-ENABLEMENT.confirm

6.3.37.3.1 Function

This primitive reports the results of an enablement attempt with a specified peer MAC entity.

6.3.37.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ENABLEMENT.confirm(
RequesterSTAAddress,
ResponderSTAAddress,

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ResultCode,
Protected,
EnablementIdentifier,
VendorSpecificInfo
)

Name	Type	Valid range	Description
RequesterSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the MAC entity that initiated the enablement process. This value matches the RequesterSTAAddress parameter specified in the corresponding MLME-ENABLEMENT.request primitive.
ResponderSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the enablement process was attempted.This value matches the ResponderSTAAddress parameter specified in the corresponding MLME-ENABLEMENT.request primitive.
ResultCode	Enumeration	SUCCESS, REFUSED, TOO_MANY_SIMULTANEOUS_REQUESTS	Indicates the result of MLME-ENABLEMENT.request primitive.
EnablementIdentifier	Integer	0–65 535	Specifies the dependent enablement identifier.
Protected	Boolean	true, false	Specifies whether the response was received using a protected robust Management frame. If true, the response was received using the Protected DSE Enablement frame. If false, the response was received using the DSE Enablement frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.37.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-ENABLEMENT.request primitive for enablement with a specified peer MAC entity.

6.3.37.3.4 Effect of receipt

The SME is notified of the results of the enablement procedure.

6.3.37.4 MLME-ENABLEMENT.indication

6.3.37.4.1 Function

This primitive indicates receipt of a request from a specific peer MAC entity to establish an enablement relationship with the STA processing this primitive.

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6.3.37.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ENABLEMENT.indication(
RequesterSTAAddress,
ResponderSTAAddress,
Protected,
VendorSpecificInfo
)

Name	Type	Valid range	Description
RequesterSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity that initiated the enablement process.
ResponderSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity that is the enabling STA.
Protected	Boolean	true, false	Specifies whether the request was sent using a protected robust Management frame. If true, the request was sent using the Protected DSE Enablement frame. If false, the request was sent using the DSE Enablement frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.37.4.3 When generated

This primitive is generated by the MLME as a result of the receipt of an enablement request from a specific peer MAC entity.

6.3.37.4.4 Effect of receipt

The SME is notified of the receipt of this enablement request.

6.3.37.5 MLME-ENABLEMENT.response

6.3.37.5.1 Function

This primitive is used to send a response to a specified peer MAC entity that requested enablement with the STA that issued this primitive.

6.3.37.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ENABLEMENT.response(
RequesterSTAAddress,
ResponderSTAAddress,
ResultCode,
EnablementIdentifier,
Protected,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
RequesterSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the MAC entity that initiated the enablement process.
ResponderSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity that is the enabling STA.
ResultCode	Enumeration	SUCCESS, REFUSED, TOO_MANY_SIMULTANEOUS_REQUESTS	Indicates the result response to the enablement request from the peer MAC entity.
EnablementIdentifier	Integer	0-65 535	Specifies the dependent enablement identifier.
Protected	Boolean	true, false	Specifies whether the response is sent using a protected robust Management frame. If true, the response is sent using the Protected DSE Enablement frame. If false, the response is sent using the DSE Enablement frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.37.5.3 When generated

This primitive is generated by the SME of a STA as a response to an MLME-ENABLEMENT.indication primitive.

6.3.37.5.4 Effect of receipt

This primitive initiates transmission of a response to the specific peer MAC entity that requested enablement.

6.3.38 Deenablement

6.3.38.1 MLME-DEENABLEMENT.request

6.3.38.1.1 Function

This primitive requests that the enablement relationship with a specified peer MAC entity be invalidated.

6.3.38.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DEENABLEMENT.request(
                                RequesterSTAAddress,
                                ResponderSTAAddress,
                                ReasonCode,
                                Protected,
                                VendorSpecificInfo
                                )
```

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Name	Type	Valid range	Description
RequesterSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity that requests the deenablement process.
ResponderSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the MAC entity that becomes deenabled in the process.
ReasonCode	Reason Result Code field	As defined in 9.6.7.5	Specifies the reason code for initiating the deenablement process.
Protected	Boolean	true, false	Specifies whether the request is sent using a protected robust Management frame. If true, the request is sent using the Protected DSE Deenablement frame. If false, the request is sent using the DSE Deenablement frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.38.1.3 When generated

This primitive is generated by the SME for a STA to invalidate enablement with a specified peer MAC entity in order to prevent the exchange of (Protected Dual of) Public Action frames between the two STAs. During the deenablement procedure, the SME can generate additional MLME-DEENABLEMENT.request primitives.

6.3.38.1.4 Effect of receipt

This primitive initiates a deenablement procedure.

6.3.38.2 MLME-DEENABLEMENT.indication

6.3.38.2.1 Function

This primitive reports the invalidation of an enablement relationship with a specified peer MAC entity.

6.3.38.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DEENABLEMENT.indication(
                                RequesterSTAAddress,
                                ResponderSTAAddress,
                                ReasonCode,
                                Protected,
                                VendorSpecificInfo
                                )
```

Name	Type	Valid range	Description
RequesterSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the enablement relationship was invalidated.
ResponderSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the MAC entity with which the enablement relationship was invalidated.

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Name	Type	Valid range	Description
ReasonCode	Reason Result Code field	As defined in 9.6.7.5	Specifies the reason the deenablement procedure was initiated.
Protected	Boolean	true, false	Specifies whether the request was received using a protected robust Management frame. If true, the request was received using the Protected DSE Deenablement frame. If false, the request was received using the DSE Deenablement frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.38.2.3 When generated

This primitive is generated by the MLME as a result of the invalidation of an enablement relationship with a specific peer MAC entity.

6.3.38.2.4 Effect of receipt

The SME is notified of the invalidation of the specific enablement relationship.

6.3.39 SA Query support

6.3.39.1 MLME-SA-QUERY.request

6.3.39.1.1 Function

This primitive requests that an SA Query Request frame be sent to a specified peer STA to which the STA is associated.

6.3.39.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SA-QUERY.request(
                      PeerSTAAddress,
                      TransactionIdentifier,
                      VendorSpecificInfo
                      )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity for the SA Query.
TransactionIdentifier	2 octets	As defined in 9.6.9.2	The Transaction Identifier to identify the SA Query Request and Response transaction.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.39.1.3 When generated

This primitive is generated by the SME to request that an SA Query Request frame be sent to a specified peer STA with which the STA is associated.

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6.3.39.1.4 Effect of receipt

On receipt of this primitive, the MLME constructs an SA Query Request frame. The STA then attempts to transmit this to the peer STA with which it is associated.

6.3.39.2 MLME-SA-QUERY.confirm

6.3.39.2.1 Function

This primitive reports the result of an SA Query procedure.

6.3.39.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SA-QUERY.confirm(
                    PeerSTAAddress,
                    TransactionIdentifier,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid Range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity for the SA Query.
TransactionIdentifier	2 octets	As defined in 9.6.9.2	The Transaction Identifier to identify the SA Query Request and Response transaction.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.39.2.3 When generated

This primitive is generated by the MLME as a result of the receipt of a valid SA Query Response frame.

6.3.39.2.4 Effect of receipt

On receipt of this primitive, the SME may use the response as a sign of liveness of the peer STA.

6.3.39.3 MLME-SA-QUERY.indication

6.3.39.3.1 Function

This primitive indicates that an SA Query Request frame was received from a STA.

6.3.39.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SA-QUERY.indication(
                    PeerSTAAddress,
                    TransactionIdentifier,
                    VendorSpecificInfo
                    )
```

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity for the SA Query.
TransactionIdentifier	2 octets	As defined in 9.6.9.2	The Transaction Identifier to identify the SA Query Request and Response transaction.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.39.3.3 When generated

This primitive is generated by the MLME when a SA Query Request frame is received.

6.3.39.3.4 Effect of receipt

On receipt of this primitive, the SME operates according to the procedure in 11.3.

6.3.39.4 MLME-SA-QUERY.response

6.3.39.4.1 Function

This primitive is generated in response to an MLME-SA-QUERY.indication primitive requesting an SA Query Response frame be sent to a STA.

6.3.39.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SA-QUERY.response(
                        PeerSTAAddress,
                        TransactionIdentifier,
                        VendorSpecificInfo
                        )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity for the SA Query.
TransactionIdentifier	2 octets	As defined in 9.6.9.2	The Transaction Identifier to identify the SA Query Request and Response transaction.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.39.4.3 When generated

This primitive is generated by the SME, in response to an MLME-SA-QUERY.indication primitive, requesting an SA Query Response frame be sent to a STA.

6.3.39.4.4 Effect of receipt

On receipt of this primitive, the MLME constructs an SA Query Response frame. The STA then attempts to transmit this to the STA indicated by the PeerSTAAddress parameter.

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6.3.40 Get TSF timer

6.3.40.1 General

This mechanism is used to request the current value of the TSF timer that the STA maintains.

6.3.40.2 MLME-GETTSFTIME.request

6.3.40.2.1 Function

This primitive is generated by the SME to request that the MLME returns the value of its TSF timer. The value returned in TSFtime (as specified in 6.3.40.3.2) is the value of the TSF timer at the instant the MLME-GETTSFTIME.request primitive is received.

6.3.40.2.2 Semantics of the service primitive

This primitive has no parameters.

6.3.40.2.3 When generated

This primitive is generated by the SME to request the value of the TSF timer from the MLME.

6.3.40.2.4 Effect of receipt

The MLME issues an MLME-GETTSFTIME.confirm primitive.

6.3.40.3 MLME-GETTSFTIME.confirm

6.3.40.3.1 Function

This primitive is generated by the MLME to report to the SME the result of a request to get the value of the TSF timer.

6.3.40.3.2 Semantics of the service primitive

This primitive uses the following parameters:

```
MLME-GETTSFTIME.confirm(
                        ResultCode,
                        TSFtime
                        )
```

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, FAILURE	Reports the outcome of an MLME-GETTSFTIME.request primitive.
TSFtime	Integer	$0 – (2^{64} – 1)$	The value of the TSF timer. Present if ResultCode is SUCCESS; otherwise not present.

6.3.40.3.3 When generated

This primitive is generated by the MLME to report to the SME the result of an MLME-GETTSFTIME.request primitive.

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6.3.40.3.4 Effect of receipt

The SME is notified of the result of an MLME-GETTSFTIME.request primitive and, if successful, has the value of the TSF timer at the instant the MLME-GETTSFTIME.request primitive was received by the MLME. If the result of an MLME-GETTSFTIME.request primitive is failure, the TSFtime parameter is not included in the MLME-GETTSFTIME.confirm primitive.

NOTE—The TSF timer value can be used, along with other information, by the SME to compute an offset between an external time standard such as a version of Coordinated Universal Time (UTC) from a Global Positioning System (GPS) unit and the TSF timer.

6.3.41 Timing Advertisement

6.3.41.1 General

The Timing Advertisement primitives are used to communicate timing and other information from the higher layers or the SME of one STA to the higher layers or SME of other STAs.

6.3.41.2 MLME-TIMING-ADVERTISEMENT.request

6.3.41.2.1 Function

This primitive is generated by the SME to request that the MLME generate a Timing Advertisement frame to transmit timing and, optionally, higher layer information.

6.3.41.2.2 Semantics of the service primitive

This primitive provides the following parameters:

MLME-TIMING-ADVERTISEMENT.request(
PeerMACAddress,
Capability Information,
Country,
Power Constraint,
Time Advertisement,
Extended Capabilities,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual or group MAC address	The address of the peer MAC entity or group of entities to which the Timing Advertisement frame is sent.
Capability Information	As defined in 9.4.1.4	As defined in 9.4.1.4	The announced capabilities of the STA.
Country	As defined in 9.4.2.8	As defined in 9.4.2.8	The information required to identify the regulatory domain in which the STA is located and to configure its PHY for operation in that regulatory domain. Present only when TPC functionality is required, as specified in 11.7 or when dot11MultiDomainCapabilityActivated is true.
Power Constraint	As defined in 9.4.2.13	As defined in 9.4.2.13	Optional. The Power Constraint element contains the information necessary to allow a STA to determine the local maximum transmit power in the current channel.

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Name	Type	Valid range	Description
Time Advertisement	As defined in 9.4.2.60	As defined in 9.4.2.60	Timing announced by the STA.
Extended Capabilities	As defined in 9.4.2.26	As defined in 9.4.2.26	The Extended Capabilities element is present if any of the fields in this element are nonzero.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.41.2.3 When generated

This primitive is generated by the SME to request that the MLME generates a Timing Advertisement frame for transmission.

6.3.41.2.4 Effect of receipt

Upon the receipt of this primitive, the MLME attempts to transmit a Timing Advertisement frame to the specified MAC address, using the procedures defined in 11.19.

6.3.41.3 MLME-TIMING-ADVERTISEMENT.indication

6.3.41.3.1 Function

This primitive is generated by the MLME to indicate to the SME the reception of a Timing Advertisement frame.

6.3.41.3.2 Semantics of the service primitive

This primitive provides the following parameters:

MLME-TIMING-ADVERTISEMENT.indication(
Timestamp,
Capability Information,
Local Time,
Country,
Power Constraint,
Time Advertisement,
Extended Capabilities,
RCPI,
Source MAC address,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Timestamp	Integer	N/A	The timestamp of the received frame.
Capability Information	As defined in 9.4.1.4	As defined in 9.4.1.4	The announced capabilities of the STA.
Local Time	Integer	N/A	Local Time is the value of a STA's TSF timer at the start of reception of the first octet of the timestamp field of the received Timing Advertisement frame.

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Name	Type	Valid range	Description
Country	As defined in 9.4.2.8	As defined in 9.4.2.8	The information required to identify the regulatory domain in which the STA is located and to configure its PHY for operation in that regulatory domain. Present only when TPC functionality is required, as specified in 11.7 or when dot11MultiDomainCapabilityActivated is true.
Power Constraint	As defined in 9.4.2.13	As defined in 9.4.2.13	The Power Constraint element contains the information necessary to allow a STA to determine the local maximum transmit power in the current channel.
Time Advertisement	As defined in 9.4.2.60	As defined in 9.4.2.60	Timing announced by the STA.
Extended Capabilities	As defined in 9.4.2.26	As defined in 9.4.2.26	The Extended Capabilities element is present if any of the fields in this element are nonzero.
RCPI	Integer as defined in 9.4.2.37	As defined in 9.4.2.37	RCPI is the measured value of received channel power on the received Timing Advertisement frame.
Source MAC Address	As defined in 9.2.4.3.6	As defined in 9.2.4.3.6	The SA field of the MAC header from the received Timing Advertisement frame.
VendorSpecific Info	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.41.3.3 When generated

This primitive is generated by the MLME when a Timing Advertisement frame is received.

6.3.41.3.4 Effect of receipt

Upon the receipt of this primitive, the SME is notified that a Timing Advertisement frame has been received.

6.3.42 TDLS Discovery

6.3.42.1 General

The following MLME primitives support the signaling of TDLS Discovery.

6.3.42.2 MLME-TDLSDISCOVERY.request

6.3.42.2.1 Function

This primitive requests that a TDLS Discovery Request frame be sent through the AP path.

6.3.42.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TDLSDISCOVERY.request(
                                    DestinationAddress,
                                    TDLSDiscoveryRequest
                                    )
```

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Name	Type	Valid range	Description
DestinationAddress	MAC address	Any valid individual MAC address	Specifies the DA to which a TDLS Discovery Request frame is transmitted.
TDLSDiscoveryRequest	Sequence of octets	As defined in TDLS Discovery Request frame	Specifies the proposed service parameters for the TDLS Discovery Request frame.

6.3.42.2.3 When generated

This primitive is generated by the SME to request that a TDLS Discovery Request frame be sent through the AP.

6.3.42.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TDLS Discovery Request frame. The STA then attempts to transmit this frame.

6.3.42.3 MLME-TDLSDISCOVERY.confirm

6.3.42.3.1 Function

This primitive is generated when a TDLS Discovery Response frame is received.

6.3.42.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TDLSDISCOVERY.confirm(
                                TDLSPeerSTAAddress,
                                TDLSDiscoveryResponse
                                )
```

Name	Type	Valid range	Description
TDLSPeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the TDLS peer STA from which a TDLS Discovery Response frame was received.
TDLSDiscoveryResponse	Sequence of octets	As defined in TDLS Discovery Response frame	Specifies the service parameters contained in the received TDLS Discovery Response frame.

6.3.42.3.3 When generated

This primitive is generated when a TDLS Discovery Response frame is received.

6.3.42.3.4 Effect of receipt

On receipt of this primitive, the SME evaluates the MLME-TDLSDISCOVERY.confirm primitive and may use the reported data.

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6.3.42.4 MLME-TDLSDISCOVERY.indication

6.3.42.4.1 Function

This primitive indicates that a TDLS Discovery Request frame was received from a TDLS peer STA.

6.3.42.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TDLSDISCOVERY.indication(
                    TDLSPeerSTAAddress,
                    TDLSDiscoveryRequest
                    )
```

Name	Type	Valid range	Description
TDLSPeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the TDLS peer STA from which a TDLS Discovery Request frame was received.
TDLSDiscoveryRequest	Sequence of octets	As defined in TDLS Discovery Request frame	Specifies the proposed service parameters of the TDLS Discovery Request frame.

6.3.42.4.3 When generated

This primitive is generated by the MLME when a TDLS Discovery Request frame is received.

6.3.42.4.4 Effect of receipt

On receipt of this primitive, the SME operates according to the procedure in 11.20.

6.3.42.5 MLME-TDLSDISCOVERY.response

6.3.42.5.1 Function

This primitive requests that a TDLS Discovery Response frame be sent directly to the TDLS peer STA from which a TDLS Discovery Request frame was received.

6.3.42.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TDLSDISCOVERY.response(
                    TDLSPeerSTAAddress,
                    TDLSDiscoveryResponse
                    )
```

Name	Type	Valid range	Description
TDLSPeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the TDLS peer STA to which a TDLS Discovery Response frame is transmitted.
TDLSDiscoveryResponse	Sequence of octets	As defined in TDLS Discovery Response frame	Specifies the proposed service parameters for the TDLS Discovery Response frame.

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6.3.42.5.3 When generated

This primitive is generated by the SME to request that a TDLS Discovery Response frame be sent to the TDLS peer STA from which a TDLS Discovery Request frame was received.

6.3.42.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TDLS Discovery Response frame. The STA then attempts to transmit this frame to the TDLS peer STA.

6.3.43 TDLS direct-link establishment

6.3.43.1 General

The following MLME primitives support the signaling of tunneled direct-link setup. Figure 6-7 depicts the TDLS direct-link establishment process. The figure is an example of only the basic procedure and is not meant to be exhaustive of all possible uses of the protocol.

6.3.43.2 MLME-TDLSSETUPREQUEST.request

6.3.43.2.1 Function

This primitive requests that a TDLS Setup Request frame be sent to a candidate TDLS responder STA.

6.3.43.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TDLSSETUPREQUEST.request(
                                    TDLSResponderAddress,
                                    TDLSSetupRequest
                                    )
```

Name	Type	Valid range	Description
TDLSResponderAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA to which the TDLS Setup Request frame is transmitted.
TDLSSetupRequest	Sequence of octets	As defined in TDLS Setup Request frame	Specifies the proposed service parameters for the TDLS Setup.

6.3.43.2.3 When generated

This primitive is generated by the SME to request that a TDLS Setup Request frame be sent to a candidate TDLS responder STA.

6.3.43.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TDLS Setup Request frame. The STA then attempts to transmit this frame to the candidate TDLS responder STA.

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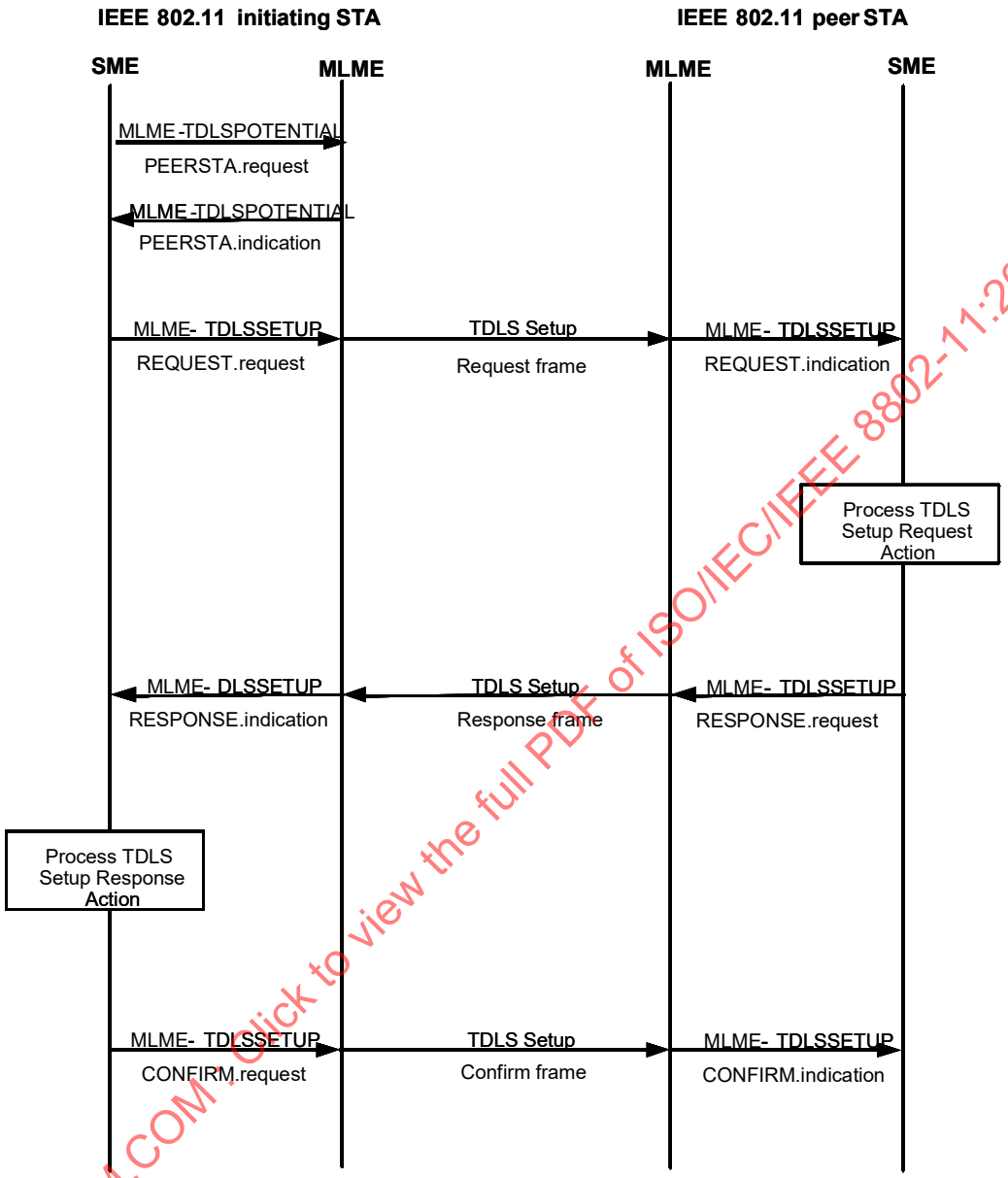

Figure 6-7—TDLS direct-link establishment

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6.3.43.3 MLME-TDLSSETUPREQUEST.indication

6.3.43.3.1 Function

This primitive indicates that a TDLS Setup Request frame was received.

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6.3.43.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TDLSSETUPREQUEST.indication(
TDLSInitiatorAddress,
TDLSSetupRequest
)

Name	Type	Valid range	Description
TDLSInitiatorAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the TDLS initiator STA from which a TDLS Setup Request frame was received.
TDLSSetupRequest	Sequence of octets	As defined in TDLS Setup Request frame	Specifies the proposed service parameters for the TDLS Setup.

6.3.43.3.3 When generated

This primitive is generated by the MLME when a TDLS Setup Request frame is received.

6.3.43.3.4 Effect of receipt

On receipt of this primitive, the SME operates according to the procedure in 11.20.

6.3.43.4 MLME-TDLSSETUPRESPONSE.request

6.3.43.4.1 Function

This primitive requests that a TDLS Setup Response frame be sent to the TDLS initiator STA.

6.3.43.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TDLSSETUPRESPONSE.request(
TDLSInitiatorAddress,
TDLSSetupResponse
)

Name	Type	Valid range	Description
TDLSInitiatorAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the TDLS initiator STA to which a TDLS Setup Response frame is transmitted.
TDLSSetupResponse	Sequence of octets	As defined in TDLS Setup Response frame	Specifies the proposed service parameters for the TDLS Setup.

6.3.43.4.3 When generated

This primitive is generated by the SME to request that a TDLS Setup Response frame be sent to the TDLS initiator STA.

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6.3.43.4.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TDLS Setup Response frame. The STA then attempts to transmit this to the TDLS initiator STA.

6.3.43.5 MLME-TDLSSETUPRESPONSE.indication

6.3.43.5.1 Function

This primitive indicates that a TDLS Setup Response frame was received from the TDLS responder STA.

6.3.43.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TDLSSETUPRESPONSE.indication(
TDLSResponderAddress,
TDLSSetupResponse
)

Name	Type	Valid range	Description
TDLSResponderAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the TDLS responder STA from which a TDLS Setup Response frame was received.
TDLSSetupResponse	Sequence of octets	As defined in TDLS Setup Response frame	Specifies the proposed service parameters for the TDLS Setup.

6.3.43.5.3 When generated

This primitive is generated by the MLME when a TDLS Setup Response frame is received.

6.3.43.5.4 Effect of receipt

On receipt of this primitive, the SME operates according to the procedure in 11.20.

6.3.43.6 MLME-TDLSSETUPCONFIRM.request

6.3.43.6.1 Function

This primitive requests that a TDLS Setup Confirm frame be sent to the TDLS responder STA.

6.3.43.6.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TDLSSETUPCONFIRM.request(
TDLSResponderAddress,
TDLSSetupConfirm
)

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Name	Type	Valid range	Description
TDLSResponderAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the TDLS responder STA to which a TDLS Setup Confirm frame is transmitted.
TDLSSetupConfirm	Sequence of octets	As defined in TDLS Setup Confirm frame	Specifies the proposed service parameters for the TDLS Setup.

6.3.43.6.3 When generated

This primitive is generated by the SME to request that a TDLS Setup Confirm frame be sent to the TDLS responder STA.

6.3.43.6.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TDLS Setup Confirm frame. The STA then attempts to transmit this to the TDLS responder STA.

6.3.43.7 MLME-TDLSSETUPCONFIRM.indication

6.3.43.7.1 Function

This primitive indicates that a TDLS Setup Confirm frame was received from the TDLS initiator STA.

6.3.43.7.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TDLSSETUPCONFIRM.indication(
                                    TDLSInitiatorAddress,
                                    TDLSSetupConfirm
                                    )
```

Name	Type	Valid range	Description
TDLSInitiatorAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the TDLS initiator STA from which a TDLS Setup Confirm frame was received.
TDLSSetupConfirm	Sequence of octets	As defined in TDLS Setup Confirm frame	Specifies the proposed service parameters for the TDLS setup.

6.3.43.7.3 When generated

This primitive is generated by the MLME when a TDLS Setup Confirm frame is received.

6.3.43.7.4 Effect of receipt

On receipt of this primitive, the SME operates according to the procedure in 11.20.

6.3.43.8 MLME-TDLSPOTENTIALPEERSTA.request

6.3.43.8.1 Function

This primitive requests information about a potential TDLS peer STA.

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6.3.43.8.2 Semantics of the service primitive

The primitive parameter is as follows:

MLME-TDLSPOTENTIALPEERSTA.request(
MACAddress
)

Name	Type	Valid Range	Description
MACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the potential TDLS peer STA.

6.3.43.8.3 When generated

This primitive is generated by the SME to request the MLME to provide information about a potential TDLS peer STA.

6.3.43.8.4 Effect of receipt

On receipt of this primitive, the MLME responds with the requested information about the identified STA.

6.3.43.9 MLME-TDLSPOTENTIALPEERSTA.confirm

6.3.43.9.1 Function

This primitive informs the SME about a potential TDLS peer STA.

6.3.43.9.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TDLSPOTENTIALPEERSTA.confirm(
MACAddress,
RSSI
)

Name	Type	Valid range	Description
MACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA for which information is requested.
RSSI	Integer	–1 to 255	Specifies the RSSI from the STA. –1 indicates that the STA is not present.

6.3.43.9.3 When generated

This primitive is generated by the MLME to indicate to the SME that a potential TDLS peer STA has been detected.

6.3.43.9.4 Effect of receipt

On receipt of this primitive, the SME may attempt to set up a TDLS direct link by issuing an MLME-TDLSSETUPREQUEST.request primitive to the MLME.

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6.3.44 TDLS direct-link teardown

6.3.44.1 General

The following MLME primitives support the signaling of tunneled direct-link setup. Figure 6-8 depicts the TDLS direct-link teardown process. The figure is an example of only the basic procedure and is not meant to be exhaustive of all possible uses of the protocol.

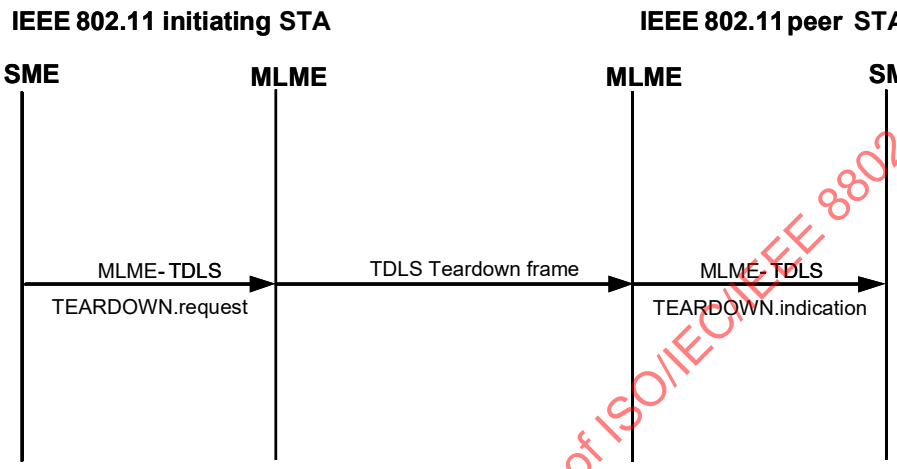

Figure 6-8—TDLS direct-link teardown

6.3.44.2 MLME-TDLSTEARDOWN.request

6.3.44.2.1 Function

This primitive requests that a TDLS Teardown frame be sent to the TDLS peer STA.

6.3.44.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TDLSTEARDOWN.request(
                        TDLSPeerSTAAddress,
                        TDLSTeardown
                        )
```

Name	Type	Valid range	Description
TDLSPeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the TDLS peer STA to which a TDLS Teardown frame is transmitted.
TDLSTeardown	Sequence of octets	As defined in TDLS Teardown frame	Specifies the proposed service parameters for the TDLS teardown.

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6.3.44.2.3 When generated

This primitive is generated by the SME to request that a TDLS Teardown frame be sent to the TDLS peer STA.

6.3.44.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TDLS Teardown frame. The STA then attempts to transmit this frame to the TDLS peer STA.

6.3.44.3 MLME-TDLSTEARDOWN.indication

6.3.44.3.1 Function

This primitive indicates that a TDLS Teardown frame was received from a TDLS peer STA.

6.3.44.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TDLSTEARDOWN.indication(
                    TDLSPeerSTAAddress,
                    TDLSTeardown
                    )
```

Name	Type	Valid range	Description
TDLSPeerSTAAddress	MAC address	Any valid individual MAC address	The MAC address of the TDLS peer STA from which a TDLS Teardown frame was received.
TDLSTeardown	Sequence of octets	As defined in TDLS Teardown frame	Specifies the proposed service parameters for the TDLS teardown.

6.3.44.3.3 When generated

This primitive is generated by the MLME when a TDLS Teardown frame is received.

6.3.44.3.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 11.20.

6.3.45 TDLS peer U-APSD (TPU)

6.3.45.1 General

The following MLME primitives support the signaling of TPU. Figure 6-9 depicts the TPU process. The figure is an example of only the basic procedure and is not meant to be exhaustive of all possible uses of the protocol.

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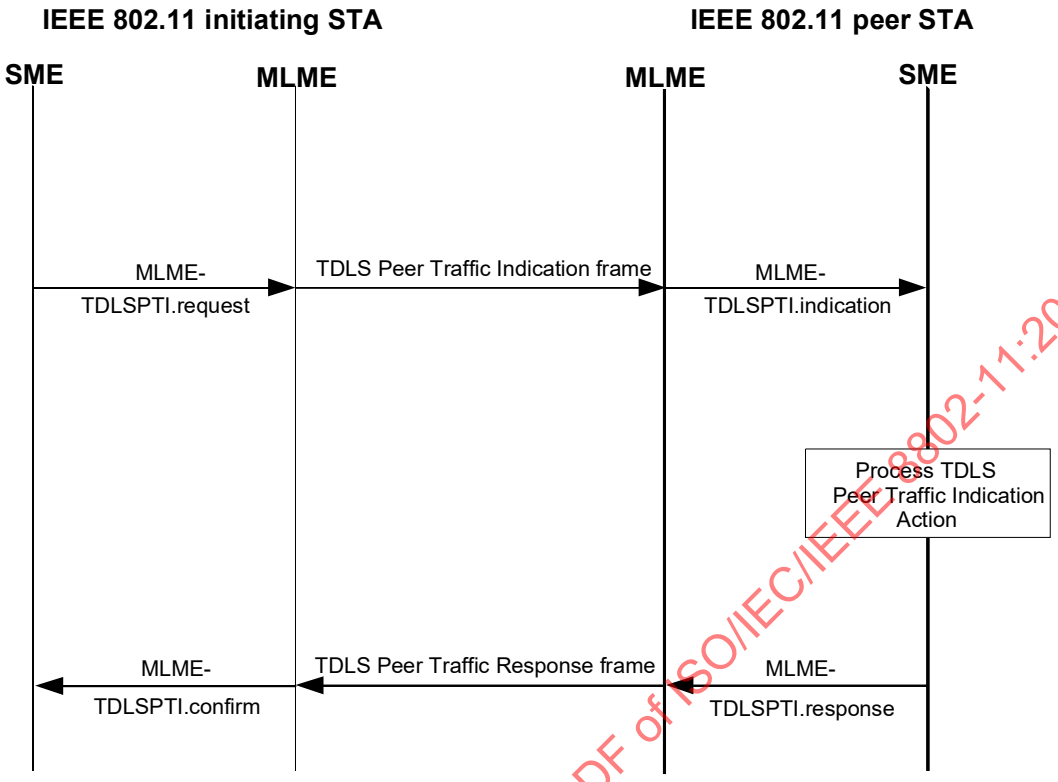

Figure 6-9—TPU

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6.3.45.2 MLME-TDLSPTI.request

6.3.45.2.1 Function

This primitive requests that a TDLS Peer Traffic Indication frame be sent to a TDLS peer STA.

6.3.45.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TDLSPTI.request(
                    TDLSPeerSTAAddress,
                    TDLSPTI
                    )
```

Name	Type	Valid range	Description
TDLSPeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the MAC entity with which to perform the TPU process.
TDLSPTI	Sequence of octets	As defined in TDLS Peer Traffic Indication frame	Specifies the proposed service parameters for the TPU.

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6.3.45.2.3 When generated

This primitive is generated by the SME to request that a TDLS Peer Traffic Indication frame be sent to the TDLS peer STA.

6.3.45.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TDLS Peer Traffic Indication frame. The STA then attempts to transmit this to the TDLS peer STA.

6.3.45.3 MLME-TDLSPTI.confirm

6.3.45.3.1 Function

This primitive reports the result of an MLME-TDLSPTI.request primitive to trigger an unscheduled SP from a candidate TDLS peer STA. This primitive is generated after transmitting a Peer Traffic Indication frame when this frame contains a PTI Control field, and after receiving a Peer Traffic Response frame otherwise.

6.3.45.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TDLSPTI.confirm(
                    TDLSPeerSTAAddress,
                    TDLSPTR
                    )
```

Name	Type	Valid range	Description
TDLSPeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the peer MAC entity with which to perform the TPU process.
TDLSPTR	Sequence of octets	As defined in TDLS Peer Traffic Response frame	Specifies the proposed service parameters for the TPU.

6.3.45.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-TDLSPTI.request primitive and indicates the results of the request.

This primitive is generated when the STA receives a TDLS Peer Traffic Response frame from the TDLS peer STA or when an unspecified failure occurs.

6.3.45.3.4 Effect of receipt

On receipt of this primitive, the SME evaluates the results of the MLME-TDLSPTI.request primitive and may use the reported data.

6.3.45.4 MLME-TDLSPTI.indication

6.3.45.4.1 Function

This primitive indicates that a TDLS Peer Traffic Indication frame was received from a TDLS peer STA.

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6.3.45.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TDLSPTI.indication(
TDLSPeerSTAAddress,
TDLSPTI
)

Name	Type	Valid range	Description
TDLSPeerSTAAddress	MAC address	Any valid individual MAC address	The MAC address of the non-AP STA MAC entity from which a TDLS Peer Traffic Indication frame was received.
TDLSPTI	Sequence of octets	As defined in TDLS Peer Traffic Indication frame	Specifies the proposed service parameters for the TPU.

6.3.45.4.3 When generated

This primitive is generated by the MLME when a TDLS Peer Traffic Indication frame is received.

6.3.45.4.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure as specified in 11.2.3.13.

6.3.45.5 MLME-TDLSPTI.response

6.3.45.5.1 Function

This primitive requests that a TDLS Peer Traffic Response frame be sent to the TDLS peer STA.

6.3.45.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TDLSPTI.response(
PeerSTAAddress,
TDLSPTR
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the TPU.
TDLSPTR	Sequence of octets	As defined in TDLS Peer Traffic Response frame	Specifies the proposed service parameters for the TPU.

6.3.45.5.3 When generated

This primitive is generated by the SME to request that a TDLS Peer Traffic Response frame be sent to the TDLS peer STA.

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6.3.45.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TDLS Peer Traffic Response frame. The STA then attempts to transmit this to the TDLS peer STA.

6.3.46 TDLS channel switching

6.3.46.1 General

The following MLME primitives support the signaling of a TDLS channel switch. Figure 6-10 depicts the TDLS channel switching process. The figure is an example of only the basic procedure and is not meant to be exhaustive of all possible uses of the protocol.

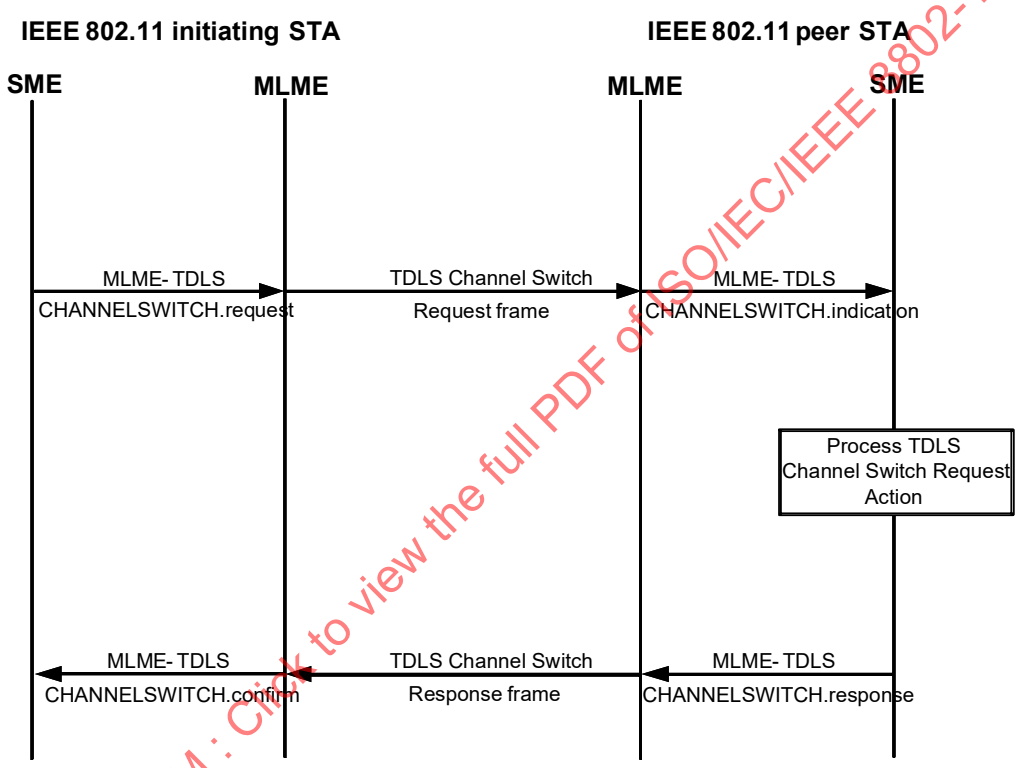

Figure 6-10—TDLS channel switching

6.3.46.2 MLME-TDLSCHANNELSWITCH.request

6.3.46.2.1 Function

This primitive requests that a TDLS Channel Switch Request frame be sent to the TDLS peer STA.

6.3.46.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TDLSCHANNELSWITCH.request(
                                    TDLSPeerSTAAddress,
                                    TDLSChannelSwitchRequest
                                    )
```

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Name	Type	Valid range	Description
TDLSPeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the TDLS peer MAC entity to which a TDLS Channel Switch Request frame is transmitted.
TDLSChannelSwitchRequest	Sequence of octets	As defined in TDLS Channel Switch Request frame	Specifies the proposed service parameters for the TDLS Channel Switch.

6.3.46.2.3 When generated

This primitive is generated by the SME to request that a TDLS Channel Switch Request frame be sent to the TDLS peer STA.

6.3.46.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TDLS Channel Switch Request frame. The STA then attempts to transmit this to the TDLS peer STA.

6.3.46.3 MLME-TDLSCHANNELSWITCH.confirm

6.3.46.3.1 Function

This primitive reports the result of an MLME-TDLSCHANNELSWITCH.request primitive to switch a channel with a TDLS peer STA.

6.3.46.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TDLSCHANNELSWITCH.confirm(
                    TDLSPeerSTAAddress,
                    TDLSChannelSwitchResponse
                    )
```

Name	Type	Valid range	Description
TDLSPeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the TDLS peer STA from which a TDLS Channel Switch Response frame was received.
TDLSChannelSwitchResponse	Sequence of octets	As defined in TDLS Channel Switch Response frame	Specifies the proposed service parameters for the TDLS Channel Switch.

6.3.46.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-TDLSCHANNELSWITCH.request primitive and indicates the results of the request.

This primitive is generated when the STA receives a TDLS Channel Switch Response frame from the TDLS peer STA.

6.3.46.3.4 Effect of receipt

On receipt of this primitive, the SME evaluates the results of the MLME-TDLSCHANNELSWITCH.request primitive and may use the reported data.

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6.3.46.4 MLME-TDLSCHANNELSWITCH.indication

6.3.46.4.1 Function

This primitive indicates that a TDLS Channel Switch Request frame was received from a TDLS peer STA.

6.3.46.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TDLSCHANNELSWITCH.indication(
                                    TDLSPeerSTAAddress,
                                    TDLSChannelSwitchRequest
                                    )
```

Name	Type	Valid range	Description
TDLSPeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the TDLS peer STA from which a TDLS Channel Switch Request frame was received.
TDLSChannelSwitchRequest	Sequence of octets	As defined in TDLS Channel Switch Request frame	Specifies the proposed service parameters for the TDLS Channel Switch.

6.3.46.4.3 When generated

This primitive is generated by the MLME when a TDLS Channel Switch Request frame is received.

6.3.46.4.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 11.20.

6.3.46.5 MLME-TDLSCHANNELSWITCH.response

6.3.46.5.1 Function

This primitive requests that a TDLS Channel Switch Response frame be sent to the TDLS peer STA.

6.3.46.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TDLSCHANNELSWITCH.response(
                                    TDLSPeerSTAAddress,
                                    TDLSChannelSwitchResponse
                                    )
```

Name	Type	Valid range	Description
TDLSPeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the TDLS peer STA to which a TDLS Channel Switch Response frame is transmitted.
TDLSChannelSwitchResponse	Sequence of octets	As defined in TDLS Channel Switch Response frame	Specifies the proposed service parameters for the TDLS Channel Switch.

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6.3.46.5.3 When generated

This primitive is generated by the SME to request that a TDLS Channel Switch Response frame be sent to the TDLS peer STA.

6.3.46.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TDLS Channel Switch Response frame. The STA then attempts to transmit this frame to the TDLS peer STA.

6.3.47 TDLS peer PSM

6.3.47.1 General

The following MLME primitives support the management of TDLS peer PSM. Figure 6-11 depicts the TDLS peer PSM process. The figure is an example of only the basic procedure and is not meant to be exhaustive of all possible uses of the protocol.

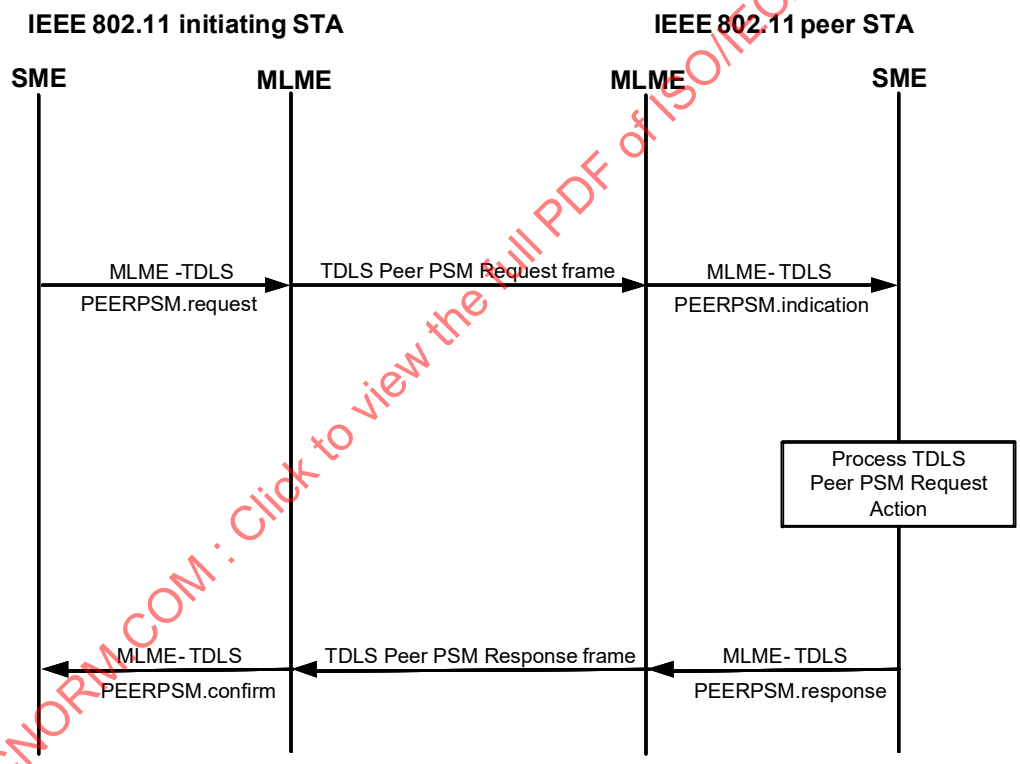

Figure 6-11—TDLS peer PSM

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6.3.47.2 MLME-TDLSPEERPSM.request

6.3.47.2.1 Function

This primitive requests that a TDLS Peer PSM Request frame be sent to the TDLS peer STA.

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6.3.47.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TDLSPEERPSM.request(
TDLSPeerSTAAddress,
TDLSPeerPSMRequest
)

Name	Type	Valid range	Description
TDLSPeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the TDLS peer STA to which a TDLS Peer PSM Request frame is transmitted.
TDLSPeerPSMRequest	Sequence of octets	As defined in TDLS Peer PSM Request frame	Specifies the proposed service parameters for the TDLS peer PSM.

6.3.47.2.3 When generated

This primitive is generated by the SME to request that a TDLS Peer PSM Request frame be sent to the TDLS peer STA.

6.3.47.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TDLS Peer PSM Request frame. The STA then attempts to transmit this to the TDLS peer STA.

6.3.47.3 MLME-TDLSPEERPSM.confirm

6.3.47.3.1 Function

This primitive reports the result of an MLME-TDLSPEERPSM.request primitive to initiate power save mode based on scheduled service periods with a TDLS peer STA.

6.3.47.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TDLSPEERPSM.confirm(
TDLSPeerSTAAddress,
TDLSPeerPSMResponse
)

Name	Type	Valid range	Description
TDLSPeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the TDLS peer STA from which a TDLS Peer PSM Response frame was received.
TDLSPeerPSMResponse	Sequence of octets	As defined in TDLS Peer PSM Response frame	Specifies the proposed service parameters for the TDLS peer PSM.

6.3.47.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-TDLSPEERPSM.request primitive and indicates the results of the request.

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This primitive is generated when the STA receives a TDLS Peer PSM Response frame from the TDLS peer STA or when an unspecified failure occurs.

6.3.47.3.4 Effect of receipt

On receipt of this primitive, the SME evaluates the results of the MLME-TDLSPEERPSM.request primitive and may use the reported data.

6.3.47.4 MLME-TDLSPEERPSM.indication

6.3.47.4.1 Function

This primitive indicates that a TDLS Peer PSM Request frame was received from a TDLS peer STA.

6.3.47.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TDLSPEERPSM.indication(
                    TDLSPeerSTAAddress,
                    TDLSPeerPSMRequest
                    )
```

Name	Type	Valid range	Description
TDLSPeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the TDLS peer STA MAC entity from which a TDLS Peer PSM Request frame was received.
TDLSPeerPSMRequest	Sequence of octets	As defined in TDLS Peer PSM Request frame	Specifies the proposed service parameters for the TDLS peer PSM.

6.3.47.4.3 When generated

This primitive is generated by the MLME when a TDLS Peer PSM Request frame is received.

6.3.47.4.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 11.2.3.12.

6.3.47.5 MLME-TDLSPEERPSM.response

6.3.47.5.1 Function

This primitive requests that a TDLS Peer PSM Response frame be sent to the TDLS peer STA.

6.3.47.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TDLSPEERPSM.response(
                    TDLSPeerSTAAddress,
                    TDLSPeerPSMResponse
                    )
```

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Name	Type	Valid range	Description
TDLSPeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the TDLS peer STA to which a TDLS Peer PSM Response frame is transmitted.
TDLSPeerPSMResponse	Sequence of octets	As defined in TDLS Peer PSM Response frame	Specifies the proposed service parameters for the TDLS peer PSM.

6.3.47.5.3 When generated

This primitive is generated by the SME to request that a TDLS Peer PSM Response frame be sent to the TDLS peer STA.

6.3.47.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TDLS Peer PSM Response frame. The STA then attempts to transmit this to the TDLS peer STA.

6.3.48 Event request

6.3.48.1 General

This set of primitives supports the exchange of Event Request and Event Report frames. The diagram in Figure 6-12 shows the Event Request and Event Report process.

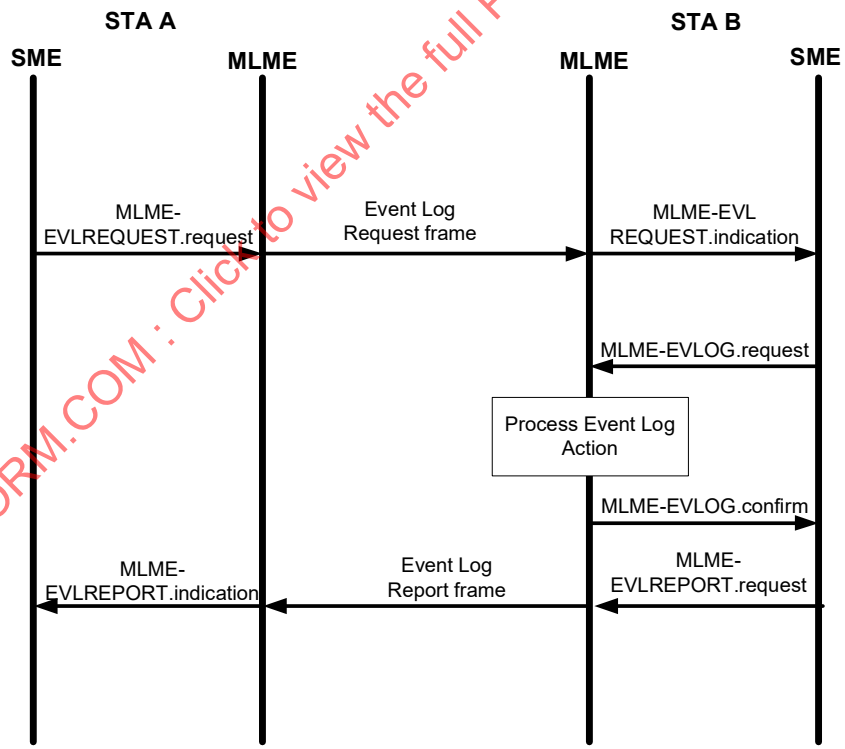

Figure 6-12—Event protocol exchange

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6.3.48.2 MLME-EVLREQUEST.request

6.3.48.2.1 Function

This primitive requests the transmission of an event request to a peer entity.

6.3.48.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EVLREQUEST.request(
Peer MAC Address,
Dialog Token,
Event Request Set,
Destination URI,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the event request is sent.
Dialog Token	Integer	1–255	The dialog token to identify the event transaction.
Event Request Set	Set of event elements	Set of event elements	A set of event elements describing the requested event.
Destination URI	Destination URI element	Destination URI element	The Destination URI element as defined in 9.4.2.89.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.48.2.3 When generated

This primitive is generated by the SME to request that an Event Request frame be sent to a peer entity to initiate one or more transactions.

6.3.48.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs an Event Request frame containing the set of event elements specified. This frame is then scheduled for transmission.

6.3.48.3 MLME-EVLREQUEST.indication

6.3.48.3.1 Function

This primitive indicates that an Event Request frame requesting an event transaction has been received.

6.3.48.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EVLREQUEST.indication(
Peer MAC Address,
Dialog Token,
Event Request Set,

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Destination URI,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the event request was received.
Dialog Token	Integer	1–255	The dialog token to identify the event transaction.
Event Request Set	Set of event elements	Set of event elements	A set of event elements describing the requested event.
Destination URI	Destination URI element	Destination URI element	The Destination URI element as defined in 9.4.2.89.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.48.3.3 When generated

This primitive is generated by the MLME when an Event Request frame is received.

6.3.48.3.4 Effect of receipt

On receipt of this primitive, the SME either rejects the request or commences the event transaction.

6.3.49 Event report

6.3.49.1 General

This set of primitives supports the signaling of event reports.

6.3.49.2 MLME-EVLREPORT.request

6.3.49.2.1 Function

This primitive supports the signaling of event reports between peer SMEs.

6.3.49.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EVLREPORT.request(
Peer MAC Address,
Dialog Token,
Event Report Set,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the event report is sent.
Dialog Token	Integer	1–255	The dialog token to identify the event transaction.
Event Report Set	Set of event elements	Set of event elements	A set of event elements describing the response to the event request.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.49.2.3 When generated

This primitive is generated by the SME to request that an Event Report frame be sent to a peer entity to report the results of one or more transactions.

6.3.49.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs an Event Report frame containing the set of event elements. This frame is then scheduled for transmission.

6.3.49.3 MLME-EVLREPORT.indication

6.3.49.3.1 Function

This primitive indicates that an Event Report frame has been received from a peer entity.

6.3.49.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-EVLREPORT.indication(
                    Peer MAC Address,
                    Dialog Token,
                    Event Report Set,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the event report was received.
Dialog Token	Integer	1–255	The dialog token to identify the event transaction.
Event Report Set	Set of event elements	Set of event elements	A set of event elements describing the response to the event request.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.49.3.3 When generated

This primitive is generated by the MLME when an Event Report frame is received.

6.3.49.3.4 Effect of receipt

On receipt of this primitive, the event data can be made available for SME processes.

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6.3.50 Event

6.3.50.1 General

This set of primitives supports the requesting and reporting of event data.

6.3.50.2 MLME-EVLOG.request

6.3.50.2.1 Function

This primitive is generated by the SME to request that the MLME identify specific events.

6.3.50.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EVLOG.request(
Dialog Token,
Event Request Set
)

Name	Type	Valid range	Description
Dialog Token	Integer	1–255	The dialog token to identify the event transaction.
Event Request Set	Set of event elements	Set of event elements	A set of event elements describing the response to the event request.

6.3.50.2.3 When generated

This primitive is generated by the SME to request that the MLME initiate the specified event.

6.3.50.2.4 Effect of receipt

On receipt of this primitive, the MLME commences the identification of events.

6.3.50.3 MLME-EVLOG.confirm

6.3.50.3.1 Function

This primitive reports the result of an event.

6.3.50.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EVLOG.confirm(
Dialog Token,
Event Report Set
)

Name	Type	Valid range	Description
Dialog Token	Integer	1–255	The dialog token to identify the event transaction.
Event Report Set	Set of event report elements	Set of event report elements	A set of event report elements describing the reported event.

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6.3.50.3.3 When generated

This primitive is generated by the MLME to report the results when event identification completes.

6.3.50.3.4 Effect of receipt

On receipt of this primitive, the SME evaluates the result and, if appropriate, stores the events pending communication to the requesting entity or for local use.

6.3.51 Diagnostic request

6.3.51.1 General

This set of primitives supports the initiation of diagnostics between peer SMEs. The diagram in Figure 6-13 shows the diagnostic reporting process.

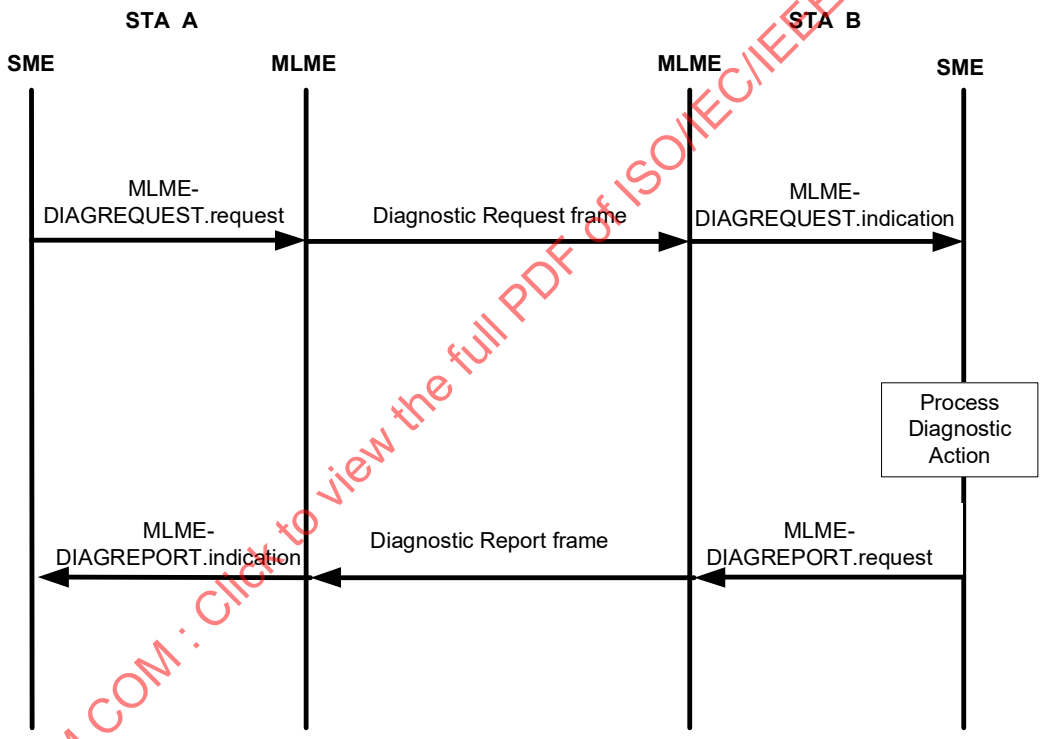

Figure 6-13—Diagnostic protocol exchange

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6.3.51.2 MLME-DIAGREQUEST.request

6.3.51.2.1 Function

This primitive requests the transmission of a Diagnostic Request frame to a peer entity.

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6.3.51.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DIAGREQUEST.request(
Peer MAC Address,
Dialog Token,
Diagnostic Request Set,
Destination URI,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the diagnostic request is sent.
Dialog Token	Integer	1–255	The dialog token to identify the diagnostic transaction.
Diagnostic Request Set	Set of diagnostic elements	Set of diagnostic elements	A set of diagnostic elements describing the requested diagnostics.
Destination URI	Destination URI element	Destination URI element	The Destination URI element as defined in 9.4.2.89.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.51.2.3 When generated

This primitive is generated by the SME to request that a Diagnostic Request frame be sent to a peer entity to initiate one or more diagnostic transactions.

6.3.51.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Diagnostic Request frame containing the set of diagnostic elements specified. This frame is then scheduled for transmission.

6.3.51.3 MLME-DIAGREQUEST.indication

6.3.51.3.1 Function

This primitive indicates that a Diagnostic Request frame requesting a Diagnostic transaction has been received.

6.3.51.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DIAGREQUEST.indication(
Peer MAC Address,
Dialog Token,
Diagnostic Request Set,
Destination URI,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the diagnostic request was received.
Dialog Token	Integer	1–255	The dialog token to identify the diagnostic transaction.
Diagnostic Request Set	Set of diagnostic elements	Set of diagnostic elements	A set of diagnostic elements describing the requested diagnostics.
Destination URI	Destination URI element	Destination URI element	The Destination URI element as defined in 9.4.2.89.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.51.3.3 When generated

This primitive is generated by the MLME when a Diagnostic Request frame is received.

6.3.51.3.4 Effect of receipt

On receipt of this primitive, the SME either rejects the request or commences the diagnostic transaction.

6.3.52 Diagnostic report

6.3.52.1 MLME-DIAGREPORT.request

6.3.52.1.1 Function

This primitive supports the signaling of diagnostic reports between peer SMEs.

6.3.52.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DIAGREPORT.request(
                        Peer MAC Address,
                        Dialog Token,
                        Diagnostic Report Set,
                        VendorSpecificInfo
                        )
```

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the diagnostic report was received.
Dialog Token	Integer	1–255	The dialog token to identify the diagnostic transaction.
Diagnostic Report Set	Set of diagnostic elements	Set of diagnostic elements	A set of diagnostic elements describing the results of the requested diagnostics.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.52.1.3 When generated

This primitive is generated by the SME to request that a Diagnostic Report frame be sent to a peer entity to report the results of one or more diagnostic transactions.

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6.3.52.1.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Diagnostic Report frame containing the set of diagnostic elements. This frame is then scheduled for transmission.

6.3.52.2 MLME-DIAGREPORT.indication

6.3.52.2.1 Function

This primitive indicates that a Diagnostic Report frame has been received from a peer entity.

6.3.52.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DIAGREPORT.indication(
Peer MAC Address,
Dialog Token,
Diagnostic Report Set,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the diagnostic report is sent.
Dialog Token	Integer	1–255	The dialog token to identify the diagnostic transaction.
Diagnostic Report Set	Set of diagnostic elements	Set of diagnostic elements	A set of diagnostic elements describing the results of the requested diagnostics.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.52.2.3 When generated

This primitive is generated by the MLME when a Diagnostic Report frame is received.

6.3.52.2.4 Effect of receipt

On receipt of this primitive, the diagnostic data can be made available for SME processes.

6.3.53 Location configuration request

6.3.53.1 General

This set of primitives supports the exchange of location configuration parameter information between peer SMEs. The diagram in Figure 6-14 shows the location configuration request and response process.

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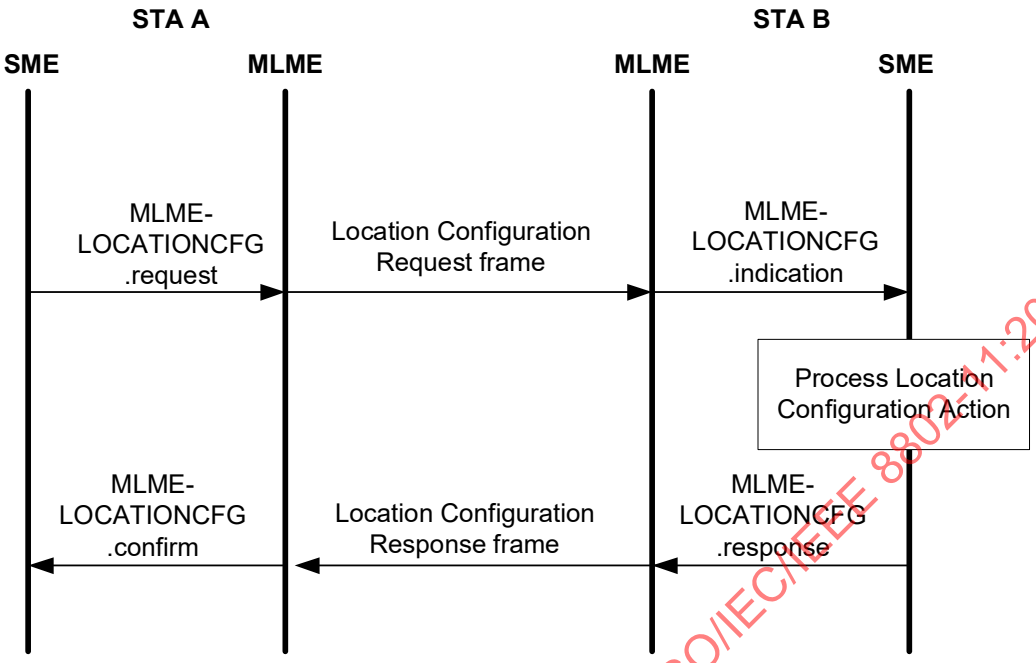

Figure 6-14—Location configuration request and response protocol exchange

6.3.53.2 MLME-LOCATIONCFG.request

6.3.53.2.1 Function

This primitive requests the transmission of a Location Configuration Request frame to a peer entity.

6.3.53.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-LOCATIONCFG.request(
Peer MAC Address,
Dialog Token,
Location Parameters,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the location configuration request is sent.
Dialog Token	Integer	1–255	The dialog token to identify the location transaction.
Location Parameters	Location Parameters element	Location Parameters element	A Location Parameters element containing one or more subelements describing the STA location information. See 9.4.2.70.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.53.2.3 When generated

This primitive is generated by the SME to request that a Location Configuration Request frame be sent to a peer entity to convey location configuration information.

6.3.53.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Location Configuration Request frame containing the set of Location Parameters elements specified. This frame is then scheduled for transmission.

6.3.53.3 MLME-LOCATIONCFG.confirm

6.3.53.3.1 Function

This primitive reports the result of a location configuration request.

6.3.53.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-LOCATIONCFG.confirm(
Dialog Token,
Peer MAC Address,
Location Parameters,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Dialog Token	Integer	1–255	The dialog token to identify the location transaction.
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the location configuration response is sent.
Location Parameters	Location Parameters element	Location Parameters element	A Location Parameters element containing one or more subelements describing the STA location information. See 9.4.2.70.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.53.3.3 When generated

This primitive is generated by the MLME when transmission of the Location Configuration Request frame is acknowledged, when (re)transmission of the Location Configuration Request frame fails, or when a failure reason is unspecified.

6.3.53.3.4 Effect of receipt

No effect of receipt is specified.

6.3.53.4 MLME-LOCATIONCFG.indication

6.3.53.4.1 Function

This primitive indicates that a Location Configuration Request frame has been received requesting a location transaction.

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6.3.53.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-LOCATIONCFG.indication(
Peer MAC Address,
Dialog Token,
Location Parameters,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the location configuration request was received.
Dialog Token	Integer	1–255	The dialog token to identify the location transaction.
Location Parameters	Location Parameters element	Location Parameters element	A Location Parameters element containing one or more subelements describing the STA location information. See 9.4.2.70.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.53.4.3 When generated

This primitive is generated by the MLME when a Location Configuration Request frame is received.

6.3.53.4.4 Effect of receipt

On receipt of this primitive, the SME either rejects the request or commences the location transaction.

6.3.53.5 MLME-LOCATIONCFG.response

6.3.53.5.1 Function

This primitive requests the transmission of location information to a peer entity, in response to a Location Configuration Request frame.

6.3.53.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-LOCATIONCFG.response(
Peer MAC Address,
Dialog Token,
Location Parameters,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the location request is sent.
Dialog Token	Integer	1–255	The dialog token to identify the location transaction.

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Name	Type	Valid range	Description
Location Parameters	Location Parameters element	Location Parameters element	A location parameters element containing one or more subelements describing the STA location information. See 9.4.2.70.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.53.5.3 When generated

This primitive is generated by the SME to request that a Location Configuration Response frame be sent to a peer entity to convey location configuration information.

6.3.53.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Location Configuration Response frame containing the set of location parameters elements specified. This frame is then scheduled for transmission.

6.3.54 Location track notification

6.3.54.1 General

This set of primitives supports the location track notification from one SME to one or more receiving SMEs. The diagram in Figure 6-15 shows the location track notification process.

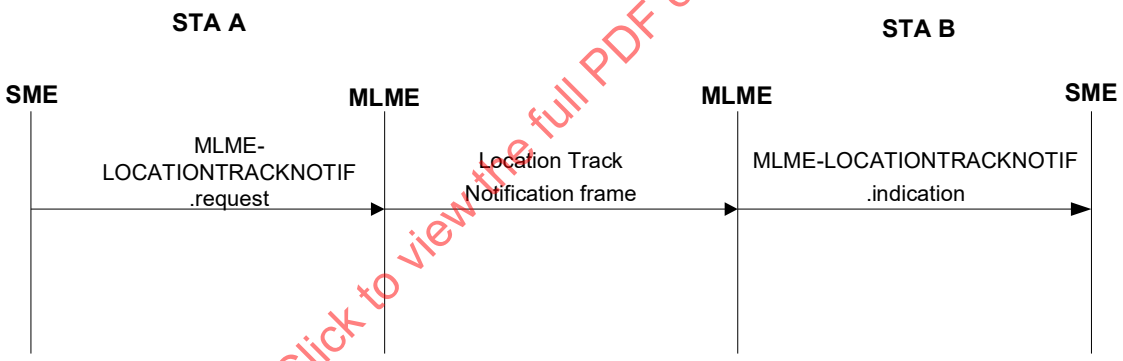

Figure 6-15—Location track notification protocol exchange

6.3.54.2 MLME-LOCATIONTRACKNOTIF.request

6.3.54.2.1 Function

This primitive requests the transmission of Location Configuration Request frame to a peer entity.

6.3.54.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-LOCATIONTRACKNOTIF.request(
                                    Peer MAC Address,
                                    Location Parameters,
                                    Measurement Report,
                                    VendorSpecificInfo
                                    )
```

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Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual or group addressed MAC address	The address of the peer MAC entity to which the location track notification is sent.
Location Parameters	Location Parameters element	Location Parameters element	A location parameters element containing one or more subelements describing the STA location information. See 9.4.2.70.
Measurement Report	Measurement Report element	Measurement Report element	A Measurement Report element contains the beacon measurement information. See 9.4.2.21.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.54.2.3 When generated

This primitive is generated by the SME to request that a Location Track Notification frame be sent to a peer entity to help convey location information.

6.3.54.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Location Track Notification frame containing the set of location parameters elements specified. This frame is then scheduled for transmission.

6.3.54.3 MLME-LOCATIONTRACKNOTIF.indication

6.3.54.3.1 Function

This primitive indicates that a Location Track Notification frame has been received.

6.3.54.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-LOCATIONTRACKNOTIF.indication(
Peer MAC Address,
Location Parameters,
Measurement Report,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual or group addressed MAC address	The address of the peer MAC entity from which the location track notification was received.
Location Parameters	Location Parameters element	Location Parameters element	A location parameters element containing one or more subelements describing the STA location information. See 9.4.2.70.
Measurement Report	Measurement Report element	Measurement Report element	A Measurement Report element contains the beacon measurement information. See 9.4.2.21.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.54.3.3 When generated

This primitive is generated by the MLME when a Location Track Notification frame is received.

6.3.54.3.4 Effect of receipt

On receipt of this primitive, the SME uses the information contained within the notification.

6.3.55 Timing measurement

6.3.55.1 General

The following set of primitives supports triggering a Timing Measurement procedure or stopping an ongoing Timing Measurement procedure, and exchange of timing measurement information from one SME to another. Figure 6-16 shows the use of these primitives and various points in time that are of interest to the timing measurement procedure.

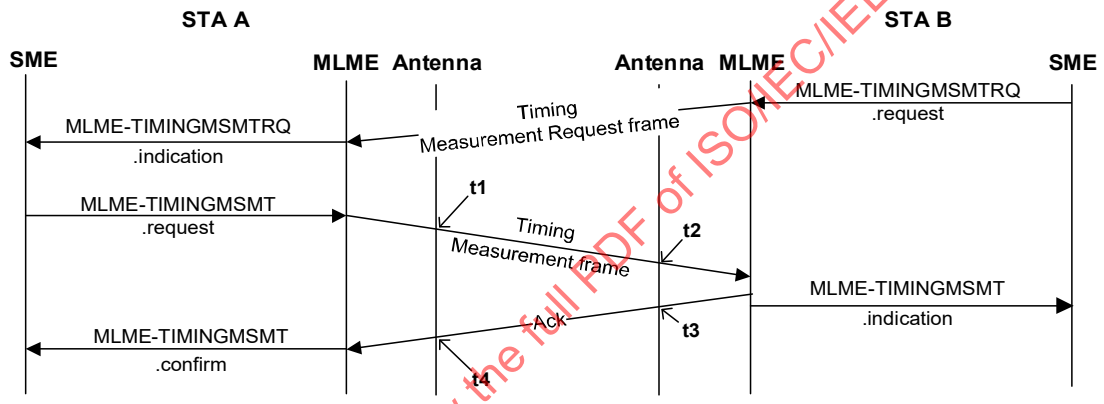

Figure 6-16—Timing measurement primitives and timestamps capture

NOTE 1—In Figure 6-16, t1 and t3 correspond to the point in time at which the start of the preamble for the transmitted frame appears at the transmit antenna connector. An implementation may capture a timestamp during the transmit processing earlier or later than the point at which it actually occurs and offset the value to compensate for the time difference.

NOTE 2—In Figure 6-16, t2 and t4 correspond to the point in time at which the start of the preamble for the incoming frame arrives at the receive antenna connector. Because time is needed to detect the frame and synchronize with its logical structure, an implementation determines when the start of the preamble for the incoming frame arrived at the receive antenna connector by capturing a timestamp some time after it occurred and compensating for the delay by subtracting an offset from the captured value.

6.3.55.2 MLME-TIMINGMSMTRQ.request

6.3.55.2.1 Function

This primitive requests the transmission of a Timing Measurement Request frame to a peer entity.

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6.3.55.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TIMINGMSMTRQ.request(
                                    Peer MAC Address,
                                    Trigger,
                                    VendorSpecificInfo
                                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the Timing Measurement Request frame is sent.
Trigger	Integer	0–1	The trigger to identify the action.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.55.2.3 When generated

This primitive is generated by the SME to request that a Timing Measurement Request frame be sent to a peer entity.

6.3.55.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Timing Measurement Request frame with the specified parameters. This frame is then scheduled for transmission.

6.3.55.3 MLME-TIMINGMSMTRQ.indication

6.3.55.3.1 Function

This primitive indicates that a Timing Measurement Request frame has been received and the corresponding Ack frame has been transmitted.

6.3.55.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TIMINGMSMTRQ.indication(
                                    Peer MAC Address,
                                    Trigger,
                                    VendorSpecificInfo
                                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the Timing Measurement Request frame is sent.
Trigger	Integer	0–1	The trigger to identify the action.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.55.3.3 When generated

This primitive is generated by the MLME when a Timing Measurement Request frame is received.

6.3.55.3.4 Effect of receipt

On receipt of this primitive, the SME uses the information contained within the notification.

6.3.55.4 MLME-TIMINGMSMT.request

6.3.55.4.1 Function

This primitive requests the transmission of Timing Measurement frame to a peer entity.

6.3.55.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TIMINGMSMT.request(
Peer MAC Address,
Dialog Token,
Follow Up Dialog Token,
t1,
Max t1 Error,
t4,
Max t4 Error,
VendorSpecific
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual addressed MAC address	The address of the peer MAC entity to which the Timing Measurement frame is sent.
Dialog Token	Integer	1–255	The dialog token to identify the Timing Measurement frame.
Follow Up Dialog Token	Integer	0–255	The dialog token of a Timing Measurement frame which the current frame follows, or 0 if there is no such frame. See 11.21.5.
t1	Integer	$0–(2^{32}–1)$	The value of t1 (see Figure 6-16) for the Timing Measurement frame identified by the Follow Up Dialog Token, in units of 10 ns, or null if the Follow Up Dialog Token is 0.
Max t1 Error	Integer	0–255	The maximum error in the t1 value in units of 10 ns; see 9.6.14.3, or null if the Follow Up Dialog Token is 0.
t4	Integer	$0–(2^{32}–1)$	The value of t4 (see Figure 6-16) for the Timing Measurement frame identified by the Follow Up Dialog Token, in units of 10 ns, or null if the Follow Up Dialog Token is 0.
Max t4 Error	Integer	0–255	The maximum error in the t4 value in units of 10 ns, or null if the Follow Up Dialog Token is 0.
VendorSpecific	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.55.4.3 When generated

This primitive is generated by the SME to request that a Timing Measurement frame be sent to a peer entity.

6.3.55.4.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Timing Measurement frame with the specified parameters. This frame is then scheduled for transmission.

6.3.55.5 MLME-TIMINGMSMT.confirm

6.3.55.5.1 Function

This primitive indicates that a Timing Measurement frame has been received by the peer STA to which it was sent.

6.3.55.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TIMINGMSMT.confirm(
Peer MAC Address,
Dialog Token,
t1,
Max t1 Error,
t4,
Max t4 Error
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual addressed MAC address	The address of the peer MAC entity to which acknowledges the receipt of the Timing Measurement frame.
Dialog Token	Integer	1–255	The dialog token to identify the Timing Measurement frame.
t1	Integer	$0 – (2^{32}–1)$	The value of t1 (see Figure 6-16) for the Timing Measurement frame identified by the Dialog Token, in units of 10 ns, or null if the Dialog Token is 0.
Max t1 Error	Integer	0–255	The maximum error in the t1 value in units of 10 ns; see 9.6.14.3, or null if the Dialog Token is 0.
t4	Integer	$0 – (2^{32}–1)$	The value of t4 (see Figure 6-16) for the Timing Measurement frame identified by the Dialog Token, in units of 10 ns, or null if the Dialog Token is 0.
Max t4 Error	Integer	0–255	The maximum error in the t4 value in units of 10 ns, or null if the Dialog Token is 0.

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6.3.55.5.3 When generated

This primitive is generated by the MLME when an Ack frame corresponding to the Timing Measurement frame is received from the peer STA.

6.3.55.5.4 Effect of receipt

On receipt of this primitive, the SME uses the information contained within the notification.

6.3.55.6 MLME-TIMINGMSMT.indication

6.3.55.6.1 Function

This primitive indicates that a Timing Measurement frame has been received and the corresponding Ack frame has been transmitted.

6.3.55.6.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TIMINGMSMT.indication(
Peer MAC Address,
Dialog Token,
Follow Up Dialog Token,
t1,
Max t1 Error,
t4,
Max t4 Error,
t2,
Max t2 Error,
t3,
Max t3 Error,
VendorSpecific
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual addressed MAC address	The address of the peer MAC entity from which the Timing Measurement frame was sent.
Dialog Token	Integer	1–255	The dialog token to identify the Timing Measurement frame.
Follow Up Dialog Token	Integer	1–255	The dialog token of a Timing Measurement frame which the current frame follows, or 0 if there is no such frame. See 11.21.5.
t1	Integer	$0 – (2^{32}–1)$	The value of t1 (see Figure 6-16) for the Timing Measurement frame identified by the Follow Up Dialog Token, contained in the Timing Measurement frame identified by the Dialog Token, in units of 10 ns, or null if the Follow Up Dialog Token is 0.
Max t1 Error	Integer	0–255	The maximum error in the t1 value in units of 10 ns; see 9.6.14.3, or null if the Follow Up Dialog Token is 0.

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Name	Type	Valid range	Description
t4	Integer	0 – (2^{32}–1)	The value of t4 (see Figure 6-16) for the Timing Measurement frame identified by the Follow Up Dialog Token, contained in the Timing Measurement frame identified by the Dialog Token, in units of 10 ns, or null if the Follow Up Dialog Token is 0.
Max t4 Error	Integer	0–255	The maximum error in the t4 value in units of 10 ns, or null if the Follow Up Dialog Token is 0.
t2	Integer	0 – (2^{32}–1)	The value of t2 (see Figure 6-16) for the Timing Measurement frame identified by the Dialog Token, in units of 10 ns, or null if the Dialog Token is 0.
Max t2 Error	Integer	0–255	The maximum error in the t2 value in units of 10 ns, or null if the Dialog Token is 0.
t3	Integer	0 – (2^{32}–1)	The value of t3 (see Figure 6-16) for the Timing Measurement frame identified by the Dialog Token, in units of 10 ns, or null if the Dialog Token is 0.
Max t3 Error	Integer	0–255	The maximum error in the t3 value in units of 10 ns, or null if the Dialog Token is 0.
VendorSpecific	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.55.6.3 When generated

This primitive is generated by the MLME when a Timing Measurement frame is received.

6.3.55.6.4 Effect of receipt

On receipt of this primitive, the SME uses the information contained within the notification.

6.3.56 Fine timing measurement (FTM)

6.3.56.1 General

The following set of primitives supports triggering an FTM procedure or stopping an ongoing FTM procedure, and exchange of FTM information from one SME to another. Figure 6-17 shows the use of these primitives and various points in time that are of interest to the FTM procedure.

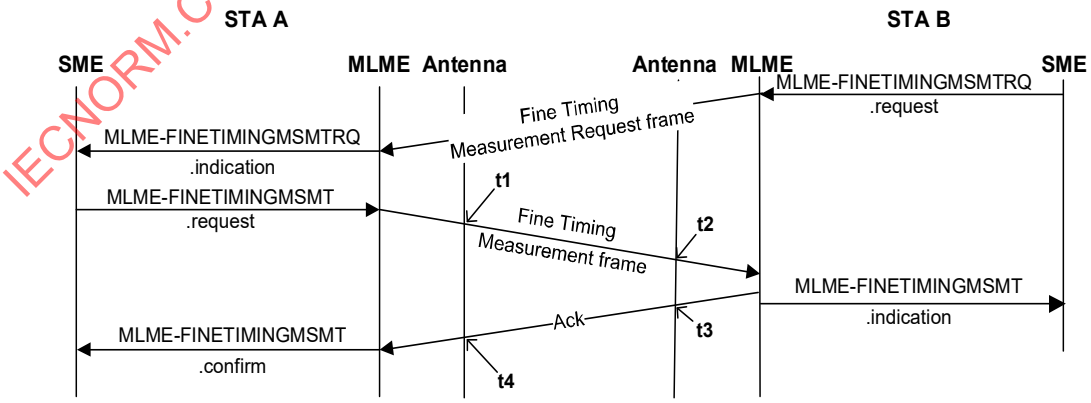

Figure 6-17—Fine timing measurement primitives and timestamps capture

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NOTE 1—In Figure 6-17, t1 and t3 correspond to the point in time at which the start of the preamble for the transmitted frame appears at the transmit antenna connector. An implementation may capture a timestamp during the transmit processing earlier or later than the point at which it actually occurs and offset the value to compensate for the time difference.

NOTE 2—In Figure 6-17, t2 and t4 correspond to the point in time at which the start of the preamble for the incoming frame arrives at the receive antenna connector. Because time is needed to detect the frame and synchronize with its logical structure, an implementation determines when the start of the preamble for the incoming frame arrived at the receive antenna connector by capturing a timestamp some time after it occurred and compensating for the delay by subtracting an offset from the captured value.

NOTE 3—In the MLME-FINETIMINGMSMT.request primitive the t1, Max t1 Error Exponent, t4 and Max t4 Error Exponent parameters are set to the values in the prior MLME-FINETIMINGMSMT.confirm primitive for that Peer MAC Address and with a Dialog Token parameter equal to the Follow Up Dialog Token parameter in the request, or 0 if there was none. In the MLME-FINETIMIMGMSMT.confirm primitive the t1, Max t1 Error Exponent, t4 and Max t4 Error Exponent parameters are set to the values determined for the Fine Timing Measurement frame and its acknowledgment. This primitive is not issued if no acknowledgment is received. In the MLME-FINETIMINGMSMT.indication primitive the t1, Max t1 Error Exponent, t4 and Max t4 Error Exponent parameters are set to the values in the Fine Timing Measurement frame and the t2, Max t2 Error Exponent, t3 and Max t3 Error Exponent parameters are set to the values determined for the Fine Timing Measurement frame and its acknowledgment.

6.3.56.2 MLME-FINETIMINGMSMTRQ.request

6.3.56.2.1 Function

This primitive requests the transmission of a Fine Timing Measurement Request frame to a peer entity.

6.3.56.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-FINETIMINGMSMTRQ.request(
Peer MAC Address,
Trigger,
LCI requested,
LCI optional subelements,
Location Civic requested,
Civic Location Type,
Location Civic optional subelements,
Fine Timing Measurement Parameters,
Vendor Specific
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the Fine Timing Measurement Request frame is sent.
Trigger	Integer	0–1	The trigger to identify the action.
LCI requested	Boolean	true, false	Indicates whether an LCI Measurement Request field is to be included in the generated Fine Timing Measurement Request frame.
LCI optional subelements	As defined in 9.4.2.20.10	As listed in Table 9-111	Optionally present if LCI requested is true. Zero or more subelements to include in the request.
Location Civic requested	Boolean	true, false	Indicates whether a Location Civic Measurement Request field is to be included in the generated Fine Timing Measurement Request frame.

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Name	Type	Valid range	Description
Civic Location Type	Enumeration	IETF_RFC_4776, VENDOR_SPECIFIC	Present if Location Civic requested is true. Indicates the format of the location information in the Location Civic optional subelements, if included.
Location Civic optional subelements	As defined in 9.4.2.20.14	As listed in Table 9-118	Optionally present if Location Civic requested is true. Zero or more subelements to include in the request.
Fine Timing Measurement Parameters	As defined in 9.4.2.167	As defined in 9.4.2.167	Optional element containing the requested FTM configuration.
VendorSpecific	A set of elements	As defined by 9.4.2.25	Zero or more elements.

6.3.56.2.3 When generated

This primitive is generated by the SME to request that a Fine Timing Measurement Request frame be sent to a peer entity.

6.3.56.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Fine Timing Measurement Request frame with the specified parameters. This frame is then scheduled for transmission.

6.3.56.3 MLME-FINETIMINGMSMTRQ.indication

6.3.56.3.1 Function

This primitive indicates that a Fine Timing Measurement Request frame has been received and the corresponding Ack frame has been transmitted.

6.3.56.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-FINETIMINGMSMTRQ.indication(
                    Peer MAC Address,
                    Trigger,
                    LCI requested,
                    LCI optional subelements,
                    Location Civic requested,
                    Civic Location Type,
                    Location Civic optional subelements,
                    Fine Timing Measurement Parameters,
                    Vendor Specific
                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the Fine Timing Measurement Request frame is sent.
Trigger	Integer	0–1	The trigger to identify the action.
LCI requested	Boolean	true, false	Indicates whether an LCI Measurement Request field is included in the received Fine Timing Measurement Request frame.

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Name	Type	Valid range	Description
LCI optional subelements	As defined in 9.4.2.20.10	As listed in Table 9-111	Optionally present if LCI requested is true. Zero or more subelements to include in the request.
Location Civic requested	Boolean	true, false	Indicates whether a Location Civic Measurement Request field is included in the received Fine Timing Measurement Request frame.
Civic Location Type	Enumeration	IETF_RFC_4776, VENDOR_SPECIFIC	Present if Location Civic requested is true. Indicates the format of the location information in the Location Civic optional subelements, if included.
Location Civic optional subelements	As defined in 9.4.2.20.14	As listed in Table 9-118	Optionally present if Location Civic requested is true. Zero or more subelements to include in the request.
Fine Timing Measurement Parameters	As defined in 9.4.2.167	As defined in 9.4.2.167	Optional element containing the requested FTM configuration.
VendorSpecific	A set of elements	As defined by 9.4.2.25	Zero or more elements.

6.3.56.3.3 When generated

This primitive is generated by the MLME when a Fine Timing Measurement Request frame is received.

6.3.56.3.4 1 Effect of receipt

On receipt of this primitive, the SME uses the information contained within the notification.

6.3.56.4 MLME-FINETIMINGMSMT.request

6.3.56.4.1 Function

This primitive requests the transmission of a Fine Timing Measurement frame to a peer entity.

6.3.56.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-FINETIMINGMSMT.request(
Peer MAC Address,
Dialog Token,
Follow Up Dialog Token,
t1,
Max t1 Error Exponent,
t4,
Max t4 Error Exponent,
LCI Report,
Location Civic Report,
Fine Timing Measurement Parameters,
VendorSpecific
)

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Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual addressed MAC address	The address of the peer MAC entity to which the Fine Timing Measurement frame is sent.
Dialog Token	Integer	0–255	The dialog token to identify the Fine Timing Measurement frame. A value of 0 indicates the end of the FTM session.
Follow Up Dialog Token	Integer	0–255	The dialog token of a Fine Timing Measurement frame which the current frame follows, or 0 if there is no such frame. See 11.21.6.
t1	Integer	$0–(2^{48}–1)$	The value of t1 (see Figure 6-17) for the Fine Timing Measurement frame identified by the Follow Up Dialog Token, in units of picoseconds, or null if the Follow Up Dialog Token is 0.
Max t1 Error Exponent	Integer	0–31	The maximum error in the t1 value. This is represented using a function of the Max t1 Error Exponent parameter as defined in Equation (9-4), or is null if the Follow Up Dialog Token is 0.
t4	Integer	$0–(2^{48}–1)$	The value of t4 (see Figure 6-17) for the Fine Timing Measurement frame identified by the Follow Up Dialog Token, in units of picoseconds, or null if the Follow Up Dialog Token is 0.
Max t4 Error Exponent	Integer	0–31	The maximum error in the t4 value. This is represented using a function of the Max t4 Error Exponent parameter as defined in Equation (9-4), or is null if the Follow Up Dialog Token is 0.
LCI Report	As defined in 9.6.7.33	As defined in 9.6.7.33	Optional element to report LCI information of sender.
Location Civic Report	As defined in 9.6.7.33	As defined in 9.6.7.33	Optional element to report location civic information of sender.
Fine Timing Measurement Parameters	As defined in 9.4.2.167	As defined in 9.4.2.167	Optional element containing the proposed FTM configuration.
VendorSpecific	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.56.4.3 When generated

This primitive is generated by the SME to request that a Fine Timing Measurement frame be sent to a peer entity.

6.3.56.4.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Fine Timing Measurement frame with the specified parameters. This frame is then scheduled for transmission.

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6.3.56.5 MLME-FINETIMINGMSMT.confirm

6.3.56.5.1 Function

This primitive indicates that a Fine Timing Measurement frame has been received by the peer STA to which it was sent.

6.3.56.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-FINETIMINGMSMT.confirm(
Peer MAC Address,
Dialog Token,
t1,
Max t1 Error Exponent,
t4,
Max t4 Error Exponent
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual addressed MAC address	The address of the peer MAC entity to which acknowledges the receipt of the Fine Timing Measurement frame.
Dialog Token	Integer	0–255	The dialog token to identify the Fine Timing Measurement frame. A value of 0 indicates the end of the FTM session.
t1	Integer	0–(2^{48}–1)	The value of t1 (see Figure 6-17) for the Fine Timing Measurement frame identified by the Dialog Token, in units of picoseconds, or null if the Dialog Token is 0.
Max t1 Error Exponent	Integer	0–31	The maximum error in the t1 value. This is represented using a function of the Max t1 Error Exponent parameter as defined in Equation (9-4), or is null if the Dialog Token is 0.
t4	Integer	0–(2^{48}–1)	The value of t4 (see Figure 6-17) for the Fine Timing Measurement frame identified by the Dialog Token, in units of picoseconds, or null if the Dialog Token is 0.
Max t4 Error Exponent	Integer	0–31	The maximum error in the t4 value. This is represented using a function of the Max t4 Error Exponent parameter as defined in Equation (9-4), or is null if the Dialog Token is 0.

6.3.56.5.3 When generated

This primitive is generated by the MLME when an Ack frame corresponding to the Fine Timing Measurement frame is received from the peer STA.

6.3.56.5.4 Effect of receipt

On receipt of this primitive, the SME uses the information contained within the notification.

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6.3.56.6 MLME-FINETIMINGMSMT.indication

6.3.56.6.1 Function

This primitive indicates that a Fine Timing Measurement frame has been received and the corresponding Ack frame has been transmitted.

6.3.56.6.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-FINETIMINGMSMT.indication(
Peer MAC Address,
Dialog Token,
Follow Up Dialog Token,
t1,
Max t1 Error Exponent,
t4,
Max t4 Error Exponent,
t2,
Max t2 Error Exponent
t3,
Max t3 Error Exponent,
LCI Report,
Location Civic Report,
Fine Timing Measurement Parameters,
VendorSpecific
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual addressed MAC address	The address of the peer MAC entity from which the Fine Timing Measurement frame was sent.
Dialog Token	Integer	0–255	The dialog token to identify the Fine Timing Measurement frame. A value of 0 indicates the end of the FTM session.
Follow Up Dialog Token	Integer	0–255	The dialog token of a Fine Timing Measurement frame which the current frame follows, or 0 if there is no such frame. See 11.21.6.
t1	Integer	0–(2^{48}–1)	The value of t1 (see Figure 6-17) for the Fine Timing Measurement frame identified by the Follow Up Dialog Token, contained in the Fine Timing Measurement frame identified by the Dialog Token, in units of picoseconds, or null if the Follow Up Dialog Token is 0.
Max t1 Error Exponent	Integer	0–31	The maximum error in the t1 value. This is represented using a function of the Max t1 Error Exponent parameter as defined in Equation (9-4), or is null if the Follow Up Dialog Token is 0.

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Name	Type	Valid range	Description
t4	Integer	0–(2^{48}–1)	The value of t4 (see Figure 6-17) for the Fine Timing Measurement frame identified by the Follow Up Dialog Token, contained in the Fine Timing Measurement frame identified by the Dialog Token, in units of picoseconds, or null if the Follow Up Dialog Token is 0.
Max t4 Error Exponent	Integer	0–31	The maximum error in the t4 value. This is represented using a function of the Max t4 Error Exponent parameter as defined in Equation (9-4), or is null if the Follow Up Dialog Token is 0.
t2	Integer	0–(2^{48}–1)	The value of t2 (see Figure 6-17) for the Fine Timing Measurement frame identified by the Dialog Token, in units of picoseconds, or null if the Dialog Token is 0.
Max t2 Error Exponent	Integer	0–31	The maximum error in the t2 value. This is represented using a function of the Max t2 Error Exponent parameter defined in Equation (9-4), or is null if the Dialog Token is 0.
t3	Integer	0–(2^{48}–1)	The value of t3 (see Figure 6-17) for the Fine Timing Measurement frame identified by the Dialog Token, in units of picoseconds, or null if the Dialog Token is 0.
Max t3 Error Exponent	Integer	0–31	The maximum error in the t3 value. This is represented using a function of the Max t3 Error Exponent parameter defined in Equation (9-4), or is null if the Dialog Token is 0.
LCI Report	As defined in 9.6.7.33	As defined in 9.6.7.33	Optional element to report LCI information of sender.
Location Civic Report	As defined in 9.6.7.33	As defined in 9.6.7.33	Optional element to report location civic information of sender.
Fine Timing Measurement Parameters	As defined in 9.4.2.167	As defined in 9.4.2.167	Optional element containing the proposed FTM configuration.
VendorSpecific	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.56.6.3 When generated

This primitive is generated by the MLME when a Fine Timing Measurement frame is received.

6.3.56.6.4 Effect of receipt

On receipt of this primitive, the SME uses the information contained within the notification.

6.3.57 BSS transition management

6.3.57.1 BSS transition management procedure

The diagram in Figure 6-18 shows the BSS transition management procedure.

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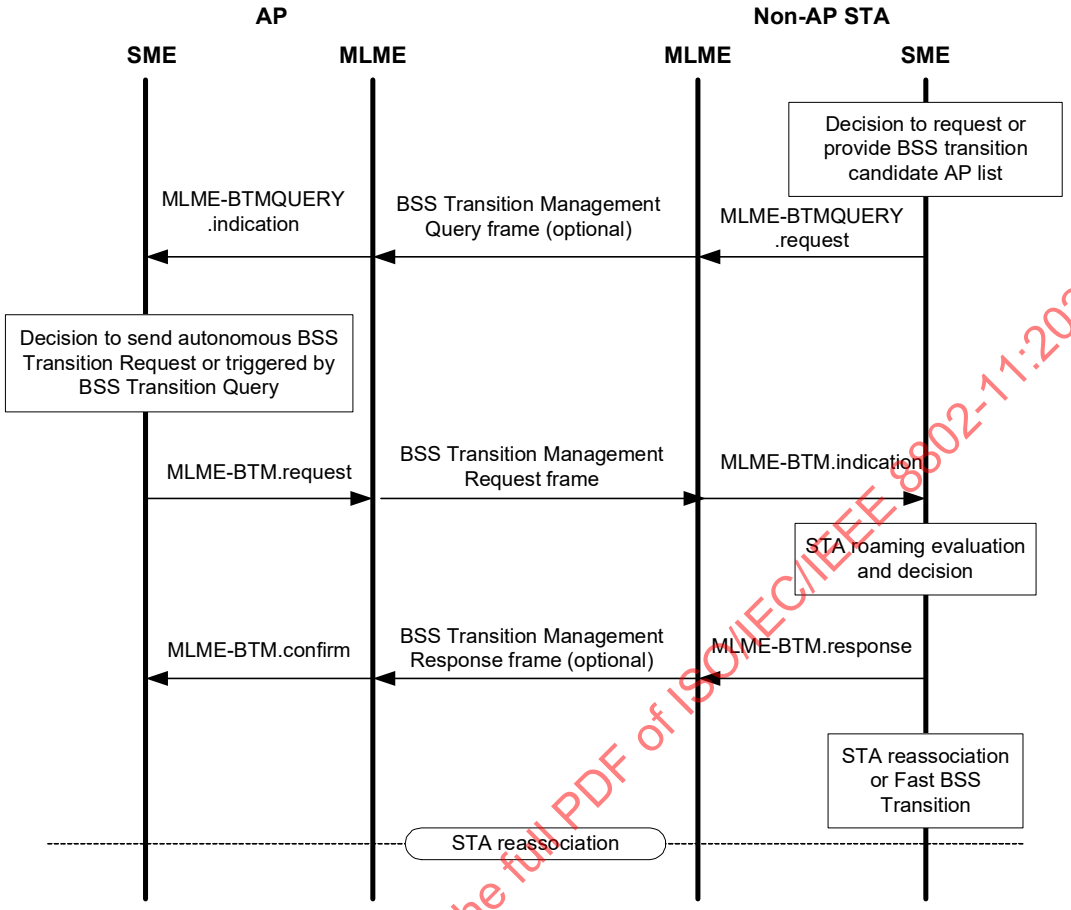

Figure 6-18—BSS transition management request—accepted

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6.3.57.2 MLME-BTMQUERY.request

This set of primitives supports the signaling of BSS Transition Management Query frames between non-AP STAs and an AP.

6.3.57.2.1 Function

This primitive requests transmission of a BSS Transition Management Query frame to the AP with which the STA is associated.

6.3.57.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-BTMQUERY.request(
Peer MAC Address,
DialogToken,
BSSTransitionQueryReason,
BSSTransitionCandidateListEntries,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the BSS Transition Management Query frame is sent.
DialogToken	Integer	1–255	The dialog token to identify this BSS transition management transaction.
BSSTransitionQuery Reason	Integer	0–255	As defined in 9.6.13.8.
BSSTransitionCandidateListEntries	Set of Neighbor Report Elements	Set of Neighbor Report Elements as defined in the Neighbor Report Element in 9.4.2.36	The description of candidate BSS transition APs and their capabilities as described in 9.4.2.36.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.57.2.3 When generated

This primitive is generated by the SME to request that a BSS Transition Management Query frame be sent to the AP with which the STA is associated to initiate a BSS transition management procedure.

6.3.57.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a BSS Transition Management Query frame. The STA then attempts to transmit the frame to the AP with which it is associated.

6.3.57.3 MLME-BTMQUERY.indication

6.3.57.3.1 Function

This primitive indicates that a BSS Transition Management Query frame was received from a non-AP STA.

6.3.57.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-BTMQUERY.indication(
                        Peer MAC Address,
                        DialogToken,
                        BSSTransitionQueryReason,
                        BSSTransitionCandidateListEntries,
                        VendorSpecificInfo
                        )
```

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which a BSS Transition Management Query frame was received.
DialogToken	Integer	1–255	The dialog token to identify the BSS transition management transaction received in the BSS Transition Management Query frame.
BSSTransitionQuery Reason	Integer	0–255	The BSS Transition Query Reason Code in the BSS Transition Management Query frame that was received.

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Name	Type	Valid range	Description
BSSTransitionCandidateListEntries	Set of Neighbor Report Elements	Set of Neighbor Report Elements as defined in the Neighbor Report Element in 9.4.2.36	The description of candidate BSS transition APs and their capabilities as described in 9.4.2.36.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.57.3.3 When generated

This primitive is generated by the MLME when a BSS Transition Management Query frame is received.

6.3.57.3.4 Effect of receipt

On receipt of this primitive, the SME shall operate according to the procedure in 11.21.7.

6.3.57.4 MLME-BTM.request

6.3.57.4.1 Function

This primitive requests transmission of a BSS Transition Management Request frame to a non-AP STA.

6.3.57.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-BTM.request(
Peer MAC Address,
DialogToken,
RequestMode,
DisassociationTimer,
ValidityInterval,
BSSTerminationDuration,
SessionInformationURL,
BSSTransitionCandidateListEntries,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the BSS Transition Management Request frame is sent.
DialogToken	Integer	1–255	The dialog token to identify the BSS transition management transaction. Set to 0 for an autonomous BSS Transition Management Request frame.
RequestMode	Integer	As specified in 9.6.13.9	RequestMode for the BSS Transition Management Request frame.
DisassociationTimer	Integer	0–65 535	Specifies the number of TBTTs until the AP disassociates the non-AP STA. A value of 0 indicates time of disassociation has not yet been determined and a value of 1 indicates disassociation shall occur before the next TBTT.

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Name	Type	Valid range	Description
ValidityInterval	Integer	1–255	Specifies the number of beacon transmission times (TBTTs) until this recommendation of this BSS transition candidate list is no longer valid.
BSSTerminationDuration	BSS Termination Duration subelement	BSS Termination Duration subelement	The BSS Termination Duration subelement (see 9.4.2.36) for the current BSS and is present only when the BSS Termination Included field is 1 in the Request mode field.
SessionInformationURL	URL	n/a	Optionally contains a URL formatted per IETF RFC 3986 where additional information pertaining to the user's accounting session is found.
BSSTransitionCandidateListEntries	Set of Neighbor Report Elements	Set of Neighbor Report Elements as defined in the Neighbor Report Element in 9.4.2.36	The description of candidate BSS transition APs and their capabilities as described in 9.4.2.36.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.57.4.3 When generated

This primitive is generated by the SME to request that a BSS Transition Management Request frame be sent to an associated non-AP STA. This request is sent either following the reception of an MLME-BTMQUERY.indication primitive or may be sent autonomously.

6.3.57.4.4 Effect of receipt

On receipt of this primitive, the MLME constructs a BSS Transition Management Request frame. The STA then attempts to transmit this frame to the indicated non-AP STA.

6.3.57.5 MLME-BTM.indication

6.3.57.5.1 Function

This primitive indicates that a BSS Transition Management Request frame was received from the AP with which the STA is associated.

6.3.57.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-BTM.indication(
                    PeerMACAddress,
                    DialogToken,
                    RequestMode,
                    DisassociationTimer,
                    ValidityInterval,
                    BSSTerminationDuration,
                    SessionInformationURL,
                    BSSTransitionCandidateListEntries,
                    VendorSpecificInfo
                    )
```

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Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the MAC entity from which a BSS Transition Management Request frame was received.
DialogToken	Integer	1–255	The dialog token to identity the BSS transition management transaction as received in the BSS Transition Management Request frame.
RequestMode	Integer	As specified in 9.6.13.9	The RequestMode for the BSS Transition Management Request frame.
Disassociation Timer	Integer	0–65 535	Specifies the number of TBTTs until the AP disassociates the non-AP STA. A value of 0 indicates time of disassociation has not been determined yet and a value of 1 indicates disassociation shall occur before the next TBTT.
ValidityInterval	Integer	1–255	Specifies the number of beacon transmission times (TBTTs) until this recommendation of this BSS transition candidate list is no longer valid.
BSSTerminationDuration	BSS Termination Duration subelement	BSS Termination Duration subelement	The BSS Termination Duration subelement (see 9.4.2.36) for the current BSS and is present only when the BSS Termination Included field is 1 in the Request mode field.
SessionInformationURL	URL	n/a	Optionally contains a URL formatted per IETF RFC 3986 where additional information pertaining to the user's accounting session may be found.
BSSTransitionCandidateListEntries	Set of Neighbor Report Elements	Set of Neighbor Report Elements as defined in the Neighbor Report Element in 9.4.2.36	The description of candidate BSS transition APs and their capabilities as described in 9.4.2.36.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.57.5.3 When generated

This primitive is generated by the MLME when a BSS Transition Management Request frame is received.

6.3.57.5.4 Effect of receipt

On receipt of this primitive the SME shall operate according to the procedure in 11.21.7.

6.3.57.6 MLME-BTM.response

6.3.57.6.1 Function

This primitive requests transmission of a BSS Transition Management Response frame to the AP with which the STA is associated.

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6.3.57.6.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-BTM.response(
Peer MAC Address
DialogToken,
BTMStatusCode,
BSSTerminationDelay,
TargetBSSID,
BSSTransitionCandidateListEntries,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the BSS Transition Management Query frame is sent.
DialogToken	Integer	1–255	The dialog token to identify the BSS transition management transaction.
BTMStatusCode	Integer	0–255	As defined in 9.6.13.10.
BSSTerminationDelay	Integer	0–255	As defined in 9.6.13.10.
TargetBSSID	MAC address	Any valid individual MAC address	The BSSID of the BSS that the STA decided to transition to. Field shall be null if STA decided not to transition.
BSSTransitionCandidateListEntries	Set of Neighbor Report Elements	Set of Neighbor Report Elements as defined in the Neighbor Report Element in 9.4.2.36	The description of candidate BSS transition APs and their capabilities as described in 9.4.2.36.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.57.6.3 When generated

This primitive is generated by the SME to request that a BSS Transition Management Response frame be sent to the AP with which the STA is associated.

6.3.57.6.4 Effect of receipt

On receipt of this primitive, the MLME constructs a BSS Transition Management Response frame. The non-AP STA then attempts to transmit this to the AP with which it is associated.

6.3.57.7 MLME-BTM.confirm

6.3.57.7.1 Function

This primitive reports the results of a BSS Transition Management attempt with a specified peer MAC entity that is within an AP.

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6.3.57.7.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-BTM.confirm(
Peer MAC Address,
DialogToken,
BSSTransitionQueryReason,
BTMStatusCode,
BSSTerminationDelay,
TargetBSSID,
BSSTransitionCandidateListEntries,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which a BSS Transition Management Response frame was received.
DialogToken	Integer	1–255	The dialog token to identify the BSS transition management transaction as received in the BSS Transition Management Response frame.
BTMStatusCode	Integer	0–255	As defined in 9.6.13.10.
BSSTerminationDelay	Integer	0–255	As defined in 9.6.13.10.
TargetBSSID	MAC address	Any valid individual MAC address	The BSSID of the BSS that the STA indicated to transition to as received in the BSS Transition Management Response frame.
BSSTransitionCandidateListEntries	Set of Neighbor Report Elements	Set of Neighbor Report Elements as defined in the Neighbor Report Element in 9.4.2.36	The BSS Transition Candidate List Entries in the received BSS Transition Management Response frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.57.7.3 When generated

This primitive is generated by the MLME when transmission of the BSS Transition Management Request frame is acknowledged, when (re)transmission of the BSS Transition Management Request frame fails, or when a failure reason is unspecified.

6.3.57.7.4 Effect of receipt

On receipt of this primitive, the SME shall operate according to the procedure in 11.21.7.

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6.3.58 FMS setup

6.3.58.1 General

The following MLME primitives support the signaling of FMS setup. The diagram shown in Figure 6-19 shows the FMS setup process.

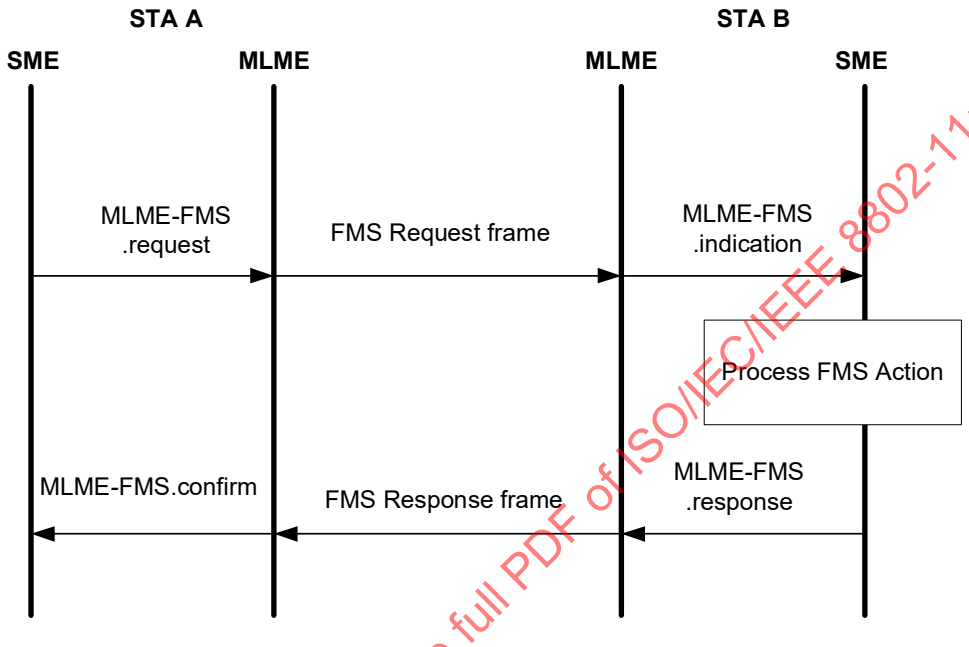

Figure 6-19—FMS setup protocol exchange

6.3.58.2 MLME-FMS.request

6.3.58.2.1 Function

This primitive requests that an FMS Request frame be sent to the AP with which the non-AP STA is associated.

6.3.58.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-FMS.request(
                    PeerSTAAddress,
                    DialogToken,
                    FMSRequest,
                    VendorSpecificInfo
                    )
```

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the FMS process.
Dialog Token	Integer	1–255	The dialog token to identify the FMS transaction.
FMSRequest	FMS Request element	As defined in 9.4.2.75	Specifies the proposed service parameters for the FMS.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.58.2.3 When generated

This primitive is generated by the SME to request that an FMS Request frame be sent to the AP with which the STA is associated.

6.3.58.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs an FMS Request frame. The STA then attempts to transmit this to the AP with which it is associated.

6.3.58.3 MLME-FMS.confirm

6.3.58.3.1 Function

This primitive reports the result of an FMS procedure.

6.3.58.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME- FMS.confirm(
Peer MAC Address,
Dialog Token,
FMSResponse,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the location response is sent.
Dialog Token	Integer	0–255	The dialog token to identify the FMS transaction.
FMSResponse	FMS Response element	As defined in 9.4.2.76	Specifies service parameters for the FMS.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.58.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-FMS.request primitive and indicates the results of the request. This primitive is generated when the STA receives an FMS Response frame from the AP.

6.3.58.3.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 11.2.3.14.

6.3.58.4 MLME-FMS.indication

6.3.58.4.1 Function

This primitive indicates that an FMS Request frame was received from a non-AP STA.

6.3.58.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME- FMS.indication(
PeerSTAAddress,
DialogToken,
FMSRequest,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which an FMS Request frame was received.
Dialog Token	Integer	1–255	The dialog token to identify the FMS transaction.
FMSRequest	FMS Request element	As defined in 9.4.2.75	Specifies the proposed service parameters for the FMS.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.58.4.3 When generated

This primitive is generated by the MLME when an FMS Request frame is received.

6.3.58.4.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 11.2.3.14.

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6.3.58.5 MLME-FMS.response

6.3.58.5.1 Function

This primitive is either generated in response to an FMS Request frame or autonomously by the AP and requests the transmission of an FMS Response frame.

6.3.58.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-FMS.response(
                    PeerSTAAddress,
                    FMSResponse,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which an FMS Request frame was received.
Dialog Token	Integer	0–255	The dialog token to identify the FMS transaction.
FMSResponse	FMS Response element	As defined in 9.4.2.76	Specifies service parameters for the FMS.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.58.5.3 When generated

This primitive is generated by the SME to request that an FMS Response frame be sent to a peer entity to convey FMS information.

6.3.58.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs an FMS Response frame. The STA then attempts to transmit this to the non-AP STA indicated by the PeerSTAAddress parameter.

6.3.59 Collocated Interference request

6.3.59.1 General

This set of primitives supports the exchange of collocated interference information between peer SMEs. The diagram in Figure 6-20 depicts the Collocated Interference request and response process.

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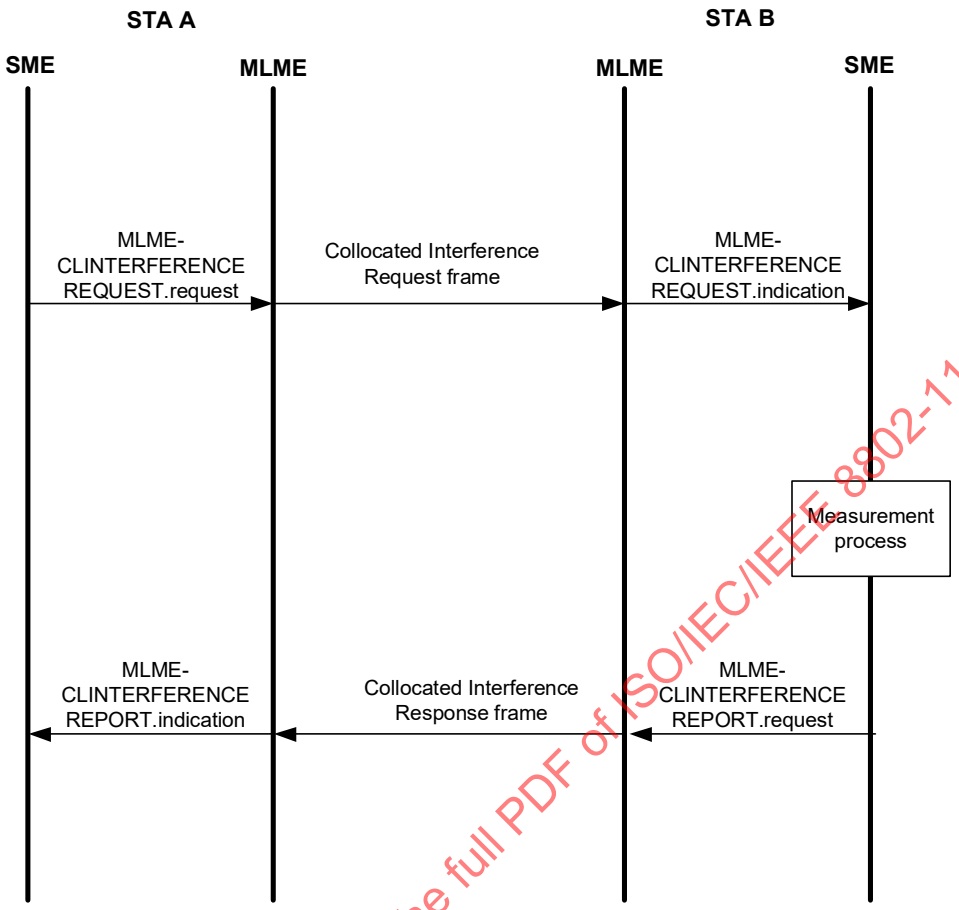

Figure 6-20—Collocated interference protocol exchange

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6.3.59.2 MLME-CLINTERFERENCEREQUEST.request

6.3.59.2.1 Function

This primitive requests the transmission of Collocated Interference Request frame to a peer entity.

6.3.59.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-CLINTERFERENCEREQUEST.request(
Peer MAC Address,
Dialog Token,
Automatic Report Enabled,
Report Timeout,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address, or the group MAC address	The address of the peer MAC entity to which the collocated interference request is sent.
Dialog Token	Integer	1–255	The dialog token to identify the collocated interference transaction.
Automatic Report Enabled	Enumeration	CANCEL, CHANGES_ONLY, PERIODICALLY_ONLY, PERIODICALLY_AND_CHANGES	Indicates the requested interference reports, as defined in 9.6.13.13.
Report Timeout	Integer	0-63	Indicates minimum duration between reports, see 9.6.13.13.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.59.2.3 When generated

This primitive is generated by the SME to request that a Collocated Interference Request frame be sent to a peer entity.

6.3.59.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Collocated Interference Request frame. This frame is then scheduled for transmission.

6.3.59.3 MLME-CLINTERFERENCEREQUEST.indication

6.3.59.3.1 Function

This primitive indicates that a Collocated Interference Request frame has been received requesting a Collocated Interference report.

6.3.59.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-CLINTERFERENCEREQUEST.indication(
Peer MAC Address,
Dialog Token,
Automatic Report Enabled,
Report Timeout,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address or the group MAC address	The address of the peer MAC entity from which the Collocated Interference request was received.
Dialog Token	Integer	1–255	The dialog token to identify the collocated interference transaction.
Automatic Report Enabled	Enumeration	CANCEL, CHANGES_ONLY, PERIODICALLY_ONLY, PERIODICALLY_AND_CHANGES	Indicates the requested interference resports, as defined in 9.6.13.13.
Report Timeout	Integer	0-63	Indicates minimum duration between reports, see 9.6.13.13.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.59.3.3 When generated

This primitive is generated by the MLME when a Collocated Interference Request frame is received.

6.3.59.3.4 Effect of receipt

On receipt of this primitive, the SME either rejects the request or commences the Collocated Interference reporting procedure as described in 11.21.9.

6.3.60 Collocated Interference report

6.3.60.1 General

This set of primitives supports the exchange of collocated interference information between peer SMEs.

6.3.60.2 MLME-CLINTERFERENCEREPORT.request

6.3.60.2.1 Function

This primitive requests the transmission of Collocated Interference Report to a peer entity, in response to a Collocated Interference Request frame.

6.3.60.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-CLINTERFERENCEREPORT.request(
                                    Peer MAC Address,
                                    Dialog Token,
                                    Collocated Interference Report,
                                    VendorSpecificInfo
                                    )
```

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Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the Collocated Interference Report is sent.
Dialog Token	Integer	1–255	The dialog token to identify the collocated interference transaction.
Collocated Interference Report	Collocated Interference Report elements	As defined in 9.4.2.84	Specifies the collocated interference characteristics.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.60.2.3 When generated

This primitive is generated by the SME to request that a Collocated Interference Report frame be sent to a peer entity to convey collocated interference information.

6.3.60.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Collocated Interference Report frame. This frame is then scheduled for transmission.

6.3.60.3 MLME-CLINTERFERENCEREPORT.indication

6.3.60.3.1 Function

This primitive indicates that a Collocated Interference Report frame has been received.

6.3.60.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-CLINTERFERENCEREPORT.indication(
                                    Peer MAC Address,
                                    Dialog Token,
                                    Collocated Interference Report,
                                    VendorSpecificInfo
                                    )
```

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the location response was received.
Dialog Token	Integer	1–255	The dialog token to identify the location transaction.
Collocated Interference Report	Collocated Interference Report elements	As defined in 9.4.2.84	Specifies the collocated interference characteristics.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.60.3.3 When generated

This primitive is generated by the MLME when a Collocated Interference Report frame is received.

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6.3.61 TFS setup

6.3.61.1 General

This set of primitives supports the exchange of the signaling of TFS setup between peer SMEs. The diagram in Figure 6-21 depicts the TFS request and response process.

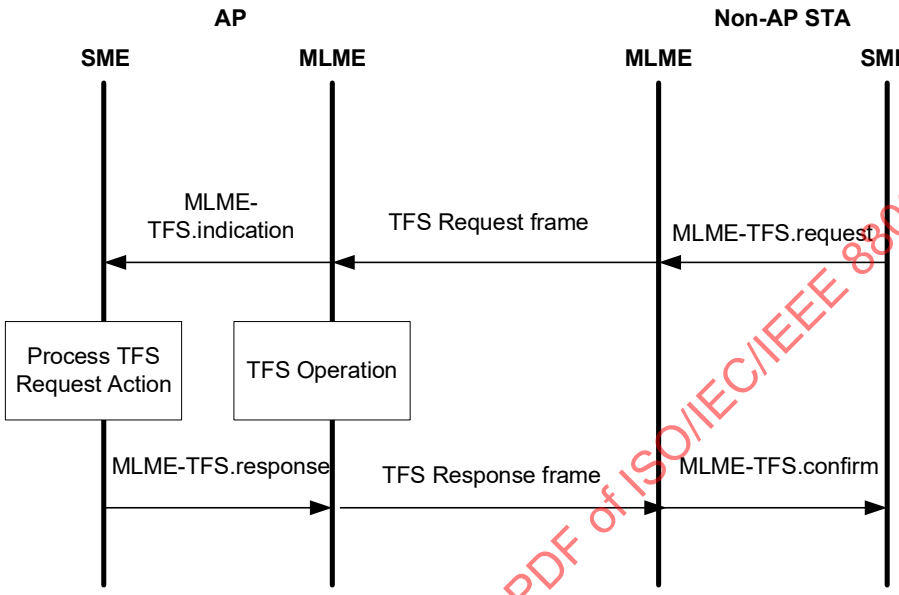

Figure 6-21—TFS request and response exchange

6.3.61.2 MLME-TFS.request

6.3.61.2.1 Function

This primitive requests that a TFS Request frame be sent to the AP with which the STA is associated.

6.3.61.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TFS.request(
                    PeerSTAAddress,
                    DialogToken,
                    TFSRequest,
                    VendorSpecific
                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity for TFS.
DialogToken	Integer	0–255	The dialog token to identify the TFS Request and Response transaction.

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Name	Type	Valid range	Description
TFSRequest	A set of TFS Request elements	As defined in the TFS Request element	Specifies the proposed service parameters for the TFS. One or more TFS Request elements.
VendorSpecific	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.61.2.3 When generated

This primitive is generated by the SME to request that a TFS Request frame be sent to the AP with which the STA is associated.

6.3.61.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TFS Request frame. The STA then attempts to transmit this to the AP with which it is associated.

6.3.61.3 MLME-TFS.confirm

6.3.61.3.1 Function

This primitive reports the result of a TFS procedure.

6.3.61.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TFS.confirm(
                    PeerSTAAddress,
                    DialogToken,
                    TFSResponse,
                    VendorSpecific
                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the TFS Response frame is received.
DialogToken	Integer	0–255	The dialog token to identify the TFS Request and Response transaction.
TFSResponse	A set of TFS Response elements	As defined in the TFS Response element	Specifies service parameters for the TFS. One or more TFS Response elements.
VendorSpecific	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.61.3.3 When generated

This primitive is generated by the MLME when the STA receives a TFS Response frame from the AP.

6.3.61.3.4 Effect of receipt

On receipt of this primitive, the SME evaluates the result and may use the reported data. The SME should operate according to the procedure in 11.21.12.

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6.3.61.4 MLME-TFS.indication

6.3.61.4.1 Function

This primitive indicates that a TFS Request frame was received from a non-AP STA.

6.3.61.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TFS.indication(
                    PeerSTAAddress,
                    DialogToken,
                    TFSRequest,
                    VendorSpecific
                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which a TFS Request frame was received.
DialogToken	Integer	0–255	The dialog token to identify the TFS Request and Response transaction.
TFSRequest	A set of TFS Request elements	As defined in the TFS Request element	Specifies the proposed service parameters for the TFS. One or more TFS Request elements.
VendorSpecific	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.61.4.3 When generated

This primitive is generated by the MLME when a TFS Request frame is received.

6.3.61.4.4 Effect of receipt

On receipt of this primitive the SME should operate according to the procedure in 11.21.12.

6.3.61.5 MLME-TFS.response

6.3.61.5.1 Function

This primitive is generated in response to an MLME-TFS.indication primitive requesting a TFS Response frame be sent to a non-AP STA.

6.3.61.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TFS.response(
                  PeerSTAAddress,
                  DialogToken,
                  TFSResponse,
                  VendorSpecific
                  )
```

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which a TFS Request frame was received.
DialogToken	Integer	0–255	The dialog token to identify the TFS Request and Response transaction.
TFSResponse	A set of TFS Response elements	As defined in 9.4.2.80	Specifies service parameters for the TFS. One or more TFS Response elements.
VendorSpecific	A set of elements.	As defined in 9.4.2.25	Zero or more elements.

6.3.61.5.3 When generated

This primitive is generated by the SME in response to an MLME-TFS.indication primitive requesting a TFS Response be sent to a non-AP STA.

6.3.61.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TFS Response frame. The STA then attempts to transmit this to the non-AP STA indicated by the PeerSTAAddress parameter.

6.3.62 WNM sleep mode request

6.3.62.1 General

This set of primitives supports the exchange of sleep mode parameter information between peer SMEs. The diagram shown in Figure 6-22 shows the sleep mode request and response process.

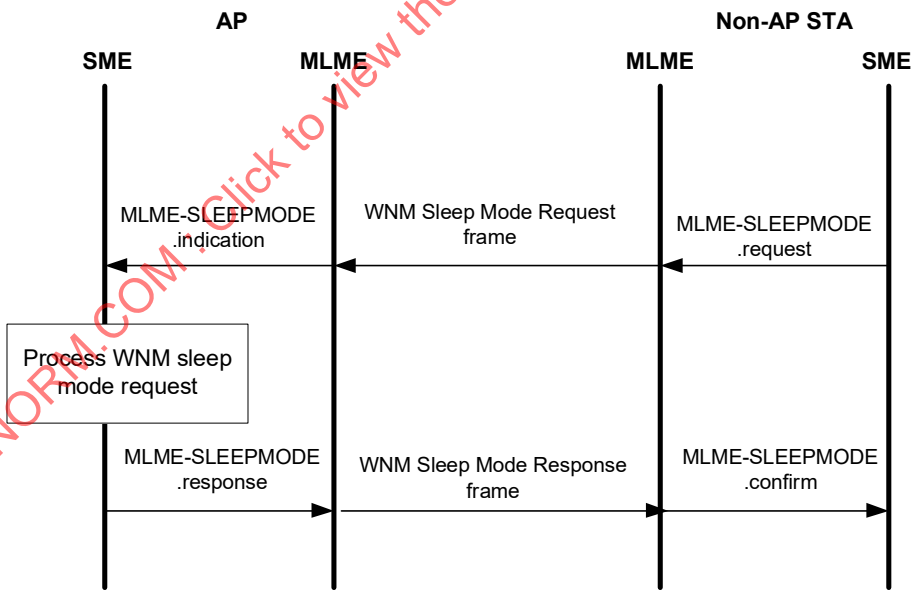

Figure 6-22—WNM sleep mode request and response exchange

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6.3.62.2 MLME-SLEEPMODE.request

6.3.62.2.1 Function

This primitive requests that a WNM Sleep Mode Request frame be sent to the AP with which the STA is associated.

6.3.62.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SLEEPMODE.request(
                        PeerSTAAddress,
                        DialogToken,
                        SleepMode,
                        TFSRequest,
                        VendorSpecificInfo
                        )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the WNM Sleep Mode Request frame is to be sent.
DialogToken	Integer	0–255	The dialog token to identify the WNM sleep mode request and response transaction.
SleepMode	As defined in the WNM Sleep Mode element	As defined in the WNM Sleep Mode element	Specifies the proposed WNM sleep mode service parameters for the WNM Sleep Mode Request frame.
TFSRequest	A set of TFS Request elements	As defined in 9.4.2.79	Specifies the proposed TFS service parameters for the WNM Sleep Mode Request frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.62.2.3 When generated

This primitive is generated by the SME to request that a WNM Sleep Mode Request frame be sent to the AP with which the STA is associated.

6.3.62.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a WNM Sleep Mode Request frame. The STA then attempts to transmit this to the AP with which it is associated.

6.3.62.3 MLME-SLEEPMODE.indication

6.3.62.3.1 Function

This primitive indicates that a WNM Sleep Mode Request frame was received from a non-AP STA.

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6.3.62.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-SLEEPMODE.indication(
PeerSTAAddress,
DialogToken,
SleepMode,
TFSRequest,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the WNM Sleep Mode Request frame is received.
DialogToken	Integer	0–255	The dialog token to identify the WNM sleep mode request and response transaction.
SleepMode	As defined in the WNM Sleep Mode element	As defined in the WNM Sleep Mode element	Specifies the proposed WNM sleep mode service parameters for the WNM Sleep Mode Request frame.
TFSRequest	A set of TFS Request elements	As defined in 9.4.2.79	Specifies the proposed TFS service parameters for the WNM Sleep Mode Request frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.62.3.3 When generated

This primitive is generated by the MLME when a WNM Sleep Mode Request frame is received.

6.3.62.3.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 11.2.3.16.

6.3.62.4 MLME-SLEEPMODE.response

6.3.62.4.1 Function

This primitive requests the transmission of sleep mode information to a peer entity, in response to a WNM Sleep Mode Request frame.

6.3.62.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-SLEEPMODE.response(
PeerSTAAddress,
DialogToken,
SleepMode,
TFSResponse,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the WNM Sleep Mode Response frame is to be sent.
DialogToken	Integer	0–255	The dialog token to identify the WNM sleep mode request and response transaction.
SleepMode	As defined in the WNM Sleep Mode element	As defined in the WNM Sleep Mode element	Specifies the proposed WNM sleep mode service parameters for the WNM Sleep Mode Response frame.
TFSResponse	A set of TFS Request elements	As defined in 9.4.2.80	Specifies the proposed TFS service parameters for the WNM Sleep Mode Response frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.62.4.3 When generated

This primitive is generated by the SME to request that a WNM Sleep Mode Response frame be sent to a peer entity to convey WNM sleep mode information.

6.3.62.4.4 Effect of receipt

On receipt of this primitive, the MLME constructs a WNM Sleep Mode Response frame containing the WNM Sleep Mode elements specified. This frame is then scheduled for transmission.

6.3.62.5 MLME-SLEEPMODE.confirm

6.3.62.5.1 Function

This primitive reports the result of a request to send a WNM Sleep Mode Response frame.

6.3.62.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SLEEPMODE.confirm(
                        PeerSTAAddress,
                        DialogToken,
                        SleepMode,
                        TFSResponse,
                        VendorSpecificInfo
                        )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the WNM Sleep Mode Response frame is received.
DialogToken	Integer	0–255	The dialog token to identify the WNM sleep mode request and response transaction.
SleepMode	As defined in the WNM Sleep Mode element	As defined in the WNM Sleep Mode element	Specifies the proposed WNM sleep mode service parameters for the WNM Sleep Mode Response frame.

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Name	Type	Valid range	Description
TFSResponse	A set of TFS Request elements	As defined in the TFS Response element	Specifies the proposed TFS service parameters for the WNM Sleep Mode Response frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.62.5.3 When generated

This primitive is generated by the MLME when the STA receives a WNM Sleep Mode Response frame from the AP.

6.3.62.5.4 Effect of receipt

No effect of receipt is specified.

6.3.63 TIM broadcast setup

6.3.63.1 General

The following MLME primitives support the signaling of TIM Broadcast Setup. The diagram in Figure 6-23 shows the TIM Broadcast setup process.

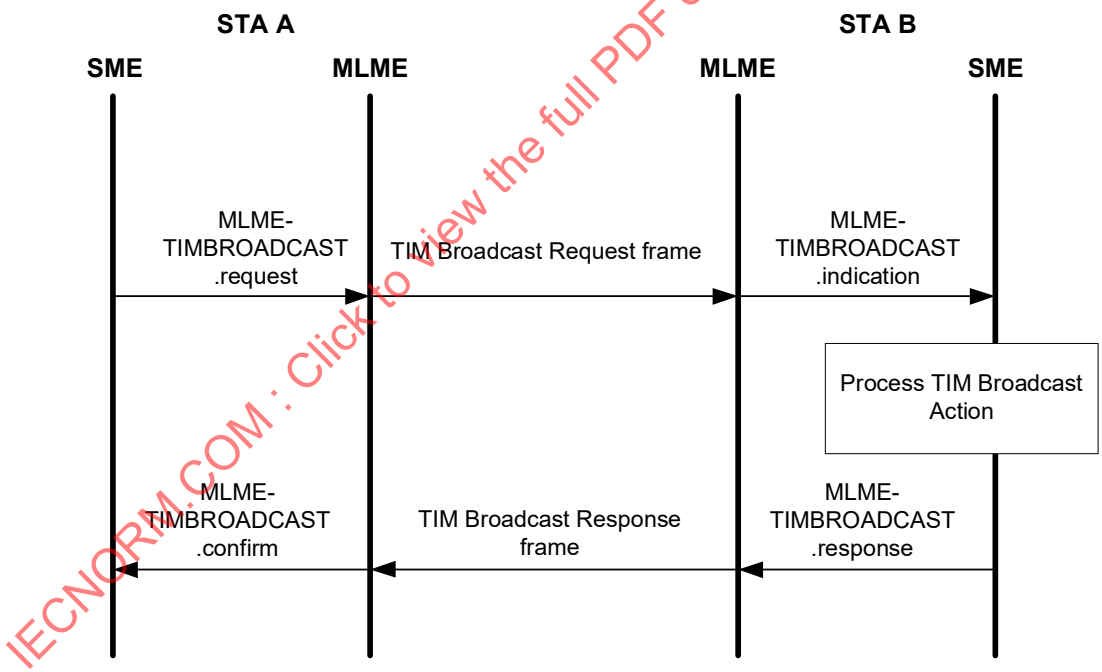

Figure 6-23—TIM broadcast setup protocol exchange

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6.3.63.2 MLME-TIMBROADCAST.request

6.3.63.2.1 Function

This primitive requests that a TIM Broadcast Request frame be sent to the AP with which the non-AP STA is associated.

6.3.63.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TIMBROADCAST.request(
                    PeerSTAAddress,
                    Dialog Token,
                    TIMBroadcastRequest,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the TIM Broadcast process.
Dialog Token	Integer	1–255	The dialog token to identify the TIM Broadcast request and response transaction.
TIMBroadcastRequest	As defined in TIM Broadcast Request element	As defined in 9.4.2.82	Specifies the proposed service parameters for the TIM Broadcast.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.63.2.3 When generated

This primitive is generated by the SME to request that a TIM Broadcast Request frame be sent to the AP with which the STA is associated.

6.3.63.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TIM Broadcast Request frame. The STA then attempts to transmit this to the AP with which it is associated.

6.3.63.3 MLME-TIMBROADCAST.confirm

6.3.63.3.1 Function

This primitive reports the result of a TIM Broadcast procedure.

6.3.63.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TIMBROADCAST.confirm(
                    PeerSTAAddress,
                    Dialog Token,
                    TIMBroadcastResponse,
                    VendorSpecificInfo
                    )
```

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the TIM Broadcast process.
Dialog Token	Integer	0–255	The dialog token to identify the TIM Broadcast request and response transaction.
TIMBroadcastResponse	As defined in TIM Broadcast Response element	As defined in 9.4.2.83	Specifies service parameters for the TIM Broadcast.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.63.3.3 When generated

This primitive is generated by the MLME when the STA receives a TIM Broadcast Response frame from the AP.

6.3.63.3.4 Effect of receipt

On receipt of this primitive, the SME evaluates the results in the TIMBroadcastResponse element and may use the reported data.

6.3.63.4 MLME-TIMBROADCAST.indication

6.3.63.4.1 Function

This primitive indicates that a TIM Broadcast Request frame was received from a non-AP STA.

6.3.63.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TIMBROADCAST.indication(
                    PeerSTAAddress,
                    Dialog Token,
                    TIMBroadcastRequest,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which a TIM Broadcast Request frame was received.
Dialog Token	Integer	1–255	The dialog token to identify the TIM Broadcast request and response transaction.
TIMBroadcastRequest	As defined in TIM Broadcast Request element	As defined in 9.4.2.82	Specifies the proposed service parameters for the TIM Broadcast.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.63.4.3 When generated

This primitive is generated by the MLME when a TIM Broadcast Request frame is received.

6.3.63.4.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 11.2.3.15.

6.3.63.5 MLME-TIMBROADCAST.response

6.3.63.5.1 Function

This primitive is generated in response to an MLME-TIMBROADCAST.indication primitive requesting a TIM Broadcast Response frame be sent to a non-AP STA.

6.3.63.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TIMBROADCAST.response(
PeerSTAAddress,
Dialog Token,
TIMBroadcastResponse,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which a TIM Broadcast Request frame was received.
Dialog Token	Integer	0–255	The dialog token to identify the TIM Broadcast request and response transaction.
TIM Broadcast Response	As defined in TIM Broadcast Response element	As defined in 9.4.2.83	Specifies service parameters for the TIM Broadcast.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.63.5.3 When generated

This primitive is generated by the SME in response to an MLME-TIMBROADCAST.indication primitive requesting a TIM Broadcast Response be sent to a non-AP STA.

6.3.63.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TIM Broadcast Response frame. The STA then attempts to transmit this to the non-AP STA indicated by the PeerSTAAddress parameter.

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6.3.64 QoS traffic capability update

6.3.64.1 General

The MLME-QOSTRAFFICCAPUPDATE.request and MLME-QOSTRAFFICCAPUPDATE.indication primitives provide the transport of QoS Traffic Capability information from a non-AP STA to the AP with which the STA is associated. The diagram in Figure 6-24 shows the QoS traffic capability update process.

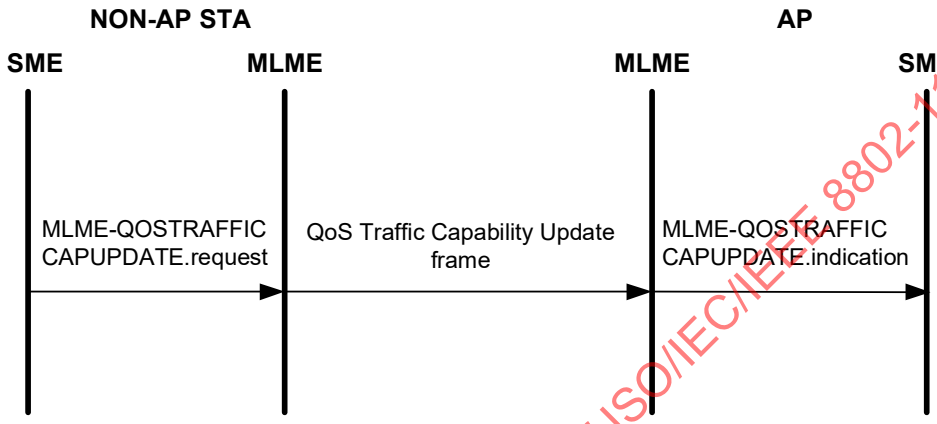

Figure 6-24—QoS traffic capability update protocol exchange

6.3.64.2 MLME-QOSTRAFFICCAPUPDATE.request

6.3.64.2.1 Function

This primitive requests that a QoS Traffic Capability Update frame be sent to the AP with which the STA is associated.

6.3.64.2.2 Semantics of the service primitive

The primitive parameter is as follows:

```
MLME-QOSTRAFFICCAPUPDATE.request(
                                    QoSTrafficCapability,
                                    VendorSpecificInfo
                                    )
```

Name	Type	Valid range	Description
QoSTraffic Capability	Bit field as defined in 9.6.13.23	As defined in 9.6.13.23	Specifies the QoS Traffic Capability flags of the non-AP STA. This parameter is present if dot11WirelessManagementImplemented is true and dot11QoSTrafficCapabilityActivated is true, and it is not present otherwise.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.64.2.3 When generated

This primitive is generated by the SME to request that a QoS Traffic Capability Update frame be sent to the AP with which the STA is associated.

6.3.64.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a QoS Traffic Capability Update frame. The STA then attempts to transmit this to the AP with which it is associated.

6.3.64.3 MLME-QOSTRAFFICCAPUPDATE.indication

6.3.64.3.1 Function

This primitive indicates that a QoS Traffic Capability Update frame was received from a non-AP STA.

6.3.64.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-QOSTRAFFICCAPUPDATE.indication(
PeerSTAAddress,
QoS Traffic Capability,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which a QoS Traffic Capability Update frame was received.
QoS Traffic Capability	Bit field as defined in 9.6.13.23	As defined in 9.6.13.23	Specifies the QoS Traffic Capability flags of the non-AP STA. This parameter is present if dot11WirelessManagementImplemented is true and dot11QoSTrafficCapabilityActivated is true, and it is not present otherwise.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.64.3.3 When generated

This primitive is generated by the MLME when a QoS Traffic Capability Update frame is received.

6.3.64.3.4 Effect of receipt

On receipt of this primitive the SME should operate according to the procedure in 11.21.10.

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6.3.65 Channel Usage request

6.3.65.1 General

The following MLME primitives support the signaling of Channel Usage request. Figure 6-25 depicts the Channel Usage request process. The figure illustrates the basic protocol and is only an example and therefore is not meant to be exhaustive of all possible protocol uses.

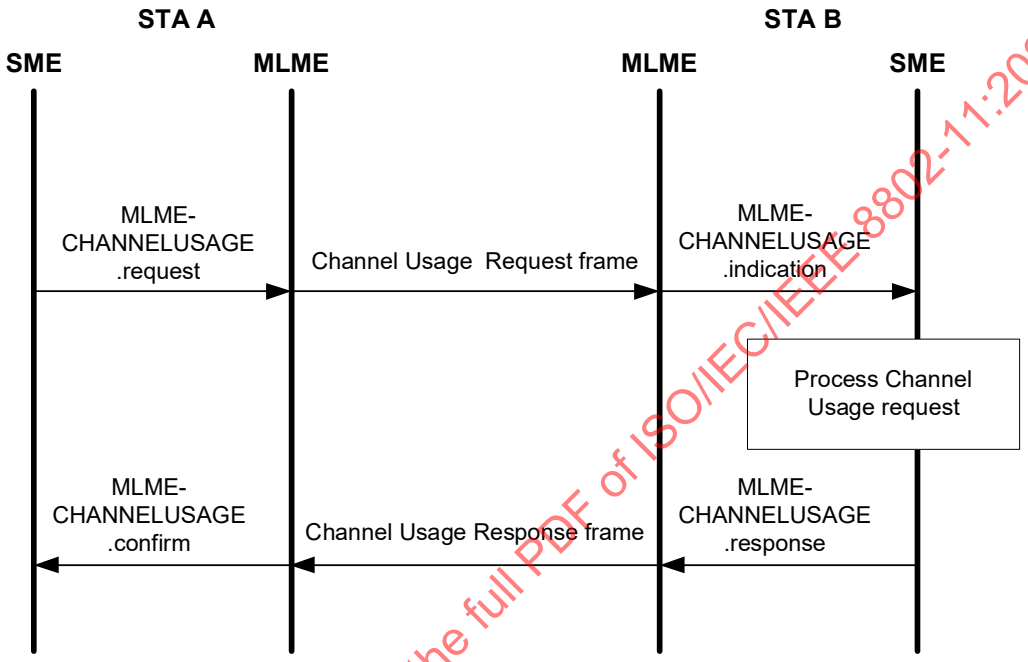

Figure 6-25—Channel usage request protocol exchange

6.3.65.2 MLME-CHANNELUSAGE.request

6.3.65.2.1 Function

This primitive requests the transmission of a Channel Usage Request frame be sent to an AP.

6.3.65.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-CHANNELUSAGE.request(
PeerSTAAddress,
Dialog Token,
ChannelUsage,
SSID,
SupportedOperatingClasses,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the Channel Usage process.
Dialog Token	Integer	1–255	The dialog token to identify the Channel Usage request and response transaction.
ChannelUsage	A set of Channel Usage element	As defined in 9.4.2.85	Specifies request types for the Channel Usage request.
SSID	Octet string	0–32 octets	Specifies the desired SSID or the wildcard SSID.
SupportedOperating Classes	As defined in Supported Operating Classes element	As defined in 9.4.2.53	Specifies the supported operating classes.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.65.2.3 When generated

This primitive is generated by the SME to request that a Channel Usage Request frame be sent to the BSS which is advertising the SSID passed down in this primitive.

6.3.65.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Channel Usage Request frame. The STA then attempts to transmit this to the BSS which is advertising the SSID included in this primitive request. When wild card SSID is passed down, the MLME-CHANNELREQUEST.request primitive shall be transmitted to all BSSs in the current scan list as determined by the most recent MLME-SCAN.request primitive.

6.3.65.3 MLME-CHANNELUSAGE.confirm

6.3.65.3.1 Function

This primitive reports the result of a Channel Usage procedure.

6.3.65.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-CHANNELUSAGE.confirm(
PeerSTAAddress,
Dialog Token,
ChannelUsage,
SSID,
Country String,
Power Constraint,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the Channel Usage process.
Dialog Token	Integer	1–255	The dialog token to identify the Channel Usage request and response transaction.
ChannelUsage	A set of Channel Usage element	As defined in 9.4.2.85	Specifies parameters for the Channel Usage.
SSID	Octet string	0–32 octets	Specifies the SSID or the wildcard SSID used in the request.
Country String	Octet string	3 octets	Specifies Country strings.
Power Constraint	An element	As defined in 9.4.2.13	Zero or one Power Constraint elements.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.65.3.3 When generated

This primitive is generated when the STA receives a Channel Usage Response frame from the AP.

6.3.65.3.4 Effect of receipt

On receipt of this primitive the SME should operate according to the procedure in 11.21.15.

6.3.65.4 MLME-CHANNELUSAGE.indication

6.3.65.4.1 Function

This primitive indicates that a Channel Usage Request frame was received from a non-AP STA.

6.3.65.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-CHANNELUSAGE.indication(
PeerSTAAddress,
Dialog Token,
ChannelUsage,
SSID,
SupportedOperatingClasses,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which a Channel Usage Request frame was received.
Dialog Token	Integer	0–255	The dialog token to identify the Channel Usage request and response transaction.
ChannelUsage	A set of Channel Usage element	As defined in 9.4.2.85	Specifies request types for the Channel Usage request.
SSID	Octet string	0–32 octets	Specifies the desired SSID or the wildcard SSID.

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Name	Type	Valid range	Description
SupportedOperating Classes	As defined in Supported Operating Classes element	As defined in 9.4.2.53	Indicates the supported operating classes.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.65.4.3 When generated

This primitive is generated by the MLME when a Channel Usage Request frame is received.

6.3.65.4.4 Effect of receipt

On receipt of this primitive the SME should operate according to the procedure in 11.21.15.

6.3.65.5 MLME-CHANNELUSAGE.response

6.3.65.5.1 Function

This primitive is generated in response to an MLME-CHANNELUSAGE.indication primitive requesting a Channel Usage Response frame be sent to a non-AP STA.

6.3.65.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-CHANNELUSAGE.response(
PeerSTAAddress,
Dialog Token,
ChannelUsage,
SSID,
Country String,
Power Constraint,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which a Channel Usage Request frame was received.
Dialog Token	Integer	0–255	The dialog token to identify the Channel Usage request and response transaction.
ChannelUsage	A set of Channel Usage elements	As defined in 9.4.2.85	Specifies parameters for the Channel Usage.
SSID	Octet string	0–32 octets	Specifies the desired SSID or the wildcard SSID.
Country String	Octet string	3 octets	Specifies Country strings.
Power Constraint	An element	As defined in 9.4.2.13	Zero or one Power Constraint elements.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.65.5.3 When generated

This primitive is generated by the SME in response to an MLME-CHANNELUSAGE.indication primitive requesting a Channel Usage Response be sent to a non-AP STA.

6.3.65.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Channel Usage Response frame. The STA then attempts to transmit this to the non-AP STA indicated by the PeerSTAAddress parameter.

6.3.66 DMS or GCR request and response procedure

6.3.66.1 General

The following MLME primitives support the signaling of DMS or GCR request and response procedure. The diagram in Figure 6-26 shows the DMS or GCR request and response process.

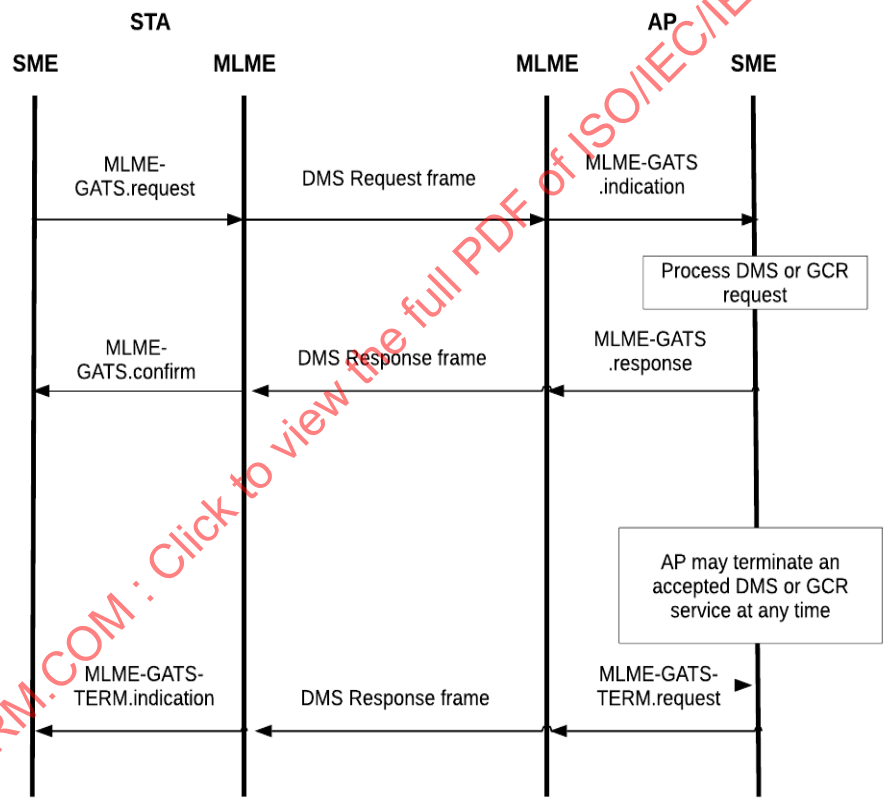

Figure 6-26—DMS or GCR setup protocol exchange

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6.3.66.2 MLME-GATS.request

6.3.66.2.1 Function

This primitive requests the transmission of a DMS Request frame be sent to an AP or peer mesh STA.

6.3.66.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-GATS.request(
                    PeerSTAAddress,
                    Dialog Token,
                    DMSRequest,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the DMS or GCR process.
Dialog Token	Integer	1–255	The dialog token to identify the DMS or GCR request and response transaction.
DMSRequest	Sequence of DMS Request elements	As defined in 9.4.2.87	Specifies group addressed frames and parameters for the requested DMS or GCR stream.
VendorSpecific Info	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.66.2.3 When generated

This primitive is generated by the SME to request that a DMS Request frame be sent to the AP with which the STA is associated or peer mesh STA.

6.3.66.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a DMS Request frame. The STA then attempts to transmit this to the AP with which the STA is associated or peer mesh STA.

6.3.66.3 MLME-GATS.confirm

6.3.66.3.1 Function

This primitive reports the result of a DMS or GCR procedure.

6.3.66.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-GATS.confirm(
                    PeerSTAAddress,
                    Dialog Token,
                    DMSResponse,
                    VendorSpecificInfo
                    )
```

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the DMS or GCR process.
Dialog Token	Integer	1–255	The dialog token to identify the DMS or GCR request and response transaction.
DMSResponse	Sequence of DMS Response elements	As defined in 9.4.2.88	Specifies the status returned by the AP or peer mesh STA responding to the STA's requested DMS or GCR stream.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.66.3.3 When generated

This primitive is generated when the STA receives a DMS Response frame from the AP or peer mesh STA.

6.3.66.3.4 Effect of receipt

On receipt of this primitive the SME should operate according to the procedure in 11.21.16.

6.3.66.4 MLME-GATS.indication

6.3.66.4.1 Function

This primitive indicates that a DMS Request frame was received from a non-AP STA or peer mesh STA.

6.3.66.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-GATS.indication(
                    PeerSTAAddress,
                    Dialog Token,
                    DMSRequest,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA or peer mesh STA MAC entity from which a DMS Request frame was received.
Dialog Token	Integer	1–255	The dialog token to identify the DMS or GCR request and response transaction.
DMSRequest	Sequence of DMS Request elements	As defined in 9.4.2.87	Specifies group addressed frames for the requested DMS or GCR stream.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.66.4.3 When generated

This primitive is generated by the MLME when a DMS Request frame is received.

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6.3.66.4.4 Effect of receipt

On receipt of this primitive the SME should operate according to the procedure in 11.21.16.

6.3.66.5 MLME-GATS.response

6.3.66.5.1 Function

This primitive is generated in response to an MLME-GATS.indication primitive requesting a DMS Response frame be sent to a non-AP STA or peer mesh STA.

6.3.66.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-GATS.response(
PeerSTAAddress,
Dialog Token,
DMSResponse,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA or peer mesh STA MAC entity from which a DMS Request frame was received.
Dialog Token	Integer	1–255	The Dialog Token to identify the DMS or GCR request and response transaction.
DMSResponse	Sequence of DMS Response elements	As defined in 9.4.2.88	Specifies the status returned by the AP or peer mesh STA responding to the STA's requested DMS or GCR stream.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.66.5.3 When generated

This primitive is generated by the SME in response to an MLME-GATS.indication primitive requesting a DMS Response be sent to a non-AP STA or peer mesh STA.

6.3.66.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs a DMS Response frame. The STA then attempts to transmit this to the non-AP STA or peer mesh STA indicated by the PeerSTAAddress parameter.

6.3.66.6 MLME-GATS-TERM.request

6.3.66.6.1 Function

This primitive requests the transmission of a DMS Response frame to terminate a granted DMS or GCR service.

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6.3.66.6.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-GATS-TERM.request(
PeerSTAAddress,
Dialog Token,
DMSResponse,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA or peer mesh STA MAC entity from which a DMS Request frame was received.
Dialog Token	Integer	0	Set to 0 for an autonomous DMS Response frame.
DMSResponse	Sequence of DMS Response elements	As defined in 9.4.2.88	Specifies the requested DMS or GCR stream that is canceled by the AP or peer mesh STA.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.66.6.3 When generated

This primitive is generated by the SME to terminate DMS or GCR service.

6.3.66.6.4 Effect of receipt

On receipt of this primitive, the MLME constructs a DMS Response frame. The STA then attempts to transmit this to the non-AP STA or peer mesh STA indicated by the PeerSTAAddress parameter.

6.3.66.7 MLME-GATS-TERM.indication

6.3.66.7.1 Function

This primitive is generated by the MLME when an unsolicited DMS Response frame is received.

6.3.66.7.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-GATS-TERM.indication(
PeerSTAAddress,
Dialog Token,
DMSResponse,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the DMS or GCR process.
Dialog Token	Integer	0	Set to 0 for an autonomous DMS Response frame.

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Name	Type	Valid range	Description
DMSResponse	Sequence of DMS Response elements	As defined in 9.4.2.88	Specifies the requested DMS or GCR stream that is canceled by the AP or peer mesh STA.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.66.7.3 When generated

This primitive is generated when the STA receives an unsolicited DMS Response frame from the AP or peer mesh STA.

6.3.66.7.4 Effect of receipt

On receipt of this primitive the SME should operate according to the procedure in 11.21.16.

6.3.67 WNM notification request

6.3.67.1 General

This set of primitives supports the exchange of WNM Notification Request and Response frames between peer SMEs.

6.3.67.2 MLME-WNMNOTIFICATIONREQUEST.request

6.3.67.2.1 Function

This primitive requests the transmission of a WNM Notification Request frame to a peer entity.

6.3.67.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-WNMNOTIFICATIONREQUEST.request(
Peer MAC Address,
Dialog Token,
Type,
Optional Subelements,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the WNM Notification Request frame is sent.
Dialog Token	Integer	1–255	The dialog token to identify the WNM notification transaction.
Type	Integer	1–255	The type of WNM notification.
Optional Subelements	Set subelements	As defined in 9.6.13.29	A set of subelements describing the notification.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.67.2.3 When generated

This primitive is generated by the SME to request that a WNM Notification Request frame be sent to a peer entity to initiate a WNM notification.

6.3.67.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a WNM Notification Request frame containing the elements specified. This frame is then scheduled for transmission.

6.3.67.3 MLME-WNMNOTIFICATIONREQUEST.indication

6.3.67.3.1 Function

This primitive indicates that a WNM Notification Request frame has been received.

6.3.67.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-WNMNOTIFICATIONREQUEST.indication(
Peer MAC Address,
Dialog Token,
Type,
Optional Subelements,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the WNM notification request was received.
Dialog Token	Integer	1–255	The dialog token to identify the WNM notification transaction.
Type	Integer	1–255	The type of WNM notification request.
Optional Subelements	Set subelements	As defined in 9.6.13.29	A set of subelements describing the notification.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.67.3.3 When generated

This primitive is generated by the MLME when a WNM Notification Request frame is received.

6.3.67.3.4 Effect of receipt

On receipt of this primitive, the SME replies to the request.

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6.3.68 WNM notification response

6.3.68.1 MLME-WNMNOTIFICATIONRESPONSE.request

6.3.68.1.1 Function

This primitive supports the signaling of the WNM Notification Response frame between peer SMEs.

6.3.68.1.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-WNMNOTIFICATIONRESPONSE.request(
Peer MAC Address,
Dialog Token,
Response Status,
Optional Subelements,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the WNM Notification Response frame is sent.
Dialog Token	Integer	1–255	The dialog token to identify the WNM notification transaction.
Response Status	Integer	1–255	The response status of the WNM notification.
Optional Subelements	Set subelements	As defined in 9.6.13.30	A set of subelements describing the results of the WNM notification.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.68.1.3 When generated

This primitive is generated by the SME to request that a WNM Notification Response frame be sent to a peer entity to report the results of the WNM notification.

6.3.68.1.4 Effect of receipt

On receipt of this primitive, the MLME constructs a WNM Notification Response frame containing the indicated fields. This frame is then scheduled for transmission.

6.3.68.2 MLME-WNMNOTIFICATIONRESPONSE.indication

6.3.68.2.1 Function

This primitive indicates that a WNM Notification Response frame has been received from a peer entity.

6.3.68.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-WNMNOTIFICATIONRESPONSE.indication(
Peer MAC Address,
Dialog Token,
Response Status,

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Optional Subelements,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the WNM Notification Response frame was received.
Dialog Token	Integer	1–255	The dialog token to identify the WNM notification transaction.
Response Status	Integer	1–255	The response status of the WNM notification.
Optional Subelements	Set subelements	As defined in 9.6.13.30	A set of subelements describing the results of the WNM notification.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.68.2.3 When generated

This primitive is generated by the MLME when a WNM Notification Response frame is received.

6.3.68.2.4 Effect of receipt

On receipt of this primitive, the WNM notification can be made available for SME processes.

6.3.69 Network discovery and selection support

6.3.69.1 General

This set of primitives supports the process of GAS.

6.3.69.2 MLME-GAS.request

6.3.69.2.1 Function

This primitive requests the information of a specific advertisement service from another STA and requests the STA to provide GAS.

6.3.69.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-GAS.request(
STAAddress,
DialogToken,
AdvertisementProtocolID,
Query,
QueryFailureTimeout,
Protected,
Multi-band,
GAMode,
GASExtension,
CAGNumber,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
STAAddress	MAC address	Any valid individual MAC address. For a group address GAS frame, this is the broadcast address.	Specifies the address of the peer MAC entity or the broadcast address to which query is transmitted.
DialogToken	Integer	0–255	The dialog token to identify the GAS transaction.
AdvertisementProtocolID	Integer	As defined in Table 9-237	An advertisement protocol ID (see 9.4.2.92), which might be IEEE 802.11 assigned or vendor specified.
Query	String	N/A	Query string formatted using protocol identified in AdvertisementProtocolID.
QueryFailureTimeout	Integer	> 1	The time limit, in units of beacon intervals, after which the GAS procedure is terminated.
Protected	Boolean	true, false	Specifies whether the request is sent using a protected robust Management frame. If true, the request is sent using a Protected Dual of Public Action frame. Otherwise, the request is sent using a Public Action frame.
Multi-band	Multi-band element	As defined in 9.4.2.138	Specifies the frequency band and channel number to which the GAS transaction applies. The parameter is absent if the GAS transaction applies to the same frequency band and channel where the frame is transmitted.
GAMode	Boolean	true, false	If true, the request is sent using a group address GAS frame. Otherwise, the request is sent using an individually addressed GAS frame.
GASExtension	GAS Extension element	As defined in 9.4.2.239	Specifies GAS extensions information in the GAS frame to be transmitted. This parameter is optionally present if dot11GASExtensionImplemented is true; otherwise not present.
CAGNumber	CAG Number element	As defined in 9.4.2.176	One or more Common Advertisement Group (CAG) tuples. Each CAG Tuple specifies a pair of CAG Version and CAG Information Type cached by the transmitting STA. This parameter is optionally present when dot11FILSActivated is true or dot11SolicitedPADActivated is true; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.69.2.3 When generated

This primitive is generated by the SME to request a specific Advertisement Service from another STA.

6.3.69.2.4 Effect of receipt

The STA operates according to the procedures defined in 11.22.3 and 11.23.

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6.3.69.3 MLME-GAS.confirm

6.3.69.3.1 Function

This primitive reports the status code and Query Response from an Advertisement Server to the requesting STA.

6.3.69.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-GAS.confirm(
PeerSTAAddress,
DialogToken,
ResultCode,
ResponseInfo,
Protected,
Multi-band,
GASExtension,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity from which Query Response is received.
DialogToken	Integer	0–255	The dialog token to identify the GAS transaction.
ResultCode	Enumeration	SUCCESS, NO_OUTSTANDING_GAS_REQUEST, GAS_ADVERTISEMENT_PROTOCOL_NOT_SUPPORTED, GAS_QUERY_RESPONSE_OUTSTANDING, GAS_QUERY_RESPONSE_TOO_LARGE, SERVER_UNREACHABLE, GAS_QUERY_TIMEOUT, GAS_RESPONSE_NOT_RECEIVED_FROM_SERVER, SUCCESS_CAG_VERSIONS_MATCH	Indicates the result response to the GAS request from the peer MAC entity.
ResponseInfo	String	N/A	Query Response string.
Protected	Boolean	true, false	Specifies whether the response was received in a protected robust Management frame. If true, the response was received using a Protected Dual of Public Action frame. Otherwise, the response was received using a Public Action frame.

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Name	Type	Valid range	Description
Multi-band	Multi-band element	As defined in 9.4.2.138	Specifies the frequency band and channel number to which the GAS transaction applies. The parameter is absent if the GAS transaction applies to the same frequency band and channel where the frame is transmitted.
GASExtension	GAS Extension element	As defined in 9.4.2.239	Specifies GAS extensions information in the GAS frame received. The values from the GAS Extension element in the GAS response received, if present; else null.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

The mapping of Status Code received in the GAS Response frame is mapped to the corresponding Result Code in Table 9-50.

6.3.69.3.3 When generated

This primitive is generated by the MLME as a response to the MLME-GAS.request primitive indicating the result of that request.

The primitive is generated when the requesting STA receives a query response in a (Protected) GAS Initial Response frame or one or more (Protected) GAS Comeback Response frames, or a Group Addressed GAS Response frame.

6.3.69.3.4 Effect of receipt

The STA operates according to the procedures defined in 11.22.3, and 11.23.

6.3.69.4 MLME-GAS.indication

6.3.69.4.1 Function

This primitive reports to the STA's SME about the GAS Request.

6.3.69.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-GAS.indication(
PeerSTAAddress,
DialogToken,
AdvertisementProtocolID,
Query,
Protected,
Multi-band,
GAMode,
GASExtension,

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CAGNumber,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity from which the query message was received.
DialogToken	Integer	0–255	The dialog token to identify the GAS transaction.
AdvertisementProtocolID	Integer	As defined in Table 9-237	An advertisement protocol ID (see 9.4.2.92), which might be IEEE 802.11 assigned or vendor specified.
Query	String	N/A	Query string formatted using protocol identified in AdvertisementProtocolID.
Protected	Boolean	true, false	Specifies whether the request was received in a protected robust Management frame. If true, the request was received in a Protected Dual of Public Action frame. Otherwise, the request was received in a Public Action frame.
Multi-band	Multi-band element	As defined in 9.4.2.138	Specifies the frequency band and channel number to which the GAS transaction applies. The parameter is absent if the GAS transaction applies to the same frequency band and channel where the frame is transmitted.
GAMode	Boolean	true, false	Set to true if the request is received in a Group Addressed GAS Request frame; otherwise set to false.
GASExtension	GAS Extension element	As defined in 9.4.2.239	Specifies GAS extensions information in the GAS frame received. The values from the GAS Extension element in the GAS request received, if present; else null.
CAGNumber	CAG Number element	As defined in 9.4.2.176	One or more Common Advertisement Group (CAG) tuples. Each CAG Tuple specifies a pair of CAG Version and CAG Information Type received from a requesting STA.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.69.4.3 When generated

This primitive is generated by the MLME as a result of receipt of a GAS request from STA.

6.3.69.4.4 Effect of receipt

The SME is notified of the request from the STA.

The SME operates according to the procedures defined in 11.22.3 and 11.23.

The SME generates an MLME-GAS.response primitive within a dot11GASResponseTimeout.

6.3.69.5 MLME-GAS.response

6.3.69.5.1 Function

This primitive responds to the request for an advertisement service by a specified STA MAC entity.

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6.3.69.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-GAS.response(
STAAddress,
DialogToken,
ResultCode,
ResponseInfo,
Protected,
Multi-band,
GAMode,
GASExtension,
VendorSpecificInfo
)

Name	Type	Valid range	Description
STAAddress	MAC address	Any valid individual MAC address. For a group address GAS frame, this is the broadcast address.	Specifies the address of the MAC entity or the broadcast address to which the query response information is transmitted.
DialogToken	Integer	0–255	The dialog token to identify the GAS transaction.
ResultCode	Enumeration	SUCCESS, NO_OUTSTANDING_GAS_REQUEST, GAS_ADVERTISEMENT_PROTOCOL_NOT_SUPPORTED, GAS_QUERY_RESPONSE_OUTSTANDING, GAS_QUERY_RESPONSE_TOO_LARGE, SERVER_UNREACHABLE, GAS_QUERY_TIMEOUT, GAS_RESPONSE_NOT_RECEIVED_FROM_SERVER, SUCCESS_CAG_VERSIONS_MATCH	Indicates the result response to the GAS-request from the peer MAC entity. See Table 9-50.
ResponseInfo	String	N/A	Query Response string.
Protected	Boolean	true, false	Specifies whether the response is sent using a protected robust Management frame. If true, the response is sent using a Protected Dual of Public Action frame. Otherwise, the response is sent using a Public Action frame.
Multi-band	Multi-band element	As defined in 9.4.2.138	Specifies the frequency band and channel number where the GAS transaction applies. The parameter is absent if the GAS transaction applies to the same frequency band and channel where the frame is transmitted.

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Name	Type	Valid range	Description
GAMode	Boolean	true, false	Specifies whether the response is sent using a group address GAS frame. If true, the response is sent using a group address GAS frame. Otherwise, the response is sent using an individually addressed GAS frame.
GASExtension	GAS Extension element	As defined in 9.4.2.239	Specifies GAS extensions information in the GAS frame to be transmitted. The parameter is present if GAMode is true, or if the STA is capable of retransmitting a GAS Query Response fragment upon request and the query response's length is larger than the maximum MMPDU size; else the parameter is null.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.69.5.3 When generated

This primitive is generated by the SME as a response to an MLME-GAS.indication primitive.

6.3.69.5.4 Effect of receipt

This primitive causes the MAC entity at the STA to send a (Protected) GAS Initial Response frame to the requesting STA and optionally one or more (Protected) GAS Comeback Response frames or one Group Addressed GAS Response frame.

6.3.70 QoS Map element management

6.3.70.1 General

The QoS Map element is provided to non-AP STAs in (Re)Association Response frames. However, if the SME of an AP detects a change of the QoS Map information while one or more non-AP STAs are associated to the BSS, then the AP may transmit an unsolicited QoS Map element to associated STAs. The AP's SME invokes the MLME-QOS-MAP.request primitive to cause individually addressed frames containing a QoS Map element to be transmitted to associated STAs. The AP's SME invokes the MLME-QOS-MAP.request primitive to transmit individually addressed frames containing a QoS Map element to associated STAs. When a non-AP STA receives such unsolicited QoS Map information, its MLME generates an MLME-QOS-MAP.indication primitive to the STA's SME. In turn, the SME should take appropriate action, e.g., initiate an ADDTS or DELTS if admission control changes are necessary.

6.3.70.2 MLME-QOS-MAP.request

6.3.70.2.1 Function

This primitive is used by an AP to transmit an unsolicited QoS Map Configure frame to a specified non-AP STA MAC entity. The specified non-AP STA MAC address is an individual MAC address.

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6.3.70.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-QOS-MAP.request(
Non-APSTAAddress,
QoSMapSet,
IntraAccessCategoryPriority,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Non-APSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity from which query message is received.
QoSMapSet	As defined in frame format	As defined in 9.4.2.94	Specifies the QoS Map information the non-AP STA should use.
IntraAccessCategoryPriority	Intra-Access Category Priority element	As defined in 9.4.2.120	Specifies the intra-AC priorities the STA should use. The parameter is present if dot11SCSActivated is true; otherwise not present.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.70.2.3 When generated

This primitive is generated by the MLME at the AP as a result of any change in the AP QoS Map configurations.

6.3.70.2.4 Effect of receipt

This primitive causes the MAC entity at the AP to send a QoS Map element in a QoS Map Configure frame to the non-AP STA.

6.3.70.3 MLME-QOS-MAP.indication

6.3.70.3.1 Function

This primitive reports the QoS mapping information sent from the AP to the non-AP STA.

6.3.70.3.2 Semantics of the service primitive

The primitive parameter is as follows:

MLME-QOS-MAP.indication(
QoSMapSet,
IntraAccessCategoryPriority,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
QoSMapSet	As defined in frame format	As defined in 9.4.2.94	Specifies the QoS Map information to be used by the non-AP STA.
IntraAccessCategoryPriority	Intra-Access Category Priority element	As defined in 9.4.2.120	Specifies the intra-AC priorities the STA should use.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.70.3.3 When generated

This primitive is generated when the non-AP STA receives a QoS Map element in an unsolicited QoS Map Configure frame from the AP.

The SME of the non-AP STA should use the information to decide proper actions. For example, an ADDTS or DELTS procedure should be activated if the QoS Map information indicates a change in the admission control.

6.3.70.3.4 Effect of receipt

The non-AP STA operates according to the procedures defined in 11.22.9.

6.3.71 Mesh peering management

6.3.71.1 Introduction

The following primitives facilitate the mesh peering management protocol and authenticated mesh peering exchange protocol.

6.3.71.2 MLME-MESHPEERINGMANAGEMENT.request

6.3.71.2.1 Function

This primitive requests that the MAC entity establish, confirm, or close a mesh peering with the specified peer MAC entity by sending a mesh peering Management frame to the peer MAC entity. The mesh peering management procedures are specified in 14.3.

6.3.71.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MESHPEERINGMANAGEMENT.request(
                                    PeerMACAddress,
                                    MeshPeeringMgmtFrameContent,
                                    VendorSpecificInfo
                                    )
```

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Name	Type	Valid range	Description
PeerMACAddress	MAC address	Valid individual MAC address	Specifies the address of the peer MAC entity to which the mesh peering Management frame is to be sent.
MeshPeeringMgmtFrameContent	Sequence of octets	As defined in 9.6.15.2, 9.6.15.3, or 9.6.15.4	The contents of the Action field of the Mesh Peering Open, Mesh Peering Confirm, or Mesh Peering Close frame to send to the peer MAC entity.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.71.2.3 When generated

This primitive is generated by the SME to request that a mesh peering Management frame be sent to the specified mesh STA.

6.3.71.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a mesh peering Management frame containing the information specified. The frame is scheduled for transmission.

6.3.71.3 MLME-MESHPEERINGMANAGEMENT.confirm

6.3.71.3.1 Function

This primitive reports the results of a request to send a mesh peering Management frame.

6.3.71.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MESHPEERINGMANAGEMENT.confirm(
                                    PeerMACAddress,
                                    MeshPeeringMgmtFrameContent,
                                    VendorSpecificInfo
                                    )
```

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Valid individual MAC address	Specifies the address of the peer MAC entity to which the mesh peering Management frame was sent.
MeshPeeringMgmtFrameContent	Sequence of octets	As defined in 9.6.15.2, 9.6.15.3, or 9.6.15.4	The contents of the Action field of the Mesh Peering Open, Mesh Peering Confirm, or Mesh Peering Close frame received from the peer MAC entity.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.71.3.3 When generated

This primitive is generated as a result of an MLME-MESHPEERINGMANAGEMENT.request primitive with a specified MAC peer.

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6.3.71.3.4 Effect of receipt

The SME is notified of the results of the mesh peering management protocol request.

6.3.71.4 MLME-MESHPEERINGMANAGEMENT.indication

6.3.71.4.1 Function

This primitive indicates to the SME that the MLME has received a mesh peering Management frame from a peer MAC entity.

6.3.71.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MESHPEERINGMANAGEMENT.indication(
                                    PeerMACAddress,
                                    MeshPeeringMgmtFrameContent,
                                    VendorSpecificInfo
                                    )
```

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Valid individual MAC address	Specifies the address of the peer MAC entity from which the mesh peering Management frame was received.
MeshPeeringMgmtFrameContent	Sequence of octets	As defined in 9.6.15.2, 9.6.15.3, or 9.6.15.4	The contents of the Action field of the Mesh Peering Open, Mesh Peering Confirm, or Mesh Peering Close frame received from the peer MAC entity.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.71.4.3 When generated

This primitive is generated by the MLME as a result of the receipt of a mesh peering Management frame from a peer MAC entity.

6.3.71.4.4 Effect of receipt

The SME is notified of the reception of a mesh peering Management frame and is provided the contents of the frame.

6.3.71.5 MLME-MESHPEERINGMANAGEMENT.response

6.3.71.5.1 Function

This primitive is used to send a response to a mesh peering Management frame to the specified peer MAC entity.

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6.3.71.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MESHPEERINGMANAGEMENT.response(
PeerMACAddress,
ResultCode,
MeshPeeringMgmtFrameContent,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Valid individual MAC address	Specifies the address of the peer MAC entity to which the mesh peering Management frame is to be sent.
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS	Reports the result response to the mesh peering Management frame from the peer MAC entity.
MeshPeeringMgmtFrameContent	Sequence of octets	As defined in 9.6.15.2, 9.6.15.3, or 9.6.15.4	The contents of the Action field of the Mesh Peering Open, Mesh Peering Confirm, or Mesh Peering Close frame to send to the peer MAC entity.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.71.5.3 When generated

This primitive is generated by the SME as a response to an MLME-MESHPEERINGMANAGEMENT.indication primitive.

6.3.71.5.4 Effect of receipt

This primitive indicates scheduling for transmission of a Mesh Peering frame containing the indicated response.

6.3.72 Mesh power management

6.3.72.1 Introduction

The following primitives describe how a mesh entity changes its mesh power management mode for a mesh peering.

6.3.72.2 MLME-MESHPOWERMGT.request

6.3.72.2.1 Function

This primitive requests a change in the mesh STAs mesh power management mode for the mesh peering.

6.3.72.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MESHPOWERMGT.request(
PeerMACAddress,
Mesh Power Management Mode
)

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Name	Type	Valid Range	Description
PeerMACAd-dress	MAC Address	Valid individual MAC address	Specifies the address of the peer MAC entity to which the mesh power management mode is changed.
Mesh Power Management Mode	Enumeration	ACTIVE_MODE, LIGHT_SLEEP_MODE, DEEP_SLEEP_MODE	Specifies the mesh power management mode that the local mesh STA is using for the mesh peering.

6.3.72.2.3 When generated

The primitive is generated when the mesh entity wishes to change the mesh power management mode of a mesh peering.

6.3.72.2.4 Effect of receipt

This primitive initiates the local mesh STA's mesh power management mode change of the mesh peering. The MLME subsequently issues an MLME-MESHPOWERMGT.confirm primitive that reflects the results.

6.3.72.3 MLME-MESHPOWERMGT.confirm

6.3.72.3.1 Function

This primitive reports the result of a mesh power management mode change attempt.

6.3.72.3.2 Semantics of the service primitive

The primitive parameter is as follows:

```
MLME-MESHPOWERMGT.confirm(
                                PeerMACAddress
                                )
```

Name	Type	Valid Range	Description
PeerMAC Address	MAC Address	Valid individual MAC address	Specifies the address of the peer MAC entity to which the mesh power management mode is changed.

6.3.72.3.3 When generated

This primitive is generated as a result of an MLME-MESHPOWERMGT.request primitive.

6.3.72.3.4 Effect of receipt

The SME is notified of the results of the mesh power management mode change for a mesh peering procedure.

6.3.73 Mesh neighbor offset synchronization

6.3.73.1 Introduction

This mechanism manages the neighbor offset synchronization method with the specified neighbor STA.

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6.3.73.2 MLME-MESHNEIGHBOROFFSETSYNCSTART.request

6.3.73.2.1 Function

This primitive requests to start the neighbor offset synchronization method with the specified neighbor STA.

6.3.73.2.2 Semantics of the service primitive

The primitive parameter is as follows:

MLME-MESHNEIGHBOROFFSETSYNCSTART.request(
PeerMACAddress
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to start the neighbor offset synchronization method.

6.3.73.2.3 When generated

This primitive is generated by the SME to start the neighbor offset synchronization method with the specified neighbor STA.

6.3.73.2.4 Effect of receipt

On receipt of this primitive, the MLME commences the neighbor offset synchronization method and the calculation of the TSF timer offset value. The MLME subsequently issues an MLME-MESHNEIGHBOROFFSETSYNCSTART.confirm primitive that reflects the results of this request.

6.3.73.3 MLME-MESHNEIGHBOROFFSETSYNCSTART.confirm

6.3.73.3.1 Function

This primitive reports the results of a mesh neighbor offset synchronization request.

6.3.73.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MESHNEIGHBOROFFSETSYNCSTART.confirm(
PeerMACAddress,
TSFOffsetValue
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Valid individual MAC address	Specifies the address of the peer MAC entity to which the neighbor offset synchronization is requested.
TSFOffsetValue	Integer	-2^{63} to $(2^{63}-1)$	Indicates the TSF offset value with the specified neighbor STA, expressed in 2s complement in μs.

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6.3.73.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-MESHNEIGHBOROFFSETSYNCSTART.request primitive and report the TSF offset value.

6.3.73.3.4 Effect of receipt

The SME is notified of the results of the mesh neighbor offset synchronization request.

6.3.73.4 MLME-MESHNEIGHBOROFFSETCALCULATE.request

6.3.73.4.1 Function

This primitive requests a calculation result of the TSF timer offset value for the specified neighbor STA.

6.3.73.4.2 Semantics of the service primitive

The primitive parameter is as follows:

```
MLME-MESHNEIGHBOROFFSETCALCULATE.request(
                                        PeerMACAddress
                                        )
```

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to report the TSF offset value.

6.3.73.4.3 When generated

This primitive is generated by the SME to order a calculation of the TSF timer offset value with the specified neighbor STA.

6.3.73.4.4 Effect of receipt

On receipt of this primitive, the MLME receives a Beacon or Probe Response frame and calculates the TSF timer offset value from the received frame. The MLME tries to receive a Beacon frame immediately after the issue of MLME-MESHNEIGHBOROFFSETCALCULATE.request primitive even if the mesh STA does not listen to the Beacon frame from the specified neighbor STA regularly (i.e., in deep sleep mode toward the specified neighbor STA). The MLME subsequently issues an MLME-MESHNEIGHBOROFFSETCALCULATE.confirm primitive that reflects the results of this request.

6.3.73.5 MLME-MESHNEIGHBOROFFSETCALCULATE.confirm

6.3.73.5.1 Function

This primitive reports the results of a mesh neighbor offset calculation request.

6.3.73.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MESHNEIGHBOROFFSETCALCULATE.confirm(
                                        PeerMACAddress,
                                        TSFOffsetValue
                                        )
```

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Name	Type	Valid range	Description
PeerMACAddress	MAC address	Valid individual MAC address	Specifies the address of the peer MAC entity to which the Neighbor Offset Measure is requested.
TSFOffsetValue	Integer	-2^{63} to $(2^{63}-1)$	Indicates the TSF offset value with the specified neighbor STA, expressed in 2s complement in μs.

6.3.73.5.3 When generated

This primitive is generated by the MLME as a result of an MLME-MESHNEIGHBOROFFSETCALCULATE.request primitive to report a TSF offset value.

6.3.73.5.4 Effect of receipt

The SME is notified of the results of the mesh neighbor offset calculation request.

6.3.73.6 MLME-MESHNEIGHBOROFFSETSYNCSTOP.request

6.3.73.6.1 Function

This primitive requests to stop the neighbor offset synchronization method with the specified neighbor STA.

6.3.73.6.2 Semantics of the service primitive

The primitive parameter is as follows:

```
MLME-MESHNEIGHBOROFFSETSYNCSTOP.request(
                                        PeerMACAddress
                                        )
```

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to stop the neighbor offset synchronization method.

6.3.73.6.3 When generated

This primitive is generated by the SME to stop the maintenance of the neighbor offset synchronization method with the specified neighbor STA.

6.3.73.6.4 Effect of receipt

On receipt of this primitive, the MLME stops the neighbor offset synchronization method with the specified peer. The MLME subsequently issues an MLME-MESHNEIGHBOROFFSETSYNCSTOP.confirm primitive that reflects the results of this request.

6.3.73.7 MLME-MESHNEIGHBOROFFSETSYNCSTOP.confirm

6.3.73.7.1 Function

This primitive reports the results of a neighbor offset synchronization method stop request.

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6.3.73.7.2 Semantics of the service primitive

The primitive parameter is as follows:

MLME-MESHNEIGHBOROFFSETSYNCSTOP.confirm(
PeerMACAddress
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Valid individual MAC address	Specifies the address of the peer MAC entity to which the Neighbor Offset Stop is requested.

6.3.73.7.3 When generated

This primitive is generated by the MLME as a result of an MLME-MESHNEIGHBOROFFSETSYNCSTOP.request primitive.

6.3.73.7.4 Effect of receipt

The SME is notified of the results of the mesh neighbor offset synchronization stop request.

6.3.74 Mesh TBTT adjustment

6.3.74.1 Introduction

The following primitives describe how a mesh STA requests a TBTT adjustment from a neighboring peer mesh STA.

6.3.74.2 MLME-MESHTBTTADJUSTMENT.request

6.3.74.2.1 Function

This primitive requests transmission of a TBTT Adjustment Request frame.

6.3.74.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MESHTBTTADJUSTMENT.request(
PeerMACAddress,
BeaconTiming,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity to which the TBTT Adjustment Request is sent.
BeaconTiming	A set of Beacon Timing elements	As defined in 9.4.2.104	A set of Beacon Timing elements of the mesh STA.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.74.2.3 When generated

This primitive is generated by the SME to request that a TBTT Adjustment Request frame be sent to a peer entity to request the adjustment of the peer entity's TBTT.

6.3.74.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TBTT Adjustment Request frame containing the Beacon Timing elements. This frame is then scheduled for transmission. The MLME subsequently issues an MLME-MESHTBTTADJUSTMENT.confirm primitive that reflects the result of this request.

6.3.74.3 MLME-MESHTBTTADJUSTMENT.confirm

6.3.74.3.1 Function

This primitive reports the result of a mesh TBTT adjustment request.

6.3.74.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MESHTBTTADJUSTMENT.confirm(
PeerMACAddress,
ResultCode,
BeaconTiming,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity from which the TBTT Adjustment Response is received.
ResultCode	Enumeration	SUCCESS, REFUSED_REASON_ UNSPECIFIED, CANNOT_FIND_ ALTERNATIVE_TBTT	Indicates the result of the TBTT adjustment request.
BeaconTiming	A set of Beacon Timing elements	As defined in 9.4.2.104	A set of Beacon Timing elements of the responding mesh STA. Present only when such an element was present in the TBTT Adjustment Response frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.74.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-MESHTBTTADJUSTMENT.request primitive to indicate the result of that request.

6.3.74.3.4 Effect of receipt

The SME is notified of the result of the mesh TBTT adjustment request.

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6.3.74.4 MLME-MESHTBTTADJUSTMENT.indication

6.3.74.4.1 Function

This primitive indicates that a specific peer MAC entity is requesting adjustment of the TBTT.

6.3.74.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MESHTBTTADJUSTMENT.indication(
PeerMACAddress,
BeaconTiming,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity from which the TBTT Adjustment request was received.
BeaconTiming	A set of Beacon Timing elements	As defined in 9.4.2.104	A set of Beacon Timing elements of the requesting mesh STA.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.74.4.3 When generated

This primitive is generated by the MLME as a result of the receipt of a TBTT Adjustment Request frame from the specified peer MAC entity.

6.3.74.4.4 Effect of receipt

The SME is notified of the receipt of the TBTT adjustment request by the specified peer MAC entity. The mesh STA that received this primitive subsequently processes the TBTT scanning and adjustment procedure described in 14.13.4.4.3, and responds with the MLME-MESHTBTTADJUSTMENT.response primitive.

6.3.74.5 MLME-MESHTBTTADJUSTMENT.response

6.3.74.5.1 Function

This primitive is used to send a response to the specified peer MAC entity that requested a TBTT adjustment from the mesh STA that issued this primitive.

6.3.74.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MESHTBTTADJUSTMENT.response(
PeerMACAddress,
Status Code,
BeaconTiming,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity to which the TBTT Adjustment Response is sent.
Status Code	As defined in frame format	SUCCESS, REFUSED_REASON_ UNSPECIFIED, CANNOT_FIND_ ALTERNATIVE_TBTT	Indicates the result response to the TBTT adjustment request from the peer mesh STA.
BeaconTiming	A set of Beacon Timing elements	As defined in 9.4.2.104	A set of Beacon Timing elements of the mesh STA. Present only when the STA could not find an alternative TBTT.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.74.5.3 When generated

This primitive is generated by the SME of a mesh STA as response to an MLME-MESHTBTTADJUSTMENT.indication primitive.

6.3.74.5.4 Effect of receipt

This primitive initiates the transmission of a TBTT Adjustment Response frame to the peer MAC entity that requested the TBTT adjustment.

On receipt of this primitive, the MLME constructs a TBTT Adjustment Response frame. This frame is then scheduled for transmission.

6.3.75 MCCA management interface

6.3.75.1 Introduction

The following primitives describe how a mesh entity manages its MCCA operation.

6.3.75.2 MLME-ACTIVATEMCCA.request

6.3.75.2.1 Function

This primitive requests that the MAC entity activate MCCA.

6.3.75.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-ACTIVATEMCCA.request(
                                    MCCAScanDuration,
                                    MAFLimit,
                                    MCCAAdvertPeriodMax,
                                    MCCAMaxTrackStates,
                                    MCCACWmin,
                                    MCCACWmax,
                                    MCCAAIFSN
                                    )
```

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Name	Type	Valid range	Description
MCCAScanDuration	Integer	0–65 535	Specifies the duration in TUs that the mesh STA shall not initiate or accept MCCA Setup Request frames.
MAFLimit	Integer	0–255	Specifies the maximum MCCA access fraction allowed at the mesh STA. This number is always a multiple of (1/255) of the DTIM Interval.
MCCAAdvertPeriodMax	Integer	0–255	Specifies the maximum interval that a mesh STA with dot11MCCAActivated equal to true waits for an MCCAOP advertisement. It is expressed in number of DTIM intervals.
MCCAMaxTrackStates	Integer	83–dot11MCCATrackStatesCapable	Specifies the total number of MCCAOP reservations that the MAC entity is able to track.
MCCACWmin	Integer	0–15	Specifies the value of the minimum size of the contention window that the MAC entity uses for channel access during an MCCAOP.
MCCACWmax	Integer	0–63	Specifies the value of the maximum size of the contention that the MAC entity uses for channel access during an MCCAOP.
MCCAAIFSN	Integer	0–15	Specifies the value of the AIFSN that the MAC entity uses for channel access during an MCCAOP.

6.3.75.2.3 When generated

This primitive is generated by the SME to start the use of MCCA.

6.3.75.2.4 Effect of receipt

This primitive sets dot11MCCAActivated to true and initializes the MCCA parameters.

6.3.75.3 MLME-MCCASETUP.request

6.3.75.3.1 Function

This primitive requests that the MAC entity set up an MCCAOP reservation.

6.3.75.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MCCASETUP.request(
                        MCCAOPDuration,
                        MCCAOPPeriodicity,
                        MCCAOPOffset,
                        MCCAOPResponder,
                        VendorSpecificInfo
                        )
```

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Name	Type	Valid range	Description
MCCAOPDuration	Integer	0–65 535	Specifies the MCCAOP Duration of the needed MCCAOPs as described in 9.4.2.105.2.
MCCAOPPeriodicity	Integer	0–255	Specifies the MCCAOP Periodicity of the needed MCCAOPs as described in 9.4.2.105.2.
MCCAOPOffset	Integer	0–16 777 215	Specifies the MCCAOP offset of the needed MCCAOPs as described in 9.4.2.105.2.
MCCAOPResponder	MAC address	Any valid individual or group MAC address	Specifies the MAC address of the intended MCCAOP responder.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.75.3.3 When generated

This primitive is generated by the SME to start an MCCAOP setup procedure.

6.3.75.3.4 Effect of receipt

This primitive causes the transmission of an MCCA Setup Request frame to the MCCAOP responder provided that the conditions for the transmission are met. In the case that a response is received from the responder STA, the MLME subsequently issues an MLME-MCCASETUP.confirm primitive that reflects the results.

6.3.75.4 MLME-MCCASETUP.confirm

6.3.75.4.1 Function

This primitive is generated by the MLME to report the result of an MLME-MCCASETUP.request primitive, which was issued in order to establish an MCCAOP reservation with the peer MAC entity specified in MCCAOPResponder.

6.3.75.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MCCASETUP.confirm(
                        MCCAOPParameters,
                        MCCAOPID,
                        MCCAOPResponder,
                        ResultCode,
                        VendorSpecificInfo
                        )
```

Name	Type	Valid range	Description
MCCAOPParameters	MCCAOP Reservation	See 9.4.2.105.2	The MCCAOP reservation parameters.
MCCAOPID	Integer	0–254	MCCAOP reservation ID of the MCCAOP reservation.
MCCAOPResponder	MAC address	Any valid individual or group MAC address	Specifies the MAC address of the intended MCCAOP responder.

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Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, MCCAOP_RESERVATION_CONFLICT, MAF_LIMIT_EXCEEDED, MCCA_TRACK_LIMIT_EXCEEDED	Indicates the result of the MLME-MCCASETUP.request primitive.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.75.4.3 When generated

This primitive is generated by the MLME as a result of an MLME-MCCASETUP.request primitive to establish an MCCAOP reservation with the peer mesh STA identified in MCCAOPResponder or upon receipt of an MCCA Setup Reply frame from the peer mesh STA identified in MCCAOPResponder.

6.3.75.4.4 Effect of receipt

The SME is notified of the results of the MCCAOP setup procedure.

6.3.75.5 MLME-MCCASETUP.indication

6.3.75.5.1 Function

This primitive indicates the receipt of an MCCA Setup Request frame from the peer MAC entity specified in MCCAOPOwner.

6.3.75.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MCCASETUP.indication(
                          MCCAOPParameters,
                          MCCAOPID,
                          MCCAOPOwner,
                          VendorSpecificInfo
                          )
```

Name	Type	Valid range	Description
MCCAOPParameters	MCCAOP Reservation	See 9.4.2.105.2	The MCCAOP reservation parameters.
MCCAOPID	Integer	0–254	MCCAOP reservation ID of the MCCAOP reservation.
MCCAOPOwner	MAC address	Any valid individual MAC address	Specifies the MAC address of the MCCAOP owner.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.75.5.3 When generated

This primitive is generated by the MLME as result of the receipt of an MCCA Setup Request frame from the peer MAC entity specified in MCCAOPOwner.

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6.3.75.5.4 Effect of receipt

The SME is notified of the request to establish an MCCAOP reservation with the peer MAC entity specified in MCCAOPOwner.

6.3.75.6 MLME-MCCASETUP.response

6.3.75.6.1 Function

This primitive is used to send a response to the peer MAC entity specified in MCCAOPOwner that requested the set up of the MCCAOP reservation.

6.3.75.6.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MCCASETUP.response(
MCCAOPParameters,
MCCAOPID,
MCCAOPOwner,
ResultCode,
VendorSpecificInfo
)

Name	Type	Valid range	Description
MCCAOPParameters	MCCAOP Reservation	See 9.4.2.105.2	The MCCAOP reservation parameters.
MCCAOPID	Integer	0–254	MCCAOP reservation ID of the MCCAOP reservation.
MCCAOPOwner	MAC address	Any valid individual MAC address	Specifies the MAC address of the MCCAOP owner.
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, MCCAOP_RESERVATION_CONFLICT, MAF_LIMIT_EXCEEDED, MCCA_TRACK_LIMIT_EXCEEDED	Indicates the result of the MLME-MCCASETUP.request primitive.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.75.6.3 When generated

This primitive is generated by the SME of a STA as a response to an MLME-MCCASETUP.indication primitive.

6.3.75.6.4 Effect of receipt

This primitive initiates transmission of a response to the peer MAC entity specified in the MCCAOPOwner that requested the set up of an MCCAOP reservation.

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6.3.75.7 MLME-MCCAADVERTISEMENT.request

6.3.75.7.1 Function

This primitive requests that the MAC entity request an MCCAOP advertisement from the specified peer MAC entity by sending an MCCA Advertisement Request frame to the peer MAC entity.

6.3.75.7.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MCCAADVERTISEMENT.request(
PeerMACAddress,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the peer MAC that sends the Advertisement.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.75.7.3 When generated

This primitive is generated by the SME to request an MCCAOP advertisement from the specified peer MAC entity.

6.3.75.7.4 Effect of receipt

This primitive causes the transmission of an MCCA Advertisement Request frame to the specified peer MAC entity. In the case that a response is received from the responder STA, the MLME subsequently issues an MLME-MCCAADVERTISEMENT.confirm primitive that reflects the results.

6.3.75.8 MLME-MCCAADVERTISEMENT.confirm

6.3.75.8.1 Function

This primitive reports the result of an MLME-MCCAADVERTISEMENT.request primitive.

6.3.75.8.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MCCAADVERTISEMENT.confirm(
MCCAOPAdvertisement,
PeerMACAddress,
ResultCode,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
MCCAOPAdvertisement	MCCAOP Advertisement	See 9.4.2.108	One or more MCCAOP Advertisement elements.
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the transmitter of the MCCAOP advertisement.
ResultCode	Enumeration	SUCCESS, REFUSED	Indicates the result of the MLME-MCCAADVERTISEMENT.request primitive.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.75.8.3 When generated

This primitive is generated by the MLME as a result of an MLME-MCCAADVERTISEMENT.request primitive.

6.3.75.8.4 Effect of receipt

The SME is notified of the results of the MCCA Advertisement Request frame.

6.3.75.9 MLME-MCCAADVERTISEMENT.indication

6.3.75.9.1 Function

This primitive reports that an MCCA Advertisement Request frame has been received from the specified peer MAC entity.

6.3.75.9.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MCCAADVERTISEMENT.indication(
                    PeerMACAddress,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the transmitter of the MCCA Advertisement Request frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.75.9.3 When generated

This primitive is generated by the MLME upon receipt of an MCCA Advertisement Request frame from the specified peer MAC entity.

6.3.75.9.4 Effect of receipt

The SME is notified of the request to advertise its MCCAOP reservations.

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6.3.75.10 MLME-MCCAADVERTISEMENT.response

6.3.75.10.1 Function

This primitive requests that the MAC entity respond to the MCCAOP advertisement request from the specified peer MAC entity by sending an MCCA Advertisement frame to the peer MAC entity.

6.3.75.10.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MCCAADVERTISEMENT.response(
MCCAOPAdvertisement,
PeerMACAddress,
ResultCode,
VendorSpecificInfo
)

Name	Type	Valid range	Description
MCCAOPAdvertisement	MCCAOP Advertisement	See 9.4.2.108	One or more MCCAOP Advertisement elements.
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the transmitter of the MCCA Advertisement frame.
ResultCode	Enumeration	SUCCESS, REFUSED	Indicates the result of the MLME-MCCAADVERTISEMENT.response primitive.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.75.10.3 When generated

This primitive is generated by the SME of a STA as a response to an MLME-MCCAADVERTISEMENT.indication procedure.

6.3.75.10.4 Effect of receipt

This primitive initiates transmission of a response to the specified peer MAC entity that requested advertisement of the MCCAOP reservations.

6.3.75.11 MLME-MCCATEARDOWN.request

6.3.75.11.1 Function

This primitive requests that the MAC entity tear down an MCCAOP reservation.

6.3.75.11.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MCCATEARDOWN.request(
MCCAOPID,
PeerMACAddress,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
MCCAOPID	Integer	0–255	Specifies the MCCAOP reservation ID of the MCCAOP reservation to be torn down.
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the peer MAC for the MCCAOP reservation.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.75.11.3 When generated

This primitive is generated by the SME to start an MCCAOP teardown procedure.

6.3.75.11.4 Effect of receipt

This primitive causes the teardown MCCAOP reservation identified by means of the MCCAOP reservation ID in MCCAOPID, and the transmission of an MCCA Teardown frame to the peer MAC entity in PeerMACAddress.

6.3.75.12 MLME-MCCATEARDOWN.indication

6.3.75.12.1 Function

This primitive reports that an MCCA Teardown frame has been received from the specified peer MAC entity.

6.3.75.12.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MCCATEARDOWN.indication(
                              MCCAOPID,
                              PeerMACAddress,
                              VendorSpecificInfo
                              )
```

Name	Type	Valid range	Description
MCCAOPID	Integer	0–255	MCCAOP reservation ID of the MCCAOP reservation to be torn down.
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the peer MAC for the MCCAOP reservation.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.75.12.3 When generated

This primitive is generated by the MLME as result of receipt of an MCCA Teardown frame.

6.3.75.12.4 Effect of receipt

The SME is notified of the request to start an MCCAOP teardown procedure.

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6.3.76 MBSS congestion control

6.3.76.1 Introduction

The following primitives describe how a mesh STA manages its congestion control operation.

6.3.76.2 MLME-MBSSCONGESTIONCONTROL.request

6.3.76.2.1 Function

This primitive requests that the MAC entity notify the peer MAC entity on the congestion level or requests to traffic generation by transmitting a Congestion Control Notification frame to the specified peer MAC entity.

6.3.76.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME- MBSSCONGESTIONCONTROL.request(
PeerMACAddress,
CongestionNotification,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity to which the Congestion Control Notification frame is sent.
CongestionNotification	A set of Congestion Notification elements	As defined in 9.4.2.100	Congestion notification information generated by the mesh STA.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.76.2.3 When generated

The SME generates this primitive to request that the MAC notify its peer MAC about the current congestion level.

6.3.76.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Congestion Control Notification frame. This frame is then scheduled for transmission.

6.3.76.3 MLME-MBSSCONGESTIONCONTROL.indication

6.3.76.3.1 Function

This primitive indicates that a congestion notification has been received.

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6.3.76.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME- MBSSCONGESTIONCONTROL.indication(
PeerMACAddress,
CongestionNotification,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity from which the Congestion Control Notification frame was received.
CongestionNotification	A set of Congestion Notification elements	As defined in 9.4.2.100	Congestion notification information contained in the received Congestion Control Notification frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.76.3.3 When generated

This primitive is generated by the MLME as a result of the receipt of a Congestion Control Notification frame from a specific peer MAC entity.

6.3.76.3.4 Effect of receipt

The SME is notified of the results of the receipt of the congestion control notification from the specified peer MAC entity. The mesh STA that received this primitive subsequently activates the local rate control as described in 14.12.

6.3.77 MBSS proxy update

6.3.77.1 Introduction

The following primitives describe how a mesh STA reports the proxy update information to another mesh STA in the MBSS.

6.3.77.2 MLME-MBSSPROXYUPDATE.request

6.3.77.2.1 Function

This primitive requests that the MAC entity inform a destination mesh STA about its proxy information by transmitting a Proxy Update frame to the specified peer MAC entity.

6.3.77.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME- MBSSPROXYUPDATE.request(
PeerMACAddress,
ProxyUpdate,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity to which the Proxy Update frame is sent.
ProxyUpdate	A set of PXU elements	As defined in 9.4.2.115	A set of proxy information available at the mesh STA.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.77.2.3 When generated

This primitive is generated by the SME to request that a Proxy Update frame be sent to the specified peer MAC entity.

6.3.77.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Proxy Update frame containing the PXU element. This frame is then scheduled for transmission. In the case that a response is received from the responder STA, the MLME subsequently issues an MLME- MBSSPROXYUPDATE.confirm primitive that reflects the results of this request.

6.3.77.3 MLME-MBSSPROXYUPDATE.confirm

6.3.77.3.1 Function

This primitive reports the results of a proxy update request.

6.3.77.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME- MBSSPROXYUPDATE.confirm(
                    PeerMACAddress,
                    ProxyUpdateConfirmation,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity from which the Proxy Update Confirmation frame is received.
ProxyUpdateConfirmation	A set of PXUC elements	As defined in 9.4.2.116	A set of proxy update confirmation information from the peer MAC entity to which the Proxy Update frame was sent.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.77.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-MBSSPROXYUPDATE.request primitive.

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6.3.77.3.4 Effect of receipt

The SME is notified of the results of the MBSS proxy update request.

6.3.77.4 MLME-MBSSPROXYUPDATE.indication

6.3.77.4.1 Function

This primitive indicates that an update of the proxy information has been received from a specific peer MAC entity.

6.3.77.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME- MBSSPROXYUPDATE.indication(
PeerMACAddress,
ProxyUpdate,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity from which the update of the proxy information was received.
ProxyUpdate	A set of PXU elements	As defined in 9.4.2.115	A set of proxy information received from the peer mesh STA.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.77.4.3 When generated

This primitive is generated by the MLME as a result of the receipt of a Proxy Update frame from a specific peer MAC entity.

6.3.77.4.4 Effect of receipt

The SME is notified of the results of the receipt of the proxy update request by the specified peer MAC entity. The mesh STA that received this primitive subsequently updates the proxy information as described in 14.11.4.3.

6.3.77.5 MLME-MBSSPROXYUPDATE.response

6.3.77.5.1 Function

This primitive is used to send a response to a specific peer MAC entity that sent an update of the proxy information to the mesh STA that issued this primitive.

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6.3.77.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME- MBSSPROXYUPDATE.response(
PeerMACAddress,
ProxyUpdateConfirmation,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity to which the Proxy Update Confirmation frame is sent.
ProxyUpdateConfirmation	A set of PXUC elements	As defined in 9.4.2.116	A set of proxy update confirmation information to be sent to the peer MAC entity.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.77.5.3 When generated

This primitive is generated by the SME of a STA as a response to an MLME-MBSSPROXYUPDATE.indication primitive.

6.3.77.5.4 Effect of receipt

This primitive initiates transmission of a response to the specific peer MAC entity that sent an update of the proxy information.

On receipt of this primitive, the MLME constructs a Proxy Update Confirmation frame. The frame contains one or more PXUC elements. This frame is then scheduled for transmission.

6.3.78 MBSS mesh gate announcement

6.3.78.1 Introduction

The following primitives describe how a mesh STA announces mesh gate reachability.

6.3.78.2 MLME-MBSSGATEANNOUNCEMENT.request

6.3.78.2.1 Function

This primitive requests that the MAC entity update the mesh gate information by transmitting a Gate Announcement frame to the specified MAC entity.

6.3.78.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME- MBSSGATEANNOUNCEMENT.request(
PeerMACAddress,
GateAnnouncement,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid group MAC address	Specifies the address of the MAC entity to which the Gate announcement frame is sent.
GateAnnouncement	GANN element	As defined in 9.4.2.110	A set of gate announcement information to be sent through a Gate Announcement frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.78.2.3 When generated

This primitive is generated by the SME to request that a Gate Announcement frame be sent to the specified MAC entity.

6.3.78.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Gate Announcement frame containing the GANN element. This frame is then scheduled for transmission following the interval specified by dot11MeshGateAnnouncementInterval.

6.3.78.3 MLME-MBSSGATEANNOUNCEMENT.indication

6.3.78.3.1 Function

This primitive indicates that a mesh gate announcement has been received from the specific peer MAC entity.

6.3.78.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME- MBSSGATEANNOUNCEMENT.indication(
                    PeerMACAddress,
                    GateAnnouncement,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity from which the gate announcement was received.
GateAnnouncement	GANN element	As defined in 9.4.2.110	A set of gate announcement information contained in the received Gate Announcement frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.78.3.3 When generated

This primitive is generated by the MLME as a result of the receipt of a Gate Announcement frame from a specific peer MAC entity.

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6.3.78.3.4 Effect of receipt

The SME is notified of the reachability to a mesh gate in the mesh BSS. The mesh STA received this primitive subsequently triggers an MBSSGATEANNOUNCEMENT.request primitive as described in 14.11.2.

6.3.79 Mesh link metric

6.3.79.1 Introduction

Subclause 6.3.79 describes the management procedures associated with mesh link metric reporting.

6.3.79.2 MLME-MESHLINKMETRICREAD.request

6.3.79.2.1 Function

This primitive requests to read a link metric value between the local MAC entity and a specific peer MAC entity.

6.3.79.2.2 Semantics of the service primitive

The primitive parameter is as follows:

```
MLME-MESHLINKMETRICREAD.request(
                    PeerMACAddress
                    )
```

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity for which the link metric value is read.

6.3.79.2.3 When generated

This primitive is generated by the SME to read the link metric value for the mesh link to the specified peer MAC entity.

6.3.79.2.4 Effect of receipt

On receipt of this primitive, the MLME reports the link metric value. The MLME subsequently issues an MLME-MESHLINKMETRICREAD.confirm primitive that reflects the results of this request.

6.3.79.3 MLME-MESHLINKMETRICREAD.confirm

6.3.79.3.1 Function

This primitive reports the results of a link metric read request.

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6.3.79.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME- MESHLINKMETRICREAD.confirm(
                    LinkMetricValue,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
LinkMetricValue	Mesh Link Metric Report element	As defined in 9.4.2.99	The link metric value for the mesh link to the specified peer MAC entity.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.79.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-MESHLINKMETRICREAD.request primitive to request a link metric value.

6.3.79.3.4 Effect of receipt

The SME is notified of the results of the link metric read request.

6.3.79.4 MLME-MESHLINKMETRICREPORT.request

6.3.79.4.1 Function

This primitive requests that the MAC entity either transmit a link metric to or request a link metric from the specified peer MAC entity.

6.3.79.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MESHLINKMETRICREPORT.request(
                    PeerMACAddress,
                    LinkMetricRequestFlag,
                    MeshLinkMetricReport,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity to which the Mesh Link Metric Report is sent.
LinkMetricRequestFlag	Enumeration	REPORT_ONLY, REPORT_AND_REQUEST	Indicates whether the mesh STA requests a link metric report from the peer MAC entity.

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Name	Type	Valid range	Description
MeshLinkMetricReport	Mesh Link Metric Report element	As defined in 9.4.2.99	A metric value computed for the corresponding link.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.79.4.3 When generated

This primitive is generated by the SME to request that a Mesh Link Metric Report frame be sent to a peer MAC entity in order to report a link metric value and to request a mesh link metric report from the peer MAC entity if LinkMetricRequestFlag is equal to REPORT_AND_REQUEST.

6.3.79.4.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Mesh Link Metric Report frame. The Request subfield in the Flags field of the Mesh Link Metric Report element is set depending on the parameter given by the LinkMetricRequestFlag. If LinkMetricRequestFlag is equal to REPORT_ONLY, the Request subfield is set to 0. If LinkMetricRequestFlag is equal to REPORT_AND_REQUEST, the Request subfield is set to 1. This frame is then scheduled for transmission.

6.3.79.5 MLME-MESHLINKMETRICREPORT.indication

6.3.79.5.1 Function

This primitive indicates that a Mesh Link Metric Report frame has been received from a peer MAC entity. This Mesh Link Metric Request Report can be in response to an earlier MLME-MESHLINKMETRICREPORT.request primitive with LinkMetricRequestFlag equal to REPORT_AND_REQUEST.

6.3.79.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME- MESHLINKMETRICREPORT.indication(
                PeerMACAddress,
                LinkMetricRequestFlag,
                MeshLinkMetricReport,
                VendorSpecificInfo
                )
```

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity from which the Mesh Link Metric Report frame was received.
LinkMetricRequestFlag	Enumeration	REPORT_ONLY, REPORT_AND_ REQUEST	Indicates whether the peer MAC entity requests a link metric report.
MeshLinkMetricReport	Mesh Link Metric Report element	As defined in 9.4.2.99	A metric value reported from the specified peer MAC entity.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.79.5.3 When generated

This primitive is generated by the MLME as a result of the receipt of a Mesh Link Metric Report frame from a specific peer MAC entity.

6.3.79.5.4 Effect of receipt

The SME is notified of the receipt of the link metric report from the specified peer MAC entity. When LinkMetricRequestFlag is equal to REPORT_AND_REQUEST, the mesh STA responds with a Mesh Link Metric Report frame.

6.3.80 HWMP mesh path selection

6.3.80.1 Introduction

The following primitives describe how a mesh STA establishes and maintains a mesh path to a specified peer MAC entity.

6.3.80.2 MLME-HWMPMESHPATHSELECTION.request

6.3.80.2.1 Function

This primitive requests that the MAC entity establish or maintain a mesh path to the specified peer MAC entity by transmitting an HWMP Mesh Path Selection frame to the specified peer MAC entity.

6.3.80.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-HWMPMESHPATHSELECTION.request(
PeerMACAddress,
RootAnnouncement,
PathRequest,
PathReply,
PathError,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual or group MAC address	Specifies the address of the peer MAC entity to which the HWMP Mesh Path Selection frame is sent.
RootAnnouncement	RANN element	As defined in 9.4.2.111	A set of RANN elements generated by the mesh STA. Present if the mesh STA is configured as a root mesh STA using the proactive RANN mechanism [dot11MeshHWMProotMode = rann (4)], and as described in 14.10.12; otherwise not present.
PathRequest	PREQ element	As defined in 9.4.2.112	A set of PREQ elements generated by the mesh STA. Present as described in 14.10.9.
PathReply	PREP element	As defined in 9.4.2.113	A set of PREP elements generated by the mesh STA. Present as described in 14.10.10.

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Name	Type	Valid range	Description
PathError	PERR element	As defined in 9.4.2.114	A set of PERR elements generated by the mesh STA. Present as described in 14.10.11.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.80.2.3 When generated

This primitive is generated by the SME to request that an HWMP Mesh Path Selection frame be sent to a specified peer entity.

6.3.80.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs an HWMP Mesh Path Selection frame. This frame is then scheduled for transmission.

6.3.80.3 MLME-HWMPMESHPATHSELECTION.indication

6.3.80.3.1 Function

This primitive indicates that an HWMP Mesh Path Selection frame has been received from the specified peer MAC entity.

6.3.80.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-HWMPMESHPATHSELECTION.indication(
                        PeerMACAddress,
                        RootAnnouncement,
                        PathRequest,
                        PathReply,
                        PathError,
                        VendorSpecificInfo
                        )
```

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity from which the HWMP Mesh Path Selection frame was received.
RootAnnouncement	RANN element	As defined in 9.4.2.111	A set of RANN elements contained in the received frame. Present only when such an element was present in the received frame.
PathRequest	PREQ element	As defined in 9.4.2.112	A set of PREQ elements contained in the received frame. Present only when such an element was present in the received frame.
PathReply	PREP element	As defined in 9.4.2.113	A set of PREP elements contained in the received frame. Present only when such an element was present in the received frame.

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Name	Type	Valid range	Description
PathError	PERR element	As defined in 9.4.2.114	A set of PERR elements contained in the received frame. Present only when such an element was present in the received frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.80.3.3 When generated

This primitive is generated by the MLME as a result of the receipt of an HWMP Mesh Path Selection frame from a specific peer MAC entity.

6.3.80.3.4 Effect of receipt

The SME is notified of the results of the receipt of the HWMP Mesh Path Selection from the specified peer MAC entity. The mesh STA received this primitive subsequently activates path selection procedures described in 14.10.

6.3.81 QMF policy

6.3.81.1 Introduction

The following MLME primitives support the signaling of QMF policy.

6.3.81.2 MLME-QMFPOLICY.request

6.3.81.2.1 Function

This primitive requests the transmission of an unsolicited QMF Policy frame to a peer entity.

6.3.81.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-QMFPOLICY.request(
                        Peer STA Address,
                        QMFPolicy,
                        VendorSpecificInfo
                        )
```

Name	Type	Valid range	Description
Peer STA Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the QMF policy is sent.
QMFPolicy	QMF Policy element	As defined in 9.4.2.119	This parameter describes the QMF policy the peer STA is required to use.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.81.2.3 When generated

This primitive is generated by the SME to request that a QMF Policy frame be sent to a peer entity to communicate QMF policy information.

6.3.81.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a QMF Policy frame. This frame is then scheduled for transmission.

6.3.81.3 MLME-QMFPOLICY.indication

6.3.81.3.1 Function

This primitive indicates that an unsolicited QMF Policy frame has been received from a peer entity.

6.3.81.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-QMFPOLICY.indication (
                        Peer STA Address,
                        QMFPolicy,
                        VendorSpecificInfo
                        )
```

Name	Type	Valid range	Description
Peer STA Address	MAC address	Any valid individual MAC address	The address of the peer MAC from which the QMF policy was received.
QMFPolicy	QMF Policy element	As defined in 9.4.2.119	This parameter describes the QMF policy the peer STA is requiring to be used.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.81.3.3 When generated

This primitive is generated by the MLME when a QMF Policy frame with dialog token equal to 0 is received from a peer entity.

6.3.81.3.4 Effect of receipt

The SME is notified of the receipt of a QMF policy.

6.3.81.4 MLME-QMFPOLICYCHANGE.request

6.3.81.4.1 Function

This primitive supports the change of QMF Policy between peer STAs. The SME requests the transmission of a QMF Policy Change frame in order to request a change in the QMF policy the STA uses to transmit to the peer STA.

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6.3.81.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-QMFPOLICYCHANGE.request (
Peer STA Address,
Dialog Token,
QMFPolicy,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer STA Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the QMF policy change request is sent.
Dialog Token	Integer	1–255	The dialog token to identify the QMF policy change transaction.
QMFPolicy	QMF Policy element	As defined in 9.4.2.119	This parameters describes the QMF policy the STA is requesting to use.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.81.4.3 When generated

This primitive is generated by the SME when a STA wishes to request a change of the QMF policy it uses to transmit Management frames to a peer entity.

6.3.81.4.4 Effect of receipt

On receipt of this primitive, the MLME constructs a QMF Policy Change frame containing the set of QMF policy parameters. This frame is then scheduled for transmission.

6.3.81.5 MLME-QMFPOLICYCHANGE.confirm

6.3.81.5.1 Function

This primitive reports the results of a policy change attempt with a peer QMF STA.

6.3.81.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-QMFPOLICYCHANGE.confirm (
Peer STA Address,
Dialog Token,
Result Code,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
Peer STA Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the QMF policy was received.
Dialog Token	Integer	1–255	The dialog token to identify the QMF policy change transaction.
Result Code	Enumeration	SUCCESS, REJECT	Reports the receipt of a QMF Policy frame and the result of the QMF policy change at the peer SME or if no matching response is received within dot11QMFPolicyChangeTimeout TU.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.81.5.3 When generated

This primitive is generated by the MLME as a result of receipt of a QMF Policy frame with a dialog token that matches the dialog token from the MLME-QMFPOLICYCHANGE.request primitive.

6.3.81.5.4 Effect of receipt

The SME is notified of the results of the QMF policy change procedure.

6.3.81.6 MLME-QMFPOLICYCHANGE.indication

6.3.81.6.1 Function

This primitive indicates that a QMF Policy Change frame has been received from a peer entity.

6.3.81.6.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-QMFPOLICYCHANGE.indication (
                                    Peer STA Address,
                                    Dialog Token,
                                    QMFPolicy,
                                    VendorSpecificInfo
                                    )
```

Name	Type	Valid range	Description
Peer STA Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the QMF policy change request was received.
Dialog Token	Integer	1–255	The dialog token to identify the QMF policy change transaction.
QMFPolicy	QMF Policy element	As defined in 9.4.2.119	This parameter describes the QMF policy the peer STA is requesting to use.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.81.6.3 When generated

This primitive is generated by the MLME when a QMF Policy Change frame is received from a peer entity.

6.3.81.6.4 Effect of receipt

On receipt of this primitive, the parameters of the QMF Policy Change frame are provided to the SME to be processed.

6.3.81.7 MLME-QMFPOLICYCHANGE.response

6.3.81.7.1 Function

This primitive requests the transmission of a QMF Policy frame with no QMF Policy field to a peer entity, in response to a QMF Policy Change frame.

6.3.81.7.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-QMFPOLICYCHANGE.response (
Peer STA Address,
Dialog Token,
Result Code,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer STA Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the QMF Policy frame is sent in response to a QMF policy change request.
Dialog Token	Integer	1–255	The dialog token identifying the QMF policy change transaction.
Result Code	Enumeration	SUCCESS, REJECT	Reports the outcome of the transaction.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.81.7.3 When generated

This primitive is generated by the SME to request that a QMF Policy frame be transmitted to a peer entity to convey the results of the QMF policy change procedure.

6.3.81.7.4 Effect of receipt

On receipt of this primitive, the MLME constructs a QMF Policy frame containing the set of QMF Policy elements specified. This frame is then scheduled for transmission.

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6.3.81.8 MLME-QMFPOLICYSET.request

6.3.81.8.1 Function

This primitive directs the setting of a specific QMF policy in the local MLM.

6.3.81.8.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-QMFPOLICYSET.request (
Peer STA address,
QMFPolicy
)

Name	Type	Valid range	Description
Peer STA Address	MAC address	Any valid individual MAC address	The address of the peer STA for which the QMF policy is to be used. If this parameter is null, the QMF policy applies to all transmissions.
QMFPolicy	QMF Policy element	As defined in 9.4.2.119	This parameter describes the QMF policy the MLME is directed to use for all QMFs transmitted to the Peer STA Address.

6.3.81.8.3 When generated

This primitive is generated by the SME to set the MLME's QMF policy for a peer STA.

6.3.81.8.4 Effect of receipt

On receipt of this primitive, the MLME uses the supplied set of QMF policy parameters in future transmissions to the peer.

6.3.82 SCS request and response procedure

6.3.82.1 General

The following MLME primitives support the signaling of the SCS request and response procedure. The diagram in Figure 6-27 shows the SCS request and response process.

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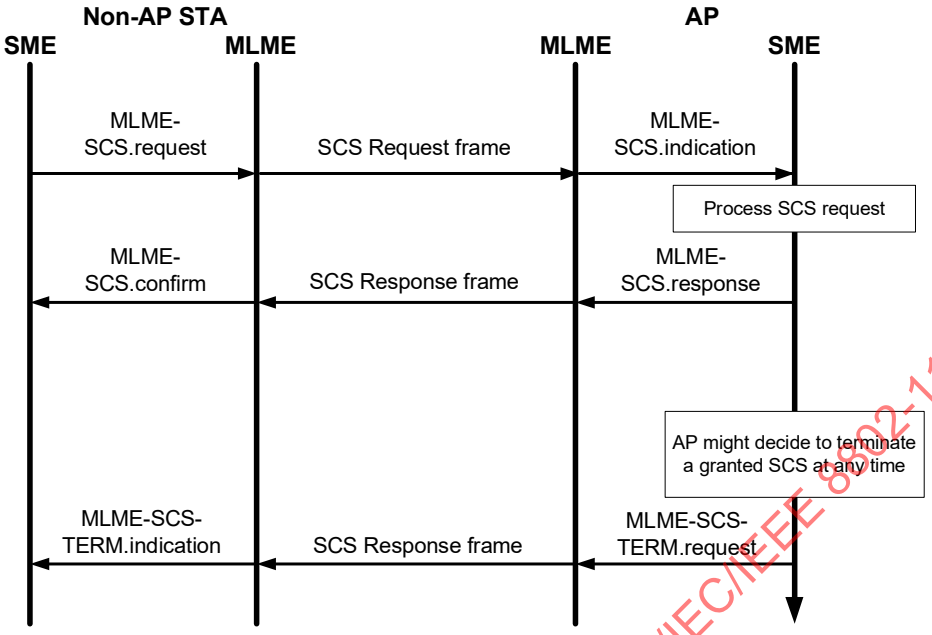

Figure 6-27—Example SCS setup and termination protocol exchange

6.3.82.2 MLME-SCS.request

6.3.82.2.1 Function

This primitive requests transmission of an SCS Request frame to an AP.

6.3.82.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-SCS.request(
PeerSTAAddress,
DialogToken,
SCSRequest,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the SCS process.
DialogToken	Integer	1–255	The dialog token to identify the SCS request and response transaction.
SCSRequest	SCS Descriptor element	SCS Descriptor element, as defined in 9.4.2.121	Specifies frame classifiers and priority for the requested SCS stream.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.82.2.3 When generated

This primitive is generated by the SME to request that a SCS Request frame be sent to the AP with which the STA is associated.

6.3.82.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a SCS Request frame. The STA then attempts to transmit this frame to the AP with which the STA is associated.

6.3.82.3 MLME-SCS.confirm

6.3.82.3.1 Function

This primitive reports the result of a SCS procedure.

6.3.82.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SCS.confirm(
                    PeerSTAAddress,
                    DialogToken,
                    SCSID,
                    Status,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the SCS process.
DialogToken	Integer	1–255	The dialog token to identify the SCS request and response transaction.
SCSID	Integer	1–255	Identifies the SCS stream that is being classified.
Status	Enumeration	See Table 9-50	Indicates the result response of the requested SCSID. See Table 9-50.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.82.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-SCS.request primitive and indicates the results of the request.

This primitive is generated when the STA receives a SCS Response frame from the AP.

6.3.82.3.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 11.25.2.

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6.3.82.4 MLME-SCS.indication

6.3.82.4.1 Function

This primitive indicates that an SCS Request frame was received from a non-AP STA.

6.3.82.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-SCS.indication(
PeerSTAAddress,
DialogToken,
SCSRequest,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which an SCS Request frame was received.
DialogToken	Integer	1–255	The dialog token to identify the SCS request and response transaction.
SCSRequest	SCS Descriptor element	SCS Descriptor element, as defined in 9.4.2.121	Specifies frame classifiers and priority for the requested SCS stream.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.82.4.3 When generated

This primitive is generated by the MLME when an SCS Request frame is received.

6.3.82.4.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 11.25.2.

6.3.82.5 MLME-SCS.response

6.3.82.5.1 Function

This primitive is generated in response to an MLME-SCS.indication primitive requesting an SCS Response frame be sent to a non-AP STA.

6.3.82.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-SCS.response(
PeerSTAAddress,
DialogToken,
SCSID,
Status,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which a SCS Request frame was received.
DialogToken	Integer	1–255	The dialog token to identify the SCS request and response transaction.
SCSID	Integer	1–255	Identifies the SCS stream that is being classified.
Status	Enumeration	See Table 9-50	Indicates the result response of the requested SCSID. See Table 9-50.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.82.5.3 When generated

This primitive is generated by the SME in response to an MLME-SCS.indication primitive requesting an SCS Response frame be sent to a non-AP STA.

6.3.82.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs a SCS Response frame. The STA then attempts to transmit this frame to the non-AP STA indicated by the PeerSTAAddress parameter.

6.3.82.6 MLME-SCS-TERM.request

6.3.82.6.1 Function

This primitive requests the transmission of a SCS Response frame to a non-AP STA to terminate an established SCS stream.

6.3.82.6.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SCS-TERM.request(
                      PeerSTAAddress,
                      DialogToken,
                      SCSID,
                      Status,
                      VendorSpecificInfo
                      )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity to which the SCS Response frame is to be sent.
DialogToken	Integer	0	Set to 0 for an autonomous SCS Response frame.
SCSID	Integer	1–255	Identifies the SCS stream that is being classified.

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Name	Type	Valid range	Description
Status	Enumeration	See Table 9-50	Indicates the result response of the requested SCSID. See Table 9-50.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.82.6.3 When generated

This primitive is generated by the SME to terminate an SCS stream.

6.3.82.6.4 Effect of receipt

On receipt of this primitive, the MLME constructs an SCS Response frame. The STA then attempts to transmit this frame to the non-AP STA indicated by the PeerSTAAddress parameter.

6.3.82.7 MLME-SCS-TERM.indication

6.3.82.7.1 Function

This primitive is generated by the MLME when an unsolicited SCS Response frame is received.

6.3.82.7.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-SCS-TERM.indication(
ResultCode,
DialogToken,
SCSID,
Status,
VendorSpecificInfo
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, FAILURE	Indicates the result of the MLME-SCS-TERM.request primitive.
DialogToken	Integer	0	Set to 0 for an autonomous SCS Response frame.
SCSID	Integer	1–255	Identifies the SCS stream that is being classified.
Status	Enumeration	See Table 9-50	Indicates the result response of the requested SCSID. See Table 9-50.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.82.7.3 When generated

This primitive is generated when the STA receives an unsolicited SCS Response frame from the AP.

6.3.82.7.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 11.25.2.

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6.3.83 QLoad report management

6.3.83.1 General

The QLoad report management primitives support the process of QLoad reporting between APs as described in 11.26.2.

6.3.83.2 MLME-QLOAD.request

6.3.83.2.1 Function

This primitive is used by an AP to transmit a QLoad Request frame to a specified AP.

6.3.83.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-QLOAD.request(
                    PeerMACAddress,
                    DialogToken,
                    Protected,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the QLoad Request frame is sent.
DialogToken	Integer	1–255	Specifies a number unique to the MLME-QLOAD.request primitive.
Protected	Boolean	true, false	If true, the request is sent using the Protected QLoad Request frame. If false, the request is sent using the QLoad Request frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.83.2.3 When generated

This primitive is generated by the SME at an AP to request the transmission of a QLoad Request frame to the AP indicated by the PeerMACAddress parameter.

6.3.83.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a QLoad Request frame if the Protected parameter is false or a Protected QLoad Request frame if the Protected parameter is true. The AP then attempts to transmit this frame to the AP indicated by the PeerMACAddress parameter.

6.3.83.3 MLME-QLOAD.confirm

6.3.83.3.1 Function

This primitive reports the result of a request to send a QLoad Request frame.

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6.3.83.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-QLOAD.confirm(
PeerMACAddress,
DialogToken,
Protected,
QLoadReport,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the QLoad Request frame was sent.
DialogToken	Integer	0–255	Specifies a number unique to the QLoad Report request and response transaction or 0 when an unsolicited report was sent.
Protected	Boolean	true, false	If true, the response was sent using the Protected QLoad Report frame. If false, the response was sent using the QLoad Report frame.
QLoadReport	Set of QLoad Report elements	Set of reports, each as defined in the QLoad Report element	Set of reports, each as defined in the QLoad Report element.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.83.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-QLOAD.request primitive indicating the results of that request. This primitive is generated when the STA receives a response in the form of a QLoad Report frame in the corresponding Robust AV Streaming Action frame.

6.3.83.3.4 Effect of receipt

The SME is notified of the results of the QLoad request procedure.

The SME should operate according to the procedures defined in 11.26.2.

6.3.83.4 MLME-QLOAD.indication

6.3.83.4.1 Function

This primitive indicates that a QLoad Request frame has been received.

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6.3.83.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-QLOAD.indication(
PeerMACAddress,
DialogToken,
Protected,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the QLoad Request frame was received.
DialogToken	Integer	1–255	Specifies a number unique to the MLME-QLOAD.request primitive.
Protected	Boolean	true, false	If true, the request was sent using the Protected QLoad Request frame. If false, the request was sent using the QLoad Request frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.83.4.3 When generated

This primitive is generated by the MLME when a (Protected) QLoad Request frame is received.

6.3.83.4.4 Effect of receipt

On receipt of this primitive, the SME either rejects the request or commences the transaction as described in 11.26.2.

6.3.83.5 MLME-QLOAD.response

6.3.83.5.1 Function

This primitive is used by an AP to transmit a QLoad Report frame to a specified AP in response to a QLoad Request frame.

6.3.83.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-QLOAD.response(
PeerMACAddress,
DialogToken,
Protected,
QLoadReport,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the QLoad Report frame is sent.
DialogToken	Integer	0–255	The dialog token of the matching MLME-QLOAD.indication primitive or 0 when sending an unsolicited report.
Protected	Boolean	true, false	If true, the response is sent using the Protected QLoad Report frame. If false, the response is sent using the QLoad Report frame.
QLoadReport	Set of QLoad Report elements	Set of reports, each as defined in the QLoad Report element	Set of reports, each as defined in the QLoad Report element.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.83.5.3 When generated

This primitive is generated by the SME at an AP in response to a QLoad Request frame from the AP indicated by the PeerMACAddress parameter.

6.3.83.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs a QLoad Report frame if the Protected parameter is false or a Protected QLoad Report frame if the Protected parameter is true. The AP then attempts to transmit this frame to the other AP indicated by the PeerMACAddress parameter.

6.3.84 HCCA TXOP advertisement management

6.3.84.1 General

The TXOP advertisement management primitives support the process of TSPEC schedule negotiation between APs, as described in 11.26.

6.3.84.2 MLME-TXOPADVERTISEMENT.request

6.3.84.2.1 Function

This primitive is used by an AP to transmit an HCCA TXOP advertisement to a specified AP.

6.3.84.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-TXOPADVERTISEMENT.request(
                                    PeerMACAddress,
                                    DialogToken,
                                    Protected,
                                    ActiveTXOPReservations,
                                    PendingTXOPReservations,
                                    VendorSpecificInfo
                                    )
```

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Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the TXOP Advertisement frame is sent.
DialogToken	Integer	0–255	Specifies a number unique to the TXOPAdvertisement.request primitive.
Protected	Boolean	true, false	If true, the request is sent using the Protected HCCA TXOP Advertisement frame. If false, the request is sent using the HCCA TXOP Advertisement frame.
ActiveTXOPReservations	TXOP Reservation	As defined in 9.4.1.43	Specifies the HCCA TXOPs that have been created.
PendingTXOPReservations	TXOP Reservation	As defined in 9.4.1.43	Specifies the HCCA TXOPs that are in the process of being created.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.84.2.3 When generated

This primitive is generated by the SME at an AP to request a (Protected) HCCA TXOP Advertisement frame be sent to the AP indicated by the PeerMACAddress parameter.

6.3.84.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs an HCCA TXOP Advertisement frame if the Protected parameter is false or constructs a Protected HCCA TXOP Advertisement frame if the Protected parameter is true. This frame is then scheduled for transmission.

6.3.84.3 MLME-TXOPADVERTISEMENT.confirm

6.3.84.3.1 Function

This primitive reports the result of a request to perform HCCA TXOP negotiation.

6.3.84.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TXOPADVERTISEMENT.confirm(
ResultCode,
PeerMACAddress,
DialogToken,
Protected,
AlternateSchedule,
AvoidanceRequest,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, TS_SCHEDULE_ CONFLICT	Reports the outcome of a request to send a TXOP advertisement. Indicates the results of the corresponding MLME-TXOPADVERTISE.request primitive.
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the Scheduled TXOP Response frame was received.
DialogToken	Integer	0–255	The dialog token to identify the scheduled TXOP advertisement and scheduled TXOP response transaction.
Protected	Boolean	true, false	If true, the response was sent using the Protected HCCA TXOP Response frame. If false, the response was sent using the HCCA TXOP Response frame.
AlternateSchedule	TXOP Reservation	As defined in 9.4.1.43	Specifies an alternate TXOP when status code is not SUCCESS.
AvoidanceRequest	TXOP Reservation	As defined in 9.4.1.43	Specifies a TXOP to avoid when status code is not SUCCESS.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.84.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-TXOPADVERTISEMENT.request primitive indicating the results of that request. This primitive is generated when the STA receives a response in the form of an HCCA TXOP Response frame in the corresponding Public Action frame, or when the STA receives a response in the form of a Protected HCCA TXOP Response frame in the corresponding frame.

6.3.84.3.4 Effect of receipt

On receipt of this primitive, the SME performs the behavior defined in 11.26.3.

6.3.84.4 MLME-TXOPADVERTISEMENT.indication

6.3.84.4.1 Function

This primitive indicates that an HCCA TXOP Advertisement frame has been received from a peer entity.

6.3.84.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TXOPADVERTISEMENT.indication(
PeerMACAddress,
DialogToken,
Protected,
ActiveTXOPReservations,

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PendingTXOPReservations,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the HCCA TXOP Advertisement frame was sent.
DialogToken	Integer	0–255	Specifies a number unique to the MLME-TXOPADVERTISEMENT.request primitive.
Protected	Boolean	true, false	If true, the request was sent using the Protected HCCA TXOP Request frame. If false, the request was sent using the HCCA TXOP Request frame.
ActiveTXOPReservations	TXOP Reservation	As defined in 9.4.1.43	Specifies the HCCA TXOPs that have been created.
PendingTXOPReservations	TXOP Reservation	As defined in 9.4.1.43	Specifies the HCCA TXOPs that are in the process of being created.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.84.4.3 When generated

This primitive is generated by the MLME when an HCCA TXOP Advertisement frame is received.

6.3.84.4.4 Effect of receipt

On receipt of this primitive, the SME performs the behavior defined in 11.26.3.

6.3.84.5 MLME-TXOPADVERTISEMENT.response

6.3.84.5.1 Function

This primitive is used by an AP to transmit an HCCA TXOP Response frame to a specified AP.

6.3.84.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TXOPADVERTISEMENT.response(
PeerMACAddress,
DialogToken,
Protected,
StatusCode,
ScheduleConflict,
AlternateSchedule,
AvoidanceRequest,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the HCCA TXOP Response frame is sent.
DialogToken	Integer	0–255	The dialog token to identify the TXOP advertisement and TXOP response transaction.
Protected	Boolean	true, false	If true, the response is sent using the Protected HCCA TXOP Response frame. If false, the response is sent using the HCCA TXOP Response frame.
StatusCode	Enumeration	SUCCESS, TS_SCHEDULE_ CONFLICT (as defined in 9.4.1.9)	The result of checking the TXOP reservation from the corresponding TXOP advertisement.
ScheduleConflict	Integer	1–number of TXOP reservations	The TXOP reservation from the HCCA TXOP Advertisement frame that conflicts with an existing or in-progress schedule.
AlternateSchedule	TXOP Reservation	As defined in 9.4.1.43	Specifies an alternate TXOP when status code is not SUCCESS.
AvoidanceRequest	TXOP Reservation	As defined in 9.4.1.43	Specifies a TXOP to avoid when status code is not SUCCESS.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.84.5.3 When generated

This primitive is generated by the SME at an AP to request the sending of an HCCA TXOP Response frame to another AP indicated by the PeerMACAddress parameter.

6.3.84.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs an HCCA TXOP Response frame if the Protected parameter is false or constructs a Protected HCCA TXOP Response frame if the Protected parameter is true. The AP then attempts to transmit this frame to the AP indicated by the PeerMACAddress parameter.

6.3.85 GCR group membership management

6.3.85.1 General

The group membership primitives support the process of group membership requesting and reporting between an AP and its associated STAs as described in 11.21.16.3.2.

6.3.85.2 MLME-GROUP-MEMBERSHIP.request

6.3.85.2.1 Function

This primitive is used by an AP to initiate a Group Membership Request frame to a specified associated STA.

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6.3.85.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-GROUP-MEMBERSHIP.request(
PeerMACAddress,
DialogToken,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the Group Membership Request frame is to be sent.
DialogToken	Integer	0–255	Specifies a number unique to the MLME-GROUP-MEMBERSHIP.request primitive.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.85.2.3 When generated

This primitive is generated by the SME at an AP to request the sending of a Group Membership Request frame to the associated STA indicated by the PeerMACAddress parameter.

6.3.85.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Group Membership Request frame. The AP then attempts to transmit this frame to the STA indicated by the PeerMACAddress parameter.

6.3.85.3 MLME-GROUP-MEMBERSHIP.confirm

6.3.85.3.1 Function

This primitive reports the result of a request for a STA's group membership.

6.3.85.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-GROUP-MEMBERSHIP.confirm(
GroupAddress,
VendorSpecificInfo
)

Name	Type	Valid range	Description
GroupAddress	MAC address	Any valid MAC address that has the Individual/Group Address bit set	Zero or more MAC addresses that correspond to the contents of the dot11GroupAddressesTable of the STA that responded to the group address request.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.85.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-GROUP-MEMBERSHIP.request primitive indicating the results of that request.

This primitive is generated when the STA receives a response in the form of a Group Membership Response frame in the corresponding robust Action frame from the associated STA.

6.3.85.3.4 Effect of receipt

The SME is notified of the results of the group membership request procedure.

The SME should operate according to the procedures defined in 11.21.16.3.2.

6.3.85.4 MLME-GROUP-MEMBERSHIP.indication

6.3.85.4.1 Function

This primitive indicates that a Group Membership Request frame has been received from a peer entity.

6.3.85.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-GROUP-MEMBERSHIP.indication(
PeerMACAddress,
DialogToken,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the Group Membership Request frame was sent.
DialogToken	Integer	0–255	Specifies a number unique to the MLME-GROUP-MEMBERSHIP primitive.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.85.4.3 When generated

This primitive is generated by the MLME when a Group Membership Request frame is received.

6.3.85.4.4 Effect of receipt

On receipt of this primitive, the SME performs the behavior defined in 11.21.16.3.2.

6.3.85.5 MLME-GROUP-MEMBERSHIP.response

6.3.85.5.1 Function

This primitive responds to the request for the contents of the group address table by a specified STA's MAC entity.

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6.3.85.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-GROUP-MEMBERSHIP.response(
PeerMACAddress,
DialogToken,
GroupAddress,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the Group Membership Response frame is sent.
DialogToken	Integer	0–255	Specifies a number unique to the MLME-GROUP-MEMBERSHIP primitive.
GroupAddress	MAC address	Any valid MAC address that has the Individual/ Group Address bit set	Zero or more MAC addresses that correspond to the contents of the dot11GroupAddressesTable of the STA that is responding to the group address request.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.85.5.3 When generated

This primitive is generated by the SME as a response to an MLME-GROUP-MEMBERSHIP.indication primitive.

6.3.85.5.4 Effect of receipt

On receipt of this primitive, the SME performs the behavior defined in 11.21.16.3.2.

6.3.86 AP PeerKey management

6.3.86.1 General

The AP PeerKey management primitives support the AP PeerKey protocol to provide session identification and data confidentiality for an AP-to-AP connection, as described in 12.10.

6.3.86.2 MLME-APPEERKEY.request

6.3.86.2.1 Function

This primitive is used by an AP to transmit a public key to a specified AP and to request the peer's public key.

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6.3.86.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-APPEERKEY.request(
PeerMACAddress,
RequestType,
Group,
PublicKey,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the Public Key frame is sent.
RequestType	Integer	As defined in Table 9-378	Specifies the type of request.
Group	Finite Cyclic Group field	As defined in 9.4.1.40	Specifies cyclic group from which the public key was generated.
PublicKey	Scalar field	As defined 9.4.1.39	The public key of the AP sending this Public Key frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.86.2.3 When generated

This primitive is generated by the SME at an AP to request the sending of a Public Key frame to another AP indicated by the PeerMACAddress parameter.

6.3.86.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Public Key frame. The AP then attempts to transmit this frame to the AP indicated by the PeerMACAddress parameter.

6.3.86.3 MLME-APPEERKEY.indication

6.3.86.3.1 Function

This primitive indicates that a Public Key frame has been received from a peer entity.

6.3.86.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-APPEERKEY.indication(
PeerMACAddress,
RequestType,
Group,
PublicKey,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the Public Key frame has been received.
RequestType	Integer	As defined in Table 9-378	Specifies the type of request.
Group	Finite Cyclic Group field	As defined in 9.4.1.40	Specifies cyclic group from which the public key was generated.
PublicKey	Scalar field	As defined in 9.4.1.39	The public key of the AP that sent this Public Key frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.86.3.3 When generated

This primitive is generated by the MLME when a Public Key frame is received.

6.3.86.3.4 Effect of receipt

On receipt of this primitive, the SME performs the behavior defined in 12.10.

6.3.87 On-channel Tunneling operation

6.3.87.1 General

On-channel tunneling (OCT) primitives are used as part of multi-band operation (see 11.31). OCT frames are used to transport Management frames between peer MLME entities of multi-band capable devices.

The operation of the OCT is illustrated in Figure 6-28.

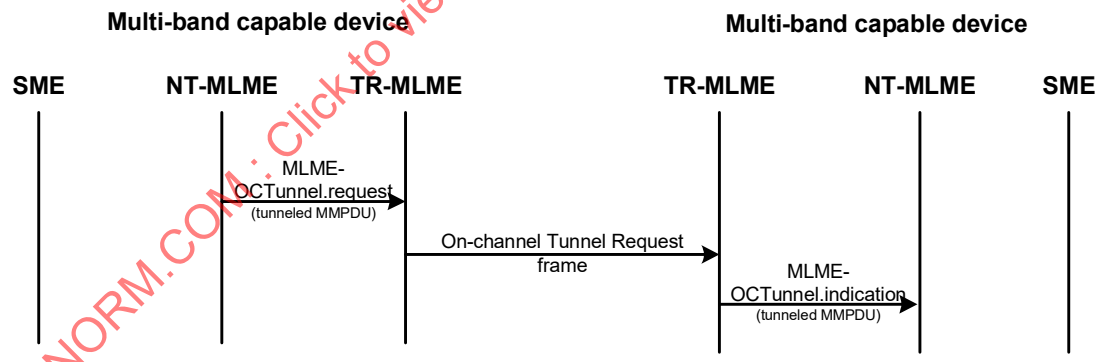

Figure 6-28—Operation of OCT

An initiator MLME of a STA that might not be currently enabled to transmit generates an MLME-OCTunnel.request primitive to a local MLME entity of a STA that is enabled to transmit. This request carries the contents of a Management frame and replaces transmission over the WM of that frame.

The recipient MLME generates the MLME-OCTunnel.indication primitive to the local MLME entity identified in the On-channel Tunnel Request frame.

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The direct MLME-to-MLME primitive exchange should be viewed as shorthand for an exchange through the SMEs and multi-band entity, i.e., an MLME addresses another local MLME entity by sending that primitive through its SME and the multi-band entity to the SME of the MLME entity of a STA that is enabled to transmit, which reflects that primitive to the appropriate recipient.

6.3.87.2 MLME-OCTunnel.request

6.3.87.2.1 Function

This primitive requests transmission of an On-channel Tunnel Request frame.

6.3.87.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-OCTunnel.request(
PeerSTAAddress,
OCT MMPDU,
Multi-band peer,
OCT source
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA to which the On-channel Tunnel Request frame is transmitted.
OCT MMPDU	OCT MMPDU Descriptor field	As defined in the On-channel Tunnel Request frame format (see 9.6.20.7)	The OCT MMPDU carries the MMPDU to be tunneled to the specified MLME entity of the specified STA.
Multi-band peer	Multi-band element	As defined in the Multi-band element format (see 9.4.2.138)	The Multi-band element identifies the peer MLME entity that should receive the OCT MMPDU.
OCT source	OCT Source element	As defined in the OCT Source element format (see 9.4.2.245)	The OCT Source element identifies the MLME entity that generated (i.e., is the source) of the OCT MMPDU.

6.3.87.2.3 When generated

This primitive is generated by another MLME to request that an On-channel Tunnel Request frame be sent to another STA.

6.3.87.2.4 Effect on receipt

On receipt of this primitive, the MLME constructs and attempts to transmit an On-channel Tunnel Request frame.

6.3.87.3 MLME-OCTunnel.indication

6.3.87.3.1 Function

This primitive indicates that an On-channel Tunnel Request frame was received.

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6.3.87.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-OCTunnel.indication(
PeerSTAAddress,
OCT MMPDU,
Multi-band local,
OCT source,
Tunneled RXVECTOR
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA from which the On-channel Tunnel Request frame was received.
OCT MMPDU	OCT MMPDU Descriptor field	As defined in the On-channel Tunnel Request frame format (see 9.6.20.7)	The OCT MMPDU carries the MMPDU that is being tunneled to the local MLME entity.
Multi-band local	Multi-band element	As defined in the Multi-band element format (see 9.4.2.138)	The Multi-band element identifies the local MLME entity that should receive the OCT MMPDU.
OCT source	OCT Source element	As defined in the OCT Source element format (see 9.4.2.245)	The OCT Source element identifies the MLME entity that generated (i.e., is the source) of the OCT MMPDU.
Tunneled RXVECTOR	RXVECTOR	As defined by the PHY of the STA	A copy of the RXVECTOR that the PHY passes to the MAC upon reception of the On-channel Tunnel Request frame.

6.3.87.3.3 When generated

This primitive is generated by the MLME to notify another MLME when an On-channel Tunnel Request frame is received.

6.3.87.3.4 Effect on receipt

The recipient of this primitive is an MLME entity in a multi-band device.

On receipt of this primitive, the MLME retrieves the tunneled frame and processes it as though it were received over the WM.

6.3.87.4 MLME-OCTunnel.confirm

6.3.87.4.1 Function

This primitive reports the results of a request to transmit an On-channel Tunnel Request frame.

6.3.87.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-OCTunnel.confirm(
ResultCode
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, FAILURE	Indicates the result of the OCTunnel.request primitive.

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6.3.87.4.3 When generated

This primitive is generated by the MLME as a result of an MLME-OCTunnel.request primitive to transmit an On-channel Tunnel Request frame.

6.3.87.4.4 Effect of receipt

The MLME is notified of the results of the frame transmission.

6.3.88 Multi-band operation

6.3.88.1 General

This subclause describes the management procedures associated with the multi-band operation mechanism.

6.3.88.2 MLME-FST-SETUP.request

6.3.88.2.1 Function

This primitive requests transmission of an FST Setup Request frame.

6.3.88.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-FST-SETUP.request(
                        FSTResponderAddress,
                        FSTSetupRequest
                        )
```

Name	Type	Valid range	Description
FSTResponderAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA to which the FST Setup Request frame is transmitted.
FSTSetupRequest	FST Setup Request Action field	As defined in the FST Setup Request frame format	Specifies the parameters of the FST Setup.

6.3.88.2.3 When generated

This primitive is generated by the SME to request that an FST Setup Request frame be sent to another STA.

6.3.88.2.4 Effect on receipt

On receipt of this primitive, the MLME constructs and attempts to transmit an FST Setup Request frame.

6.3.88.3 MLME-FST-SETUP.indication

6.3.88.3.1 Function

This primitive indicates that an FST Setup Request frame was received.

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6.3.88.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-FST-SETUP.indication(
FSTInitiatorAddress,
FSTSetupRequest
)

Name	Type	Valid range	Description
FSTInitiatorAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA from which the FST Setup Request frame was received.
FSTSetupRequest	FST Setup Request Action field	As defined in FST Setup Request frame	Specifies the parameters of the FST Setup.

6.3.88.3.3 When generated

This primitive is generated by the MLME when an FST Setup Request frame is received.

6.3.88.3.4 Effect on receipt

On receipt of this primitive, the SME operates according to the procedure in 11.31.

6.3.88.4 MLME-FST-SETUP.response

6.3.88.4.1 Function

This primitive requests that an FST Setup Response frame be transmitted to the FST initiator STA.

6.3.88.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-FST-SETUP.response(
FSTInitiatorAddress,
FSTSetupResponse
)

Name	Type	Valid range	Description
FSTInitiatorAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA to which the FST Setup Response frame is transmitted.
FSTSetupResponse	FST Setup Response Action field	As defined in FST Setup Response frame	Specifies the parameters of the FST Setup.

6.3.88.4.3 When generated

This primitive is generated by the SME to request that an FST Setup Response frame is be transmitted to the FST initiator STA.

6.3.88.4.4 Effect on receipt

On receipt of this primitive, the MLME constructs and attempts to transmit an FST Setup Response frame.

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6.3.88.5 MLME-FST-SETUP.confirm

6.3.88.5.1 Function

This primitive indicates that an FST Setup Response frame was received.

6.3.88.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-FST-SETUP.confirm(
                    FSTResponderAddress,
                    FSTSetupResponse
                    )
```

Name	Type	Valid range	Description
FSTResponderAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA from which the FST Setup Response frame was received.
FSTSetupResponse	FST Setup Response Action field	As defined in FST Setup Response frame	Specifies the parameters of the FST Setup.

6.3.88.5.3 When generated

This primitive is generated by the MLME when an FST Setup Response frame is received.

6.3.88.5.4 Effect on receipt

On receipt of this primitive, the SME operates according to the procedure in 11.31.

6.3.88.6 MLME-FST-ACK.request

6.3.88.6.1 Function

This primitive requests transmission of an FST Ack Request frame.

6.3.88.6.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-FST-ACK.request(
                    FSTResponderAddress,
                    FSTAckRequest
                    )
```

Name	Type	Valid range	Description
FSTResponderAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA to which the FST Ack Request frame is transmitted.
FSTAckRequest	FST Ack Request Action field	As defined in FST Ack Request frame	Specifies the parameters of the FST Ack Request.

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6.3.88.6.3 When generated

This primitive is generated by the SME to request that an FST Ack Request frame be sent to another STA.

6.3.88.6.4 Effect on receipt

On receipt of this primitive, the MLME constructs and attempts to transmit an FST Ack Request frame.

6.3.88.7 MLME-FST-ACK.indication

6.3.88.7.1 Function

This primitive indicates that an FST Ack Request frame was received.

6.3.88.7.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-FST-ACK.indication(
                        FSTInitiatorAddress,
                        FSTAckRequest
                        )
```

Name	Type	Valid range	Description
FSTInitiatorAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA from which the FST Ack Request frame was received.
FSTAckRequest	FST Ack Request Action field	As defined in FST Ack Request frame	Specifies the parameters of the FST Ack Request.

6.3.88.7.3 When generated

This primitive is generated by the MLME when an FST Ack Request frame is received.

6.3.88.7.4 Effect on receipt

On receipt of this primitive, the MLME operates according to the procedure in 11.31.

6.3.88.8 MLME-FST-ACK.response

6.3.88.8.1 Function

This primitive requests that an FST Ack Response frame be transmitted to the FST initiator STA.

6.3.88.8.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-FST-ACK.response(
                        FSTInitiatorAddress,
                        FSTAckResponse
                        )
```

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Name	Type	Valid range	Description
FSTInitiatorAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA to which the FST Ack Response frame is transmitted.
FSTAckResponse	FST Ack Response Action field	As defined in FST Ack Response frame	Specifies the parameters of the FST Ack Response.

6.3.88.8.3 When generated

This primitive is generated by the SME to request that an FST Ack Response frame be transmitted to the FST initiator STA.

6.3.88.8.4 Effect on receipt

On receipt of this primitive, the MLME constructs and attempts to transmit an FST Ack Response frame.

6.3.88.9 MLME-FST-ACK.confirm

6.3.88.9.1 Function

This primitive indicates that an FST Ack Response frame was received.

6.3.88.9.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-FST-ACK.confirm(
                    FSTResponderAddress,
                    FSTAckResponse
                    )
```

Name	Type	Valid range	Description
FSTResponderAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA from which the FST Ack Response frame was received.
FSTAckResponse	FST Ack Response Action field	As defined in FST Ack Response frame	Specifies the parameters of the FST Ack Response.

6.3.88.9.3 When generated

This primitive is generated by the MLME when an FST Ack Response frame is received.

6.3.88.9.4 Effect on receipt

On receipt of this primitive, the MLME operates according to the procedure in 11.31.

6.3.88.10 MLME-FST-TEARDOWN.request

6.3.88.10.1 Function

This primitive requests that an FST Teardown frame be transmitted to the FST initiator STA.

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6.3.88.10.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-FST-TEARDOWN.request(
                        FSTPeerSTAAddress,
                        FSTTeardown
                        )
```

Name	Type	Valid range	Description
FSTPeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA to which the FST Teardown frame is transmitted.
FSTTeardown	FST Teardown Action field	As defined in FST Teardown frame	Specifies the parameters of the FST teardown.

6.3.88.10.3 When generated

This primitive is generated by the SME to request that an FST Teardown frame be transmitted to the FST peer STA.

6.3.88.10.4 Effect on receipt

On receipt of this primitive, the MLME constructs and attempts to transmit an FST Teardown frame.

6.3.88.11 MLME-FST-TEARDOWN.indication

6.3.88.11.1 Function

This primitive indicates that an FST Teardown frame was received.

6.3.88.11.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-FST-TEARDOWN.indication(
                        FSTPeerSTAAddress,
                        FSTAckResponse
                        )
```

Name	Type	Valid range	Description
FSTPeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA from which the FST Teardown frame was received.
FSTTeardown	FST Teardown Action field	As defined in FST Teardown frame	Specifies the parameters of the FST teardown.

6.3.88.11.3 When generated

This primitive is generated by the MLME when an FST Teardown frame is received.

6.3.88.11.4 Effect on receipt

On receipt of this primitive, the MLME operates according to the procedure in 11.31.

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6.3.88.12 MLME-FST-INCOMING.request

6.3.88.12.1 Function

This primitive announces an incoming FST from another band/channel. This primitive does not result in the transmission of a frame.

6.3.88.12.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-FST-INCOMING.request(
                    FSTInitiatorAddress,
                    FSTResponderAddress,
                    FSTSetupRequest,
                    FSTSetupResponse,
                    FSTIsInitiator
                    )
```

Name	Type	Valid range	Description
FSTInitiatorAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA that is the FST initiator.
FSTResponderAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA that is the FST responder.
FSTSetupRequest	FST Setup Request Action field	As defined in FST Setup Request frame	Specifies the parameters of the last FST Setup Request frame exchanged between the initiator and responder.
FSTSetupResponse	FST Setup Response Action field	As defined in FST Setup Response frame	Specifies the parameters of the last FST Setup Response frame exchanged between the initiator and responder.
FSTIsInitiator	Boolean	true, false	Indicates the role that the STA performs in the FST. Set to true if the STA performs in the role of initiator STA, and set to false otherwise.

6.3.88.12.3 When generated

This primitive is generated by the SME to announce that an FST session is being transferred from another band/channel.

6.3.88.12.4 Effect on receipt

On receipt of this primitive, the MLME is notified of an incoming FST session. The MLME does not transmit a frame as a result of this primitive.

6.3.89 DMG relay operation

6.3.89.1 General

This subclause describes the management procedures associated with DMG relay.

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6.3.89.2 MLME-RELAY-SEARCH.request

6.3.89.2.1 Function

This primitive requests a list of relay DMG STAs (RDSs) in the BSS.

6.3.89.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-RELAY-SEARCH.request(
                    DestinationMACAddress
                    )
```

Name	Type	Valid range	Description
DestinationMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the non-AP and non-PCP STA that is the intended immediate recipient of the data flow.

6.3.89.2.3 When generated

This primitive is generated by the SME at a non-AP and non-PCP STA to transmit a request to the AP or PCP for a list of RDSs in the BSS.

6.3.89.2.4 Effect on receipt

This primitive initiates a relay search procedure. The MLME subsequently issues an MLME-RELAY-SEARCH.confirm primitive that reflects the results.

6.3.89.3 MLME-RELAY-SEARCH.confirm

6.3.89.3.1 Function

This primitive reports a list of RDSs in the BSS.

6.3.89.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-RELAY-SEARCH.confirm(
                    RelayCapableSTAInfo,
                    ResultCode
                    )
```

Name	Type	Valid range	Description
RelayCapableSTAInfo (zero or more)	As defined in frame format	As defined in 9.4.1.44	As described in 9.4.1.44.
ResultCode	Enumeration	SUCCESS, REFUSED	Indicates the results of the corresponding MLME-RELAY-SEARCH.request primitive.

6.3.89.3.3 When generated

This primitive is generated when a Relay Search Response frame is received.

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6.3.89.3.4 Effect on receipt

The SME is notified of the results of the relay search procedure.

6.3.89.4 MLME-RELAY-SEARCH.indication

6.3.89.4.1 Function

This primitive reports to the SME the request for obtaining a list of RDSs in the BSS.

6.3.89.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-RELAY-SEARCH.indication(
SourceMACAddress
)

Name	Type	Valid range	Description
SourceMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the non-AP and non-PCP STA that is the intended immediate recipient of the data flow.

6.3.89.4.3 When generated

This primitive is generated by the MLME as a result of the receipt of a request to obtain a list of RDSs in the BSS. The receipt of the request resulted from a relay search procedure that was initiated by the STA indicated by the source MAC address specified in the primitive.

6.3.89.4.4 Effect on receipt

The SME is notified of a request by a specified non-AP and non-PCP STA to obtain a list of RDSs in the BSS.

6.3.89.5 MLME-RELAY-SEARCH.response

6.3.89.5.1 Function

This primitive is used to provide the results of a Relay Search Request.

6.3.89.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-RELAY-SEARCH.response(
PeerMACAddress,
RelayCapableSTAInfo,
StatusCode
)

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Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the MAC entity to which the Relay Search Response frame was sent.
RelayCapableSTAInfo (zero or more)	As defined in frame format	As defined in 9.4.1.44	As described in 9.4.1.44.
StatusCode	As defined in frame format	As defined in 9.4.1.9	As described in 9.4.1.9.

6.3.89.5.3 When generated

This primitive is generated by the SME to provide the results of a Relay Search Request.

6.3.89.5.4 Effect on receipt

On receipt of this primitive, the MLME constructs and attempts to transmit a Relay Search Response frame.

6.3.89.6 MLME-RLS.request

6.3.89.6.1 Function

This primitive requests the set up of a relay link with a specified peer MAC entity via a specified relay MAC entity.

6.3.89.6.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-RLS.request(
                    DestinationMACAddress,
                    RelayMACAddress,
                    DestinationCapabilityInformation,
                    RelayCapabilityInformation,
                    RelayTransferParameterSet
                    )
```

Name	Type	Valid range	Description
DestinationMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the non-AP and non-PCP STA that is the intended immediate recipient of the data flow.
RelayMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the selected RDS.
DestinationCapabilityInformation	As defined in frame format	As defined in frame format	Indicates the Relay Capability Information field within the Relay Capabilities element of the target destination relay endpoint DMG STA (REDS).
RelayCapabilityInformation	As defined in frame format	As defined in frame format	Indicates the Relay Capability Information field within the Relay Capabilities element of the selected RDS.
RelayTransferParameterSet	As defined in frame format	As defined in frame format	Specifies the parameters for the relay operation.

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6.3.89.6.3 When generated

This primitive is generated by the SME at a non-AP and non-PCP STA to set up a relay link with another non-AP and non-PCP STA.

6.3.89.6.4 Effect on receipt

This primitive initiates a relay link setup procedure.

6.3.89.7 MLME-RLS.confirm

6.3.89.7.1 Function

This primitive reports the results of a relay link setup attempt with a specified peer MAC entity.

6.3.89.7.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-RLS.confirm(
                    PeerMACAddress,
                    RelayMACAddress,
                    ResultCode
                    )
```

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the non-AP and non-PCP STA from which the frame was received.
RelayMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the selected RDS.
ResultCode	Enumeration	SUCCESS, REFUSED	Indicates the results of the corresponding MLME-RLS.request primitive.

6.3.89.7.3 When generated

This primitive is generated when a RLS Response frame is received.

6.3.89.7.4 Effect on receipt

The SME is notified of the results of the relay link setup procedure.

6.3.89.8 MLME-RLS.indication

6.3.89.8.1 Function

This primitive reports the establishment of a relay link with a specified peer MAC entity.

6.3.89.8.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-RLS.indication(
                    SourceMACAddress,
                    RelayMACAddress,
                    SourceCapabilityInformation,
```

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RelayCapabilityInformation,
RelayTransferParameterSet
)

Name	Type	Valid range	Description
SourceMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA that is the intended immediate recipient of the data flow.
RelayMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the selected RDS.
SourceCapabilityInformation	As defined in frame format	As defined in frame format	Specifies the operational capability definitions to be used by the peer MAC entity.
RelayCapabilityInformation	As defined in frame format	As defined in frame format	Indicates the Relay Capability Information field within the Relay Capabilities element of the selected RDS.
RelayTransferParameterSet	As defined in frame format	As defined in frame format	Specifies the parameters for the relay operation.

6.3.89.8.3 When generated

This primitive is generated by the MLME as a result of the establishment of a relay link with a specific peer MAC entity, and that resulted from a relay link setup procedure that was initiated by that specific source MAC entity.

6.3.89.8.4 Effect on receipt

The SME is notified of the establishment of the relay link setup.

6.3.89.9 MLME-RLS.response

6.3.89.9.1 Function

This primitive is used to provide the results of an RLS Request.

6.3.89.9.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-RLS.response(
PeerMACAddress,
DestinationStatusCode,
RelayStatusCode
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the peer STA.
DestinationStatusCode	As defined in frame format	As defined in 9.4.1.9	As described in 9.4.1.9.
RelayStatusCode	As defined in frame format	As defined in 9.4.1.9	As described in 9.4.1.9.

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6.3.89.9.3 When generated

This primitive is generated by the SME to provide the results of a RLS Request.

6.3.89.9.4 Effect on receipt

On receipt of this primitive, the MLME constructs and attempts to transmit an RLS Response frame.

6.3.89.10 MLME-RLS-TEARDOWN.request

6.3.89.10.1 Function

This primitive requests the teardown of the relay link with a specified peer MAC entity.

6.3.89.10.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-RLS-TEARDOWN.request(
DestinationMACAddress,
RelayMACAddress,
Reason
)

Name	Type	Valid range	Description
DestinationMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the non-AP and non-PCP STA that is the intended immediate recipient of the data flow.
RelayMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the selected RDS.
Reason	Enumeration	REQUESTED	Indicates the reason why the relay link is being torn down.

6.3.89.10.3 When generated

This primitive is generated by the SME for tearing down a relay link with another non-AP and non-PCP STA.

6.3.89.10.4 Effect on receipt

This primitive initiates a relay link teardown procedure. The MLME subsequently issues an MLME-RLS-TEARDOWN.confirm primitive that reflects the results.

6.3.89.11 MLME-RLS-TEARDOWN.indication

6.3.89.11.1 Function

This primitive indicates the teardown of an already established relay link with a specific peer MAC entity.

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6.3.89.11.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-RLS-TEARDOWN.indication(
SourceMACAddress,
Reason
)

Name	Type	Valid range	Description
SourceMACAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the non-AP and non-PCP STA that is the intended immediate recipient of the data flow.
Reason	Enumeration	REQUESTED	Indicates the reason why the relay link is being torn down.

6.3.89.11.3 When generated

This primitive is generated by the MLME as result of the teardown of a relay link with a specific peer MAC entity, and that resulted from a relay link teardown procedure that was initiated either by that specific peer MAC entity or by the local MAC entity.

6.3.89.11.4 Effect on receipt

The SME is notified of the relay link teardown.

6.3.90 Quieting adjacent BSS operation

6.3.90.1 General

This subclause describes the management procedure associated with the QAB operation.

The primitives defined are MLME-QAB.request, MLME-QAB.confirm, MLME-QAB.indication, and MLME-QAB.response primitive.

6.3.90.2 MLME-QAB.request

6.3.90.2.1 Function

This primitive requests transmission of a (protected) QAB Request frame.

6.3.90.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-QAB.request(
DialogToken,
RequesterAP Address,
ResponderAP Address,
QuietPeriodRequest,
Protected,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
DialogToken	Integer	1–255	The dialog token to identify the QAB transaction.
RequesterAP Address	MAC address	Any valid individual MAC address	The address of the MAC entity from which the (protected) QAB Request frame was sent.
ResponderAP Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the (protected) QAB request was sent.
QuietPeriodRequest	A set of information subfields	As described in 9.4.2.149	As described in 9.4.2.149.
Protected	Boolean	true, false	Specifies whether the request is sent using a protected robust Management frame. If true, the request is sent using the Protected QAB Request frame. If false, the request is sent using the QAB Request frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.90.2.3 When generated

This primitive is generated by the STA management entity (SME) to request that a (Protected) QAB frame be sent by a STA.

6.3.90.2.4 Effect on receipt

On receipt of this primitive, the MLME constructs and transmits a (Protected) QAB Request frame.

6.3.90.3 MLME-QAB.confirm

6.3.90.3.1 Function

This primitive reports the result of a transmission of a QAB Request frame.

6.3.90.3.2 Semantics of the service primitive

The primitive parameters as follows:

```
MLME-QAB.confirm(
                    DialogToken,
                    RequesterAP Address,
                    ResponderAP Address,
                    QuietPeriodResponse,
                    ResultCode,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
DialogToken	Integer	1–255	The dialog token to identify the QAB transaction.
RequesterAP Address	MAC address	Any valid individual MAC address	The address of the MAC entity to which the (protected) QAB Response frame was addressed.

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Name	Type	Valid range	Description
ResponderAP Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the (protected) QAB Response was received.
QuietPeriodResponse	A set of information subfields	As described in 9.4.2.150	As described in 9.4.2.150.
ResultCode	Enumeration	SUCCESS	Reports the result of an QAB request.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.90.3.3 When generated

This primitive is generated by the MLME when a QAB request completes. Possible unspecified failure causes include an inability to provide the Quiet Period Request element.

6.3.90.3.4 Effect on receipt

The SME is notified of the results of the QAB request procedure.

6.3.90.4 MLME-QAB.indication

6.3.90.4.1 Function

This primitive indicates that a (Protected) QAB Request frame was received.

6.3.90.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-QAB.indication(
                    DialogToken
                    PeerMACAddress,
                    QuietPeriodRequest,
                    Protected,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
DialogToken	Integer	1–255	The dialog token to identify the QAB transaction.
PeerMACAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the QAB Request frame was received.
QuietPeriodRequest	A set of information subfields	As described in 9.4.2.149	As described in 9.4.2.149.
Protected	Boolean	true, false	Specifies whether the request was received using a protected robust Management frame. If true, the request was received using the Protected QAB Request frame. If false, the request was received using the QAB Request frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.90.4.3 When generated

This primitive is generated by the MLME when a (Protected) QAB Request frame is received.

6.3.90.4.4 Effect on receipt

On receipt of this primitive, the SME decides whether to schedule quiet periods as requested.

6.3.90.5 MLME-QAB.response

6.3.90.5.1 Function

This primitive is used to provide the results of a QAB Request.

6.3.90.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-QAB.response(
                    DialogToken,
                    RequesterAP Address,
                    ResponderAP Address,
                    QuietPeriodResponse,
                    VendorSpecificInfo
                    )
```

Name	Type	Valid range	Description
DialogToken	Integer	1–255	The dialog token to identify the QAB transaction.
RequesterAP Address	MAC address	Any valid individual MAC address	The address of the MAC entity to which the (protected) QAB Response frame was sent.
ResponderAP Address	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the (protected) QAB Response was sent.
QuietPeriodResponse	A set of information subfields	As described in 9.4.2.150	As described in 9.4.2.150.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.90.5.3 When generated

This primitive is generated by the SME to provide the results of a QAB Request.

6.3.90.5.4 Effect on receipt

On receipt of this primitive, the MLME provides the results of a QAB Request.

6.3.91 DMG beamforming

6.3.91.1 General

This subclause describes the management procedures associated with DMG beamforming.

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6.3.91.2 MLME-BF-TRAINING.request

6.3.91.2.1 Function

This primitive requests that beamforming training occur with a peer STA.

6.3.91.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-BF-TRAINING.request(
PeerSTAAddress,
RequestBRP
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform beamforming training.
RequestBRP	Boolean	true, false	If true, the beam refinement protocol (BRP) is performed as part of the beamforming training. If false, only sector-level sweep (SLS) is performed.

6.3.91.2.3 When generated

This primitive is generated by the SME to request that beamforming training be performed with a peer STA.

6.3.91.2.4 Effect on receipt

On receipt of this primitive, the MLME invokes the MAC sublayer beamforming training procedures defined in 10.42.

6.3.91.3 MLME-BF-TRAINING.confirm

6.3.91.3.1 Function

This primitive reports the outcome of a requested beamforming training procedure.

6.3.91.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-BF-TRAINING.confirm(
PeerSTAAddress,
ResultCode
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which beamforming training was performed or attempted.
ResultCode	Enumeration	SUCCESS, BF_TIMEOUT	Indicates the result of the beamforming procedure.

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6.3.91.3.3 When generated

This primitive is generated by the MLME to report the result of beamforming training with a peer STA.

6.3.91.3.4 Effect on receipt

The SME is notified of the result of the procedure.

6.3.91.4 MLME-BF-TRAINING.indication

6.3.91.4.1 Function

This primitive indicates that beamforming training with a peer STA, and at the request of that peer, has completed.

6.3.91.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-BF-TRAINING.indication(
PeerSTAAddress,
ResultCode
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which beamforming training was performed.
ResultCode	Enumeration	SUCCESS, BF_TIMEOUT	Indicates the result of the beamforming procedure.

6.3.91.4.3 When generated

This primitive is generated by the MLME to indicate successful completion of a beamforming training procedure requested by a peer STA.

6.3.91.4.4 Effect on receipt

The SME is notified of the result of the procedure.

6.3.92 PN event report

6.3.92.1 General

This subclause describes the management procedures associated with PN event report.

6.3.92.2 MLME-PN-EXHAUSTION.indication

6.3.92.2.1 Function

This primitive indicates that the PN associated with a temporal key exceeds the threshold that is defined in dot11PNExhaustionThresholdLow and dot11PNExhaustionThresholdHigh.

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6.3.92.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-PN-EXHAUSTION.indication(
Key ID,
Key Type,
Address
)

Name	Type	Valid range	Description
Key ID	Integer	0-3 shall be used with CCMP and GCMP; 4-5 with BIP for IGTK; 6-7 with BIP for BIGTK; and 8-4095 are reserved	Key identifier.
Key Type	Enumeration	Group, Pairwise, PeerKey, IGTK, BITGK	Defines whether this key is a group key, pairwise key, PeerKey, integrity group key, or beacon protection key.
Address	MAC address	Any valid individual MAC address	This parameter is valid only when the Key Type value is Pairwise, or when the Key Type value is Group and is from an IBSS STA, or when the Key Type value is PeerKey.

6.3.92.2.3 When generated

This primitive is generated by the MLME when the PN associated with a temporal key exceeds the threshold that is defined in dot11PNExhaustionThresholdLow and dot11PNExhaustionThresholdHigh.

6.3.92.2.4 Effect of receipt

On receipt of this primitive, the SME deletes the temporal key associated with the PN.

6.3.92.3 MLME-PN-WARNING.indication

6.3.92.3.1 Function

This primitive indicates that the PN associated with a temporal key exceeds the threshold that is defined in dot11PNWarningThresholdLow and dot11PNWarningThresholdHigh.

6.3.92.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-PN-WARNING.indication(
Key ID,
Key Type,
Address
)

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Name	Type	Valid range	Description
Key ID	Integer	0-3 shall be used with CCMP and GCMP; 4-5 with BIP for IGTK; 6-7 with BIP for BIGTK; and 8-4095 are reserved	Key identifier.
Key Type	Enumeration	Group, Pairwise, PeerKey, IGTK, BIGTK	Defines whether this key is a group key, pairwise key, PeerKey, integrity group key, or beacon protection key.
Address	MAC address	Any valid individual MAC address	This parameter is valid only when the Key Type value is Pairwise, or when the Key Type value is Group and is from an IBSS STA, or when the Key Type value is PeerKey.

6.3.92.3.3 When generated

This primitive is generated by the MLME when the PN associated with a temporal key exceeds the threshold that is defined in dot11PNWarningThresholdLow and dot11PNWarningThresholdHigh.

6.3.92.3.4 Effect of receipt

On receipt of this primitive, the SME can create a new temporal key before the PN space is exhausted.

6.3.93 Channel Availability Query

6.3.93.1 Introduction

The following MLME primitives support the signaling of channel availability query process for the channel query requests and responses.

6.3.93.2 MLME-CHANNELAVAILABILITYQUERY.request

6.3.93.2.1 Function

This primitive requests that a (Protected) Channel Availability Query frame be sent to a specified peer MAC entity.

6.3.93.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-CHANNELAVAILABILITYQUERY.request (
                                        PeerSTAAddress,
                                        ChannelAvailabilityQuery,
                                        Protected,
                                        VendorSpecificInfo
                                        )
```

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the Channel Availability Query frame is sent.
ChannelAvailabilityQuery	A set of information subfields	As defined in 9.6.7.25	Specifies the parameters of channel query.
Protected	Boolean	true, false	Specifies whether the request is sent using a protected robust Management frame. If true, the request is sent using the Protected Channel Availability Query frame. If false, the request is sent using the Channel Availability Query frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.93.2.3 When generated

This primitive is generated by the SME to request channel query procedure with a specified peer MAC entity.

6.3.93.2.4 Effect of receipt

This primitive initiates a channel query procedure. The MLME subsequently issues an MLME-CHANNELAVAILABILITYQUERY.confirm primitive that reflects the results.

6.3.93.3 MLME-CHANNELAVAILABILITYQUERY.confirm

6.3.93.3.1 Function

This primitive reports the results of a channel query attempt with a specified peer MAC entity.

6.3.93.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-CHANNELAVAILABILITYQUERY.confirm (
                                        PeerSTAAddress,
                                        ResultCode,
                                        ChannelAvailabilityQuery,
                                        Protected,
                                        VendorSpecificInfo
                                        )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the response to the Channel Availability Query frame was received.
ResultCode	Enumeration	SUCCESS, SUCCESS_MULTIPLE, REFUSED, DEVICE_VERIFICATION_FAILURE	Indicates the result of MLME-CHANNELAVAILABILITYQUERY.request primitive.
ChannelAvailabilityQuery	A set of information fields	As defined in 9.6.7.25	Specifies the parameters of channel query.

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Name	Type	Valid range	Description
Protected	Boolean	true, false	Specifies whether the response was received using a protected robust Management frame. If true, the response was received using the Protected Channel Availability Query frame. If false, the response was received using the Channel Availability Query frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.93.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-CHANNELAVAILABILITYQUERY.request primitive and indicates the results of a channel availability query procedure.

6.3.93.3.4 Effect of receipt

The SME is notified of the results of the channel query procedure.

6.3.93.4 MLME-CHANNELAVAILABILITYQUERY.indication

6.3.93.4.1 Function

This primitive indicates that a (Protected) Channel Availability Query frame was received from a peer STA.

6.3.93.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-CHANNELAVAILABILITYQUERY.indication (
                                    PeerSTAAddress,
                                    ChannelAvailabilityQuery,
                                    Protected,
                                    VendorSpecificInfo
                                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the Channel Availability Query frame was received.
ChannelAvailabilityQuery	A set of information subfields	As defined in 9.6.7.25	Specifies the parameters of channel query.
Protected	Boolean	true, false	Specifies whether the request was received using a protected robust Management frame. If true, the request was received using the Protected Channel Availability Query frame. If false, the request was received using the Channel Availability Query frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.93.4.3 When generated

This primitive is generated by the MLME as a result of the receipt of a channel query request from a specific peer MAC entity.

6.3.93.4.4 Effect of receipt

The SME is notified of the receipt of this channel query request.

6.3.93.5 MLME-CHANNELAVAILABILITYQUERY.response

6.3.93.5.1 Function

This primitive is used to send a response to a specified peer MAC entity that requested channel query with the STA that issued this primitive.

6.3.93.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-CHANNELAVAILABILITYQUERY.response (
PeerSTAAddress,
ResultCode,
ChannelAvailabilityQuery,
Protected,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the Channel Availability Query frame with the response is sent.
ResultCode	Enumeration	SUCCESS, SUCCESS_MULTIPLE, REFUSED, DEVICE_VERIFICATION_FAILURE	Indicates the result response of the channel availability query from the peer MAC entity.
ChannelAvailabilityQuery	A set of information subfields	As defined in 9.6.7.25	Specifies the parameters of channel query.
Protected	Boolean	true, false	Specifies whether the response is sent using a protected robust Management frame. If true, the response is sent using the Protected Channel Availability Query frame. If false, the response is sent using the Channel Availability Query frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.93.5.3 When generated

This primitive is generated by the SME of a STA as a response to an MLME-CHANNELAVAILABILITYQUERY.indication primitive.

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6.3.93.5.4 Effect of receipt

Upon receipt of this primitive, the MLME constructs the Channel Availability Query frame as the response. This frame is then scheduled for transmission to the peer MAC address.

6.3.94 Channel schedule management

6.3.94.1 Introduction

The following MLME primitives support the signaling of channel schedule management.

6.3.94.2 MLME-CHANNELSCHEDULEMANAGEMENT.request

6.3.94.2.1 Function

This primitive requests that a (Protected) Channel Schedule Management frame be sent.

6.3.94.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-CHANNELSCHEDULEMANAGEMENT.request (
                                        PeerSTAAddress,
                                        ReasonResultCode,
                                        ChannelScheduleManagementMode,
                                        DeviceIdentification,
                                        ChannelSchedule,
                                        Protected,
                                        VendorSpecificInfo
                                        )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the Channel Schedule Management frame is sent.
ReasonResultCode	An enumerated value	As defined in 9.6.7.26 for the Reason Result Code field	
ChannelScheduleManagementMode	An enumerated value	As defined in 9.6.7.26 for the Channel Schedule Management Mode field	
DeviceIdentification	Device Identification Information	As defined in 9.4.4.2.3	The Device Identification Information parameter indicates the regulatory identification of the STA that is requesting the schedule information.
ChannelSchedule	A set of Channel Schedule Descriptors	As defined in 9.4.4.2.5	The Channel Schedule parameter indicates the channels for which the schedule information is requested.

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Name	Type	Valid range	Description
Protected	Boolean	true, false	Specifies whether the request is sent using a protected robust Management frame. If true, the request is sent using the Protected Channel Schedule Management frame. If false, the request is sent using the Channel Schedule Management frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.94.2.3 When generated

This primitive is generated by the SME to request that a (Protected) Channel Schedule Management frame be sent by a STA.

6.3.94.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs and schedules transmission of a (Protected) Channel Schedule Management frame.

6.3.94.3 MLME-CHANNELSCHEDULEMANAGEMENT.confirm

6.3.94.3.1 Function

This primitive reports the result of a channel schedule management query.

6.3.94.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-CHANNELSCHEDULEMANAGEMENT.confirm (
                                        PeerSTAAddress,
                                        ReasonResultCode,
                                        ChannelScheduleManagementMode,
                                        DeviceIdentification,
                                        ChannelSchedule,
                                        Protected,
                                        VendorSpecificInfo
                                        )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the Channel Schedule Management frame was received.
ReasonResultCode	An enumerated value	As defined in 9.6.7.26 for the Reason Result Code field	
ChannelScheduleManagementMode	An enumerated value	As defined in 9.6.7.26 for the Channel Schedule Management Mode field	
DeviceIdentification	Device Identification Information	As defined in 9.4.4.2.3	The Device Identification Information parameter indicates the regulatory identification of the STA that is requesting the schedule information.

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Name	Type	Valid range	Description
ChannelSchedule	A set of Channel Schedule Descriptors	As defined in 9.4.4.2.5	The Channel Schedule parameter indicates the channels for which the schedule information is provided.
Protected	Boolean	true, false	Specifies whether the response is sent using a protected robust Management frame. If true, the response is sent using the Protected Channel Schedule Management frame. If false, the response is sent using the Channel Schedule Management Public Action frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.94.3.3 When generated

This primitive is generated by the MLME when a channel schedule request completes. Possible unspecified failure causes include an inability to provide the channel schedule information.

6.3.94.3.4 Effect of receipt

The SME is notified of the results of the channel schedule management procedure.

6.3.94.4 MLME-CHANNELSCHEDULEMANAGEMENT.indication

6.3.94.4.1 Function

This primitive indicates that a (Protected) Channel Schedule Management frame was received from a peer STA.

6.3.94.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-CHANNELSCHEDULEMANAGEMENT.indication (
                                    PeerSTAAddress,
                                    ReasonResultCode,
                                    ChannelScheduleManagementMode,
                                    DeviceIdentification,
                                    ChannelSchedule,
                                    Protected,
                                    VendorSpecificInfo
                                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the Channel Schedule Management frame was received.
ReasonResultCode	An enumerated value	As defined in 9.6.7.26 for the Reason Result Code field	
ChannelScheduleManagementMode	An enumerated value	As defined in 9.6.7.26 for the Channel Schedule Management Mode field	

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Name	Type	Valid range	Description
DeviceIdentification	Device Identification Information	As defined in 9.4.4.2.3	The Device Identification Information parameter indicates the regulatory identification of the STA that is requesting the schedule information.
ChannelSchedule	A set of Channel Schedule Descriptors	As defined in 9.4.4.2.5	The Channel Schedule parameter indicates the channels for which the schedule information is requested.
Protected	Boolean	true, false	Specifies whether the request was received using a protected robust Management frame. If true, the request was received using the Protected Channel Schedule Management frame. If false, the request was received using the Channel Schedule Management frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.94.4.3 When generated

This primitive is generated by the MLME when a (Protected) Channel Schedule Management frame is received.

6.3.94.4.4 Effect of receipt

On receipt of this primitive, the SME decides whether to provide the channel schedule information.

6.3.94.5 MLME-CHANNELSCHEDULEMANAGEMENT.response

6.3.94.5.1 Function

This primitive is used to provide channel schedule information on channel availability.

6.3.94.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-CHANNELSCHEDULEMANAGEMENT.response (
                                        PeerSTAAddress,
                                        ReasonResultCode,
                                        ChannelScheduleManagementMode,
                                        DeviceIdentification,
                                        ChannelSchedule,
                                        Protected,
                                        VendorSpecificInfo
                                        )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity to which the Channel Schedule Management frame is sent.
ReasonResultCode	An enumerated value	As defined in 9.6.7.26 for the Reason Result Code field	

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Name	Type	Valid range	Description
ChannelScheduleManagementMode	An enumerated value	As defined in 9.6.7.26 for the Channel Schedule Management Mode field	
DeviceIdentification	Device Identification Information	As defined in 9.4.4.2.3	The Device Identification Information parameter indicates the regulatory identification of the STA that is requesting the schedule information.
ChannelSchedule	A set of Channel Schedule Descriptors	As defined in 9.4.4.2.5	The Channel Schedule parameter indicates the channels for which the schedule information is provided.
Protected	Boolean	true, false	Specifies whether the response is sent using a protected robust Management frame. If true, the response is sent using the Protected Channel Schedule Management Public Action frame. If false, the response is sent using the Channel Schedule Management Public Action frame.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.94.5.3 When generated

This primitive is generated by the SME to provide the channel schedule information.

6.3.94.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs an appropriate response in a (Protected) Channel Schedule Management frame and schedules the transmission of the frame to the peer MAC entity.

6.3.95 Contact verification signal

6.3.95.1 Introduction

The following MLME primitives support the signaling of the contact verification signal (CVS).

6.3.95.2 MLME-CVS.request

6.3.95.2.1 Function

This primitive requests that a Contact Verification Signal frame be sent by a STA to a specified peer MAC entity in order to validate a WSM.

6.3.95.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-CVS.request (
                    PeerSTAAddress,
                    Protected,
                    MapID
                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the contact verification signal process.

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Name	Type	Valid range	Description
Protected	Boolean	true, false	Specifies whether the request is sent using a protected robust Management frame. If true, the request is sent using the Protected Contact Verification Signal frame. If false, the request is sent using the Contact Verification Signal frame.
MapID	Integer	0-255	Map ID is set to the Map ID field of the recently transmitted WSM, which is being verified.

6.3.95.2.3 When generated

This primitive is generated by the SME to request that a Protected Contact Verification Signal frame be sent by a STA to a specified peer MAC entity.

6.3.95.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Protected Contact Verification Signal frame. This frame is then scheduled for transmission.

6.3.95.3 MLME-CVS.indication

6.3.95.3.1 Function

This primitive indicates that a Contact Verification Signal frame was received from a specific peer MAC entity.

6.3.95.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-CVS.indication (
                    PeerSTAAddress,
                    Protected,
                    MapID
                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which a Contact Verification Signal frame was received.
Protected	Boolean	true, false	Specifies whether the request is sent using a protected robust Management frame. If true, the request is sent using the Protected Contact Verification Signal frame. If false, the request is sent using the Contact Verification Signal frame.
MapID	Integer	0-255	Map ID field is the Map ID field of the received Contact Verification Signal frame, and identifies the WSM that is being verified.

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6.3.95.3.3 When generated

This primitive is generated by the MLME when a Protected Contact Verification Signal frame is received.

6.3.95.3.4 Effect of receipt

On receipt of this primitive, the SME is notified of the receipt of the Contact Verification Signal frame.

6.3.96 GDD Enablement

6.3.96.1 Introduction

The following MLME primitives support the signaling of GDD enablement.

6.3.96.2 MLME-GDDENABLEMENT.request

6.3.96.2.1 Function

This primitive requests that a (Protected) GDD Enablement Request frame be sent to a peer entity.

6.3.96.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-GDDENABLEMENT.request (
                            PeerSTAAddress,
                            DialogToken,
                            Protected,
                            DeviceClass,
                            DeviceID
                            )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any individual valid MAC address	Specifies the address of the peer MAC entity with which to perform the GDD enablement process.
DialogToken	Integer	1–255	The dialog token to identify the event transaction.
Protected	Boolean	true, false	Specifies whether the request is sent using a protected robust Management frame. If true, the request is sent using the Protected GDD Enablement Request frame. If false, the request is sent using the GDD Enablement Request frame.
DeviceClass	DeviceClass	As defined in 9.4.4.2.2	Specifies the service parameters for the GDD Enablement Request frame.
DeviceID	Device Identification Information	As defined in 9.4.4.2.3	Specifies the service parameters for the GDD Enablement Request frame.

6.3.96.2.3 When generated

This primitive is generated by the SME to request that a (Protected) GDD Enablement Request frame be sent to the peer entity.

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6.3.96.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a (Protected) GDD Enablement Request frame. This frame is then scheduled for transmission.

6.3.96.3 MLME-GDDENABLEMENT.confirm

6.3.96.3.1 Function

This primitive reports the result of an MLME-GDDENABLEMENT.request primitive to initiate GDD enablement.

6.3.96.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-GDDENABLEMENT.confirm (
PeerSTAAddress,
DialogToken,
Protected,
ResultCode,
WSM
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any individual valid MAC address	Specifies the address of the peer MAC entity with which to perform the GDD enablement process.
DialogToken	Integer	1–255	The dialog token to identify the event transaction.
Protected	Boolean	true, false	Specifies whether the response is sent using a protected robust Management frame. If true, the response is sent using the Protected GDD Enablement Response frame. If false, the response is sent using the GDD Enablement Response frame.
ResultCode	Enumeration	SUCCESS, REFUSED, ENABLEMENT_DENIED.	Indicates the result response to the GDD Enablement Request frame from the peer entity. ENABLEMENT_DENIED is used to indicate denial due to restriction from GDD.
WSM	Tuple of WSM Type field and WSM Information field	As defined in 9.4.1.57	Specifies the service parameters for the white space map.

6.3.96.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-GDDENABLEMENT.request primitive and indicates the results of the request.

This primitive is generated when the STA receives a GDD Enablement Response frame from the peer entity or when an unspecified failure occurs.

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6.3.96.3.4 Effect of receipt

On receipt of this primitive, the SME evaluates the results of the MLME-GDDENABLEMENT.request primitive and may use the reported data.

6.3.96.4 MLME-GDDENABLEMENT.indication

6.3.96.4.1 Function

This primitive indicates that a (Protected) GDD Enablement Request frame was received from a peer entity.

6.3.96.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-GDDENABLEMENT.indication (
PeerSTAAddress,
DialogToken,
Protected,
DeviceClass,
DeviceID
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any individual valid MAC address	The address of the peer entity from which a GDD Enablement Request frame was received.
DialogToken	Integer	1–255	The dialog token to identify the event transaction.
Protected	Boolean	true, false	Specifies whether the request is sent using a protected robust Management frame. If true, the request is sent using the Protected GDD Enablement Request frame. If false, the request is sent using the GDD Enablement Request frame.
DeviceClass	DeviceClass	As defined in 9.4.4.2.2	Specifies the service parameters for the GDD Enablement Request frame.
DeviceID	Device Identification Information	As defined in 9.4.4.2.3	Specifies the service parameters for the GDD Enablement Request frame.

6.3.96.4.3 When generated

This primitive is generated by the MLME when a (Protected) GDD Enablement Request frame is received.

6.3.96.4.4 Effect of receipt

On receipt of this primitive, the SME operates according to the procedure in 11.42.1.

6.3.96.5 MLME-GDDENABLEMENT.response

6.3.96.5.1 Function

This primitive indicates that a (Protected) GDD Enablement Response frame be sent to the peer entity.

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6.3.96.5.2 Semantics of the service primitive

MLME-GDDENABLEMENT.response (
PeerSTAAddress,
DialogToken,
Protected,
ResultCode,
WSM
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any individual valid MAC address	The address of the peer entity from which a GDD Enablement Request frame was received.
DialogToken	Integer	1–255	The dialog token to identify the event transaction.
Protected	Boolean	true, false	Specifies whether the response is sent using a protected robust Management frame. If true, the response is sent using the Protected GDD Enablement Response frame. If false, the response is sent using the GDD Enablement Response frame.
ResultCode	Enumeration	SUCCESS, REFUSED, ENABLEMENT_DENIED.	Indicates the result response to the GDD Enablement Request frame from the peer entity. ENABLEMENT_DENIED is used to indicate denial due to restriction from GDD.
WSM	Tuple of WSM Type field and WSM Information field	As defined in 9.4.1.57	Specifies the service parameters for the white space map.

6.3.96.5.3 When generated

This primitive is generated by the SME to request that a GDD Enablement Response frame be sent to the peer entity.

6.3.96.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs a GDD Enablement Response frame. This frame is then scheduled for transmission.

6.3.97 Network channel control management

6.3.97.1 Introduction

The following MLME primitives support the signaling of network channel control management.

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6.3.97.2 MLME-NETWORKCHANNELCONTROL.request

6.3.97.2.1 Function

This primitive requests that a (Protected) Network Channel Control Public Action frame be sent by a STA to a specified peer MAC entity.

6.3.97.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-NETWORKCHANNELCONTROL.request (
                                    PeerSTAAddress,
                                    DialogToken,
                                    NetworkChannelControl,
                                    Protected,
                                    VendorSpecificInfo
                                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual or group MAC address	The address of the peer MAC entity to which the Network Channel Control frame is transmitted.
DialogToken	Integer	0–255	The dialog token to identify the network channel control transaction.
NetworkChannelControl	A set of information subfields	As defined in 9.6.7.30	Specifies the parameters of network channel control.
Protected	Boolean	true, false	Specifies whether the request is sent using a protected robust Management frame. If true, the request is sent using the Protected Network Channel Control frame. If false, the request is sent using the Network Channel Control frame.
VendorSpecificInfo	A set of vendor specific elements	As defined in 9.4.2.25	Zero or more elements.

6.3.97.2.3 When generated

This primitive is generated by the SME to request that a (Protected) Network Channel Control Public Action frame be sent by a STA to the specified peer MAC entity.

6.3.97.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a (Protected) Network Channel Control Public Action frame. This frame is then scheduled for transmission.

6.3.97.3 MLME-NETWORKCHANNELCONTROL.confirm

6.3.97.3.1 Function

This primitive reports the result of a request to network channel control.

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6.3.97.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-NETWORKCHANNELCONTROL.confirm (
PeerSTAAddress,
DialogToken,
NetworkChannelControl,
Protected,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the response in a Network Channel Control frame is received.
DialogToken	Integer	0–255	The dialog token to identify the network channel control transaction.
NetworkChannelControl	A set of information subfields	As defined in 9.6.7.30	Specifies the parameters of network channel control.
Protected	Boolean	true, false	Specifies whether the response is sent using a protected robust Management frame. If true, the response is sent using the Protected Network Channel Control Public Action frame. If false, the response is sent using the Network Channel Control Public Action frame.
VendorSpecificInfo	A set of vendor specific elements	As defined in 9.4.2.25	Zero or more elements.

6.3.97.3.3 When generated

This primitive is generated by the MLME when a network channel control request completes. Possible unspecified failure causes include an inability to schedule a Network Channel Control Public Action frame.

6.3.97.3.4 Effect of receipt

The SME is notified of the results of the network channel control procedure.

6.3.97.4 MLME-NETWORKCHANNELCONTROL.indication

6.3.97.4.1 Function

This primitive indicates that a (Protected) Network Channel Control Public Action frame was received from a STA.

6.3.97.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-NETWORKCHANNELCONTROL.indication (
PeerSTAAddress,
DialogToken,
NetworkChannelControl,

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Protected,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which the Network Channel Control frame was received.
DialogToken	Integer	0–255	The dialog token to identify the network channel control transaction.
NetworkChannelControl	A set of information subfields	As defined in 9.6.7.30	Specifies the parameters of network channel control.
Protected	Boolean	true, false	Specifies whether the request was received using a protected robust Management frame. If true, the request was received using the Protected Network Channel Control Public Action frame. If false, the request was received using the Network Channel Control Public Action frame.
VendorSpecificInfo	A set of vendor specific elements	As defined in 9.4.2.25	Zero or more elements.

6.3.97.4.3 When generated

This primitive is generated by the MLME when a (Protected) Network Channel Control Public Action frame is received.

6.3.97.4.4 Effect of receipt

On receipt of this primitive, the SME decides whether to accept the network channel control request.

6.3.97.5 MLME-NETWORKCHANNELCONTROL.response

6.3.97.5.1 Function

This primitive is generated by the SME to schedule the transmission of a network channel control response.

6.3.97.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-NETWORKCHANNELCONTROL.response (
PeerSTAAddress,
DialogToken,
NetworkChannelControl,
Protected,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual or group MAC address	The address of the peer MAC entity to which the response in a Network Channel Control frame is transmitted.

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Name	Type	Valid range	Description
DialogToken	Integer	0–255	The dialog token to identify the network channel control transaction.
NetworkChannelControl	A set of information subfields	As defined in 9.6.7.30	Specifies the parameters of network channel control.
Protected	Boolean	true, false	Specifies whether the response is sent using a protected robust Management frame. If true, the response is sent using the Protected Network Channel Control Public Action frame. If false, the response is sent using the Network Channel Control Public Action frame.
VendorSpecificInfo	A set of vendor specific elements	As defined in 9.4.2.25	Zero or more elements.

6.3.97.5.3 When generated

This primitive is generated by the SME to request that a network channel control response be sent to the peer entity.

6.3.97.5.4 Effect of receipt

On receipt of this primitive, the MLME schedules the response to the specific peer MAC entity that has requested a network channel control response.

6.3.98 White space map (WSM)

6.3.98.1 Introduction

The following MLME primitives support the signaling of the WSM.

6.3.98.2 MLME-WSM.request

6.3.98.2.1 Function

This primitive requests that a White Space Map Announcement frame be sent by a GDD enabling STA in order to provide a WSM to a GDD dependent STA.

6.3.98.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-WSM.request (
                    PeerSTAAddress,
                    WhiteSpaceMap
                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the WSM process.
WhiteSpaceMap	White Space Map element	As defined in 9.4.2.169	Specifies the service parameters for the WSM.

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6.3.98.2.3 When generated

This primitive is generated by the SME to request that a White Space Map Announcement frame be sent by a GDD enabling STA to a specified peer MAC entity.

6.3.98.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a White Space Map Announcement frame. This frame is then scheduled for transmission.

6.3.98.3 MLME-WSM.indication

6.3.98.3.1 Function

This primitive indicates receipt of a request of a White Space Map Announcement frame.

6.3.98.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-WSM.indication (
                        PeerSTAAddress,
                        WhiteSpaceMap
                        )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which a WSM was received.
WhiteSpaceMap	White Space Map element	As defined in 9.4.2.169	Specifies the service parameters for the WSM.

6.3.98.3.3 When generated

This primitive is generated by the MLME when a White Space Map Announcement frame is received.

6.3.98.3.4 Effect of receipt

On receipt of this primitive, the SME is notified of the receipt of White Space Map Announcement frame.

6.3.99 Estimated Throughput

6.3.99.1 General

The following set of MLME primitives support the transport of an estimate of the achievable throughput for a potential or an existing link between two STAs.

6.3.99.2 MLME-ESTIMATED-THROUGHPUT.request

6.3.99.2.1 Function

This primitive is generated by the SME to request that the MLME provide an estimate of the achievable throughput for a potential or an existing link between two STAs.

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6.3.99.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ESTIMATED-THROUGHPUT.request (
PeerSTAAddress,
AverageMSDUSizeOutbound,
AverageMSDUSizeInbound
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA for which throughput is to be estimated assuming an association to that STA if an association with that STA does not currently exist.
AverageMSDUSizeInbound	An ordered set of integers	–1 to 7920, for each member of the set	A set of integers providing an estimate of the average number of octets per MSDU expected to be delivered over the wireless medium to this STA by the STA corresponding to the PeerMACAddress to this STA, specified per access category in the order AC_VO, AC_VI, AC_BE, AC_BK. A value of –1 means that the size is unspecified, a value of 0 means that no MSDUs are expected to be delivered for this access category.
AverageMSDUSizeOutbound	An ordered set of integers	–1 to 7920, for each member of the set	A set of integers providing an estimate of the average number of octets per MSDU expected to be delivered over the wireless medium by this STA to the STA corresponding to the PeerMACAddress, specified per access category in the order AC_VO, AC_VI, AC_BE, AC_BK. A value of –1 means that the size is unspecified, a value of 0 means that no MSDUs are expected to be delivered for this access category.

6.3.99.2.3 When generated

This primitive is generated by the SME to request that the MLME provide an estimate of throughput for MSDUs sent between this STA and the STA which corresponds to the PeerMACAddress provided in the parameter list.

6.3.99.2.4 Effect of receipt

On receipt of this primitive, the MLME generates a set of estimates of throughput for MSDUs sent between the STA which corresponds to the PeerMACAddress provided in the parameter list and this STA.

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6.3.99.3 MLME-ESTIMATED-THROUGHPUT.confirm

6.3.99.3.1 Function

This primitive reports the result of a request to provide a set of estimated throughput values for a potential or existing link.

6.3.99.3.2 Semantics of the service primitive

The primitive uses the following parameters:

```
MLME-ESTIMATED-THROUGHPUT.confirm (
                    PeerSTAAddress,
                    EstimatedThroughputOutbound,
                    EstimatedThroughputInbound
                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address of the STA for which throughput is to be estimated assuming a link with that STA if a link with that STA does not currently exist.
EstimatedThroughputOutbound	An ordered set of Real Numbers	Non-negative real numbers	The estimated throughput in the direction from this STA to the STA corresponding to the PeerMACAddress with units of MSDU bits per second, specified per access category in the order AC_VO, AC_VI, AC_BE, AC_BK. A value of 0 means no estimate is available.
EstimatedThroughputInbound	An ordered set of Real Numbers	Non-negative real numbers	The estimated throughput in the direction from the STA corresponding to the PeerMACAddress to this STA with units of MSDU bits per second, specified per access category in the order AC_VO, AC_VI, AC_BE, AC_BK. A value of 0 means no estimate is available.

6.3.99.3.3 When generated

This primitive is generated by the MLME to provide a set of estimates of throughput for MSDUs sent between the STA which corresponds to the PeerMACAddress indicated in the parameter list and this STA.

6.3.99.3.4 Effect of receipt

On receipt of this primitive, the SME may use the reported estimates to make link, association, and forwarding decisions.

6.3.100 Get authentication and association state

6.3.100.1 General

This mechanism is used to obtain authentication and association state.

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6.3.100.2 MLME-GETAUTHASSOCSTATE.request

6.3.100.2.1 Function

This primitive is generated by the SME to request that the MLME return the authentication and association state with respect to a given peer STA.

6.3.100.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-GETAUTHASSOCSTATE.request (
                                PeerSTAAddress,
                                )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity whose authentication and association state is requested

6.3.100.2.3 When generated

This primitive is generated by the SME to request the authentication and association state from the MLME.

6.3.100.2.4 Effect of receipt

The MLME issues an MLME-GETAUTHASSOCSTATE.confirm primitive.

6.3.100.3 MLME-GETAUTHASSOCSTATE.confirm

6.3.100.3.1 Function

This primitive is generated by the MLME to report to the SME the result of a request to get the authentication and association state.

6.3.100.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-GETAUTHASSOCSTATE.confirm (
                                PeerSTAAddress,
                                AuthAssocState
                                )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity whose authentication and association state was requested.
AuthAssocState	Integer	1–4	See 11.3.1 and 14.3.2.

6.3.100.3.3 When generated

This primitive is generated by the MLME to report the authentication and association state to the SME.

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6.3.100.3.4 Effect of receipt

The SME is notified of the result of an MLME-GETAUTHASSOCSTATE.request primitive.

6.3.101 FILS Container

6.3.101.1 General

This mechanism supports the process of IP address setup with a peer MAC entity.

6.3.101.2 MLME-FILSContainer.request

6.3.101.2.1 Function

This primitive requests transmission of the FILS Container frame with a specified peer MAC entity.

6.3.101.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-FILSContainer.request(
Peer MAC Address,
FILSIPAddressAssignment,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity.
FILSIPAddressAssign-ment	FILS IP Address Assign-ment element	As defined in 9.4.2.184	The request may be for a new IP address or a speci-fied IP address.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.101.2.3 When generated

This primitive is generated by the SME for a STA to request IP address setup from the AP.

6.3.101.2.4 Effect of receipt

This primitive requests IP address setup. In the case that a response is received from the AP, the MLME subsequently issues an MLME-FILSContainer.confirm primitive that reflects the results.

6.3.101.3 MLME-FILSContainer.confirm

6.3.101.3.1 Function

This primitive reports the results of an IP address setup with an AP.

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6.3.101.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-FILSContainer.confirm(
Peer MAC Address,
FILSIPAddressAssignment,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity.
FILSIPAddressAssign-ment	FILS IP Address Assign-ment element	As defined in 9.4.2.184	IP address information.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.101.4 MLME-FILSContainer.indication

6.3.101.4.1 Function

This primitive indicates receipt of a request of IP address setup.

6.3.101.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-FILSContainer.indication(
Peer MAC Address,
FILSIPAddressAssignment,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity.
FILSIPAddressAssign-ment	FILS IP Address Assign-ment element	As defined in 9.4.2.184	An explicit request for an IP address. The request may be for a new IP address or a specified IP address.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.101.4.3 When generated

This primitive is generated by the MLME as a result of the receipt of a request to setup IP addresses from a specific peer MAC entity.

6.3.101.4.4 Effect of receipt

The SME is notified of the received IP address setup request.

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6.3.101.5 MLME-FILSContainer.response

6.3.101.5.1 Function

This primitive is used to send a response to a specified peer MAC entity that requested IP address setup with the STA that issued this primitive.

6.3.101.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-FILSContainer.response(
Peer MAC Address,
FILSIPAddressAssignment,
VendorSpecificInfo
)

Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity.
FILSIPAddressAssign-ment	FILS IP Address Assign-ment element	As defined in 9.4.2.184	IP address information.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.101.5.3 When generated

This primitive is generated by the SME of a STA as a response to an MLME-FILSContainer.indication primitive.

6.3.101.5.4 Effect of receipt

This primitive initiates transmission of a response to the specific peer MAC entity that requested IP address setup.

6.3.102 Dynamic AID assignment operation

6.3.102.1 General

The following MLME primitives support the signaling of AID switch request/response procedure described in 10.19.

6.3.102.2 MLME-AIDSWITCH.request

6.3.102.2.1 Function

This primitive requests that an AID Switch Request frame be sent to the AP with which the non-AP STA is associated.

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6.3.102.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-AIDSWITCH.request(
PeerSTAAddress,
DialogToken,
AIDRequest
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the AID switch request/response procedure.
DialogToken	Integer	1–255	The dialog token to identify the AID switch request/response transaction.
AIDRequest	AID Request element	As defined in 9.4.2.193	Specifies the proposed service parameters for the AID request.

6.3.102.2.3 When generated

This primitive is generated by the SME to request that an AID Switch Request frame be sent to the AP with which the non-AP STA is associated.

6.3.102.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs an AID Switch Request frame. The STA then attempts to transmit this frame to the AP with which it is associated.

6.3.102.3 MLME-AIDSWITCH.confirm

6.3.102.3.1 Function

This primitive reports the result of an AID switch request/response procedure.

6.3.102.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-AIDSWITCH.confirm(
PeerMACAddress,
DialogToken,
AIDResponse
)

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Name	Type	Valid range	Description
Peer MAC Address	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the AID switch request/response procedure.
DialogToken	Integer	0–255	The dialog token to identify the AID switch request/response transaction.
AIDResponse	AID Response element	As defined in 9.4.2.194	Specifies service parameters for the AID response.

6.3.102.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-AIDSWITCH.request primitive and indicates the results of the request. This primitive is generated when the STA receives an AID Switch Response frame from the AP.

6.3.102.3.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 10.19.

6.3.102.4 MLME-AIDSWITCH.indication

6.3.102.4.1 Function

This primitive indicates that an AID Switch Request frame was received from a non-AP STA.

6.3.102.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-AIDSWITCH.indication(
                          PeerSTAAddress,
                          DialogToken,
                          AIDRequest
                          )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which an AID Switch Request frame was received.
DialogToken	Integer	1–255	The dialog token to identify the AID switch request/response transaction.
AIDRequest	AID Request element	As defined in 9.4.2.193	Specifies the proposed service parameters for the AID request.

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6.3.102.4.3 When generated

This primitive is generated by the MLME when an AID Switch Request frame is received.

6.3.102.4.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 10.19.

6.3.102.5 MLME-AIDSWITCH.response

6.3.102.5.1 Function

This primitive is used to send an AID Switch Response frame, in response to an AID Switch Request frame or autonomously by the AP.

6.3.102.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-AIDSWITCH.response(
                        PeerSTAAddress,
                        DialogToken,
                        AIDResponse
                        )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which an AID Switch Request frame was received.
DialogToken	Integer	0–255	The dialog token to identify the AID switch request/response transaction. Value is 0 for an autonomous AID Switch Response frame.
AIDResponse	AID Response element	As defined in 9.4.2.194	Specifies service parameters for the AID response.

6.3.102.5.3 When generated

This primitive is generated by the SME to request that an AID Switch Response frame be sent to a peer entity to convey AID assignment information.

6.3.102.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs an AID Switch Response frame. The STA then attempts to transmit this frame to the non-AP STA indicated by the PeerSTAAddress parameter.

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6.3.103 Sync Control

6.3.103.1 General

The following MLME primitives support the signaling of a sync control procedure described in 10.49.

6.3.103.2 MLME-SYNCCONTROL.request

6.3.103.2.1 Function

This primitive requests that a Sync Control frame be sent to the AP with which the non-AP STA is associated.

6.3.103.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SYNCCONTROL.request(
                        PeerSTAAddress,
                        SyncControl
                        )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the sync control procedure.
SyncControl	Sequence of octets	As defined in 9.4.1.57	Specifies the proposed service parameters for the sync control.

6.3.103.2.3 When generated

This primitive is generated by the SME to request that a Sync Control frame be sent to the AP with which the non-AP STA is associated.

6.3.103.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Sync Control frame. The STA then attempts to transmit this frame to the AP with which it is associated.

6.3.103.3 MLME-SYNCCONTROL.indication

6.3.103.3.1 Function

This primitive indicates that a Sync Control frame was received from a non-AP STA.

6.3.103.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SYNCCONTROL.indication(
                        PeerSTAAddress,
                        SyncControl
                        )
```

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which a Sync Control frame was received.
SyncControl	Sequence of octets	As defined in 9.4.1.57	Specifies the proposed service parameters for the sync control.

6.3.103.3.3 When generated

This primitive is generated by the MLME when a Sync Control frame is received.

6.3.103.3.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 10.49.

6.3.104 STA Information Announcement

6.3.104.1 General

The following MLME primitives support the signaling of a STA information announcement procedure described in 10.19.

6.3.104.2 MLME-STAINFORMATION.request

6.3.104.2.1 Function

This primitive requests that a STA Information Announcement frame be sent to the AP with which the non-AP STA is associated.

6.3.104.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-STAINFORMATION.request(
                        PeerSTAAddress,
                        AIDAnnouncement
                        )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the STA information announcement procedure.
AIDAnnouncement	AID Announcement element	As defined in 9.4.2.208	Specifies service parameters for the AID Announcement.

6.3.104.2.3 When generated

This primitive is generated by the SME to request that a STA Information Announcement frame be sent to the AP with which the non-AP STA is associated.

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6.3.104.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a STA Information Announcement frame. The STA then attempts to transmit this frame to the AP with which it is associated.

6.3.104.3 MLME-STAINFORMATION.indication

6.3.104.3.1 Function

This primitive indicates that a STA Information Announcement frame was received from a non-AP STA.

6.3.104.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-STAINFORMATION.indication(
                                PeerSTAAddress,
                                AIDAnnouncement
                                )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which a STA Information Announcement frame was received.
AIDAnnouncement	AID Announcement element	As defined in 9.4.2.208	Specifies service parameters for the AID Announcement.

6.3.104.3.3 When generated

This primitive is generated by the MLME when a STA Information Announcement frame is received.

6.3.104.3.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 10.54.5.4 and 10.19.

6.3.105 EDCA Parameter Set update

6.3.105.1 General

The following MLME primitives support the signaling of an EDCA Parameter Set update procedure described in 10.2.3.2.

6.3.105.2 MLME-EDCAPARAMETERSET.request

6.3.105.2.1 Function

This primitive requests that an EDCA Parameter Set frame be sent to the non-AP STA.

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6.3.105.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EDCAPARAMETERSET.request(
PeerSTAAddress,
EDCAParameterSet
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the EDCA Parameter Set update.
EDCAParameterSet	EDCA Parameter Set element	As defined in 9.4.2.28	Specifies service parameters for the updated EDCA Parameter Set.

6.3.105.2.3 When generated

This primitive is generated by the SME to request that an EDCA Parameter Set frame be sent to the non-AP STA.

6.3.105.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs an EDCA Parameter Set frame. The AP then attempts to transmit this frame to the non-AP STA that is associated with it.

6.3.105.3 MLME-EDCAPARAMETERSET.indication

6.3.105.3.1 Function

This primitive indicates that an EDCA Parameter Set frame was received from an AP.

6.3.105.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EDCAPARAMETERSET.indication(
PeerSTAAddress,
EDCAParameterSet
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the EDCA Parameter Set update.
EDCAParameterSet	EDCA Parameter Set element	As defined in 9.4.2.28	Specifies service parameters for the updated EDCA Parameter Set.

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6.3.105.3.3 When generated

This primitive is generated by the MLME when an EDCA Parameter Set frame is received.

6.3.105.3.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 10.2.3.2.

6.3.106 EL Operation

6.3.106.1 General

The following MLME primitives support the signaling of an EL operation procedure described in 11.46.

6.3.106.2 MLME-ELOPERATION.request

6.3.106.2.1 Function

This primitive requests that an EL Operation frame be sent to the AP with which the non-AP STA is associated.

6.3.106.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ELOPERATION.request(
PeerSTAAddress,
ELOperation
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the EL operation procedure.
ELOperation	EL Operation element	As defined in 9.4.2.210	Specifies the proposed service parameters for the EL operation.

6.3.106.2.3 When generated

This primitive is generated by the SME to request that an EL Operation frame be sent to the AP with which the non-AP STA is associated.

6.3.106.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs an EL Operation frame. The STA then attempts to transmit this frame to the AP with which it is associated.

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6.3.106.3 MLME-ELOPERATION.indication

6.3.106.3.1 Function

This primitive indicates that an EL Operation frame was received from a non-AP STA.

6.3.106.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ELOPERATION.indication(
PeerSTAAddress,
ELOperation
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which an EL Operation frame was received.
ELOperation	EL Operation element	As defined in 9.4.2.210	Specifies the proposed service parameters for the EL operation.

6.3.106.3.3 When generated

This primitive is generated by the MLME when an EL Operation frame is received.

6.3.106.3.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 11.46.

6.3.107 TWT Setup

6.3.107.1 General

The following MLME primitives support the signaling of TWT Setup procedure described in 10.47.

6.3.107.2 MLME-TWTSETUP.request

6.3.107.2.1 Function

This primitive requests that a TWT Setup frame be sent as specified in 10.47.

6.3.107.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TWTSETUP.request(
PeerSTAAddress,
DialogToken,
TWT
)

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the TWT Setup request/ response procedure.
DialogToken	Integer	0–255	The dialog token to identify the TWT Setup request/response transaction.
TWT	TWT element	As defined in 9.4.2.199	Specifies the proposed service parameters for the TWT Setup request.

6.3.107.2.3 When generated

This primitive is generated by the SME to request that a TWT Setup frame be sent.

6.3.107.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TWT Setup frame. The STA then attempts to transmit this TWT Setup frame.

6.3.107.3 MLME-TWTSETUP.confirm

6.3.107.3.1 Function

This primitive reports the result of a TWT Setup request/response procedure.

6.3.107.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TWTSETUP.confirm(
PeerMACAddress,
DialogToken,
TWT
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the TWT Setup request/ response procedure.
DialogToken	Integer	0–255	The dialog token to identify the TWT Setup request/response transaction.
TWT	TWT element	As defined in 9.4.2.199	Specifies the proposed service parameters for the TWT Setup response.

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6.3.107.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-TWTSETUP.request primitive and indicates the results of the request. This primitive is generated when the STA receives a TWT Setup frame from another STA.

6.3.107.3.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 10.47.

6.3.107.4 MLME-TWTSETUP.indication

6.3.107.4.1 Function

This primitive indicates that a TWT Setup frame was received from another STA.

6.3.107.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TWTSETUP.indication(
PeerSTAAddress,
DialogToken,
TWT
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which a TWT Setup frame was received.
DialogToken	Integer	0–255	The dialog token to identify the TWT Setup request/response transaction.
TWT	TWT element	As defined in 9.4.2.199	Specifies the proposed service parameters for the TWT Setup request.

6.3.107.4.3 When generated

This primitive is generated by the MLME when a TWT Setup frame is received.

6.3.107.4.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 10.47.

6.3.107.5 MLME-TWTSETUP.response

6.3.107.5.1 Function

This primitive is used to send a TWT Setup frame, in response to a TWT Setup frame.

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6.3.107.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TWTSETUP.response(
PeerSTAAddress,
DialogToken,
TWT
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which a TWT Setup frame was received.
DialogToken	Integer	0–255	The dialog token to identify the TWT Setup request/response transaction.
TWT	TWT element	As defined in 9.4.2.199	Specifies service parameters for the TWT Setup response.

6.3.107.5.3 When generated

This primitive is generated by the SME to request that a TWT Setup frame be sent to a peer entity to convey TWT assignment information.

6.3.107.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TWT Setup frame. The STA then attempts to transmit this frame to the non-AP STA indicated by the PeerSTAAddress parameter.

6.3.108 TWT Teardown

6.3.108.1 General

The following MLME primitives support the signaling of a TWT Teardown procedure described in 10.47.8.

6.3.108.2 MLME-TWTTEARDOWN.request

6.3.108.2.1 Function

This primitive requests that a TWT Teardown frame be sent to the AP with which the non-AP STA is associated.

6.3.108.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TWTTEARDOWN.request(
PeerSTAAddress,
TWT Flow Identifier
)

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the TWT Teardown procedure.
TWT Flow Identifier	Integer	0-7	Set to the value of the TWT Flow Identifier field of the TWT element in the frame that successfully concluded the setup of the TWT that is the subject of the teardown request.

6.3.108.2.3 When generated

This primitive is generated by the SME to request that a TWT Teardown frame be sent to the AP with which the non-AP STA is associated.

6.3.108.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a TWT Teardown frame. The STA then attempts to transmit this frame to the AP with which it is associated.

6.3.108.3 MLME-TWTTEARDOWN.indication

6.3.108.3.1 Function

This primitive indicates that a TWT Teardown frame was received from a non-AP STA.

6.3.108.3.2 Semantics of the service primitive

The primitive parameters are as follows:

The primitive parameters are as follows:

```
MLME-TWTTEARDOWN.indication(
                        PeerSTAAddress,
                        TWT Flow Identifier
                        )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the TWT Teardown procedure.
TWT Flow Identifier	Integer	0-7	Set to the value of the TWT Flow Identifier field of the TWT element in the frame that successfully concluded the setup of the TWT that is the subject of the teardown request.

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6.3.108.3.3 When generated

This primitive is generated by the MLME when a TWT Teardown frame is received.

6.3.108.3.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 10.47.8.

6.3.109 Sectorized Group ID List management

6.3.109.1 General

The following MLME primitives support the signaling of a Sectorized Group ID List management described in 10.53.

6.3.109.2 MLME-SECTORIZEDGROUPID.request

6.3.109.2.1 Function

This primitive requests that a Sectorized Group ID List frame be sent to the non-AP STA.

6.3.109.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SECTORIZEDGROUPID.request(
                                    PeerSTAAddress,
                                    SectorizedGroupIDList
                                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the Sectorized Group ID List management.
SectorizedGroupIDList	Sectorized Group ID List element	As defined in 9.4.2.211	Specifies service parameters for the updated Sectorized Group ID List.

6.3.109.2.3 When generated

This primitive is generated by the SME to request that a Sectorized Group ID List frame be sent to the non-AP STA.

6.3.109.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Sectorized Group ID List frame. The AP then attempts to transmit this frame to the non-AP STA that is associated with it.

6.3.109.3 LME-SECTORIZEDGROUPID.indication

6.3.109.3.1 Function

This primitive indicates that a Sectorized Group ID List frame was received from an AP.

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6.3.109.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-SECTORIZEDGROUPID.indication(
PeerSTAAddress,
SectorizedGroupIDList
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the Sectorized Group ID List management.
SectorizedGroupIDList	Sectorized Group ID List element	As defined in 9.4.2.211	Specifies service parameters for the updated Sectorized Group ID List.

6.3.109.3.3 When generated

This primitive is generated by the MLME when a Sectorized Group ID List frame is received.

6.3.109.3.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 10.53.

6.3.110 Header Compression procedure

6.3.110.1 General

The following MLME primitives support the signaling of Header Compression procedure described in 10.58.

6.3.110.2 MLME-HEADERCOMPRESSION.request

6.3.110.2.1 Function

This primitive requests that a Header Compression frame be sent to a peer MAC entity.

6.3.110.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-HEADERCOMPRESSION.request(
PeerSTAAddress,
DialogToken,
HeaderCompression
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the Header Compression request/response procedure.

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Name	Type	Valid range	Description
DialogToken	Integer	0–255	The dialog token to identify the header compression request/ response transaction.
HeaderCompression	Header Compression element	As defined in 9.4.2.213	Specifies the proposed service parameters for the header compression request.

6.3.110.2.3 When generated

This primitive is generated by the SME to request that a Header Compression frame be sent to a peer MAC entity.

6.3.110.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Header Compression frame. The STA then attempts to transmit this frame to the peer MAC entity.

6.3.110.3 MLME-HEADERCOMPRESSION.confirm

6.3.110.3.1 Function

This primitive reports the result of a Header Compression request/response procedure.

6.3.110.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-HEADERCOMPRESSION.confirm(
                                PeerMACAddress,
                                DialogToken,
                                HeaderCompression
                                )
```

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the header compression request/response procedure.
DialogToken	Integer	0–255	The dialog token to identify the header compression request/ response transaction.
HeaderCompression	Header Compression element	As defined in 9.4.2.213	Specifies the proposed service parameters for the header compression response.

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6.3.110.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-HEADERCOMPRESSION.request primitive and indicates the results of the request. This primitive is generated when the STA receives a Header Compression frame from the peer MAC entity.

6.3.110.3.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 10.58.

6.3.110.4 MLME-HEADERCOMPRESSION.indication

6.3.110.4.1 Function

This primitive indicates that a Header Compression frame was received from a STA.

6.3.110.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-HEADERCOMPRESSION.indication(
PeerSTAAddress,
DialogToken,
HeaderCompression
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the STA MAC entity from which a Header Compression frame was received.
DialogToken	Integer	0–255	The dialog token to identify the header compression request/ response transaction.
HeaderCompression	Header Compression element	As defined in 9.4.2.213	Specifies the proposed service parameters for the header compression request.

6.3.110.4.3 When generated

This primitive is generated by the MLME when a Header Compression frame is received.

6.3.110.4.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 10.58.

6.3.110.5 MLME-HEADERCOMPRESSION.response

6.3.110.5.1 Function

This primitive is used to send a Header Compression frame, in response to a Header Compression frame.

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6.3.110.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-HEADERCOMPRESSION.response(
PeerSTAAddress,
DialogToken,
HeaderCompression
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the STA MAC entity from which a Header Compression frame was received.
DialogToken	Integer	0–255	The dialog token to identify the header compression request/ response transaction.
HeaderCompression	Header Compression element	As defined in 9.4.2.213	Specifies service parameters for the header compression response.

6.3.110.5.3 When generated

This primitive is generated by the SME to request that a Header Compression frame be sent to a peer entity to convey Header Compression information.

6.3.110.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Header Compression frame. The STA then attempts to transmit this frame to the peer MAC entity indicated by the PeerSTAAddress parameter.

6.3.111 Reachable Address Update

6.3.111.1 General

The following MLME primitives support the signaling of a reachable address update procedure described in 10.54.

6.3.111.2 MLME-REACHABLEADDRESSUPDATE.request

6.3.111.2.1 Function

This primitive requests that a Reachable Address Update frame be sent to the AP with which the non-AP STA is associated.

6.3.111.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-REACHABLEADDRESSUPDATE.request(
PeerSTAAddress,
ReachableAddress
)

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the reachable address update procedure.
ReachableAddress	Reachable Address element	As defined in 9.4.2.205	Specifies the proposed service parameters for the reachable address update.

6.3.111.2.3 When generated

This primitive is generated by the SME to request that a Reachable Address Update frame be sent to the AP with which the non-AP STA is associated.

6.3.111.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Reachable Address Update frame. The STA then attempts to transmit this frame to the AP with which it is associated.

6.3.111.3 MLME-REACHABLEADDRESSUPDATE.indication

6.3.111.3.1 Function

This primitive indicates that a Reachable Address Update frame was received from a non-AP STA.

6.3.111.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-REACHABLEADDRESSUPDATE.indication(
                                    PeerSTAAddress,
                                    ReachableAddress
                                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which a Reachable Address Update frame was received.
ReachableAddress	Reachable Address element	As defined in 9.4.2.205	Specifies the proposed service parameters for the reachable address update.

6.3.111.3.3 When generated

This primitive is generated by the MLME when a Reachable Address Update frame is received.

6.3.111.3.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 10.54.

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6.3.112 Control response MCS negotiation operation

6.3.112.1 General

The following MLME primitives support the signaling of control response MCS negotiation procedure described in 10.6.6.5.6.

6.3.112.2 MLME-CONTROLRESPONSEMCS.request

6.3.112.2.1 Function

This primitive requests that a Control Response MCS Negotiation Request frame be sent to a peer entity.

6.3.112.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-CONTROLRESPONSEMCS.request(
                                    PeerSTAAddress,
                                    MCSDifference
                                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the control response MCS negotiation procedure.
MCSDifference	Integer	0–255	The MCS difference between the index of the primary MCS and the index of the MCS that is preferred for use by the STA to transmit control response frame as described in 10.6.6.5.6.

6.3.112.2.3 When generated

This primitive is generated by the SME to request that a Control Response MCS Negotiation Request frame be sent to the peer entity.

6.3.112.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Control Response MCS Negotiation Request frame. The STA then attempts to transmit this frame to the peer entity.

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6.3.112.3 MLME-CONTROLRESPONSEMCS.confirm

6.3.112.3.1 Function

This primitive reports the result of an control response MCS negotiation request/response procedure.

6.3.112.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-CONTROLRESPONSEMCS.confirm(
PeerMACAddress,
Command
)

Name	Type	Valid range	Description
PeerMACAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the control response MCS negotiation request/ response procedure.
Command	As defined in frame format	As defined in 9.6.27.3	Specifies service parameters for the Control Response MCS Negotiation Response frame.

6.3.112.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-CONTROLRESPONSEMCS.request primitive and indicates the results of the request. This primitive is generated when the STA receives a Control Response MCS Negotiation Response frame from the peer entity.

6.3.112.3.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 10.6.6.5.6.

6.3.112.4 MLME-CONTROLRESPONSEMCS.indication

6.3.112.4.1 Function

This primitive indicates that a Control Response MCS Negotiation Request frame was received from a peer entity.

6.3.112.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-CONTROLRESPONSEMCS.indication(
PeerSTAAddress,
MCSDifference
)

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which a Control Response MCS Negotiation Request frame was received.
MCSDifference	As defined in frame format	As defined in 9.6.27.2	The MCS difference between the index of the primary MCS and the index of the MCS that is preferred for use by the STA to transmit control response frame as described in 10.6.6.5.6.

6.3.112.4.3 When generated

This primitive is generated by the MLME when a Control Response MCS Negotiation Request frame is received.

6.3.112.4.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 10.6.6.5.6.

6.3.112.5 MLME-CONTROLRESPONSEMCS.response

6.3.112.5.1 Function

This primitive is used to send a Control Response MCS Negotiation frame, in response to a Control Response MCS Negotiation Request frame.

6.3.112.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-CONTROLRESPONSEMCS.response(
                    PeerSTAAddress,
                    Command
                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which an Control Response MCS Negotiation Response frame was received.
Command	As defined in frame format	As defined in 9.6.27.3	Specifies service parameters for the Control Response MCS Negotiation Response frame.

6.3.112.5.3 When generated

This primitive is generated by the SME to request that a Control Response MCS Negotiation Response frame be sent to a peer entity to convey control response MCS negotiation information.

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6.3.112.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Control Response MCS Negotiation Response frame. The STA then attempts to transmit this frame to the peer entity indicated by the PeerSTAAddress parameter.

6.3.113 S1G relay (de)activation

6.3.113.1 General

The following MLME primitives support the signaling of relay activation and deactivation procedure described in 10.54.

6.3.113.2 MLME-S1GRELAYACTIVATE.request

6.3.113.2.1 Function

This primitive requests that a Relay Activation Request frame be sent to a peer entity.

6.3.113.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-S1GRELAYACTIVATE.request(
                    PeerSTAAddress,
                    S1GRelayActivation
                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the relay (de)activation procedure.
S1GRelayActivation	S1G Relay Activation element	As defined in 9.4.2.206	Specifies the proposed service parameters for the relay activation request.

6.3.113.2.3 When generated

This primitive is generated by the SME to request that a Relay Activation Request frame be sent to the peer entity.

6.3.113.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Relay Activation Request frame. The STA then attempts to transmit this frame to the peer entity.

6.3.113.3 MLME-S1GRELAYACTIVATE.confirm

6.3.113.3.1 Function

This primitive reports the result of a relay (de)activation request/response procedure.

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6.3.113.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-S1GRELAYACTIVATE.confirm(
PeerMACAddress,
S1GRelayActivation
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the relay (de)activation procedure.
S1GRelayActivation	S1G Relay Activation element	As defined in 9.4.2.206	Specifies service parameters for the relay activation response.

6.3.113.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-S1GRELAYACTIVATE.request primitive and indicates the results of the request. This primitive is generated when the STA receives a Relay Activation Response frame from the peer entity.

6.3.113.3.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 10.54.

6.3.113.4 MLME-S1GRELAYACTIVATE.indication

6.3.113.4.1 Function

This primitive indicates that a Relay Activation Request frame was received from a peer entity.

6.3.113.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-S1GRELAYACTIVATE.indication(
PeerSTAAddress,
S1GRelayActivation
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the peer MAC entity from which a Relay Activation Request frame was received.
S1GRelayActivation	S1G Relay Activation element	As defined in 9.4.2.206	Specifies the proposed service parameters for relay activation request.

6.3.113.4.3 When generated

This primitive is generated by the MLME when a Relay Activation Request frame is received.

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6.3.113.4.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 10.54.

6.3.113.5 MLME-S1GRELAYACTIVATE.response

6.3.113.5.1 Function

This primitive is used to send a Relay Activation Response frame, in response to a Relay Activation Request frame.

6.3.113.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-S1GRELAYACTIVATE.response(
PeerSTAAddress,
S1GRelayActivation
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which a Relay Activation Response frame was received.
S1GRelayActivation	S1G Relay Activation element	As defined in 9.4.2.206	Specifies service parameters for the relay activation response.

6.3.113.5.3 When generated

This primitive is generated by the SME to request that a Relay Activation Response frame be sent to a peer entity to convey relay activation information.

6.3.113.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs a Relay Activation Response frame. The STA then attempts to transmit this frame to the peer entity indicated by the PeerSTAAddress parameter.

6.3.114 DCS procedure

6.3.114.1 General

This subclause describes the management procedures associated with the dynamic channel selection mechanism.

6.3.114.2 MLME-DCSMEASUREMENT.request

6.3.114.2.1 Function

This primitive requests transmission of a DCS Measurement Request frame to the DCS responder AP or PCP with which to perform the DCS procedure.

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6.3.114.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DCSMEASUREMENT.request (
DCSResponderAddress,
DCSMeasurementRequest
)

Name	Type	Valid range	Description
DCSResponderAddress	MAC address	Any valid individual MAC address.	Specifies the MAC address of the AP or PCP to which the DCS Measurement Request frame is transmitted.
DCSMeasurementRequest	DCS Measurement Request Action field	As defined in 9.6.7.37.	Specifies the parameters of the DCS measurement request.

6.3.114.2.3 When generated

This primitive is generated by the SME to request that a DCS Measurement Request frame be sent to the DCS responder AP or PCP with which to perform the DCS procedure.

6.3.114.2.4 Effect on receipt

On receipt of this primitive, the MLME indicates the MAC sublayer to construct and attempt to transmit a DCS Measurement Request frame.

6.3.114.3 MLME-DCSMEASUREMENT.indication

6.3.114.3.1 Function

This primitive indicates that a DCS Measurement Request frame is received.

6.3.114.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DCSMEASUREMENT.indication (
DCSRequesterAddress,
DCSMeasurementRequest
)

Name	Type	Valid range	Description
DCSRequesterAddress	MAC address	Any valid individual MAC address.	Specifies the MAC address of the AP or PCP from which the DCS Measurement Request frame is received.
DCSMeasurementRequest	DCS Measurement Request Action field	As defined in 9.6.7.37.	Specifies the parameters of the DCS measurement request.

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6.3.114.3.3 When generated

This primitive is generated by the MLME when a valid DCS Measurement Request frame is received.

6.3.114.3.4 Effect on receipt

Once the SME receives this primitive, the STA operates according to the procedure defined in 11.47.

6.3.114.4 MLME-DCSMEASUREMENT.response

6.3.114.4.1 Function

This primitive requests transmission of a DCS Measurement Report frame to the DCS requester AP or PCP with which to perform the DCS procedure.

6.3.114.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DCSMEASUREMENT.response (
DCSRequesterAddress,
DCSMeasurementReport
)

Name	Type	Valid range	Description
DCSRequesterAddress	MAC address	Any valid individual MAC address.	Specifies the MAC address of the AP or PCP to which the DCS Measurement Report frame is transmitted.
DCSMeasurementReport	DCS Measurement Report Action field	As defined in 9.6.7.37.	Specifies the parameters of the DCS measurement response.

6.3.114.4.3 When generated

This primitive is generated by the SME to request that a DCS Measurement Report frame be sent to the DCS requester AP or PCP with which to perform the DCS procedure.

6.3.114.4.4 Effect on receipt

On receipt of this primitive, the MLME indicates the MAC sublayer to construct and attempt to transmit a DCS Measurement Report frame.

6.3.114.5 MLME-DCSMEASUREMENT.confirm

6.3.114.5.1 Function

This primitive indicates that a DCS Measurement Report frame was received.

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6.3.114.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DCSMEASUREMENT.confirm (
                                DCSResponderAddress,
                                DCSMeasurementReport
                                )
```

Name	Type	Valid range	Description
DCSResponderAddress	MAC address	Any valid individual MAC address.	Specifies the MAC address of the AP or PCP from which the DCS Measurement Report frame was received.
DCSMeasurementReport	DCS Measurement Report Action field	As defined in 9.6.7.37.	Specifies the parameters of the DCS measurement response.

6.3.114.5.3 When generated

This primitive is generated by the MLME when a valid DCS Measurement Report frame is received.

6.3.114.5.4 Effect on receipt

Once the SME receives this primitive, the STA operates according to the procedure defined in 11.47.

6.3.114.6 MLME-DCS.request

6.3.114.6.1 Function

This primitive requests transmission of a DCS Request frame to the DCS responder AP or PCP with which to perform the DCS procedure.

6.3.114.6.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DCS.request (
                    DCSResponderAddress,
                    DCSRequest
                    )
```

Name	Type	Valid range	Description
DCSResponderAddress	MAC address	Any valid individual MAC address.	Specifies the MAC address of the AP or PCP to which the DCS Request frame is transmitted.
DCSRequest	DCS Request Action field	As defined in 9.6.7.39.	Specifies the parameters of the DCS request.

6.3.114.6.3 When generated

This primitive is generated by the SME to request that a DCS Request frame be sent to the DCS responder AP or PCP with which to perform the DCS procedure.

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6.3.114.6.4 Effect on receipt

On receipt of this primitive, the MLME indicates the MAC sublayer to construct and attempt to transmit a DCS Request frame.

6.3.114.7 MLME-DCS.indication

6.3.114.7.1 Function

This primitive indicates that a DCS Request frame is received.

6.3.114.7.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DCS.indication (
                    DCSRequesterAddress,
                    DCSRequest
                    )
```

Name	Type	Valid range	Description
DCSRequesterAddress	MAC address	Any valid individual MAC address.	Specifies the MAC address of the AP or PCP from which the DCS Request frame is received.
DCSRequest	DCS Request Action field	As defined in 9.6.7.39.	Specifies the parameters of the DCS request.

6.3.114.7.3 When generated

This primitive is generated by the MLME when a valid DCS Request frame is received.

6.3.114.7.4 Effect on receipt

Once the SME receives this primitive, the STA operates according to the procedure defined in 11.47.

6.3.114.8 MLME-DCS.response

6.3.114.8.1 Function

This primitive requests transmission of a DCS Response frame to the DCS requester AP or PCP with which to perform the DCS procedure.

6.3.114.8.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DCS. Response (
                    DCSRequesterAddress,
                    DCSResponse
                    )
```

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Name	Type	Valid range	Description
DCSRequesterAddress	MAC address	Any valid individual MAC address.	Specifies the MAC address of the AP or PCP to which the DCS Measurement Report frame is transmitted.
DCS Response	DCS Response Action field	As defined in 9.6.7.39.	Specifies the parameters of the DCS response.

6.3.114.8.3 When generated

This primitive is generated by the SME to provide the results of a DCS request.

6.3.114.8.4 Effect on receipt

On receipt of this primitive, the MLME indicates the MAC layer to construct and attempt to transmit a DCS Response frame.

6.3.114.9 MLME-DCS.confirm

6.3.114.9.1 Function

This primitive indicates that a DCS Response frame was received.

6.3.114.9.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DCS.confirm (
                    DCSResponderAddress,
                    DCSResponse
                    )
```

Name	Type	Valid range	Description
DCSResponderAddress	MAC address	Any valid individual MAC address.	Specifies the MAC address of the AP or PCP from which the DCS Measurement Report frame was received.
DCSResponse	DCS Response Action field	As defined in 9.6.7.40.	Specifies the parameters of the DCS response.

6.3.114.9.3 When generated

This primitive is generated by the MLME when a valid DCS Measurement Report frame is received.

6.3.114.9.4 Effect on receipt

Once the SME receives this primitive, the STA operates according to the procedure defined in 11.47.

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6.3.115 Update

6.3.115.1 Introduction

This mechanism supports the process of updating one or more parameters used in the BSS without restarting the BSS.

6.3.115.2 MLME-UPDATE.request

6.3.115.2.1 Function

This primitive requests that the MAC entity to initiate a BSS update procedure to update one or more parameters used in the BSS without restarting the BSS.

6.3.115.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-UPDATE.request(
ServiceHint,
ServiceHash,
VendorSpecificInfo)

Name	Type	Valid range	Description
ServiceHint	Service Hint element	As defined in 9.4.2.237	If null, requests that Service Hint element be removed from Beacon and Probe Response frames. Otherwise, provides an indication of the services advertised in Beacon and Probe Response frames. The parameter is optionally present if dot11UnsolicitedPADActivated is true and absent otherwise.
ServiceHash	Service Hash element	As defined in 9.4.2.238	If null, requests that Service Hash element be removed from Beacon and Probe Response frames. Otherwise, specifies services advertised in Beacon and Probe Response frames. The parameter is optionally present if dot11UnsolicitedPADActivated is true and absent otherwise.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.26	Zero or more elements.

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6.3.115.2.3 When generated

This primitive is generated by the SME of an AP or PCP STA when one or more parameters used in the BSS are to be changed without restarting the BSS.

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6.3.115.2.4 Effect of receipt

If the MLME of an AP or PCP STA receives an MLME-UPDATE.request primitive with ServiceHint and or ServiceHash parameters, the AP or PCP STA shall use these parameters to update or remove the Service Hint element and/or Service Hash element in Beacon and Probe Response frames that the AP transmits or in DMG Beacon, Announce, and Probe Response frames that the PCP STA transmits.

6.3.115.3 MLME-UPDATE.confirm

6.3.115.3.1 Function

This primitive reports the results of a BSS update procedure.

6.3.115.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-UPDATE.confirm(
                    ResultCode
                    )
```

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, BSS_NOT_STARTED, NOT_SUPPORTED, UPDATE_FAILED	Indicates the result of the MLME-UPDATE.request primitive.

6.3.115.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-UPDATE.request primitive to update one or more parameters used in the BSS without restarting the BSS.

6.3.115.3.4 Effect of receipt

The SME is notified of the results of the BSS update procedure.

6.3.116 MSCS request and response procedure

6.3.116.1 General

The following MLME primitives support the signaling of the MSCS request and response procedure.

6.3.116.2 MLME-MSCS.request

6.3.116.2.1 Function

This primitive requests transmission of an MSCS Request frame to an AP.

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6.3.116.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MSCS.request(
PeerSTAAddress,
DialogToken,
MSCSDescriptor,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the MSCS process.
DialogToken	Integer	1–255	The dialog token to identify the MSCS request and response transaction.
MSCSDescriptor	MSCS Descriptor element	MSCS Descriptor element, as defined in 9.4.2.243	Specifies classifiers and parameters for the MSCS.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.116.2.3 When generated

This primitive is generated by the SME to request that a MSCS Request frame be sent to the AP with which the STA is associated

6.3.116.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs a MSCS Request frame. The STA then attempts to transmit this frame to the AP with which the STA is associated.

6.3.116.3 MLME-MSCS.confirm

6.3.116.3.1 Function

This primitive reports the result of a MSCS procedure.

6.3.116.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MSCS.confirm(
PeerSTAAddress,
DialogToken,
Status,
MSCSDescriptor,
VendorSpecificInfo
)

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Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the MSCS process.
DialogToken	Integer	1–255	The dialog token to identify the MSCS request and response transaction.
Status	Enumeration	See Table 9-50	Indicates the result response. See Table 9-50.
MSCSDescriptor	MSCS Descriptor element	MSCS Descriptor element, as defined in 9.4.2.243	Zero or more elements. Specifies suggested classifiers and parameters for the MSCS.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.116.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-MSCS.request primitive and indicates the results of the request.

This primitive is generated when the STA receives a MSCS Response frame from the AP.

6.3.116.3.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 11.25.3.

6.3.116.4 MLME-MSCS.indication

6.3.116.4.1 Function

This primitive indicates that an MSCS Request frame was received from a non-AP STA.

6.3.116.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MSCS.indication(
                        PeerSTAAddress,
                        DialogToken,
                        MSCSDescriptor,
                        VendorSpecificInfo
                        )
```

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which an MSCS Request frame was received.
DialogToken	Integer	1–255	The dialog token to identify the MSCS request and response transaction.
MSCSDescriptor	MSCS Descriptor element	MSCS Descriptor element, as defined in 9.4.2.243	Specifies classifiers and parameters for the MSCS.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

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6.3.116.4.3 When generated

This primitive is generated by the MLME when an MSCS Request frame is received.

6.3.116.4.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 11.25.3.

6.3.116.5 MLME-MSCS.response

6.3.116.5.1 Function

This primitive is generated in response to an MLME-MSCS.indication primitive requesting an MSCS Response frame be sent to a non-AP STA.

6.3.116.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MSCS.response(
PeerSTAAddress,
DialogToken,
Status,
MSCSDescriptor,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which a MSCS Request frame was received.
DialogToken	Integer	1–255	The dialog token to identify the MSCS request and response transaction.
Status	Enumeration	See Table 9-50	Indicates the result response. See Table 9-50.
MSCSDescriptor	MSCS Descriptor element	MSCS Descriptor element, as defined in 9.4.2.243	Zero or more elements. Specifies suggested classifiers and parameters for the MSCS.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.116.5.3 When generated

This primitive is generated by the SME in response to an MLME-MSCS.indication primitive requesting an MSCS Response frame be sent to a non-AP STA.

6.3.116.5.4 Effect of receipt

On receipt of this primitive, the MLME constructs a MSCS Response frame. The STA then attempts to transmit this frame to the non-AP STA indicated by the PeerSTAAddress parameter.

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6.3.116.6 MLME-MSCS-TERM.request

6.3.116.6.1 Function

This primitive requests the transmission of an MSCS Response frame to a non-AP STA to terminate an active MSCS.

6.3.116.6.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MSCS-TERM.request(
PeerSTAAddress,
DialogToken,
Status,
MSCSDescriptor,
VendorSpecificInfo
)

Name	Type	Valid range	Description
PeerSTAAddress	MAC address	Any valid individual MAC address	The address of the non-AP STA MAC entity from which the MSCS Response frame is to be sent.
DialogToken	Integer	0	Set to 0 for an autonomous MSCS Response frame.
Status	Enumeration	See Table 9-50	Indicates the result response. See Table 9-50.
MSCSDescriptor	MSCS Descriptor element	MSCS Descriptor element, as defined in 9.4.2.243	Zero or more elements. Specifies suggested classifiers and parameters for the MSCS.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.116.6.3 When generated

This primitive is generated by the SME to terminate an active MSCS.

6.3.116.6.4 Effect of receipt

On receipt of this primitive, the MLME constructs an MSCS Response frame. The STA then attempts to transmit this frame to the non-AP STA indicated by the PeerSTAAddress parameter.

6.3.116.7 MLME-MSCS-TERM.indication

6.3.116.7.1 Function

This primitive is generated by the MLME when an unsolicited MSCS Response frame is received.

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6.3.116.7.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MSCS-TERM.indication(
ResultCode,
DialogToken,
Status,
MSCSDescriptor,
VendorSpecificInfo
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, FAILURE	Indicates the result of the MLME-MSCS-TERM.request primitive.
DialogToken	Integer	0	Set to 0 for an autonomous MSCS Response frame.
Status	Enumeration	See Table 9-50	Indicates the result response. See Table 9-50.
MSCSDescriptor	MSCS Descriptor element	MSCS Descriptor element, as defined in 9.4.2.243	Zero or more elements. Specifies suggested classifiers and parameters for the MSCS.
VendorSpecificInfo	A set of elements	As defined in 9.4.2.25	Zero or more elements.

6.3.116.7.3 When generated

This primitive is generated when the STA receives an unsolicited MSCS Response frame from the AP.

6.3.116.7.4 Effect of receipt

On receipt of this primitive, the SME should operate according to the procedure in 11.25.3.

6.3.117 MAC Address Update

6.3.117.1 MLME-UPDATEMACADDRESS.request

6.3.117.1.1 Function

The primitive indicates that a MAC address change is required.

6.3.117.1.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-UPDATEMACADDRESS.request(
STAAddress
)

Name	Type	Valid range	Description
STAAddress	MAC address	Any valid individual MAC address	Specifies the MAC address that is to be used by the MAC entity.

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6.3.117.1.3 When generated

This primitive is generated by the SME when a MAC address change is needed.

6.3.117.1.4 Effect of receipt

Receipt of this primitive causes the MAC to change the MAC address.

6.3.117.2 MLME-UPDATEMACADDRESS.confirm

6.3.117.2.1 Function

The primitive is generated by the MAC to indicate the result of a MAC address change.

6.3.117.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-UPDATEMACADDRESS.confirm(
ResultCode
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, FAILURE	Indicates the result of the MAC address change.

6.3.117.2.3 When generated

This primitive is generated by the MLME in response to a request to change the MAC address. If the result of the MLME-UPDATEMACADDRESS.request primitive is FAILURE, either changing the MAC address is not supported, or the MAC address specified was not accepted.

6.3.117.2.4 Effect of receipt

The SME is notified of the result of the MAC address change.

6.4 MAC state generic convergence function (MSGCF)

6.4.1 Overview of the convergence function

The MSGCF provides an abstraction of a link between a non-AP STA and an ESS (an ESS link) to its higher layer entity. The MSGCF provides control of an ESS link and generates events based on the state of an ESS link. A non-AP STA that transitions between two APs in the same ESS can operate transparently to the LLC sublayer, and does not change state in the state machine defined within 6.4.

This clause defines interactions between the MSGCF and MLME and PLME through the MLME SAP and PLME SAP respectively, as well as with the SME via the MSGCF-SME SAP. The detailed manner in which the SAPs are implemented is not specified within this standard.

6.4.2 Overview of convergence function state machine

The convergence function maintains information on the state of the ESS, using the state machine shown in Figure 6-29. Because Figure 6-29 is defined in terms of ESS connectivity, it is not affected by changes in association provided that the transition was an intra-ESS transition.

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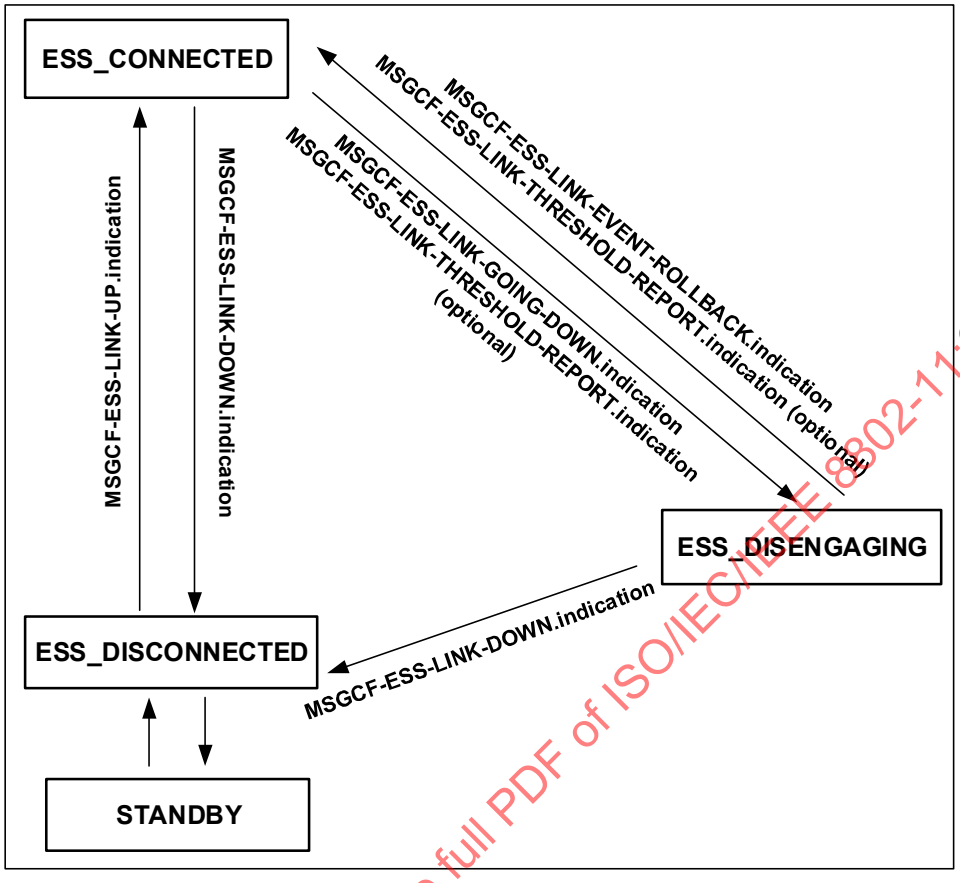

Figure 6-29—MSGCF state machine

6.4.3 Convergence function state list

6.4.3.1 ESS_CONNECTED

In the ESS_CONNECTED state, a non-AP STA has completed all layer 2 setup activities and is able to send Class 3 frames to peer LLC entities. A non-AP STA remains in this state as long as it is possible to send Class 3 frames through any AP within an ESS. A non-AP STA does not leave this state upon successful intra-ESS transitions.

6.4.3.2 ESS_DISCONNECTED

In the ESS_DISCONNECTED state, a non-AP STA is unable to send Class 3 frames to peer LLC entities. Higher layer network protocols are unavailable. In this state, a non-AP STA may use GAS to perform network discovery and selection.

6.4.3.3 ESS_DISENGAGING

In the ESS_DISENGAGING state, the non-AP STA's SME anticipates that links to all APs within the ESS will be lost in a defined time interval, but the non-AP STA is still able to send Class 3 frames to peer LLC entities. The predictive failure of the link might be due to explicit disassociation by the peer, the imminent

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invalidation of cryptographic keys because of usage limits (such as sequence counter exhaustion), or predictive signal strength algorithms. In this state, it is recommended that a non-AP STA also initiate a search to find a new ESS.

6.4.3.4 STANDBY

In the STANDBY state, the non-AP STA is powered down and unable to communicate with any other STAs.

6.4.4 Convergence function state transitions

6.4.4.1 Transitions to ESS_CONNECTED

6.4.4.1.1 From ESS_DISCONNECTED

To make this transition, a non-AP STA will have completed the network selection process and the relevant procedures to attach to the ESS, including IEEE 802.11 authentication, IEEE 802.11 association, and, if required, IEEE 802.11 RSN procedures. When this transition is completed, the MSGCF sends an MSGCF-ESS-LINK-UP.indication primitive to higher layers.

6.4.4.1.2 From ESS_DISENGAGING

To make this transition, the SME cancels a previous event that predicted an ESS link failure. This might be due to network parameters indicating renewed link strength or a successful renewal of an expiring RSN SA. When this transition is complete, the MSGCF sends an MSGCF-ESS-LINK-EVENT-ROLLBACK.indication primitive to indicate that a prior link failure predictive event is no longer valid. If the transition was due to network parameters crossing a threshold, the MSGCF also sends an MSGCF-ESS-LINK-THRESHOLD-REPORT.indication primitive to higher layers.

6.4.4.2 Transitions to ESS_ DISCONNECTED

6.4.4.2.1 From ESS_CONNECTED

This transition indicates that administrative action was taken to shut down the link, a sudden loss of signal strength or that RSN keys expired and could not be renewed. At the conclusion of this transition, the MSGCF sends an MSGCF-ESS-LINK-DOWN.indication primitive to higher layer protocols.

6.4.4.2.2 From ESS_DISENGAGING

This transition indicates that the predictive link failure event has occurred. At the conclusion of this transition, the MSGCF issues an MSGCF-ESS-LINK-DOWN.indication primitive to higher layer protocols.

6.4.4.2.3 From STANDBY

This transition occurs when the non-AP STA is powered on and initialized. No event is issued by the MSGCF.

6.4.4.3 Transitions to ESS_DISENGAGING

6.4.4.3.1 From ESS_CONNECTED

When the parameters as defined in Table 6-7 change or imminent action is taken to bring down the link, the SME may predict an imminent link failure and initiate a transition. Upon completion of this transition, the MSGCF issues an MSGCF-ESS-LINK-GOING-DOWN event. If the cause of the transition was the degradation of network parameters beyond the thresholds stored in the MIB, an MSGCF-ESS-LINK-THRESHOLD-REPORT.indication primitive is also issued to higher layers.

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6.4.4.4 Transitions to STANDBY

6.4.4.4.1 From ESS_DISCONNECTED

When the non-AP STA has disconnected from an ESS, it may be administratively powered off to extend battery life. No events are issued by the MSGCF upon completion of this transition.

6.4.5 Convergence function informational events

Informational events may occur in any state. When they occur, the SME updates the convergence function MIB with new parameters. Informational events do not cause state changes in the MSGCF state machine (see Figure 6-29). Informational events are generated when new potential ESS links are discovered, when the network parameter thresholds are set or read, and when higher layer protocols issue commands to the non-AP STA through the MSGCF-ESS-LINK-COMMAND.request primitive.

6.4.6 MAC state generic convergence SAP

The MAC state generic convergence SAP is the interface between the convergence function and higher layer protocols. It presents a standardized interface for higher layer protocols to access the state of the MAC, whether that state information is available in the MLME, PLME, or SME.

Some events on the MAC state generic convergence SAP require event identifiers for use as a dialog token in event sequencing and rollback. The EventID is an unsigned integer that is initialized to 1 when the non-AP STA leaves the STANDBY state.

6.4.7 ESS status reporting

6.4.7.1 MSGCF-ESS-LINK-UP.indication

6.4.7.1.1 Function

This event is triggered when a new ESS has been made available for sending frames.

6.4.7.1.2 Semantics of the service primitive

The primitive parameters are as follows:

MSGCF-ESS-LINK-UP.indication(
ESSIdentifier
)

Name	Type	Valid range	Description
ESSIdentifier	String	N/A	An identifier composed of the string value of the SSID element concatenated with the value of the HESSID if it is in use. The HESSID is encoded in upper-case ASCII characters with the octet values separated by dash characters, as described in IETF RFC 3580 [B39].

6.4.7.1.3 When generated

This primitive is generated when the ESS link to a network of APs is available to exchange Data frames. The generation of this primitive may vary depending on the contents of dot11WEPDefaultKeysTable and dot11WEPKeyMappingsTable and the setting of dot11RSNAOptionImplemented.

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If there are no entries in the dot11WEPDefaultKeysTable, no entry for the current AP in dot11WEPKeyMappingsTable, and dot11RSNAOptionImplemented is false, then the network does not use encryption. This event is generated upon receipt of an MLME-ASSOCIATE.confirm primitive with a result code of success.

If there are entries in the dot11WEPDefaultKeysTable, or an entry for the current AP in dot11WEPKeyMappingsTable, or dot11RSNAOptionImplemented is true, then the network requires the use of encryption on the link. Before declaring that the link is ready to exchange Data frames, the convergence function receives an MLME-ASSOCIATE.confirm primitive with a result code of success and the SME emits an MLME-SETKEYS.request primitive. The latter primitive is used to determine that a WEP key is available, or that the RSN 4-way handshake has completed.

This event is not triggered by MLME-REASSOCIATE.confirm primitives because MLME-REASSOCIATE.confirm primitives are defined as transitions within the same ESS.

The MLME-ASSOCIATE.confirm primitive may be issued upon AP transitions. It is the objective of the MSGCF to generate this event only upon the initial connection to an IEEE 802.11 network, when the MSGCF state machine moves into the ESS_CONNECTED state.

6.4.7.1.4 Effect of receipt

This event is made available to higher layer protocols by the convergence function. Actions taken by higher layers are outside of scope of this standard, but may include router discovery, IP configuration, and other higher layer protocol operations.

6.4.7.2 MSGCF-ESS-LINK-DOWN.indication

6.4.7.2.1 Function

This event is triggered to indicate that the connection to an ESS is no longer available for sending frames.

6.4.7.2.2 Semantics of the service primitive

The event's parameters are as follows:

```
MSGCF-ESS-LINK-DOWN.indication (
                                ESSIdentifier,
                                ReasonCode
                                )
```

Name	Type	Valid range	Description
ESSIdentifier	String	N/A	An identifier composed of the string value of the SSID element concatenated with the value of the HESSID if it is in use.
ReasonCode	Enumerated	EXPLICT_DISCONNECT, KEY_EXPIRATION, LOW_POWER, VENDOR_SPECIFIC	Reason code, drawn from Table 6-2.

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Table 6-2—Reason codes for network down

Name	Description
EXPLICIT_DISCONNECT	An explicit disconnection operation (disassociation or deauthentication) was initiated by the non-AP STA or the non-AP STA's current serving AP (the AP with which the STA is associated) and the non-AP STA was unable to (re)associate with an alternate AP in the same ESS.
KEY_EXPIRATION	Keys used by an RSN SA have expired due to time or traffic limitations, or TKIP countermeasures have invalidated the key hierarchy.
LOW_POWER	If the SME reports that the interface was shut down to conserve power, that event may be reported to higher level protocols.
VENDOR_SPECIFIC	Vendor-specific usage.

6.4.7.2.3 When generated

This event is generated when the SME declares that connectivity to an ESS is lost. It may be generated in the case of an explicit disconnection from the link peer, received as an MLME-DEAUTHENTICATE.indication or an MLME-DISASSOCIATE.indication primitive. The SME should wait for a period of dot11ESSDisconnectFilterInterval before declaring connectivity lost to confirm that a non-AP STA is unable to (re)associate with any alternate AP within the ESS.

6.4.7.2.4 Effect of receipt

This event is made available to higher layer protocols by the convergence function. Actions taken by those higher layers are outside the scope of this standard, but may include removing entries from routing and forwarding tables, and attempting to initiate handover of open application connections to network interfaces that are still active.

6.4.7.3 MSGCF-ESS-LINK-GOING-DOWN.indication

6.4.7.3.1 Function

This event is triggered to indicate the expectation that the connection to an ESS will no longer be available for sending frames in the near future.

6.4.7.3.2 Semantics of the service primitive

The event parameters are as follows:

```
MSGCF-ESS-LINK-GOING-DOWN.indication(
                                    ESSIdentifier,
                                    EventID,
                                    TimeInterval,
                                    ReasonCode
                                    )
```

Name	Type	Valid range	Description
ESSIdentifier	String	N/A	An identifier composed of the string value of the SSID element concatenated with the value of the HESSID if it is in use.
EventID	Integer	N/A	An integer used to identify the event that is used in the case of event rollback.

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Name	Type	Valid range	Description
TimeInterval	Integer	N/A	Time Interval, in time units, in which the link is expected to go down. Connectivity is expected to be available at least for time specified by TimeInterval.
Reason Code	Enumerated	EXPLICT_DISCONNECT, KEY_EXPIRATION, LOW_POWER, VENDOR_SPECIFIC	Indicates the reason the link is expected to go down, drawn from Table 6-3.

Table 6-3—Reason codes for ESS link down

Name	Description
EXPLICIT_DISCONNECT	An explicit disconnection operation (Disassociation or Deauthentication) was initiated by the non-AP STA or the non-AP STA's current serving AP.
KEY_EXPIRATION	Keys used by an RSN SA have expired due to time or traffic limitations, or TKIP countermeasures have invalidated the key hierarchy.
LOW_POWER	If the SME reports that the interface is going to be shut down to conserve power, that event may be reported to higher level protocols.
VENDOR_SPECIFIC	Vendor-specific usage.

6.4.7.3.3 When generated

This notification is generated by the MSGCF when the ESS link is currently established and is expected to go down within the specified time interval. The network can be expected to go down because of an event whose timing is well understood, such as an explicit disconnection event observed on the MLME SAP. It can also be expected as the result of a predictive algorithm that monitors link quality. The details of such a predictive algorithm used are beyond the scope of this standard.

The convergence function should attempt to deliver this event at least dot11ESSLinkDownTimeInterval time units before the link is predicted to go down. Different higher layer network protocols might need different levels of advance notice, and might configure dot11ESSLinkDownTimeInterval accordingly.

Not all thresholds in the dot11MACStateParameterTable are supported by every PHY. In the case when a threshold parameter is not supported it is not applied.

6.4.7.3.4 Effect of receipt

This event is made available to higher layer protocols by the convergence function. Actions taken by those higher layers are outside the scope of this standard, but may include beginning preparations for handover.

6.4.7.4 MSGCF-ESS-LINK-EVENT-ROLLBACK.indication

6.4.7.4.1 Function

This event is used to indicate that specific previous reports or events are no longer valid and should be disregarded.

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6.4.7.4.2 Semantics of the service primitive

The event parameters are as follows:

MSGCF-ESS-LINK-EVENT-ROLLBACK.indication(
ESSIdentifier,
EventID
)

Name	Type	Valid range	Description
ESSIdentifier	String	N/A	An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use.
EventID	Integer	N/A	An integer used to identify the event that is used in the case of event rollback.

6.4.7.4.3 When generated

This event is generated when a previous predictive event is no longer valid within its expiration time.

The MSGCF-ESS-LINK-EVENT-ROLLBACK.indication primitive is used in conjunction with the MSGCF-ESS-LINK-GOING-DOWN.indication primitive. The MSGCF-ESS-LINK-EVENT-ROLLBACK.indication primitive is issued when the prediction of link failure is no longer valid. Algorithms used to determine that link failure predictions are beyond the scope of this standard.

6.4.7.4.4 Effect of receipt

This event is made available to higher layer protocols by the convergence function to cancel any actions begun by the previous event. Actions taken by those higher layers are outside the scope of this standard, but may include canceling any handover procedures started by the MSGCF-ESS-LINK-GOING-DOWN event.

6.4.7.5 MSGCF-ESS-LINK-DETECTED.indication

6.4.7.5.1 Function

This event reports on the presence of a new ESS.

6.4.7.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MSGCF-ESS-LINK-DETECTED.indication(
ESSIdentifier,
ESSDescription
)

Name	Type	Valid range	Description
ESSIdentifier	String	N/A	An identifier for the network, composed of the string value of the SSID used to identify the network, concatenated with the value of the HESSID if it is in use.
ESSDescription	As defined in Table 6-4	N/A	A set of information about the ESS.

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Table 6-4—ESS description

Name	Syntax	Description
SSID	String	The SSID used by the ESS.
InformationServiceSupport	As described in Table 6-5	A set of values indicating the type of information services supported on this network.
TriggerSupport	As described in Table 6-5	A set of values indicating the support for the types of triggers that can be used to propose that the station take action.
RSN	As defined in 9.4.2.24	The RSN configuration of the ESS.
Interworking	As defined in 9.4.2.91	Interworking configuration of the ESS.

Table 6-5—Trigger support values

Name	Description
MIS_CS_ES_Support	This network supports the IEEE 802.21 MIS Command Service and Event Service.
Vendor_Specific_Trigger_Support	This network supports a vendor-specific trigger service.

6.4.7.5.3 When generated

Support for MIS is indicated by the presence or absence of the relevant advertisement protocol IDs in the Advertisement Protocol element.To maintain the list of detected networks, the SME issues recurring MLME-SCAN.request primitives to the MLME. The SME may schedule these requests to avoid interruption of user traffic. Responses to these requests, received in the MLME-SCAN.confirm primitives, contain a list of detected networks. Each network is stored in dot11MACStateESSLinkDetectedTable. This table holds a list of networks, organized by Network Identifier. Each entry in the table contains a list of BSSIDs within the network, as well as indications of support for MIS. Support for MIS is indicated by the presence or absence of the relevant advertisement protocol IDs in the Advertisement Protocol element. Each entry in the table is held for at least dot11ESSLinkDetectionHoldInterval time units. When a non-AP STA has not observed an ESS for longer than dot11ESSLinkDetectionHoldInterval, it may be removed from the table.

This event is generated when a new entry is made into the dot11MACStateESSLinkDetectedTable. Modifications to existing entries in the list, such as an update to the BSSID list, do not trigger this event.

6.4.7.5.4 Effect of receipt

This event is made available to higher layer protocols by the convergence function. Actions taken by those higher layers are outside the scope of this standard.

6.4.7.6 MSGCF-ESS-LINK-SCAN.request

6.4.7.6.1 Function

This function is used by higher layer protocols to request that the SME perform a scan operation for available ESSs.

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6.4.7.6.2 Semantics of the service primitive

The primitive parameters are as follows:

MSGCF-ESS-LINK-SCAN.request(
SSID,
HESSID,
AccessNetworkType
)

Name	Type	Valid range	Description
SSID	Octet string	0–32 octets	Specific or wildcard.
HESSID	As defined in 9.4.2.91	As defined in 9.4.2.91	The HESSID to search for. It can be set to all 1s for use as a wildcard to match all available HESSID values.
AccessNetworkType	As defined in 9.4.2.91	As defined in 9.4.2.91	This may be a specific value to match one type of networks, or all 1s to match all access network types.

6.4.7.6.3 When generated

This request is generated when higher protocol layers request a list of available ESSs.

6.4.7.6.4 Effect of receipt

The SME generates a corresponding MLME-SCAN.request primitive to find available networks.

6.4.7.7 MSGCF-ESS-LINK-SCAN.confirm

6.4.7.7.1 Function

This function reports information on available ESSs to higher protocol layers.

6.4.7.7.2 Semantics of the service primitive

The primitive parameters are as follows:

MSGCF-ESS-LINK-SCAN.confirm(
ESSIdentifiers,
ESSDescriptions
)

Name	Type	Valid range	Description
ESSIdentifiers	Set of Strings	N/A	An identifier for the network composed of the string value of the SSID used to identify the network, concatenated with the value of the HESSID if it is in use.
ESSDescriptions	Set of ESSDescriptions, as defined in Table 6-4	N/A	A set of information about each discovered ESS.

6.4.7.7.3 When generated

This primitive is generated when scan results are available for reporting to higher protocol layers, in response to an MSGCF-ESS-LINK-SCAN.request primitive.

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6.4.7.7.4 Effect of receipt

This event is made available to higher layer protocols by the convergence function. Actions taken by those higher layers are outside the scope of this standard.

6.4.8 Network configuration

6.4.8.1 MSGCF-ESS-LINK-CAPABILITY.request

6.4.8.1.1 Function

This primitive requests a list of the capabilities supported by a network.

6.4.8.1.2 Semantics of the service primitive

The primitive parameters are as follows:

MSGCF-ESS-LINK-CAPABILITY.request(
ESSIdentifier
)

Name	Type	Valid range	Description
ESSIdentifier	String	N/A	An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use.

6.4.8.1.3 When generated

This primitive is issued to service higher layer protocols by reporting on the capabilities of a particular network.

6.4.8.1.4 Effect of receipt

The convergence function retrieves the capabilities and reports them via the MSGCF-ESS-LINK-CAPABILITY.confirm primitive.

6.4.8.2 MSGCF-ESS-LINK-CAPABILITY.confirm

6.4.8.2.1 Function

This primitive reports the convergence function capabilities of the network to higher layer protocols.

6.4.8.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MSGCF-ESS-LINK-CAPABILITY.confirm(
ESSIdentifier,
EssLinkParameterSet,
ReasonCode
)

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Name	Type	Valid range	Description
ESSIdentifier	String	N/A	An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use.
EventCapability Set	As defined in Table 6-6	N/A	list of supported events.
ReasonCode	Enumerated	SUCCESS, UNKNOWN_NETWORK, UNKNOWN_CAPABILITIES	An error code, if applicable.

Table 6-6—Event Capability Set

Name	Type	Valid range	Description
NonAPSTAMacAddress	MAC address	Any valid individual MAC address	The MAC address of the non-AP STA that is reporting the new network.
ESS-Link-Up	Boolean	true, false	Indicates whether the MSGCF-ESS-LINK-UP.indication primitive as defined in 6.4.7.1 is supported.
ESS-Link-Down	Boolean	true, false	Indicates whether the MSGCF-ESS-LINK-DOWN.indication primitive as defined in 6.4.7.2 is supported.
ESS-Link-Going-Down	Boolean	true, false	Indicates whether the MSGCF-ESS-LINK-GOING-DOWN primitive as defined in 6.4.7.3 is supported.
ESS-Link-Event-Rollback	Boolean	true, false	Indicates whether the MSGCF-ESS-LINK-EVENT-ROLLBACK.indication primitive as defined in 6.4.7.4 is supported.
ESS-Link-Detected	Boolean	true, false	Indicates whether the MSGCF-ESS-LINK-DETECTED.indication primitive as defined in 6.4.7.5 is supported.
ESS-Link-Threshold-Report	Boolean	true, false	Indicates whether the MSGCF-ESS-LINK-THRESHOLD-REPORT.indication primitive as defined in 6.4.9.1 is supported.
ESS-Link-Command	Boolean	true, false	Indicates whether the MSGCF-ESS-LINK-COMMAND.request primitive as defined in 6.4.10.1 is supported.

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6.4.8.2.3 When generated

This primitive is generated in response to the MSGCF-ESS-LINK-CAPABILITY.request primitive to report whether specific events are supported.

6.4.8.2.4 Effect of receipt

This event is made available to higher layer protocols by the convergence function.

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6.4.8.3 MSGCF-ESS-LINK-PARAMETERS.request

6.4.8.3.1 Function

This primitive sets thresholds for reporting of network events.

6.4.8.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MSGCF-ESS-LINK-PARAMETERS.request(
ESSIdentifier,
EssLinkParameterSet
)

Name	Type	Valid range	Description
ESSIdentifier	String	N/A	An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use.
ESSLinkParameterSet	As defined in Table 6-7	N/A	The EssLinkParameterSet is used to configure when event reports are sent to higher protocol layers.

The ESSLinkParameterSet parameter is defined in Table 6-7. It may include any or all of the parameters in Table 6-7.

Table 6-7—ESS Link Parameter Set

Name	Type	Valid range	Description
PeakOperationalRate	Integer	As defined in 9.4.2.3	The integer representing the target peak modulation data rate used for Data frame transmission.
MinimumOperationalRate	Integer	As defined in 9.4.2.3	The integer encoding of the target minimum modulation data rate used in Data frame transmission.
NetworkDowntimeInterval	Integer	0–65 535	Target advance warning time interval, in TUs, for MSGCF-ESS-LINK-GOING-DOWN events.
DataFrameRSSI	Integer	–100 to 40	The received signal strength in dBm of received Data frames from the network. This may be time-averaged over recent history by a vendor-specific smoothing function.
BeaconRSSI	Integer	–100 to 40	The received signal strength in dBm of Beacon frames received on the channel. This may be time-averaged over recent history by a vendor-specific smoothing function.
BeaconSNR	Integer	0–100	The signal-to-noise ratio of the received Data frames, in dB. This may be time-averaged over recent history by a vendor-specific smoothing function.
DataFrameSNR	Integer	0–100	The signal-to-noise ratio of the received Beacon frames, in dB. This may be time-averaged over recent history by a vendor-specific smoothing function.
DataThroughput	Integer	0–65 535	The data throughput in megabits per second, rounded to the nearest megabit. This may be time-averaged over recent history by a vendor-specific smoothing function.

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Table 6-7—ESS Link Parameter Set *(continued)*

Name	Type	Valid range	Description
MissedBeaconRate	Real	N/A	The rate at which beacons have not been received in missed beacons per second. This may be time-averaged over recent history by a vendor-specific smoothing function.
FrameErrorRate	Real	N/A	The frame error rate of the network in errors per second. This may be time-averaged over recent history by a vendor-specific smoothing function.
VendorSpecific	Vendor Specific	As defined by 9.4.2.25	Additional vendor-specific parameters may be included in this event.

6.4.8.3.3 When generated

This event is generated when higher protocol layers wish to set the performance parameters for a network. Higher protocol layers are responsible for ensuring that the set of configured network parameters is consistent with all subscribers to those higher layer protocols.

6.4.8.3.4 Effect of receipt

Parameters supplied in the event are stored in the MIB, either in the dot11MACStateConfigTable or the dot11MACStateParameterTable.

6.4.8.4 MSGCF-ESS-LINK-PARAMETERS.confirm

6.4.8.4.1 Function

This primitive indicates whether network parameters were accepted.

6.4.8.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MSGCF-ESS-LINK-PARAMETERS.confirm(
                                    ESSIdentifier,
                                    EssLinkParameterSet,
                                    )
```

Name	Type	Valid range	Description
ESSIdentifier	String	N/A	An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use.
EssLinkParameterSet	As defined in Table 6-7	N/A	The EssLinkParameterSet is used to configure when event reports are sent to higher protocol layers.

6.4.8.4.3 When generated

This primitive is generated in response to the MSGCF-ESS-LINK-PARAMETERS.request primitive and is used to indicate whether the parameter set was accepted.

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6.4.8.4.4 Effect of receipt

The SME is notified of the new parameter set.

6.4.8.5 MSGCF-GET-ESS-LINK-PARAMETERS.request

6.4.8.5.1 Function

This primitive retrieves the current network parameters for a specific network.

6.4.8.5.2 Semantics of the service primitive

The primitive parameter is as follows:

MSGCF-GET-ESS-LINK-PARAMETERS.request(
ESSIdentifier
)

Name	Type	Valid range	Description
ESSIdentifier	String	N/A	An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use.

6.4.8.5.3 When generated

This primitive is used by higher layers to retrieve the currently stored parameters for a network.

6.4.8.5.4 Effect of receipt

The SME retrieves the network parameters and makes them available through the MSGCF-GET-ESS-LINK-PARAMETERS.confirm primitive.

6.4.8.6 MSGCF-GET-ESS-LINK-PARAMETERS.confirm

6.4.8.6.1 Function

This primitive reports the current network parameters.

6.4.8.6.2 Semantics of the service primitive

The primitive parameters are as follows:

MSGCF-GET-ESS-LINK-PARAMETERS.confirm(
ESSIdentifier,
EssLinkParameterSet,
)

Name	Type	Valid range	Description
ESSIdentifier	String	N/A	An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use.
EssLinkParameterSet	As defined 6.4.8.3	N/A	The EssLinkParameterSet is used to configure when event reports are sent to higher protocol layers.

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6.4.8.6.3 When generated

This primitive is generated by the MSGCF as a result of the MSGCF-GET-ESS-LINK-PARAMETERS.request primitive.

6.4.8.6.4 Effect of receipt

The higher layer protocols are notified of the current network parameters.

6.4.9 Network events

6.4.9.1 MSGCF-ESS-LINK-THRESHOLD-REPORT.indication

6.4.9.1.1 Function

This event reports that the layer 2 network performance has crossed a threshold set by the operations described in Table 6-5.

6.4.9.1.2 Semantics of the service primitive

The primitive parameters are as follows:

MSGCF-ESS-LINK-THRESHOLD-REPORT.indication(
ESSIdentifier,
EssLinkParameterSet,
ThresholdCrossingDirectionSet
)

Name	Type	Valid range	Description
ESSIdentifier	String	N/A	An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use.
EssLinkParameterSet	As defined in Table 6-7	N/A	A list of EssLinkParameterSets and their current values that have crossed preset thresholds for alerts.
ThresholdCrossingDirectionSet	Set of ThresholdCrossing Directions, one for each value in the EssLinkParameterSet	UPWARD, DOWNWARD	Whether the parameter has crossed the threshold while rising or falling.

6.4.9.1.3 When generated

The convergence function is responsible for monitoring network performance. If the monitored parameters cross the configured threshold, this event is generated to inform higher layer protocols.

6.4.9.1.4 Effect of receipt

This event is made available to higher layer protocols by the convergence function. Actions taken by those higher layers are outside the scope of this standard, but may include preparations for handover or assessing whether handover should be imminent.

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6.4.10 Network command interface

6.4.10.1 MSGCF-ESS-LINK-COMMAND.request

6.4.10.1.1 Function

This primitive requests that a STA take action for a network.

6.4.10.1.2 Semantics of the service primitive

The primitive parameters are as follows:

MSGCF-ESS-LINK-COMMAND.request(
ESSIdentifier,
CommandType
)

Name	Type	Valid range	Description
ESSIdentifier	String	N/A	An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use.
CommandType	Enumerated	DISCONNECT, LOW_POWER, POWER_UP, POWER_DOWN, SCAN	Type of command to perform on the link as described in the following subclauses.

6.4.10.1.3 When generated

This primitive is generated by a higher layer protocol.

6.4.10.1.4 Effect of receipt

The convergence function issues commands to the SME to implement the requested action on behalf of higher layers.

When the DISCONNECT command type is specified, the higher layer is requesting that the STA disconnect from its peer. When the SME on a non-AP STA receives this command, the SME issues an MLME-DEAUTHENTICATE.request primitive to disconnect from the network, and the SME refrains from reconnecting to that network.

When the POWER_DOWN command type is specified, the SME powers down the non-AP STA. Before doing so, it may choose to notify the AP.

When the POWER_UP command type is specified, the SME starts the non-AP STA.

When the LOW_POWER command type is specified, the higher layer is requesting that the interface be placed in a low power mode. This action is accomplished by issuing an MLME-POWERMGT.request primitive with the PowerManagementMode parameter set to POWER_SAVE.

When the SCAN command type is specified, the higher layer is requesting that the STA search for networks. This action is accomplished by issuing an MLME-SCAN.request primitive. Detected networks are made available in the dot11MACStateESSLinkDetectedTable, as well as through the MSGCF-ESS-LINK-DETECTED.indication primitive.

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6.4.11 MAC state SME SAP—mobility management

6.4.11.1 MSSME-ESS-LINK-GOING-DOWN.indication

6.4.11.1.1 Function

This primitive indicates that the SME is predicting a link failure.

6.4.11.1.2 Semantics of the service primitive

The primitive parameters are as follows:

MSSME-ESS-LINK-GOING-DOWN.indication(
ESSIdentifier,
TimeInterval,
ReasonCode
)

Name	Type	Valid range	Description
NonAPSTAMac Address	MAC address	Any valid individual MAC address	The MAC address of the non-AP STA that is reporting that an ESS is expected to go down.
ESSIdentifier	String	N/A	An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use.
TimeInterval	Integer	N/A	Time Interval, in time units, in which the link is expected to go down. Connectivity is expected to be available at least for time specified by *TimeInterval*.
Reason Code	Enumerated	EXPLICIT_DISCONNECT, LINK_PARAMETER_DEGRADATION, KEY_EXPIRATION, LOW_POWER, QOS_UNAVAILABLE, VENDOR_SPECIFIC	Indicates the reason the link is expected to go down.

6.4.11.1.3 When generated

This notification is generated by the SME when the network connection is currently established and is expected to go down. The details of the predictive algorithm used are beyond the scope of this standard. One method of implementing this function would be to generate this indication when link quality is fading and no better AP can be found.

6.4.11.1.4 Effect of receipt

This indication is received by the MSGCF and is used to generate the MSGCF-ESS-LINK-DOWN.indication primitive due to link parameter degradation.

6.5 PLME SAP interface

6.5.1 General

The PHY management service interface consists of the generic PLMEGET and PLMESET primitives on PHY MIB attributes, as described previously, together with the PLME-RESET and PLME-CHARACTERISTICS primitives and the following specific primitives.

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6.5.2 PLME-RESET.request

6.5.2.1 Function

This primitive is a request by the SME to reset the PHY. The PHY is always reset to the receive state to avoid accidental data transmission.

6.5.2.2 Semantics of the service primitive

This primitive has no parameters.

6.5.2.3 When generated

This primitive is generated at any time to reset the PHY.

6.5.2.4 Effect of receipt

Receipt of this primitive by the PHY causes the PHY entity to reset both the transmit and the receive state machines and places the PHY into the receive state.

6.5.3 PLME-CHARACTERISTICS.request

6.5.3.1 Function

This primitive is a request by the SME to provide the PHY operational characteristics.

6.5.3.2 Semantics of the service primitive

This primitive has no parameters.

6.5.3.3 When generated

This primitive is generated by the SME, at initialization time, to request the PHY entity to provide its operational characteristics.

6.5.3.4 Effect of receipt

The effect of receipt of this primitive by the PHY entity is the generation of a PLME-CHARACTERISTICS.confirm primitive that conveys its operational characteristics.

6.5.4 PLME-CHARACTERISTICS.confirm

6.5.4.1 Function

This primitive provides the PHY operational parameters.

6.5.4.2 Semantics of the service primitive

The primitive provides the following parameters:

```
PLME-CHARACTERISTICS.confirm(
                                    aSlotTime,
                                    aSIFSTime,
                                    aSignalExtension,
                                    aCCATime,
```

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aCCAMidTime,
aRxPHYStartDelay,
aRxTxTurnaroundTime,
aTxPHYDelay,
aRxPHYDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aAirPropagationTime,
aMACProcessingDelay,
aRIFSTime,
aSymbolLength,
aPSDUMaxLength,
aPSDUMaxLengthWithNoAggregation,
aPPDUMaxTime,
aIUSTime,
aDTT2UTTTime,
aCWmin,
aCWmax,
aMaxCSIMatricesReportDelay
aMaxTODError,
aMaxTOAError,
aTxPHYTxStartRFDelay,
aTxPHYTxStartRMS,
aMaxTODFineError,
aMaxTOAFineError,
aAPEPMaxLengthVHTMU20,
aAPEPMaxLengthVHTMU40,
aAPEPMaxLengthVHTMU80orMore
)

The values assigned to the parameters are as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. Not all parameters are used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	Integer	The slot time (in microseconds) that the MAC uses for defining IFSs. See 10.3.7.
aSIFSTime	Integer	The nominal time (in microseconds) that the MAC and PHY require in order to receive the last symbol of a frame on the WM, process the frame, and respond with the first symbol on the WM of the earliest possible response frame. See 10.3.7.
aSignalExtension	Integer	Duration (in microseconds) of the signal extension (i.e., a period of no transmission) that is included at the end of certain PPDU formats; see 19.3.2 and 10.3.8.
aCCATime	Integer	For Clause 15 to Clause 18 PHYs and Clause 20 PHYs, the maximum time (in microseconds) the CCA mechanism has available to assess the medium to determine whether the medium is busy or idle. For Clause 19 and Clause 21 PHYs, the maximum time (in microseconds) that the CCA mechanism has available to detect the start of an IEEE 802.11 transmission within the primary channel and to assess the energy on the medium within the primary, secondary, secondary40 (Clause 21 PHY only), and secondary80 (Clause 21 PHY only) channels that fall inside the operating channel, in order to determine the values of the STATE and channel-list parameters of the PHY-CCA.indication primitive.

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Name	Type	Description
aCCAMidTime	Integer	For Clause 21 PHYs, the maximum time (in microseconds) the CCA mechanism has available to assess the medium to determine whether an IEEE 802.11 transmission is present on a nonprimary channel.
aRxPHYStartDelay	Integer	The delay, in microseconds, from the start of the PPDU at the receiver's antenna to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	Integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. See 10.3.7.
aTxPHYDelay	Integer	The nominal time (in microseconds) that the PHY uses to deliver a symbol from the MAC interface to the air interface.
aRxPHYDelay	Integer	The nominal time (in microseconds) that the PHY uses to deliver the last bit of a received frame from end of the last symbol on the WM to the MAC.
aRxTxSwitchTime	Integer	The nominal time (in microseconds) that the PHY takes to switch from Receive to Transmit.
aTxRampOnTime	Integer	The maximum time (in microseconds) that the PHY takes to turn the Transmitter on.
aAirPropagationTime	Integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	Integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following a SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. See 10.3.7.
aRIFSTime	Integer	Value of the reduced interframe space (in microseconds), which is the time by which multiple transmissions from a single transmitter may be separated, when no SIFS-separated response transmission is expected. See 10.3.2.3.2.
aSymbolLength	Integer	The current PHY's Symbol length (in microseconds). If the actual value of the length is not an integer number of μs, the value is rounded up to the next higher value.
aPSDUMaxLength	Integer	The maximum number of octets in a PSDU that can be conveyed by a PPDU.
aPSDUMaxLengthWithNoAggregation	Integer	The maximum number of octets in a PSDU that can be conveyed by an S1G PPDU when the Aggregation field is 0.
aPPDUMaxTime	Integer	The maximum duration of a PPDU in milliseconds.
aIUSTime	Integer	The minimum time between the end of a PSMP-UTT and the start of the following PSMP-UTT in the same PSMP sequence.
aDTT2UTTTime	Integer	The minimum time between the end of a PSMP-DTT and the start of the PSMP-UTT addressed to the same STA.
aCWmin	Integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	Integer	The maximum size of the CW, in units of aSlotTime.
aMaxCSIMatricesReportDelay	Integer	The maximum time (in milliseconds) between the reception of a frame containing a CSI Feedback Request or an HT NDP announcement and the transmission of the first CSI frame containing channel state information measured from the received Sounding Complete frame. See 10.34.2.4.4.
aMaxTODError	Integer	An estimate of the maximum error (in 10 ns units) in the TX_START_OF_FRAME_OFFSET value in the PHY-TXSTART.confirm primitive. The estimated maximum error includes any error due to implementation component and environmental (including temperature) variability.
aMaxTOAError	Integer	An estimate of the maximum error (in 10 ns units) in the RX_START_OF_FRAME_OFFSET value in the PHY-RXSTART.indication primitive. The estimated maximum error includes any error due to implementation component and environmental (including temperature) variability.

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Name	Type	Description
aTxPHYTxStartRFDelay	Integer	The delay (in units of 0.5 ns) between a PHY-TXSTART.request primitive being issued and the first frame energy sent by the transmitting port, for the current channel.
aTxPHYTxStartRMS	Integer	The RMS time of departure error (in units of 0.5 ns), where the time of departure error equals the difference between TIME_OF_DEPARTURE and the time of departure measured by a reference entity using a clock synchronized to the start time and mean frequency of the local PHY entity's clock.
aMaxTODFineError	Integer	An estimate of the maximum error (in units of picoseconds) in the TX_START_OF_FRAME_OFFSET value in the PHY-TXSTART.confirm primitive. The estimated maximum error includes any error due to implementation component and environmental (including temperature) variability.
aMaxTOAFineError	Integer	An estimate of the maximum error (in units of picoseconds) in the RX_START_OF_FRAME_OFFSET value in the PHY-RXSTART.indication primitive. The estimated maximum error includes any error due to implementation component and environmental (including temperature) variability.
aAPEPMaxLengthVHTMU20	Integer	Maximum APEP_LENGTH value allowed for 20 MHz VHT MU PPDUs.
aAPEPMaxLengthVHTMU40	Integer	Maximum APEP_LENGTH value allowed for 40 MHz VHT MU PPDUs.
aAPEPMaxLengthVHTMU80orMore	Integer	Maximum APEP_LENGTH value allowed for 80 MHz, 160 MHz, and 80+80 MHz VHT MU PPDUs.

6.5.4.3 When generated

This primitive is issued by the PHY entity in response to a PLME-CHARACTERISTICS.request primitive.

6.5.4.4 Effect of receipt

The receipt of this primitive provides the operational characteristics of the PHY entity.

6.5.5 PLME-TXTIME.request

6.5.5.1 Function

This primitive is a request for the PHY to calculate the time required to transmit onto the WM a PPDU containing a specified length PSDU, and using a specified format, data rate, and signaling.

6.5.5.2 Semantics of the service primitive

This primitive provides the following parameter:

```
PLME-TXTIME.request(
                    TXVECTOR
                    )
```

The TXVECTOR represents a list of parameters that the MAC sublayer provides to the local PHY entity in order to transmit a PSDU. The minimum required PHY parameters are listed in 8.3.4.4.

6.5.5.3 When generated

This primitive is issued by the MAC sublayer to the PHY entity when the MAC sublayer needs to determine the time required to transmit a particular PSDU.

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6.5.5.4 Effect of receipt

The effect of receipt of this primitive by the PHY entity is to generate a PHY-TXTIME.confirm primitive that conveys the required transmission time.

6.5.6 PLME-TXTIME.confirm

6.5.6.1 Function

This primitive indicates the time required to transmit the PPDU described in the corresponding PLME-TXTIME.request primitive.

When the TXVECTOR parameter FORMAT in the corresponding PLME-TXTIME.request primitive is VHT, the primitive also provides the number of octets, per user, required to fill the PPDU.

6.5.6.2 Semantics of the service primitive

This primitive provides the following parameter:

```
PLME-TXTIME.confirm(
                        TXTIME
                        PSDU_LENGTH[]
                        )
```

The TXTIME represents the time, in microseconds, required to transmit the PPDU described in the corresponding PLME-TXTIME.request primitive. If the calculated time includes a fractional microsecond, a non-DMG STA rounds the TXTIME value to the next higher integer. A DMG STA does not round the TXTIME value up or down (see 20.11.3).

The PSDU_LENGTH[] parameter is an array of size TXVECTOR parameter NUM_USERS. Each value in the array indicates the number of octets required to fill the PPDU for the user represented by that array index. The parameter is present only when the TXVECTOR FORMAT parameter is VHT.

6.5.6.3 When generated

This primitive is issued by the local PHY entity in response to a PLME-TXTIME.request primitive.

6.5.6.4 Effect of receipt

The receipt of this primitive provides the MAC sublayer with the PPDU transmission time.

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7. DS SAP specification

7.1 Introduction

The DS SAP is the interface between the DS SAP service users and the DS SAP service provider. The DS SAP service users are the connected APs, mesh gates, and the portal. The DS SAP service provider is the DS. Figure 7-1 shows the location of the DS in the IEEE 802.11 architecture. The DS SAP is indicated in this Figure by the lines connecting the DS to its service users. In Figure 7-1, the DS has four users, two APs, a mesh gate, and a portal, so the DS is shown passing behind the MAC/PHYs of the STAs.

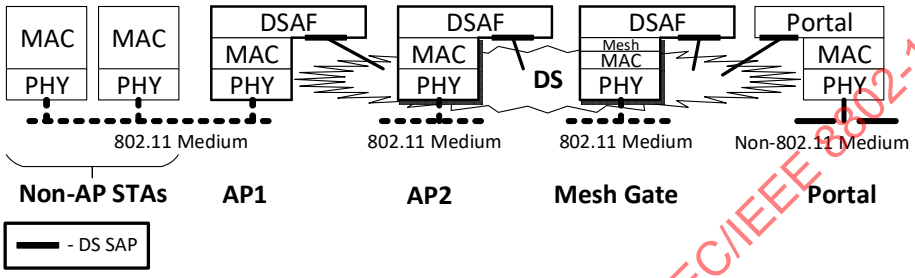

Figure 7-1—DS architecture

The DS SAP interface specification describes the primitives required to get MAC service tuples in and out of the DS and update the DS's mapping of STAs to APs or to mesh gates. Describing the DS itself or the functions thereof is out of scope of this standard.

The DS SAP actions are as follows:

a) Accept MSDUs (as part of MAC service tuples) from APs, mesh gates, and the portal.
b) Deliver MSDUs (as part of MAC service tuples) to APs, mesh gates, or the portal.
c) Accept STA-to-AP mapping updates from the APs.
d) Accept STA-to-mesh gate mapping updates from the mesh gates.

When the DS delivers the MAC service tuples to an AP, the AP then determines when and how to deliver the MAC service tuples to the AP's MAC (via the MAC SAP). When the DS delivers the MAC service tuples to a mesh gate, the mesh gate then determines when and how to deliver the MAC service tuples to the mesh gate's MAC (via the MAC SAP).

7.2 SAP primitives

7.2.1 General

The DS SAP service interface primitives are as follows:

a) DS-UNITDATA.request
b) DS-UNITDATA.indication
c) DS-STA-NOTIFY.request

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7.2.2 MSDU transfer

7.2.2.1 General

The DS-UNITDATA primitives accept and deliver IEEE 802.11 MAC service tuples, including all of the parameters and data as defined in 5.2.3.2.

7.2.2.2 DS-UNITDATA.request

7.2.2.2.1 Function

This primitive requests distribution of a MAC service tuple across the DS.

7.2.2.2.2 Semantics of the service primitive

The primitive parameters are as follows:

DS-UNITDATA.request(
MAC service tuple,
SourceType
)

Name	Type	Valid range	Description
MAC service tuple	IEEE 802.11 MSDU	Any valid data unit according to 5.2.3.2, including data and all parameters	Specifies the MAC service tuple to be distributed via the DS.
SourceType	Enumeration	SRC_AP, SRC_MESH_GATE, SRC_PORTAL	Specifies the type of entity that is requesting distribution of a MAC service tuple.

7.2.2.2.3 When generated

This primitive is generated by an AP, mesh gate, or portal to submit a MAC service tuple to the DS for distribution.

7.2.2.2.4 Effect of receipt

This primitive initiates distribution of the MAC service tuple through the DS. An individually addressed MAC service tuple from an AP, mesh gate, or portal is distributed through the DS to the corresponding AP, mesh gate, or portal. A group addressed MAC service tuple from an AP is distributed to all APs, mesh gates, and the portal, including the originating entity. A group addressed MAC service tuple from a portal is distributed to all APs and mesh gates.

7.2.2.3 DS-UNITDATA.indication

7.2.2.3.1 Function

This primitive indicates delivery of a MAC service tuple from the DS to an AP, mesh gate, or portal.

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7.2.2.3.2 Semantics of the service primitive

The primitive parameters are as follows:

DS-UNITDATA.indication(
MAC service tuple
)

Name	Type	Valid range	Description
MAC service tuple	IEEE 802.11 MSDU	Any valid data unit according to 5.2.3.2, including data and all parameters	Specifies the MAC service tuple that is being delivered by the DS.

7.2.2.3.3 When generated

This primitive is generated by the DS to deliver a MAC service tuple to an AP, mesh gate, or portal.

7.2.2.3.4 Effect of receipt

This primitive delivers a MAC service tuple to an AP, mesh gate, or portal.

7.2.3 Mapping updates

7.2.3.1 General

The DS-STA-NOTIFY primitive is used to maintain the STA-to-AP and mesh STA-to-mesh gate mapping data of the DS.

7.2.3.2 DS-STA-NOTIFY.request

7.2.3.2.1 Function

This primitive requests an update to the DS's STA-to-AP map or mesh STA-to-mesh gate map.

7.2.3.2.2 Semantics of the service primitive

The primitive parameters are as follows:

DS-STA-NOTIFY.request(
STAAddress,
UpdateType
)

Name	Type	Valid range	Description
STAAddress	MACAddress	Any valid individual MAC address	When generated by an AP, specifies the address of the STA whose association status with the AP has changed. When generated by a mesh gate, specifies the address of the mesh STA whose reachability status through the mesh gate has changed.
UpdateType	Enumeration	ADD, MOVE, DELETE	Specifies the DS mapping update operation to be performed.

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7.2.3.2.3 When generated

This primitive is generated by an AP or mesh gate to update the DS's STA-to-AP map or mesh STA-to-mesh gate map.

7.2.3.2.4 Effect of receipt

When generated by an AP, this primitive updates the DS's STA-to-AP map, which controls to which AP the DS delivers MAC service tuples that are destined for a given STA.

When generated by a mesh gate, this primitive updates the DS's mesh STA-to-mesh gate map, which controls to which mesh gate the DS delivers MAC service tuples that are destined for a given mesh STA. The mesh STA-to-mesh gate map can be incomplete.

There are many mechanisms to implement this mapping update for the cases of ADD and MOVE. One example mechanism, in the case where the DS is an IEEE 802 LAN, is to use an IEEE 802.2™ XID null frame.

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8. PHY service specification

8.1 Scope of PHY services

The PHY services provided to the MAC are described in this clause. Different PHYs are defined as part of this standard. Each PHY can consist of the following protocol functions:

a) A function that defines a method of mapping the MPDUs into a framing format suitable for sending and receiving user data and management information between two or more STAs.

b) A function that defines the characteristics of, and method of transmitting and receiving data through, a WM between two or more STAs.

8.2 PHY functions

The protocol reference model for the IEEE 802.11 architecture is shown in Figure 4-24 (in 4.9). Most PHY definitions contain two functional entities: the PHY function and the layer management function.

The PHY service is provided to the MAC entity at the STA through a SAP, called the *PHY SAP*, as shown in Figure 4-24.

8.3 Detailed PHY service specifications

8.3.1 Scope and field of application

The services provided by the PHY to the MAC are specified in this subclause. These services are described in an abstract way and do not imply any particular implementation or exposed interface.

8.3.2 Overview of the service

The function of the PHY is to provide a mechanism for transferring MPDUs between two or more STAs.

8.3.3 Overview of interactions

The primitives associated with communication between the MAC sublayer and the PHY fall into two basic categories:

a) Service primitives that support MAC peer-to-peer interactions

b) Service primitives that have local significance and support sublayer-to-sublayer interactions

8.3.4 Basic service and options

8.3.4.1 PHY SAP peer-to-peer service primitives

Table 8-1 indicates the primitives for peer-to-peer interactions.

Table 8-1—PHY SAP peer-to-peer service primitives

Primitive	Request	Indication	Confirm
PHY-DATA	X	X	X

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8.3.4.2 PHY SAP inter-(sub)layer service primitives

Table 8-2 indicates the primitives for sublayer-to-sublayer interactions.

Table 8-2—PHY SAP inter-(sub)layer service primitives

Primitive	Request	Indication	Confirm
PHY-TXSTART	X		X
PHY-TXEND	X		X
PHY-CCARESET	X		X
PHY-CCA		X	
PHY-RXSTART		X	
PHY-RXEND		X	
PHY-CONFIG	X		X
PHY-TXHEADEREND		X	

8.3.4.3 PHY SAP service primitives parameters

Table 8-3 shows the parameters used by one or more of the PHY SAP service primitives.

Table 8-3—PHY SAP service primitive parameters

Parameter	Associated primitive	Value
DATA	PHY-DATA.request PHY-DATA.indication	Octet value X'00'–X'FF'
TXVECTOR	PHY-TXSTART.request	A set of parameters
STATE	PHY-CCA.indication	(BUSY, [channel-list]) (IDLE)
RXVECTOR	PHY-RXSTART.indication	A set of parameters
RCPI	PHY-RXEND.indication	Clauses 15–19 and 21–23: 0–255; Clauses 20, 24, and 25: not present
RXERROR	PHY-RXEND.indication	NoError, FormatViolation, CarrierLost, UnsupportedRate, Filtered
IPI-STATE	PHY-CCARESET.request PHY-CCARESET.confirm	IPI-ON, IPI-OFF
IPI-REPORT	PHY-CCA.indication PHY-CCARESET.confirm	A set of IPI values for the preceding time interval

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Table 8-3—PHY SAP service primitive parameters *(continued)*

Parameter	Associated primitive	Value
PHYCONFIG_VECTOR	PHY-CONFIG	A set of parameters
TXSTATUS	PHY-TXSTART.confirm	A set of parameters
USER_INDEX	PHY-DATA.request	0 to TXVECTOR parameter NUM_USERS – 1

8.3.4.4 Vector descriptions

Several service primitives include a parameter vector. This vector is a list of parameters that may vary depending on the PHY type. Table 8-4 lists the minimum parameter values required by the MAC or PHY in each of the parameter vectors.

Table 8-4—Vector descriptions

Parameter	Associated vector	Value
DATARATE	TXVECTOR, RXVECTOR	PHY dependent. The name of the field used to specify the Tx data rate and report the Rx data rate may vary for different PHYs.
LENGTH	TXVECTOR, RXVECTOR	PHY dependent.
ACTIVE_RXCHAIN_SET	PHYCONFIG_VECTOR	The ACTIVE_RXCHAIN_SET parameter indicates which receive chains of the available receive chains are active.
OPERATING_CHANNEL	PHYCONFIG_VECTOR	The operating channel the PHY is configured use.
SECONDARY_CHANNEL_OFFSET	PHYCONFIG_VECTOR	Enumerated type: SECONDARY_CHANNEL_NONE indicates operation in 20 MHz HT STAs. SECONDARY_CHANNEL_ABOVE indicates operation in 40 MHz with the secondary channel above the primary. SECONDARY_CHANNEL_BELOW indicates operation in 40 MHz with the secondary channel below the primary.
ANT_CONFIG	PHYCONFIG_VECTOR	Indicates which antenna configuration(s) is to be used when receiving PPDUs and which configuration is to be used when switching configurations during the reception of a PPDU. Values are implementation dependent.
GROUP_ID_MANAGEMENT	PHYCONFIG_VECTOR	Specifies membership status and STA position for each of the group IDs as described in 9.6.22.3.
PARTIAL_AID_LIST_GID00	PHYCONFIG_VECTOR	For a non-S1G STA, includes the list of partial AIDs, of which the STA is an intended recipient, associated with group ID 0. The settings of the PARTIAL_AID are specified in 10.19). For an S1G STA, includes the list of partial AIDs, of which the S1G STA is an intended recipient, in which a frame is addressed to an AP. The settings of the PARTIAL_AID are specified in 10.21.

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Table 8-4—Vector descriptions *(continued)*

Parameter	Associated vector	Value
PARTIAL_AID_LIST_GID63	PHYCONFIG_VECTOR	For a non-S1G STA, includes the list of partial AIDs, of which the STA is an intended recipient, associated with group ID 63. The settings of the PARTIAL_AID are specified in 10.19). For an S1G STA, includes the list of partial AIDs, of which the S1G STA is an intended recipient, in which a frame is addressed to a non-AP STA. The settings of the PARTIAL_AID are specified in 10.21.
LISTEN_TO_GID00	PHYCONFIG_VECTOR	When true, indicates to the PHY not to filter out PPDUs with GROUP_ID field equal to the value 0.
LISTEN_TO_GID63	PHYCONFIG_VECTOR	When true, indicates to the PHY not to filter out PPDUs with GROUP_ID field equal to the value 63.
CCA_SENSITIVITY_TYPE	PHYCONFIG_VECTOR	Enumerated type: CCA_SENSITIVITY_TYPE_1 indicates that the PHY issues a PHY-CCA.indication primitive based on the CCA conditions listed in Table 23-36 and 23.3.18.5.5. CCA_SENSITIVITY_TYPE_2 indicates that the PHY issues a PHY-CCA.indication primitive based on the CCA conditions listed in Table 23-37 and 23.3.18.5.5. CCA_SENSITIVITY_TYPE_2_WIDEBAND indicates that the PHY issues a PHY-CCA.indication primitive based on the CCA conditions listed in Table 23-36 and 23.3.18.5.5.

The Clause 19 PHY TXVECTOR and RXVECTOR contain additional parameters related to the operation of the Clause 19 PHY modes of operation as described in 19.2. In certain modes of operation, the DATARATE parameter is replaced by MCS, CH_BANDWIDTH and GI_TYPE parameters. The mapping from these values to data rate is defined in 19.5.

The Clause 21 PHY TXVECTOR and RXVECTOR contain additional parameters related to the operation of the Clause 21 PHY modes of operation as described in 21.2. In certain modes of operation, the DATARATE parameter is replaced by MCS, CH_BANDWIDTH, NUM_STS, STBC and GI_TYPE parameters. The mapping from these values to data rate is defined in 21.5, where VHT-MCS is MCS and N_{SS} is NUM_STS / (STBC + 1).

8.3.5 PHY SAP detailed service specification

8.3.5.1 Introduction

Subclause 8.3.5 describes the services provided by each PHY primitive.

8.3.5.2 PHY-DATA.request

8.3.5.2.1 Function

This primitive defines the transfer of an octet of data from the MAC sublayer to the local PHY entity.

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8.3.5.2.2 Semantics of the service primitive

The primitive provides the following parameter:

```
PHY-DATA.request(
                    DATA,
                    USER_INDEX
                    )
```

The DATA parameter is an octet of value X'00' to X'FF'.

The USER_INDEX parameter (typically identified as *u* for a VHT STA; see NOTE for MU usage at the end of Table 21-1) is present for a VHT MU PPDU and indicates the index of the user in the TXVECTOR to which the accompanying DATA octet applies; otherwise, this parameter is not present.

8.3.5.2.3 When generated

This primitive is generated by the MAC sublayer to transfer an octet of data to the PHY entity. This primitive can be issued only following a transmit initialization response (a PHY-TXSTART.confirm primitive) from the PHY.

8.3.5.2.4 Effect of receipt

The receipt of this primitive by the PHY entity causes the PHY transmit state machine to transmit an octet of data. When the PHY entity receives the octet, it issues a PHY-DATA.confirm primitive to the MAC sublayer.

8.3.5.3 PHY-DATA.indication

8.3.5.3.1 Function

This primitive indicates the transfer of data from the PHY to the local MAC entity.

8.3.5.3.2 Semantics of the service primitive

The primitive provides the following parameter:

```
PHY-DATA.indication(
                    DATA
                    )
```

The DATA parameter is an octet of value X'00' to X'FF'.

8.3.5.3.3 When generated

The PHY-DATA.indication primitive is generated by a receiving PHY entity to transfer the received octet of data to the local MAC entity. The time between receipt of the last bit of the last provided octet from the WM and the receipt of this primitive by the MAC entity is aRxPHYDelay.

8.3.5.3.4 Effect of receipt

The receipt of this primitive by the MAC entity causes the MAC to collect the data octet provided by the PHY in the current receive flow (see Figure 5-1).

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8.3.5.4 PHY-DATA.confirm

8.3.5.4.1 Function

This primitive is issued by the PHY to the local MAC entity to confirm the transfer of data from the MAC entity to the PHY.

8.3.5.4.2 Semantics of the service primitive

The semantics of the primitive are as follows:
PHY-DATA.confirm

This primitive has no parameters.

8.3.5.4.3 When generated

This primitive is issued by the PHY to the MAC entity when the transfer of data from the MAC entity to the PHY has completed. The PHY issues this primitive in response to every PHY-DATA.request primitive issued by the MAC sublayer.

8.3.5.4.4 Effect of receipt

The receipt of this primitive by the MAC causes the MAC to start the next MAC entity request.

8.3.5.5 PHY-TXSTART.request

8.3.5.5.1 Function

This primitive is a request by the MAC sublayer to the local PHY entity to start the transmission of a PSDU.

8.3.5.5.2 Semantics of the service primitive

The primitive provides the following parameter:
PHY-TXSTART.request(
TXVECTOR
)

The TXVECTOR represents a list of parameters that the MAC sublayer provides to the local PHY entity in order to transmit a PSDU. The minimum required PHY parameters are listed in 8.3.4.4.

See 1.4 for interpretation of references to frames, MPDUs, A-MPDUs and PPDUs being transmitted with a certain TXVECTOR.

8.3.5.5.3 When generated

This primitive is issued by the MAC sublayer to the PHY entity when the MAC sublayer needs to begin the transmission of a PSDU.

8.3.5.5.4 Effect of receipt

The effect of receipt of this primitive by the PHY entity is to start the local transmit state machine.

The behavior expected by the MAC pursuant to the issuance of PHY-TXSTART.request primitive is shown in Figure 10-21 (in 10.3.7) and Figure 10-25.

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8.3.5.6 PHY-TXSTART.confirm

8.3.5.6.1 Function

This primitive is issued by the PHY to the local MAC entity to confirm the start of a transmission and to indicate parameters related to the start of the transmission. The PHY issues this primitive in response to every PHY-TXSTART.request primitive issued by the MAC sublayer.

8.3.5.6.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
PHY-TXSTART.confirm(
                    TXSTATUS
                    )
```

The TXSTATUS represents a list of parameters that the local PHY entity provides to the MAC sublayer related to the transmission of a PPDU. The list of parameters is PHY-dependent.

8.3.5.6.3 When generated

This primitive is issued by the PHY to the MAC entity once all of the following conditions are met:

— The PHY has received a PHY-TXSTART.request primitive from the MAC entity.
— The PHY is ready to begin accepting outgoing data octets from the MAC.

If dot11TODImplemented and dot11TODActivated are both true or dot11TimingMsmtActivated is true; and the parameter TIME_OF_DEPARTURE_REQUESTED in the TXVECTOR specified in the PHY-TXSTART.request primitive is true, then the PHY shall include the TIME_OF_DEPARTURE corresponding to the time when the first frame energy is sent by the transmitting port and TIME_OF_DEPARTURE_ClockRate parameters in the TXSTATUS, if the PHY includes these parameters in the TXSTATUS.

If dot11TimingMsmtActivated is true, then the PHY shall include TX_START_OF_FRAME_OFFSET in the TXSTATUS, if the PHY includes this parameter in the TXSTATUS.

8.3.5.6.4 Effect of receipt

The receipt of this primitive by the MAC entity causes the MAC to start the transfer of data octets. Parameters in the TXSTATUS can be included in transmitted MPDUs. See Annex P for use of TXSTATUS parameters for timing.

8.3.5.7 PHY-TXEND.request

8.3.5.7.1 Function

This primitive is a request by the MAC sublayer to the local PHY entity that the current transmission of the PSDU be completed.

8.3.5.7.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
PHY-TXEND.request
```

This primitive has no parameters.

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8.3.5.7.3 When generated

This primitive is generated when the MAC sublayer has received the last PHY-DATA.confirm primitive from the local PHY entity for the PSDU currently being transferred.

8.3.5.7.4 Effect of receipt

The effect of receipt of this primitive by the local PHY entity is to stop the transmit state machine.

8.3.5.8 PHY-TXEND.confirm

8.3.5.8.1 Function

This primitive is issued by the PHY to the local MAC entity to confirm the completion of a transmission. The PHY issues this primitive in response to every PHY-TXEND.request primitive issued by the MAC sublayer.

8.3.5.8.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
PHY-TXEND.confirm(
                    SCRAMBLER_OR_CRC
                    )
```

The SCRAMBLER_OR_CRC parameter is present if dot11S1GOptionImplemented is true. The value of SCRAMBLER_OR_CRC parameter depends on the type of the transmitted frame:

- When transmitting a PPDU that is not an NDP CMAC PPDU, the value of the SCRAMBLER_OR_CRC parameter is the Scrambler Initialization value in the Service field after scrambling (i.e., [B0:B6] of the Service field]) (as defined in 23.3.9.2) of the frame.
- When transmitting an NDP CMAC PPDU, the value of the SCRAMBLER_OR_CRC parameter is the calculated CRC value in the SIG/SIG-A field (as defined in 23.3.8.2.2.6) as follows:
  - When the frame is an NDP_1M CMAC frame, the value of SCRAMBLER_OR_CRC parameter is equal to [B26:B29] of the SIG field.
  - When the frame is an NDP_2M CMAC frame, the value of SCRAMBLER_OR_CRC parameter is equal to [B38:B41] of the ≥2 MHz SIG-A field.

8.3.5.8.3 When generated

This primitive is issued by the PHY to the MAC entity when the PHY has received a PHY-TXEND.request primitive immediately after transmitting the end of the last bit of the last data octet indicating that the symbol containing the last data octet has been transferred and any signal extension has expired.

8.3.5.8.4 Effect of receipt

The receipt of this primitive by the MAC entity provides the time reference for the contention backoff protocol.

8.3.5.9 PHY-TXHEADEREND.indication

8.3.5.9.1 Function

This primitive indicates the transmission completion of the PHY header to the local MAC entity.

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8.3.5.9.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PHY-TXHEADEREND.indication

This primitive has no parameters.

8.3.5.9.3 When generated

The PHY-TXHEADEREND.indication primitive is generated by a transmitter PHY entity at the end of transmission of the last symbol containing the PHY header.

8.3.5.9.4 Effect of receipt

The receipt of this primitive by the MAC entity causes the MAC to record the time when this primitive is received only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding PHY-TXSTART.request primitive.

8.3.5.10 PHY-CCARESET.request

8.3.5.10.1 Function

This primitive is a request by the MAC sublayer to the local PHY entity to reset the PHY to the state appropriate for the end of a received frame and to turn IPI reporting on and off by means of the IPI-STATE parameter.

8.3.5.10.2 Semantics of the service primitive

The primitive provides the following parameter:

```
PHY-CCARESET.request(
                        IPI-STATE
                        )
```

The IPI-STATE parameter is present if dot11RadioMeasurementActivated is true. The IPI-STATE parameter can be one of two values: IPI-ON or IPI-OFF. The parameter value is IPI-ON when the MAC sublayer is requesting the PHY entity to report IPI values when the PHY is neither receiving nor transmitting a PPDU. IPI-ON turns on IPI reporting in the PHY entity. IPI-OFF turns off IPI reporting in the PHY entity.

8.3.5.10.3 When generated

This primitive is generated by the MAC sublayer for the local PHY entity at the end of a NAV and at a time indicated in 10.3.2.1 after each MAC slot boundary, which is described in 10.3.7 and 10.23.2.4. This request can be used by some PHY implementations that may synchronize antenna diversity with slot timings.

8.3.5.10.4 Effect of receipt

The effect of receipt of this primitive by the PHY entity is to reset the PHY to the state appropriate for the end of a received frame and to initiate a new CCA evaluation cycle. If IPI-STATE parameter is IPI-ON, the PHY entity collects IPI values when it is not transmitting or receiving and provides those values to the MAC sublayer using the IPI-REPORT parameter.

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8.3.5.11 PHY-CCARESET.confirm

8.3.5.11.1 Function

This primitive is issued by the PHY to the local MAC entity to provide observed IPI values if IPI reporting was turned on prior to the receipt of the latest PHY-CCARESET.request primitive. This primitive is not issued by the PHY if IPI reporting was turned off prior to the receipt of the latest PHY-CCARESET.request primitive.

8.3.5.11.2 Semantics of the service primitive

The primitive provides the following parameters:

PHY-CCARESET.confirm(
IPI-REPORT
)

The IPI-REPORT parameter provides a set of IPI values for a time interval. The set of IPI values are recent values observed by the PHY entity since the generation of the most recent PHY-TXEND.confirm, PHY-RXEND.indication, PHY-CCARESET.confirm, or PHY-CCA.indication primitive, whichever occurred latest.

8.3.5.11.3 When generated

This primitive is issued by the PHY to the MAC entity when IPI reporting was turned on prior to the receipt of the latest PHY-CCARESET.request primitive.

8.3.5.11.4 Effect of receipt

The receipt of this primitive by the MAC entity causes the MAC to collect IPI values when IPI reporting was turned on prior to the receipt of the latest PHY-CCARESET.request primitive.

8.3.5.12 PHY-CCA.indication

8.3.5.12.1 Function

This primitive is an indication by the PHY to the local MAC entity of the current state of the medium and to provide observed IPI values when IPI reporting is turned on.

8.3.5.12.2 Semantics of the service primitive

The primitive provides the following parameters:

PHY-CCA.indication(
STATE,
IPI-REPORT,
channel-list
)

The STATE parameter can be one of two values: BUSY or IDLE. The parameter value is BUSY if the assessment of the channel(s) by the PHY determines that the channel(s) are not available. Otherwise, the value of the parameter is IDLE.

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The IPI-REPORT parameter is present if dot11RadioMeasurementActivated is true and if IPI reporting has been turned on by the IPI-STATE parameter. The IPI-REPORT parameter provides a set of IPI values for a time interval. The set of IPI values may be used by the MAC sublayer for radio measurement purposes. The set of IPI values are recent values observed by the PHY entity since the generation of the most recent PHY-TXEND.confirm, PHY-RXEND.indication, PHY-CCARESET.confirm, or PHY-CCA.indication primitive, whichever occurred latest.

When STATE is IDLE or when, for the type of PHY in operation, CCA is determined by a single channel, the channel-list parameter is absent. Otherwise, it carries a set indicating which channels are busy. The channel-list parameter in a PHY-CCA.indication primitive generated by a VHT or S1G STA contains at most a single entry. Table 8-5 defines the members of this set.

Table 8-5—The channel-list parameter entries

Channel-list parameter entry	Meaning
primary	In an HT STA that is not a VHT STA, indicates that the primary channel is busy according to the rules specified in 19.3.19.5.2. In a VHT STA, indicates that the primary 20 MHz channel is busy according to the rules specified in 21.3.18.5.3. In a TVHT STA, indicates that the primary channel is busy according to the rules specified in 22.3.18.6.3.
secondary	In an HT STA that is not a VHT STA, indicates that the secondary channel is busy according to the rules specified in 19.3.19.5.5. In a VHT STA, indicates that the secondary 20 MHz channel is busy according to the rules specified in 21.3.18.5.4. In a TVHT STA, indicates that the secondary channel is busy according to the rules specified in 22.3.18.6.4.
secondary40	In a VHT STA, indicates that the secondary 40 MHz channel is busy according to the rules specified in 21.3.18.5.4. In a TVHT STA, indicates that the secondary TVHT_2W channel is busy according to the rules specified in 22.3.18.6.4.
secondary80	In a VHT STA, indicates that the secondary 80 MHz channel is busy according to the rules specified in 21.3.18.5.4.
primary1	In an S1G STA, indicates that the primary 1 MHz channel is busy according to the rules specified in 23.3.18.5.4
primary2	In an S1G STA, indicates that the primary 2 MHz channel is busy according to the rules specified in 23.3.18.5.4.
secondary2	In an S1G STA, indicates that the secondary 2 MHz channel is busy according to the rules specified in 23.3.18.5.5.
secondary4	In an S1G STA, indicates that the secondary 4 MHz channel is busy according to the rules specified in 23.3.18.5.5.
secondary8	In an S1G STA, indicates that the secondary 8 MHz channel is busy according to the rules specified in 23.3.18.5.5.

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The relationship of the channel-list parameter entries to the 40 MHz, 80 MHz, and 160 MHz BSS operating channel is illustrated by example in Figure 8-1. The relationship of the channel-list parameter entries to the 80+80 MHz BSS operating channel is illustrated by example in Figure 8-2.

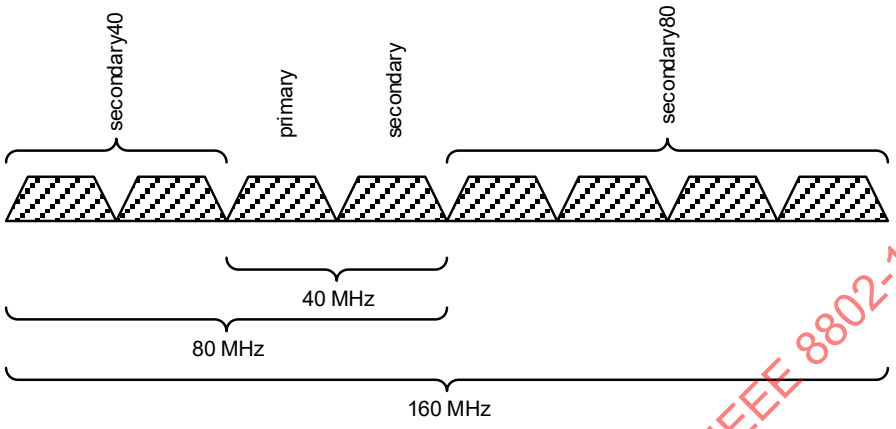

Figure 8-1—The channel-list parameter entry for 40 MHz, 80 MHz, and 160 MHz channel width

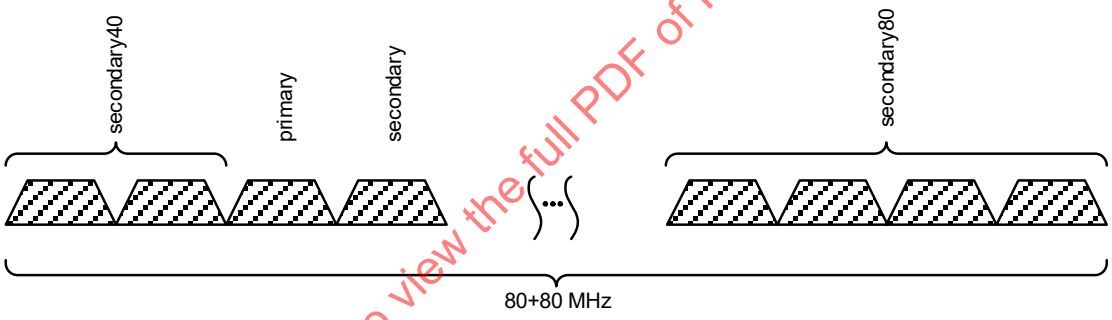

Figure 8-2—The channel-list parameter entry for 80+80 MHz channel width

For a TVHT STA, the relationship of the channel-list parameter entries to the TVHT_W, TVHT_2W, and TVHT_W+W BSS operating channel is illustrated in Figure 8-3.

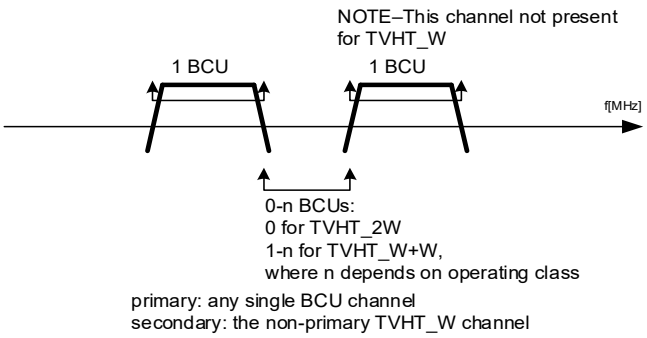

Figure 8-3—TVHT channel-list parameter entry and channel bandwidth for TVHT_W, TVHT_2W, and TVHT_W+W

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For a TVHT STA, the relationship of the channel-list parameter entries to the TVHT_4W and TVHT_2W+2W BSS operating channel is illustrated in Figure 8-4.

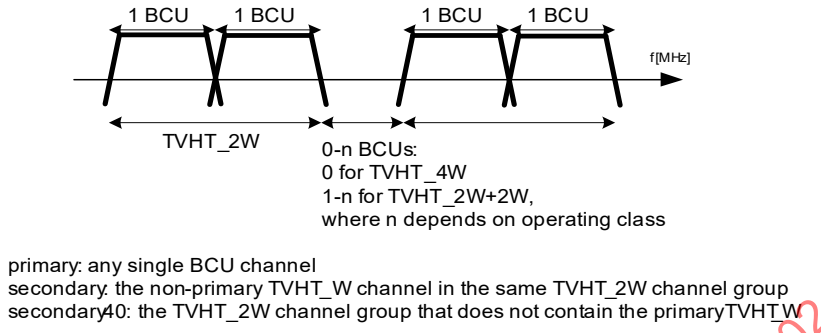

Figure 8-4—TVHT channel-list parameter entry and channel bandwidth for TVHT_4W and TVHT_2W+2W

For an S1G STA, the relationship of the channel-list parameter entries to the 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz BSS operating channel is illustrated by example Figure 8-5.

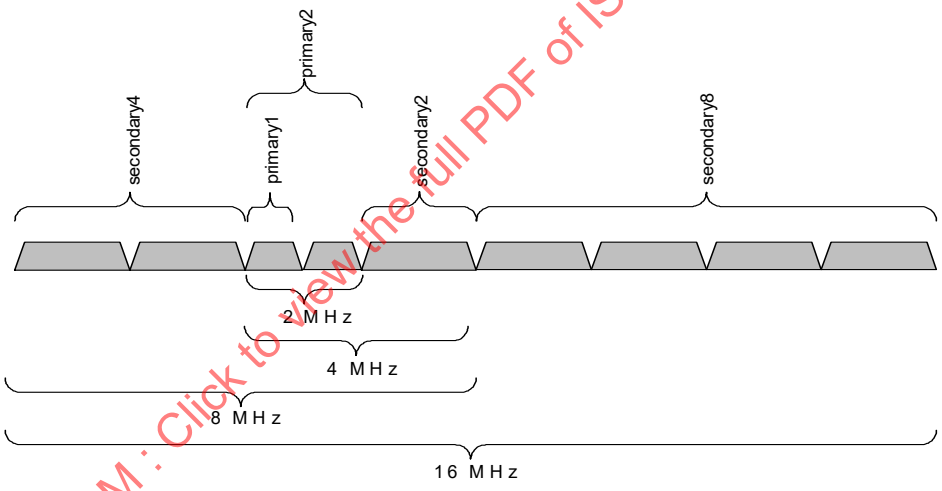

Figure 8-5—The channel-list parameter entries for the 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz channel width

8.3.5.12.3 When generated

For Clause 15 to Clause 20 PHYs, this primitive is generated within aCCATime of the occurrence of a change in the status of the primary channel from channel idle to channel busy or from channel busy to channel idle or when the entries of the channel-list parameter change. For Clause 21 and Clause 22 PHYs, this primitive is generated when the status of the channel(s) changes from channel idle to channel busy or from channel busy to channel idle or when the entries of the channel-list parameter change. This includes the period of time when the PHY is receiving data. The timing of PHY-CCA.indication primitives related to transitions on secondary channel(s) is PHY specific. Refer to specific PHY clauses for details about CCA behavior for a given PHY.

NOTE—For the VHT PHY, the timing information is omitted here and is defined in 21.3.18.5.

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If the STA is an HT STA but not a VHT STA and the operating channel width is 20 MHz, the PHY maintains the channel busy indication until the period indicated by the LENGTH field has expired, where the LENGTH field is

— In a valid SIG field if the format of the PPDU is NON_HT
— In a valid HT-SIG field if the format of the PPDU is HT_MF or HT_GF

If the STA is an HT STA but not a VHT STA and the operating channel width is 40 MHz, the PHY maintains the channel busy indication until the period indicated by the LENGTH field has expired, where the LENGTH field is

— In a valid SIG field if the format of the PPDU is NON_HT and the PPDU is received in the primary channel
— In a valid HT-SIG field if the format of the PPDU is HT_MF or HT_GF provided that the PPDU is either a 20 MHz PPDU received in the primary channel or a 40 MHz PPDU

When the PHY is supporting one or more MAC entities that are coordinated by an MM-SME, this primitive is generated upon PHY-TXSTART or PHY-TXEND actions from those MAC entities. A PHY-CCA.indication primitive with STATE set to BUSY is generated when the PHY issues a PHY-TXSTART.confirm primitive to one of the MAC entities coordinated by an MM-SME, and it is generated to all coordinated MAC entities except to the one to which it responds with the PHY-TXSTART.confirm primitive. A PHY-CCA.indication primitive with STATE set to IDLE is generated when the PHY issues a PHY-TXEND.confirm primitive to one of the MAC entities coordinated by an MM-SME, and it is generated to all coordinated MAC entities except to the one to which it responds with the PHY-TXEND.confirm primitive. The ICI-REPORT parameter of the PHY-CCA.indication primitive is set as described above. The channel-list parameter is set to indicate the channels in use per the TXVECTOR of a PHY-TXSTART.request primitive from a coordinated MAC entity, or is not present when the PHY-CCA.indication primitive is generated in response to a PHY-TXEND.confirm primitive from a coordinated MAC entity.

8.3.5.12.4 Effect of receipt

The receipt of this primitive by the MAC entity causes the MAC to update the physical CS state, and to collect IPI values when IPI reporting was turned on.

8.3.5.13 PHY-RXSTART.indication

8.3.5.13.1 Function

This primitive is an indication by the PHY to the local MAC entity that the PHY has received a valid start of a PPDU, including a valid PHY header.

NOTE—This primitive is not generated until the PHY has determined the PPDU format (e.g., a VHT PPDU, which starts with an HT PHY header).

8.3.5.13.2 Semantics of the service primitive

The primitive provides the following parameter:

```
PHY-RXSTART.indication(
                        RXVECTOR
                        )
```

The RXVECTOR represents a list of parameters that the PHY provides the local MAC entity upon receipt of a valid PHY header. The required parameters are listed in 8.3.4.4.

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See 1.4 for interpretation of references to frames, MPDUs, A-MPDUs and PPDUs being received with a certain RXVECTOR.

8.3.5.13.3 When generated

This primitive is generated by the local PHY entity to the MAC sublayer when the PHY has successfully validated the PHY header at the start of a new PPDU.

After generating a PHY-RXSTART.indication primitive, the PHY is expected to maintain physical medium busy status (not generating a PHY-CCA.indication(IDLE) primitive) during the period required by that PHY to transfer a frame of the indicated LENGTH at the indicated DATARATE. This physical medium busy condition should be maintained even if a PHY-RXEND.indication(CarrierLost) primitive or a PHY-RXEND.indication(FormatViolation) primitive is generated by the PHY prior to the end of this period.

8.3.5.13.4 Effect of receipt

The receipt of this primitive by the MAC entity causes the MAC to prepare for a new receive flow (see Figure 5-1).

8.3.5.14 PHY-RXEND.indication

8.3.5.14.1 Function

This primitive is an indication by the PHY to the local MAC entity that the PPDU currently being received is complete.

8.3.5.14.2 Semantics of the service primitive

The primitive provides the following parameters:

```
PHY-RXEND.indication(
                        RXERROR,
                        RCPI
                        )
```

The RXERROR parameter can convey NoError or one or more values indicating an error condition. A number of error conditions may occur after the PHY's receive state machine has detected what appears to be a valid preamble and SFD. The following describes the parameter returned for each of those error conditions:

- *NoError*. This value is used to indicate that no error occurred during the receive process in the PHY.
- *FormatViolation.* This value is used to indicate that the format of the received PPDU was in error.
- *CarrierLost.* This value is used to indicate that during the reception of the incoming PSDU, the carrier was lost and no further processing of the PSDU can be accomplished.
- *UnsupportedRate.* This value is used to indicate that during the reception of the incoming PPDU, a nonsupported date rate was detected.
- *Filtered*. This value is used to indicate that during the reception of the PPDU, the PPDU was filtered out due to a condition set in the PHYCONFIG_VECTOR.

  NOTE 1—The filtered condition might occur in a VHT STA due to GROUP_ID or PARTIAL_AID filtering in the PHY.

RCPI is a parameter included in the PHY-RXEND.indication primitive that the PHY provides the local MAC entity. If present, RCPI is a measure of the received RF power averaged over all of the receive chains in the data portion of a received frame. RCPI is an included parameter only when

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dot11RadioMeasurementActivated is true and the PHY is not a DMG, CDMG, or CMMG PHY. The required parameters are listed in 8.3.4.4.

NOTE 2—When dot11RadioMeasurementActiviated is true, for DMG, CDMG, or CMMG PHYs, RCPI is included in the RXVECTOR parameter of the PHY-RXSTART.indication primitive instead.

8.3.5.14.3 When generated

This primitive is generated by the PHY for the local MAC entity to indicate that the receive state machine has completed a reception with or without errors. When a signal extension is present, the primitive is generated at the end of the signal extension.

In the case of an RXERROR value of NoError, the MAC uses the PHY-RXEND.indication primitive as reference for channel access timing, as shown in Figure 10-21 (in 10.3.7) and Figure 10-25.

8.3.5.14.4 Effect of receipt

The effect of receipt of this primitive is for the MAC to begin inter-frame space processing, as described in 10.3.7 and 10.23.2.4.

8.3.5.15 PHY-CONFIG.request

8.3.5.15.1 Function

This primitive is a request by the MAC sublayer to the local PHY entity to configure the PHY.

8.3.5.15.2 Semantics of the service primitive

The primitive provides the following parameter:

```
PHY-CONFIG.request(
                        PHYCONFIG_VECTOR
                        )
```

8.3.5.15.3 When generated

This primitive is generated by the MAC sublayer for the local PHY entity when it desires to change the configuration of the PHY.

8.3.5.15.4 Effect of receipt

The effect of receipt of this primitive by the PHY is to apply the parameters provided with the primitive and to configure the PHY for future operation.

8.4 PHY management

The MIB comprises the managed objects, attributes, actions, and notifications required to manage a STA. The definition of these managed objects, attributes, actions, and notifications, as well as their structure, is presented in Annex C.

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9. Frame formats

9.1 General requirements

The format of the MAC frames is specified in this clause. A STA shall be able to properly construct a subset of the frames specified in this clause for transmission and to decode a (potentially different) subset of the frames specified in this clause upon validation following reception. The particular subset of these frames that a STA constructs and decodes is determined by the functions supported by that particular STA. A STA shall be able to validate every received frame using the frame check sequence (FCS) and to interpret certain fields from the MAC headers of all frames.

A STA shall transmit frames using only the frame formats described in Clause 9.

9.2 MAC frame formats

9.2.1 Basic components

Each frame consists of the following basic components:

a) A *MAC header*, which comprises frame control, duration, address, optional sequence control information, optional QoS Control information (QoS Data frames only), and optional HT Control fields (+HTC frames only);

b) A variable length *frame body*, which contains information specific to the frame *type* and *subtype*;

c) An *FCS*, which contains a 32-bit CRC based on ITU-T Recommendation V.42 [B55] (see 9.2.4.8).

9.2.2 Conventions

Structures defined in the MAC sublayer are described as a sequence of components (e.g., fields, subfields, elements and subelements) in specific order. Each figure and table in Clause 9 depicts the components as they appear in the MAC frame and in the order in which they are passed to the physical layer (PHY), from left to right and then from top to bottom.

Unless specified otherwise, a number in a field is encoded as an unsigned integer.

A field or subfield within the figure depiction of a frame format that includes a decimal value within parentheses indicates that this field or subfield is set to the indicated value upon transmission.

In figures, all bits within fields are numbered, from 0 to k, where the length of the field is $k + 1$ bits. Bits within numeric fields that are longer than a single bit are depicted in increasing order of significance, i.e., with the lowest numbered bit having the least significance. The octet boundaries within a field can be obtained by taking the bit numbers of the field modulo 8. Octets within numeric fields that are longer than a single octet are depicted in increasing order of significance, from lowest numbered bit to highest numbered bit. The octets in fields longer than a single octet are sent to the PHY in order from the octet containing the lowest numbered bits to the octet containing the highest numbered bits.

Any field containing a CRC is an exception to this convention and is transmitted commencing with the coefficient of the highest-order term. There are other exceptions; these are explicitly indicated in the description of the field in question.

MAC addresses are assigned as ordered sequences of bits. The Individual/Group bit is always transferred first and is bit 0 of the MAC address. Bit 47 of the MAC address is always transferred last. This is illustrated in Figure 9-1. Also see Clause 8 of IEEE Std 802-2014.

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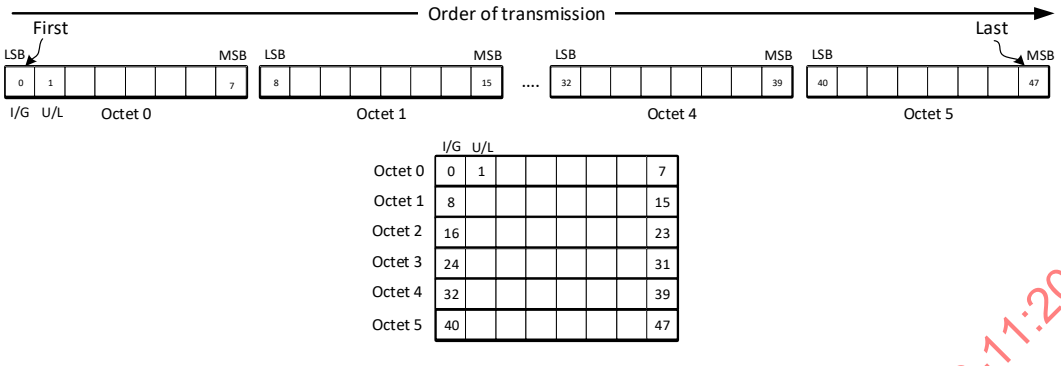

Figure 9-1—Representation of a 48-bit MAC address

A MAC address can be represented using hexadecimal values separated by hyphens, as described in IEEE Std 802.

Organizationally Unique Identifiers (OUIs), Company IDs (CIDs), and Organization Identifiers are specified in two forms: an ordered sequence of octets, and a numeric form. Treating the OUI, CID, or Organization Identifier as an ordered sequence of octets, the leftmost octet is always transferred first. This is equivalent to transmitting the most significant octet of the numeric form first.

Values specified in decimal are coded in natural binary unless otherwise stated. The values in Table 9-1 are in binary, with the bit assignments shown in the table. Values in other tables are shown in decimal notation.

ASCII and UTF-8 strings are defined in 1.4.

For evaluation purposes a nonce is interpreted as a sequence of octets with the most significant octet first and the most significant bit of an octet first.

Reception, in references to frames or fields within frames (e.g., received Beacon frames or a received Duration/ID field), applies to MPDUs indicated from the PHY without error and validated by FCS within the MAC sublayer. Without further qualification, *reception* by the MAC sublayer implies that the frame contents are valid, and that the protocol version is supported (see 9.2.4.1.2), with no implication regarding frame addressing or regarding whether the frame type or other fields in the MAC header are meaningful to the MAC entity that receives the frame.

A frame that contains the HT Control field is referred to as a *+HTC frame*. A Control Wrapper frame is a +HTC frame.

A QoS Data frame that is transmitted by a mesh STA is referred to as a *mesh Data frame*.

NOTE 1—Subclause 9.2.4.1.4 constrains the setting of the From DS and To DS subfields in mesh Data frames.

Parentheses enclosing portions of names or acronyms are used to designate a set of related names that vary based on the inclusion of the parenthesized portion. For example,

— *QoS +CF-Poll frame* refers to the three QoS data subtypes that include "+CF-Poll": the QoS Data +CF-Poll frame, subtype 1010; QoS Data +CF-Ack +CF-Poll frame, subtype 1011; and QoS CF-Ack +CF-Poll frame, subtype 1111.

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— *QoS CF-Poll frame* refers specifically to the QoS CF-Poll frame, subtype 1110.
— *QoS (+)CF-Poll frame* refers to all four QoS data subtypes with CF-Poll: the QoS CF-Poll frame, subtype 1110; the QoS CF-Ack +CF-Poll frame, subtype 1111; the QoS Data +CF-Poll frame, subtype 1010; and the QoS Data +CF-Ack +CF-Poll frame, subtype 1011.
— *QoS (+)Null frame* refers to all three QoS data subtypes with an empty frame body: the QoS Null frame, subtype 1100; the QoS CF-Poll frame, subtype 1110; and the QoS CF-Ack +CF-Poll frame, subtype 1111.
— *QoS +CF-Ack frame* refers to the three QoS data subtypes that include "+CF-Ack": the QoS Data +CF-Ack frame, subtype 1001; QoS Data +CF-Ack +CF-Poll frame, subtype 1011; and QoS CF-Ack +CF-Poll frame, subtype 1111.
— (NDP) CTS refers to CTS and NDP CTS.
— (NDP) CF-End refers to CF-End and NDP CF-End.
— (NDP) PS-Poll refers to PS-Poll and NDP PS-Poll.
— (NDP) Ack refers to Ack and NDP Ack.
— NDP (PS-Poll-)Ack refers to NDP Ack and NDP PS-Poll-Ack.
— (NDP) Block Ack refers to Block Ack and NDP Block Ack.
— PS-Poll(+BDT) refers to PS-Poll and PS-Poll+BDT.

Reserved fields and subfields defined in this clause are set to 0 upon transmission and are ignored upon reception.

NOTE 2—This applies to reserved fields and subfields in MAC headers. Reserved fields and subfields in PHY headers might be set to a nonzero value upon transmission, and might not be ignored upon reception.

Reserved field and subfield values are not used upon transmission. Upon reception of a reserved field or subfield value, the behavior is undefined.

9.2.3 General frame format

The MAC frame format comprises a set of fields that occur in a fixed order in all frames. Figure 9-2 depicts the general MAC frame format for protocol version 0 (PV0) MPDUs, and Figure 9-978 (in 9.8.2) depicts the general MAC frame format for protocol version 1 (PV1) frames. The first 2 bits of the first subfield (Protocol Version) of the Frame Control field and the last field (FCS) in Figure 9-2 are present in all PV0 MPDUs and PV1 MPDUs, including reserved types and subtypes.

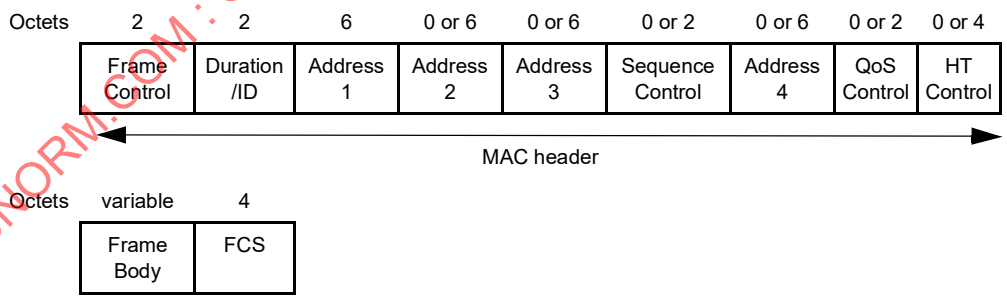

Figure 9-2—MAC frame format

For PV0 MPDUs, the first three fields (Frame Control, Duration/ID, and Address 1) and the last field (FCS) in Figure 9-2 constitute the minimal frame format and are present in all these frames, including reserved types and subtypes. The fields Address 2, Address 3, Sequence Control, Address 4, QoS Control, HT Control, and Frame Body are present only in certain frame types and subtypes. Each field is defined in 9.2.4.

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For PV1 MPDUs, the fields constituting the minimal frame format are defined in 9.8.2. The format of each of the individual subtypes of each frame type is defined in 9.3, the format of each PV1 frame type is defined in 9.8, and the format of NDP CMAC PPDUs is defined in 23.3.12. The components of (PV0) Management frame bodies are defined in 9.4. The formats of Action frame bodies (PV0 and PV1) are defined in 9.6.

The Frame Body field is of variable size, constrained as defined in 9.2.4.7.1.

9.2.4 Frame fields

9.2.4.1 Frame Control field

9.2.4.1.1 General

The first three subfields of the Frame Control field of a PV0 frame are Protocol Version, Type, and Subtype. The remaining subfields of the Frame Control field depend on the setting of the Type and Subtype subfields.

For a frame carried in an non-S1G PPDU, when the Type subfield is not 1 or the Subtype subfield is not 6, the remaining subfields within the Frame Control field are To DS, From DS, More Fragments, Retry, Power Management, More Data, Protected Frame, and +HTC. In this case, the format of the Frame Control field is shown in Figure 9-3.

	B0 B1	B2 B3	B4 B7	B8	B9	B10	B11	B12	B13	B14	B15
	Protocol Version	Type	Subtype	To DS	From DS	More Frag-ments	Retry	Power Management	More Data	Protected Frame	+HTC
Bits:	2	2	4	1	1	1	1	1	1	1	1

Figure 9-3—Frame Control field format in non-S1G PPDUs when Type subfield is not equal to 1 or Subtype subfield is not equal to 6

For a frame carried in an non-S1G PPDU when the Type subfield is 1 and the Subtype subfield is 6, the remaining subfields within the Frame Control field are the following: Control Frame Extension, Power Management, More Data, Protected Frame, and +HTC. In this case, the format of the Frame Control field is shown in Figure 9-4.

	B0 B1	B2 B3	B4 B7	B8 B11	B12	B13	B14	B15
	Protocol Version	Type	Subtype	Control Frame Extension	Power Management	More Data	Protected Frame	+HTC
Bits:	2	2	4	4	1	1	1	1

Figure 9-4—Frame Control field format in non-S1G PPDUs when Type subfield is equal to 1 and Subtype subfield is equal to 6

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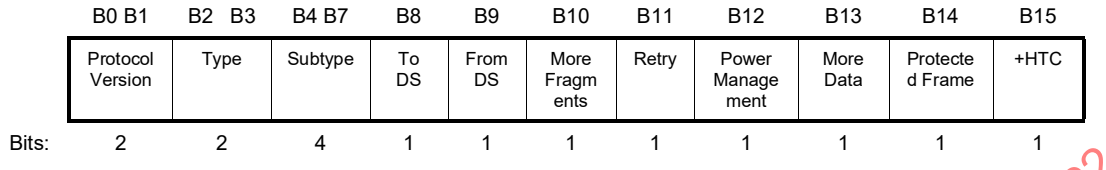
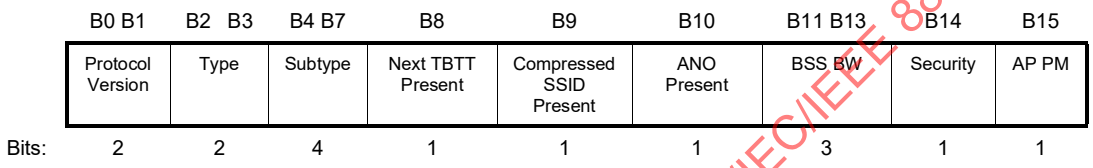
For a frame carried in an S1G PPDU, when the Type subfield is 0 or 2, the remaining subfields within the Frame Control field are: To DS, From DS, More Fragments, Retry, Power Management, More Data, Protected Frame, and +HTC. In this case, the format of the Frame Control field is shown in Figure 9-5).



	B0 B1	B2 B3	B4 B7	B8	B9	B10	B11	B12	B13	B14	B15
	Protocol Version	Type	Subtype	To DS	From DS	More Fragments	Retry	Power Management	More Data	Protected Frame	+HTC
Bits:	2	2	4	1	1	1	1	1	1	1	1

Figure 9-5—Frame Control field format in S1G PPDUs when Type subfield is equal to 0 or 2

When the Type subfield is equal to 3 and the Subtype subfield is equal to 1, the format of the Frame Control field is shown in Figure 9-6.



	B0 B1	B2 B3	B4 B7	B8	B9	B10	B11 B13	B14	B15
	Protocol Version	Type	Subtype	Next TBTT Present	Compressed SSID Present	ANO Present	BSS BW	Security	AP PM
Bits:	2	2	4	1	1	1	3	1	1

Figure 9-6—Frame Control field format when Type subfield is equal to 3 and Subtype subfield is equal to 1

9.2.4.1.2 Protocol Version subfield

The Protocol Version subfield is invariant in size and placement across all revisions of this standard. For this standard, the value of the protocol version is 0 for MAC frames as described in 9.2 and 1 for PV1 MAC frames as described in 9.8. All other values are reserved. The revision level is incremented only when a fundamental incompatibility exists between a new revision and the prior edition of the standard. See 10.28.2.

9.2.4.1.3 Type and Subtype subfields

The Type and Subtype subfields together identify the function of the frame. There are three frame types: control, data, and management. Each of the frame types has several defined subtypes. In Data frames, the most significant bit (MSB) of the Subtype subfield, B7, is defined as the QoS subfield. Table 9-1 defines the valid combinations of type and subtype. (The numeric values in Table 9-1 are shown in binary.)

Table 9-1—Valid type and subtype combinations

Type value B3 B2	Type description	Subtype value B7 B6 B5 B4	Subtype description
00	Management	0000	Association Request
00	Management	0001	Association Response
00	Management	0010	Reassociation Request
00	Management	0011	Reassociation Response
00	Management	0100	Probe Request
00	Management	0101	Probe Response
00	Management	0110	Timing Advertisement

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Table 9-1—Valid type and subtype combinations *(continued)*

Type value B3 B2	Type description	Subtype value B7 B6 B5 B4	Subtype description
00	Management	0111	Reserved
00	Management	1000	Beacon
00	Management	1001	ATIM
00	Management	1010	Disassociation
00	Management	1011	Authentication
00	Management	1100	Deauthentication
00	Management	1101	Action
00	Management	1110	Action No Ack
00	Management	1111	Reserved
01	Control	0000–0010	Reserved
01	Control	0011	TACK
01	Control	0100	Beamforming Report Poll
01	Control	0101	VHT NDP Announcement
01	Control	0110	Control Frame Extension
01	Control	0111	Control Wrapper
01	Control	1000	Block Ack Request (BlockAckReq)
01	Control	1001	Block Ack (BlockAck)
01	Control	1010	PS-Poll
01	Control	1011	RTS
01	Control	1100	CTS
01	Control	1101	Ack
01	Control	1110	CF-End
01	Control	1111	Reserved
10	Data	0000	Data
10	Data	0001	Reserved
10	Data	0010	Reserved
10	Data	0011	Reserved
10	Data	0100	Null
10	Data	0101	Reserved
10	Data	0110	Reserved
10	Data	0111	Reserved
10	Data	1000	QoS Data
10	Data	1001	QoS Data +CF-Ack
10	Data	1010	QoS Data +CF-Poll
10	Data	1011	QoS Data +CF-Ack +CF-Poll
10	Data	1100	QoS Null

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Table 9-1—Valid type and subtype combinations *(continued)*

Type value B3 B2	Type description	Subtype value B7 B6 B5 B4	Subtype description
10	Data	1101	Reserved
10	Data	1110	QoS CF-Poll
10	Data	1111	QoS CF-Ack +CF-Poll
11	Extension	0000	DMG Beacon
11	Extension	0001	S1G Beacon
11	Extension	0010–1111	Reserved

Each Subtype subfield bit position is used to indicate a specific modification of the basic Data frame (subtype 0). Frame Control bit 4 is set to 1 in data subtypes that include +CF-Ack, bit 5 is set to 1 in data subtypes that include +CF-Poll, bit 6 is set to 1 in data subtypes that contain no Frame Body field, and bit 7 is set to 1 in the QoS data subtypes, which have QoS Control fields in their MAC headers.

The Control Frame Extension subtype is used to increase the subtype space by reusing bits B8–B11. These additional Control frames are defined in Table 9-2.

Table 9-2—Control Frame Extension

Type value B3 B2	Subtype value B7 B6 B5 B4	Control Frame Extension value B11 B10 B9 B8	Description
01	0110	0000	Reserved
01	0110	0001	Reserved
01	0110	0010	Poll
01	0110	0011	SPR
01	0110	0100	Grant
01	0110	0101	DMG CTS
01	0110	0110	DMG DTS
01	0110	0111	Grant Ack
01	0110	1000	SSW
01	0110	1001	SSW-Feedback
01	0110	1010	SSW-Ack
01	0110	1011–1111	Reserved

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9.2.4.1.4 To DS and From DS subfields

The meaning of the combinations of values for the To DS and From DS subfields in Data frames are shown in Table 9-3.

Table 9-3—To/From DS combinations in Data frames

To DS and From DS values	Meaning
To DS = 0 From DS = 0	A Data frame from one STA to another STA within the same IBSS or the same PBSS, a Data frame direct from one non-AP STA to another non-AP STA within the same infrastructure BSS, or a Data frame outside the context of a BSS. This is the only valid combination for Data frames transmitted by an IBSS or PBSS STA, or outside the context of a BSS.
To DS = 1 From DS = 0	A Data frame destined for the DS or being sent by a STA associated with an AP to the Port Access Entity in that AP.
To DS = 0 From DS = 1	A Data frame exiting the DS or being sent by the Port Access Entity in an AP, or a group addressed mesh Data frame with the Mesh Control field present using the three-address MAC header format. This is the only valid combination for Data frames transmitted by a non-GLK AP and group addressed Data frames transmitted by a mesh STA.
To DS = 1 From DS = 1	A Data frame using the four-address MAC header format. This standard defines procedures for using this combination of field values in mesh BSSs by S1G relays, as specified in 10.54, or by a GLK STA. This is the only valid combination for individually addressed Data frames transmitted by a mesh STA.

The meanings of the combinations of values of the Management frame To DS and From DS subfields are shown in Table 9-4.

Table 9-4—To/From DS combinations in Management frames

To DS and From DS values	Meaning
To DS = 0 From DS = 0	All non-QMF Management frames.
To DS = 1 From DS = 0	All QMF Management frames.
To DS = 0 From DS = 1	This combination is reserved.
To DS = 1 From DS = 1	This combination is reserved.

In Control frames, To DS and From DS, when present, are both zero.

NOTE—In Control frames of subtype Control Frame Extension, the To DS and From DS subfields are not defined, and their bit positions are part of the Control Frame Extension field (see 9.2.4.1.3, Table 9-2).

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9.2.4.1.5 More Fragments subfield

The More Fragments subfield is set to 1 in all Data or Management frames that have another fragment of the current MSDU or current MMPDU to follow. It is set to 0 in all other frames in which the More Fragments subfield is present.

NOTE—In Control frames of subtype Control Frame Extension, the More Fragments subfield is not present, and its bit position is part of the Control Frame Extension field (see 9.2.4.1.3, Table 9-2).

9.2.4.1.6 Retry subfield

The Retry subfield is set to 1 in any Data or Management frame that is a retransmission of an earlier frame. It is set to 0 in all other frames in which the Retry subfield is present. A receiving STA uses this indication to aid in the process of eliminating duplicate frames. These rules do not apply for frames sent by a non-DMG STA under a block agreement.

NOTE—In Control frames of subtype Control Frame Extension, the Retry subfield is not present, and its bit position is part of the Control Frame Extension field (see 9.2.4.1.3, Table 9-2).

9.2.4.1.7 Power Management subfield

The Power Management subfield is used to indicate the power management mode of a STA. The subfield is either reserved (as defined below) or remains constant in each frame from a particular STA within a frame exchange sequence (see Annex G). The value indicates the mode of the STA after the successful completion of the frame exchange sequence.

In an infrastructure BSS or PBSS, the following applies:

- The Power Management subfield is valid only in frame exchanges as described in 11.2.3 and 11.2.7. In such exchanges, the Power Management subfield set to 1 indicates that the STA will be in PS mode. The Power Management subfield set to 0 indicates that the STA will be in active mode.
- The Power Management subfield is reserved in all Management frames transmitted by a STA to an AP or PCP with which it is not associated.
- The Power Management subfield is reserved in all frames transmitted by the AP.

In an IBSS, the Power Management subfield is valid only in certain frames as described in 11.2.4.4. In such frames, the Power Management subfield set to 1 indicates that the STA will be in PS mode. The Power Management subfield set to 0 indicates that the STA will be in active mode.

In an MBSS, the Power Management subfield is valid only in frame exchanges as described per the mesh power management mode transitions rules in 14.14. In such exchanges, the value indicates the STA's power management mode (see 14.14).

9.2.4.1.8 More Data subfield

The More Data subfield is used differently by a DMG, S1G, and other STAs.

A non-DMG and non-S1G STA uses the More Data subfield to indicate to a STA in PS mode that more BUs are buffered for that STA at the AP. The More Data subfield is valid in individually addressed Data or Management frames transmitted by an AP to a STA in PS mode. The More Data subfield is set to 1 to indicate that at least one additional buffered BU is present for the same STA.

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An AP optionally sets the More Data subfield to 1 in Ack frames to a non-DMG and non-S1G STA from which it has received a frame that contains a QoS Capability element in which the More Data Ack subfield is equal to 1 and that has one or more ACs that are delivery enabled and that is in PS mode to indicate that the AP has a pending transmission for the STA.

A TDLS peer STA optionally sets the More Data subfield to 1 in Ack frames to a STA that has TDLS peer PSM enabled and that has the More Data Ack subfield equal to 1 in the QoS Capability element of its transmitted TDLS Setup Request frame or TDLS Setup Response frame to indicate that it has a pending transmission for the STA.

The More Data subfield is 1 in individually addressed frames transmitted by a mesh STA to a peer mesh STA that is either in light sleep mode or in deep sleep mode for the corresponding mesh peering, when additional BUs remain to be transmitted to this peer mesh STA.

The More Data subfield is set to 1 in individually addressed frames transmitted by a VHT AP to a VHT STA when both support the VHT TXOP power save feature (as determined from their VHT Capabilities elements) to indicate that at least one additional buffered BU is present for the STA. See 11.2.3.17.

A non-DMG and non-S1G STA sets the More Data subfield to 0 in all other individually addressed frames.

A non-DMG and non-S1G STA sets the More Data subfield to 1 in non-GCR-SP group addressed frames transmitted by the AP when additional group addressed bufferable units (BUs) that are not part of an active GCR-SP remain to be transmitted by the AP during this beacon interval. The More Data subfield is set to 0 in non-GCR-SP group addressed frames transmitted by the AP when no more group addressed BUs that are not part of an active GCR-SP remain to be transmitted by the AP during this beacon interval and in all group addressed frames transmitted by non-AP STAs.

An S1G STA sets the More Data subfield to 1 in individually addressed frames to indicate that the S1G STA has MSDUs, MMPDU or A-MSDUs buffered for transmission to the frame's recipient during the current SP or TXOP. An S1G STA does not set the More Data subfield to 1 in individually addressed frames if it does not have any MSDUs, MMPDU or A-MSDUs buffered for transmission to the frame's recipient during the current SP or TXOP.

An S1G AP sets the More Data subfield to 1 in group addressed frames when additional group addressed BUs remain to be transmitted by the AP during this beacon interval or short beacon interval (see 11.1.3.10.2). The S1G AP sets the More Data subfield to 0 in group addressed frames transmitted by the AP when no more group addressed BUs remain to be transmitted by the AP during this beacon interval or short beacon interval.

The More Data subfield is set to 1 in GCR-SP group addressed frames transmitted by the AP when additional group addressed BUs that are part of an active GCR-SP remain to be transmitted by the AP during this GCR-SP. The More Data subfield is set to 0 in GCR-SP group addressed frames transmitted by the AP when no more group addressed BUs that are part of an active GCR-SP remain to be transmitted by the AP during this GCR-SP.

The More Data subfield is 1 in group addressed frames transmitted by a mesh STA when additional group addressed BUs remain to be transmitted. The More Data subfield is 0 in group addressed frames transmitted by a mesh STA when no more group addressed BUs remain to be transmitted.

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A DMG STA sets the More Data subfield as follows:

— In individually addressed frames, it is set to 1 to indicate that the STA has MSDUs or A-MSDUs buffered for transmission to the frame's recipient during the current SP or TXOP.

— It is set to 1 in group addressed frames transmitted by the AP when additional group addressed BUs remain to be transmitted by the AP during this beacon interval. The More Data subfield is set to 0 in group addressed frames transmitted by the AP when no more group addressed BUs remain to be transmitted by the AP during this beacon interval.

A DMG STA does not set the More Data bit to 1 if it does not have any MSDUs or A-MSDUs buffered for transmission to the frame's recipient during the current SP or TXOP.

The More Data subfield is set to 1 in individually addressed frames transmitted by a CMMG AP to a CMMG STA when both support the CMMG TXOP power save feature (as determined from their CMMG Capabilities elements) to indicate that at least one additional buffered BU is present for the STA, see 11.2.3.19.

9.2.4.1.9 Protected Frame subfield

The Protected Frame subfield is set to 1 if the Frame Body field contains information that has been processed by a cryptographic encapsulation algorithm. The Protected Frame subfield is reserved in Control frames of subtype Control Frame Extension. When the Protected Frame subfield is equal to 1, the Frame Body field is protected utilizing the cryptographic encapsulation algorithm and expanded as defined in Clause 12. The Protected Frame subfield is set to 0 in Data frames of subtype Null, QoS Null, QoS CF-Poll, and QoS CF-Ack +CF-Poll (see, for example, 12.5.2.2 and 12.5.3.1 that show that the frame body needs to be 1 octet or longer to apply the encapsulation).

9.2.4.1.10 +HTC subfield

The +HTC subfield is set as follows:

— It is set to 1 in a QoS Data or Management frame transmitted with the FORMAT parameter of the TXVECTOR set to HT_GF, HT_MF, VHT or S1G to indicate that the frame contains an HT Control field.

— It is set to 1 in an RTS frame transmitted with the FORMAT parameter of the TXVECTOR set to S1G to indicate that the intended recipient of the frame has permission to extend the TXOP as described in 10.54.5.4.

— It is set to 1 in a QoS Data or Management frame transmitted by a CMMG STA to indicate that the frame contains a CMMG variant HT Control field.

Otherwise, the +HTC subfield is set to 0.

NOTE—The +HTC subfield is always set to 0 for frames transmitted by a DMG STA.

9.2.4.1.11 Bandwidth Indication and Dynamic Indication subfields

The Bandwidth Indication subfield identifies the bandwidth of the PPDU. The Bandwidth Indication and Dynamic Indication subfields are used to negotiate the bandwidth of PPDUs within a TXOP. Table 9-5 defines the bandwidth used for exchanging PPDUs between a TXOP holder and a TXOP responder.

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Table 9-5—Bandwidth Indication subfield encoding

Bandwidth Indication encoding	Meaning
0	1 MHz
1	2 MHz
2	4 MHz
3	8 MHz
4	16 MHz
5–7	Reserved

Table 9-6 indicates whether the bandwidth used for exchanging PPDUs in a TXOP is static or can change dynamically.

Table 9-6—Dynamic Indication subfield encoding

Dynamic Indication encoding	Meaning
0	Static
1	Dynamic

9.2.4.1.12 Next TWT Info Present subfield

The Next TWT Info Present subfield is set to 1 if the Next TWT Info/Suspend Duration field is present in the frame. Otherwise, it is set to 0.

9.2.4.1.13 Flow Control subfield

The Flow Control subfield is used for flow suspension signaling as described in 10.61.

9.2.4.1.14 Poll Type subfield

The Poll Type subfield is defined in Table 9-7 if the Power Management subfield is 1 in PS-Poll frame. Otherwise, the Poll Type subfield is reserved.

Table 9-7—Poll Type subfield encoding

Poll Type subfield	Description
0	Request for a buffered frame without a request to reschedule the awake/doze cycle
1	Request for the information of change sequence of the beacon and partial timestamp
2	Request for a duration to a TBTT or Next TWT to reschedule awake/doze cycle
3	Request for a duration to a service period to reschedule awake/doze cycle

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9.2.4.1.15 Next TBTT Present subfield

The Next TBTT Present subfield is set to 1 if the Next TBTT field is present; otherwise, it is set to 0.

9.2.4.1.16 Compressed SSID Present subfield

The Compressed SSID Present subfield is set to 1 if the Compressed SSID field is present; otherwise, it is set to 0.

9.2.4.1.17 ANO Present subfield

The ANO Present subfield is set to 1 if the Access Network Options field is present; otherwise, it is set to 0.

9.2.4.1.18 BSS BW subfield

The BSS BW subfield indicates the minimum and the maximum operating bandwidths of the BSS as defined in Table 9-8.

Table 9-8—Frame Control field BSS BW setting

BSS BW	Minimum BSS BW (MHz)	Maximum BSS BW (MHz)
0	1	2
1	Equal to the BW of the PPDU carrying the BSS BW field	Equal to the BW of the PPDU carrying the BSS BW field
2	1	4
3	2	4
4	1	8
5	2	8
6	1	16
7	2	16

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9.2.4.1.19 Security subfield

The Security subfield is set to 1 if the AP is an RSNA AP.

9.2.4.1.20 AP-PM subfield

The AP-PM subfield indicates whether the AP can go to Power Save mode until the next TBTT or TSBTT. If the AP-PM subfield is equal to 1, the AP can go to Power Save mode until the next TBTT or TSBTT unless otherwise is indicated by restricted access windows (RAWs) or TWTs. If the AP-PM subfield is equal to 0, the AP does not go to Power Save mode until the next TBTT or TSBTT.

9.2.4.2 Duration/ID field

The contents of the Duration/ID field vary with frame type and subtype, and with the QoS capabilities of the sending STA. The contents of the field are defined as follows:

a) In Control frames of subtype PS-Poll other than PS-Poll+BDT frames, and for broadcast transmissions in S1G PPDUs, the Duration/ID field carries the association identifier (AID) of the

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STA that transmitted the frame in the 14 least significant bits (LSB), and the 2 most significant bits (MSB) both set to 1.

b) In all other frames sent by non-QoS STAs and other Control frames sent by QoS STAs, the Duration/ID field contains a duration value as defined for each frame type in 9.3.

c) In Data and Management frames sent by QoS STAs, the Duration/ID field contains a duration value as defined for each frame type in 9.2.5. In Extension frames the Duration/ID field contains a duration value as defined in 9.3.4.

See 10.28.3 on the processing of this field in received frames.

The encoding of the Duration/ID field is given in Table 9-9.

Table 9-9—Duration/ID field encoding

Bits 0–13	Bit 14	Bit 15	Usage
0–32 767		0	Duration value (in microseconds) within all frames except PS-Poll frames that are not PS-Poll+BDT
0–16 383	0	1	Reserved
0	1	1	AID 0 is used for broadcast transmission in S1G PPDU, reserved if not in S1G PPDU.
1–2007	1	1	AID in PS-Poll frames other than PS-Poll+BDT.
2008–8191	1	1	Additional AIDs in S1G PS-Poll frames other than PS-Poll+BDT. Reserved if not in S1G PS-Poll frames.
8192–16 383	1	1	Reserved

See also 9.7.3 on the setting of the Duration/ID field of MAC headers of MPDUs in an A-MPDU.

9.2.4.3 Address fields

9.2.4.3.1 General

There are four address fields in the MAC frame format. These fields are used to indicate the basic service set identifier (BSSID), source address (SA), destination address (DA), transmitting address (TA), and receiving address (RA). Certain frames might not contain some of the address fields.

Certain address field usage is specified by the relative position of the address field (1–4) within the MAC header, independent of the type of address present in that field. Specifically, the Address 1 field always identifies the intended receiver(s) of the frame, and the Address 2 field, where present, always identifies the transmitter of the frame.

NOTE—The Address 2 field is not equal to the MAC address of the transmitter, in the case of a bandwidth signaling TA.

9.2.4.3.2 Address representation

Each Address field contains a 48-bit address as defined in Clause 8 of IEEE Std 802-2014.

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9.2.4.3.3 Address designation

A MAC sublayer address is one of the following two types:

a) *Individual address.* The address assigned to a particular STA on the network.

b) *Group address.* A multidestination address, which might be in use by one or more STAs on a given network. The two kinds of group addresses are as follows:

   1) *Multicast-group address.* An address associated by higher level convention with a group of logically related STAs.

   2) *Broadcast address.* A distinguished, predefined group address that always denotes the set of all STAs on a given LAN. All 1s are interpreted to be the broadcast address. This group is predefined for each communication medium to consist of all STAs actively connected to that medium; it is used to broadcast to all of the active STAs on that medium.

The address space is also partitioned into locally administered and universal (globally administered) addresses. The nature of a body and the procedures by which it administers these universal (globally administered) addresses is beyond the scope of this standard. See IEEE Std 802 for more information.

9.2.4.3.4 BSSID field

The BSSID field is of the same format as an IEEE 802 MAC address. When dot11OCBActivated is false, this field uniquely identifies each BSS. This field, in an infrastructure BSS, is the MAC address currently in use by the STA in the AP of the BSS.

This field in a PBSS is set to the MAC address of the PCP.

This field in an IBSS is set to a locally administered IEEE MAC address formed from a 46-bit random number generated according to the procedure defined in 11.1.4. The Individual/Group bit of the address is set to 0. The Universal/Local bit of the address is set to 1. This mechanism is used to provide a high probability of selecting a unique BSSID.

This field is set to all 1s to indicate the wildcard BSSID. The wildcard value is not used in the BSSID field except where explicitly permitted in this standard. When dot11OCBActivated is true, the wildcard value is used in the BSSID field. When dot11OCBActivated is false and the BSSID field contains the wildcard value, the Address 1 (DA) field is also set to all 1s to indicate the broadcast address.

9.2.4.3.5 DA field

The DA field contains an IEEE MAC individual or group address that identifies the MAC entity or entities intended as the final recipient(s) of the MSDU (or fragment thereof) or A-MSDU, as defined in 9.3.2.1, contained in the frame body field.

9.2.4.3.6 SA field

The SA field contains an IEEE MAC individual address that identifies the MAC entity from which the transfer of the MSDU (or fragment thereof) or A-MSDU, as defined in 9.3.2.1, contained in the frame body field was initiated. The Individual/Group bit is always transmitted as a 0 in the source address.

9.2.4.3.7 RA field

The RA field contains an IEEE MAC individual or group address that identifies the intended immediate recipient STA(s), on the WM, for the information contained in the frame body field.

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9.2.4.3.8 TA field

The TA field contains an IEEE MAC address that identifies the STA that has transmitted, onto the WM, the MPDU contained in the frame body field. If the Individual/Group bit is 0, then the TA field is the individual address of the STA; otherwise, the TA field is a bandwidth signaling TA, indicating that the frame carries additional information in the scrambling sequence (see 9.3.1.2, 9.3.1.5.1, 9.3.1.7.1, 9.3.1.8.1, 9.3.1.19, 9.3.1.20, 10.6.6.6, and 10.6.12).

9.2.4.4 Sequence Control field

9.2.4.4.1 Sequence Control field structure

The Sequence Control field consists of two subfields, the Sequence Number and the Fragment Number. The format of the Sequence Control field is shown in Figure 9-7. The Sequence Control field is not present in Control frames.

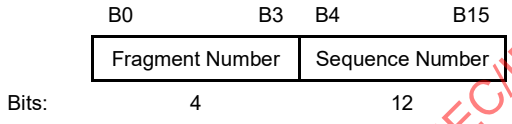

Figure 9-7—Sequence Control field format

9.2.4.4.2 Sequence Number field

Each MSDU, A-MSDU, or MMPDU is assigned a sequence number. See 10.3.2.14. Sequence numbers are not assigned to Control frames, as the Sequence Control field is not present in those frames.

The Sequence Number field in Data frames indicates the sequence number of the MSDU or A-MSDU.

The Sequence Number field in QMFs comprises the QMF Sequence Number subfield and the AC Index (ACI) subfield. The QMF Sequence Number subfield indicates the sequence number of the frame. The ACI subfield indicates the ACI of the frame. The format of the Sequence Number field in QMFs is shown in Figure 9-8.

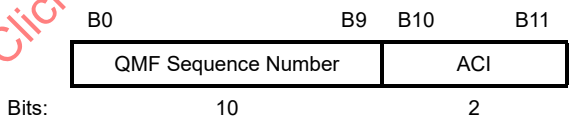

Figure 9-8—Sequence Number field format in QMFs

The ACI subfield represents the ACI of the frame as defined in 9.4.2.28.

The Sequence Number field in Management frames that are not QMFs indicates the sequence number of the frame.

Each fragment of an MSDU or MMPDU contains a copy of the sequence number assigned to that MSDU or MMPDU. The sequence number remains constant in all retransmissions of an MSDU, MMPDU, or fragment thereof, except when the MSDU is delivered via both DMS and group addressed delivery via NoAck, GCR unsolicited retry, or GCR block ack retransmission policies. In such cases, the sequence numbers assigned to the MSDUs (re)transmitted using group addressed delivery need not match the sequence number of the corresponding individually addressed A-MSDUs delivered via DMS.

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9.2.4.4.3 Fragment Number field

The Fragment Number field indicates the number of each fragment of an MSDU or MMPDU. The fragment number is set to 0 in the first or only fragment of an MSDU or MMPDU and is incremented by one for each successive fragment of that MSDU or MMPDU. The fragment number is set to 0 in an MPDU containing an A-MSDU, and in an MPDU containing an MSDU or MMPDU that is not fragmented. The fragment number remains constant in all retransmissions of the fragment.

9.2.4.5 QoS Control field

9.2.4.5.1 QoS Control field structure

The QoS Control field identifies the TC or TS to which the frame belongs as well as various other QoS-related, A-MSDU related, and mesh-related information about the frame that varies by frame type, subtype, and type of transmitting STA. The QoS Control field is present in all Data frames in which the QoS subfield of the Subtype subfield is equal to 1 (see 9.2.4.1.3).

When not transmitted within a DMG PPDU, each QoS Control field comprises five or eight subfields, as defined for the particular sender (HC or non-AP STA) and frame type and subtype. The usage of these subfields and the various possible layouts of the QoS Control field are described in 9.2.4.5.2 to 9.2.4.5.12 and shown in Table 9-10.

Table 9-10—QoS Control field

Applicable frame (sub)types	Bits 0–3	Bit 4	Bits 5–6	Bit 7	Bits 8	Bit 9	Bit 10	Bits 11–15
QoS CF-Poll and QoS CF-Ack +CF-Poll frames sent by HC	TID	EOSP	Ack Policy Indicator	Reserved	TXOP Limit			
QoS Data +CF-Poll and QoS Data +CF-Ack +CF-Poll frames sent by HC	TID	EOSP	Ack Policy Indicator	A-MSDU Present	TXOP Limit			
QoS Data and QoS Data +CF-Ack frames sent by HC	TID	EOSP	Ack Policy Indicator	A-MSDU Present	AP PS Buffer State			
QoS Null frames sent by HC	TID	EOSP	Ack Policy Indicator	Reserved	AP PS Buffer State			
QoS Data and QoS Data +CF-Ack frames sent in a nonmesh BSS by non-AP STAs that are not a TPU buffer STA or a TPU sleep STA	TID	0	Ack Policy Indicator	A-MSDU Present	TXOP Duration Requested			
	TID	1	Ack Policy Indicator	A-MSDU Present	Queue Size			
QoS Null frames sent in a nonmesh BSS by non-AP STAs that are not a TPU buffer STA or a TPU sleep STA	TID	0	Ack Policy Indicator	Reserved	TXOP Duration Requested			
	TID	1	Ack Policy Indicator	Reserved	Queue Size			
QoS Data and QoS Data +CF-Ack frames sent by TPU buffer STAs	TID	EOSP	Ack Policy Indicator	A-MSDU Present	Reserved			

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Table 9-10—QoS Control field *(continued)*

Applicable frame (sub)types	Bits 0–3	Bit 4	Bits 5–6	Bit 7	Bits 8	Bit 9	Bit 10	Bits 11–15
QoS Null frames sent by TPU buffer STAs	TID	EOSP	Ack Policy Indicator	Reserved	Reserved			
QoS Data and QoS Data +CF-Ack frames sent by TPU sleep STAs	TID	Reserved	Ack Policy Indicator	A-MSDU Present	Reserved			
QoS Null frames sent by TPU sleep STAs	TID	Reserved	Ack Policy Indicator	Reserved	Reserved			
All frames sent by mesh STAs in a mesh BSS	TID	EOSP	Ack Policy Indicator	A-MSDU Present	Mesh Control Present	Mesh Power Save Level	RSPI	Reserved

See 10.12.1 for constraints on the contents of the QoS Control field when present in an A-MPDU.

The format of the QoS Control field for MPDUs transmitted within a DMG PPDU is provided in Table 9-11. Data subtypes not shown in the table are not transmitted within a DMG PPDU.

Table 9-11—QoS Control field for frames transmitted within a DMG PPDU

Applicable frame (sub)types	Bits 0–3	Bit 4	Bits 5–6	Bit 7	Bit 8	Bit 9	Bits 10–13	Bit 14	Bit 15
QoS Data	TID	EOSP	Ack Policy Indicator	A-MSDU Present	A-MSDU Type	RDG/ More PPDU	Buffered AC	Reserved	AC Constraint
QoS Null	TID	EOSP	Ack Policy Indicator	Reserved	Reserved	RDG/ More PPDU	Buffered AC	Reserved	AC Constraint

9.2.4.5.2 TID subfield

The TID subfield identifies the TC or TS to which the corresponding MSDU (or fragment thereof) or A-MSDU in the Frame Body field belongs. The TID subfield also identifies the TC or TS of traffic for which a TXOP is being requested, through the setting of TXOP duration requested or queue size. The encoding of the TID subfield depends on the access policy (see 9.4.2.29) and is shown in Table 9-12. Additional information on the interpretation of the contents of this field appears in 5.1.1.3.

Table 9-12—TID subfield

Access policy	Usage	Allowed values
EDCA	UP for either TC or TS, regardless of whether admission control is required	0–7
HCCA, SPCA	TSID	8–15
HEMM, SEMM	TSID, regardless of the access mechanism used	8–15

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In QoS Data +CF-Poll frames, the TID subfield in the QoS Control field indicates the TID of the data. In QoS (+)CF-Poll frames of subtype Null, the TID subfield in the QoS Control field indicates the TID for which the poll is intended. The requirement to respond to that TID is nonbinding, and a STA can respond with any frame (see 10.23.3.5.1). For STAs where dot11OCBActivated is true, traffic streams are not used and the TID always corresponds to a TC.

9.2.4.5.3 EOSP (end of service period) subfield

The EOSP subfield is used by the HC to indicate the end of the current service period (SP) and by a DMG STA to indicate the end of the current SP or the end of the current allocated CBAP with a destination AID that is not the broadcast AID. The HC sets the EOSP subfield to 1 in its transmission and retransmissions of the SP's final frame to end an SP and sets it to 0 otherwise. To end an SP allocation or a CBAP allocation with a destination AID that is not the broadcast AID, the DMG STA sets the EOSP subfield to 1 in its final frame transmission and retransmissions within the allocation; otherwise, the DMG STA sets the EOSP subfield to 0.

The mesh STA uses the EOSP subfield to indicate the end of the current mesh peer service period in which it operates as the owner. The mesh STA sets the EOSP subfield to 1 in its transmission and retransmissions of the mesh peer service period's final frame to end a mesh peer service period, and sets it to 0 otherwise. See 14.14.9.4 for details.

If dot11RobustAVStreamingImplemented is true, then the HC sets the EOSP subfield to 1 in a GCR-SP group addressed frame in order to indicate that no more GCR-SP frames of that group address are to be transmitted by the AP until the next scheduled SP for this GCR-SP stream.

NOTE—As GCR-A frames are sent outside of any SP, the EOSP subfield is set to 0 in a group addressed frame delivered using the GCR-A procedures described in 11.21.16.3.8.

9.2.4.5.4 Ack Policy Indicator subfield

The Ack Policy Indicator subfield, together with other information, as shown in Table 9-13, identifies the ack policy, i.e. the behavior followed upon the delivery of the MPDU.

Table 9-13—Ack policy

Ack policy	Ack Policy Indicator subfield		Other conditions	Meaning
	Bit 0	Bit 1		
Normal Ack	0	0	MPDU is a non-A-MPDU frame	Where the frame contains a fragment and both the originator and the addressed recipient support fragment BA : The addressed recipient returns an NDP BlockAck or BAT frame after a SIFS, according to the procedures defined in 10.3.2.12 and 10.47.2. Otherwise: The addressed recipient returns an Ack, STACK, or QoS +CF-Ack frame after a short interframe space (SIFS) period, according to the procedures defined in 10.3.2.11, 10.47.2, and 10.23.3.5. A non-DMG STA uses this ack policy for individually addressed QoS Null frames.

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Table 9-13—Ack policy *(continued)*

Ack policy	Ack Policy Indicator subfield		Other conditions	Meaning
	Bit 0	Bit 1		
Implicit BAR	0	0	MPDU is not a non-A-MPDU frame NOTE—This MPDU is sent under a block ack agreement.	The addressed recipient returns a BlockAck, TACK or BAT frame, either individually or as part of an A-MPDU starting a SIFS after the PPDU carrying the frame, according to the procedures defined in 10.3.2.11, 10.25.6.5, 10.29.3, 10.29.4, 10.47.2, and 10.34.3.
No Ack	1	0	None	The addressed recipient takes no action upon receipt of the frame. More details are provided in 10.26. This ack policy is used in all individually addressed frames in which the sender does not require immediate acknowledgment. It is also used in all group addressed frames that use the QoS frame format except QoS Data frames with a TID for which a block ack agreement exists. It is not used for QoS Data frames with a TID for which a block ack agreement exists.
No Explicit Acknowledgment	0	1	Bit 6 of the Frame Control field (see 9.2.4.1.3) is equal to 1	There might be a response frame to the frame that is received, but it is neither the Ack frame nor any Data frame of subtype +CF-Ack. This ack policy is used for QoS CF-Poll and QoS CF-Ack +CF-Poll Data frames. NOTE—Bit 6 of the Frame Control field (see 9.2.4.1.3) indicates the absence of a Frame Body field in a QoS Data frame. When equal to 1, the QoS Data frame contains no Frame Body field, and any response is generated in response to a QoS CF-Poll or QoS CF-Ack +CF-Poll frame, but does not signify an acknowledgment of data.
PSMP Ack	0	1	Bit 6 of the Frame Control field (see 9.2.4.1.3) is equal to 0	The acknowledgment for a frame indicating PSMP Ack when it appears in a PSMP downlink transmission time (PSMP-DTT) is to be received in a later PSMP uplink transmission time (PSMP-UTT). The acknowledgment for a frame indicating PSMP Ack when it appears in a PSMP-UTT is to be received in a later PSMP-DTT. See 10.30.2.7.
Block Ack	1	1	None	The addressed recipient takes no action upon the receipt of the frame except for recording the state. The recipient can expect a BlockAckReq frame or implicit block ack request in the future to which it responds using the procedure described in 10.25.

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9.2.4.5.5 TXOP Limit subfield

The TXOP Limit subfield is present in QoS Data frames of subtypes that include CF-Poll and specifies the time limit on a TXOP granted by a QoS (+)CF-Poll frame from an HC in an infrastructure BSS. In QoS Data frames with subtypes that include CF-Poll, the addressed STA is granted a TXOP that begins a SIFS after

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this frame and lasts no longer than the number of 32 μs periods specified by the TXOP Limit subfield value. The range of time values is 32 μs to 8160 μs. A TXOP Limit subfield set to 0 indicates that only one MPDU or one QoS Null frame is to be transmitted immediately following the QoS (+)CF-Poll frame.

9.2.4.5.6 Queue Size subfield

The Queue Size subfield indicates the amount of buffered traffic for a given TC or TS at the STA sending this frame. The Queue Size subfield is present in QoS Data frames sent by non-AP STAs with bit 4 of the QoS Control field equal to 1. The AP might use information contained in the Queue Size subfield to determine the TXOP duration assigned to the STA.

The Queue Size subfield is set to the total size, rounded up to the nearest multiple of 256 octets and expressed in units of 256 octets, of all MSDUs and A-MSDUs buffered at the STA (excluding the MSDU or A-MSDU of the present QoS Data frame) in the delivery queue used for MSDUs and A-MSDUs with TID values equal to the value in the TID subfield of this QoS Control field. The Queue Size subfield is set to 0 to indicate the absence of any buffered traffic in the queue used for the specified TID. The Queue Size subfield is set to 254 for all sizes greater than 64 768 octets. The Queue Size subfield is set to 255 to indicate an unspecified or unknown size.

9.2.4.5.7 TXOP Duration Requested subfield

The TXOP Duration Requested subfield indicates the duration, in units of 32 μs, that the sending STA determines it needs for its next TXOP for the specified TID. The TXOP Duration Requested subfield is set to 0 to indicate that no TXOP is requested for the specified TID in the current SP. The TXOP Duration Requested subfield is set to a nonzero value to indicate a requested TXOP duration in the range 32 μs to 8160 μs in increments of 32 μs. See 10.23.3.5.2.

9.2.4.5.8 AP PS Buffer State subfield

The AP PS Buffer State subfield, defined in Figure 9-9, indicates the PS buffer state at the AP for a STA. The AP PS Buffer State subfield is further subdivided into three subfields: Buffer State Indicated, Highest Priority Buffered AC, and AP Buffered Load.

Figure 9-9—QoS AP PS Buffer State subfield format

The Buffered State Indicated subfield is used to indicate whether the AP PS buffer state is specified. This subfield is set to 1 to indicate that the AP PS buffer state is specified.

The Highest Priority Buffered AC subfield is used to indicate the AC of the highest priority traffic remaining that is buffered at the AP, excluding the MSDU or A-MSDU of the present frame.

The AP Buffered Load subfield is used to indicate the total buffer size, rounded up to the nearest multiple of 4096 octets and expressed in units of 4096 octets, of all MSDUs and A-MSDUs buffered at the QoS AP (excluding the MSDU or A-MSDU of the present QoS Data frame). An AP Buffered Load field set to 15 indicates that the buffer size is greater than 57 344 octets. An AP Buffered Load subfield set to 0 is used solely to indicate the absence of any buffered traffic for the indicated highest priority buffered AC when the Buffer State Indicated bit is 1.

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When the Buffered State Indicated subfield is equal to 0, the Highest Priority Buffered AC subfield and the AP Buffered Load subfield are reserved.

9.2.4.5.9 A-MSDU Present subfield

The A-MSDU Present subfield indicates the presence of an A-MSDU. The A-MSDU Present subfield is set to 1 to indicate that the Frame Body field contains an entire A-MSDU as defined in 9.3.2.2. The A-MSDU Present subfield is set to 0 to indicate that the Frame Body field contains an MSDU or fragment thereof as defined in 9.3.2.1.

NOTE—A DMG STA, when the A-MSDU Present subfield is set to 1, can use one of two A-MSDU formats in the Frame Body. The specific A-MSDU format present is indicated by the A-MSDU Type subfield.

9.2.4.5.10 Mesh Control Present subfield

The Mesh Control Present subfield indicates the presence of a Mesh Control field in the frame body. When the Mesh Control Present subfield is 1, the Frame Body field contains a Mesh Control field as defined in 9.2.4.7.3. The mesh STA sets the Mesh Control Present subfield to 1 in the mesh Data frame containing an unfragmented MSDU, an A-MSDU, or the first fragment of an MSDU.

9.2.4.5.11 Mesh Power Save Level subfield

The Mesh Power Save Level subfield indicates whether the mesh STA's peer-specific mesh power management mode will be deep sleep mode or light sleep mode after the successful completion of the frame exchange sequence.

When the Power Management subfield in the Frame Control field in the frame is 1, the following applies:

In individually addressed mesh Data frames, the Mesh Power Save Level subfield is set to of 0 to indicate that the mesh STA's peer-specific mesh power management mode for the recipient mesh STA will be light sleep mode (see 14.14.8.4). In individually addressed mesh Data frames, the Mesh Power Save Level subfield is set to 1 to indicate that the mesh STA's peer-specific mesh power management mode for the recipient mesh STA will be deep sleep mode (see 14.14.8.5).

In group addressed mesh Data frames, the Mesh Power Save Level subfield is set to 0 to indicate that none of the peer-specific mesh power management modes of the mesh STA will be deep sleep mode. In group addressed mesh Data frames, the Mesh Power Save Level subfield is set to 1 to indicate that at least one of the peer-specific mesh power management modes of the mesh STA is deep sleep mode.

The Mesh Power Save Level subfield is reserved if the Power Management subfield in the Frame Control field is 0.

9.2.4.5.12 Receiver Service Period Initiated (RSPI) subfield

The Receiver Service Period Initiated (RSPI) subfield is set to 0 to indicate that the mesh peer service period, of which the receiver of this frame is the owner, is not initiated. The subfield is set to 1 to indicate that the mesh peer service period, of which the receiver of this frame is the owner, is initiated. The use of the RSPI subfield is described in 14.14.9.2. The RSPI subfield is reserved in group addressed frames.

9.2.4.5.13 A-MSDU Type subfield

The A-MSDU Type subfield indicates the type of A-MSDU present in the Frame Body field. When the A-MSDU Type subfield is set to 0, the Frame Body field contains a Basic A-MSDU as defined in 9.3.2.2.2. When the A-MSDU Type subfield is set to 1, the Frame Body field contains a Short A-MSDU as defined in 9.3.2.2.3. The A-MSDU Type subfield is reserved if the A-MSDU Present subfield is set to 0.

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9.2.4.5.14 RDG/More PPDU subfield

The RDG/More PPDU subfield of the QoS Control field for DMG frames is interpreted differently depending on whether it is transmitted by a reverse direction (RD) initiator or an RD responder, as defined in Table 9-15.

9.2.4.5.15 AC Constraint subfield

The AC Constraint subfield of the QoS Control field for DMG frames indicates whether the mapped AC of an RD Data frame is constrained to a single AC, as defined in Table 9-14.

9.2.4.5.16 Buffered AC subfield

The Buffered AC subfield is a 4-bit bitmap that indicates buffered traffic for four ACs as defined in Figure 9-10. At least one BU for the indicated AC is buffered if the related subfield is 1. The Buffered AC subfield is reserved except in QoS Data frames and QoS Null frames. A non-AP and non-PCP STA can use information contained in the Buffered AC subfield to determine the ACs for which BU are buffered for it.

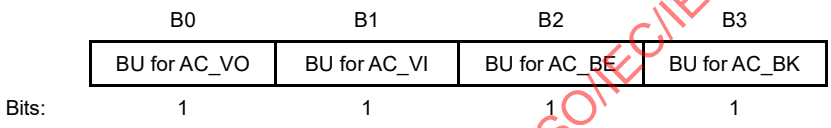

Figure 9-10—Buffered AC subfield format

9.2.4.6 HT Control field

9.2.4.6.1 General

The HT Control field is always present in a Control Wrapper frame and is present in QoS Data and Management frames as determined by the +HTC subfield of the Frame Control field as defined in 9.2.4.1.10.

NOTE 1—The only control frame subtype for which HT Control field is present is the Control Wrapper frame. A Control frame that is described as +HTC (e.g., an RTS+HTC, CTS+HTC, BlockAck+HTC or BlockAckReq+HTC frame) implies the use of the Control Wrapper frame to carry that Control frame.

The format of the HT Control field transmitted by a non-CMMG STA is shown in Figure 9-11.

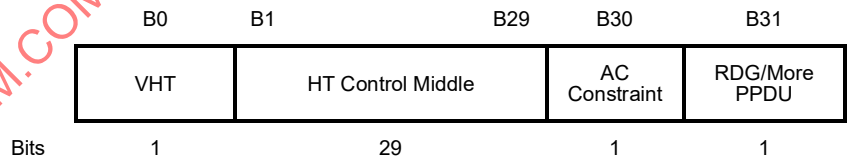

Figure 9-11—Non-CMMG variant HT Control field format

The HT Control field transmitted by a non-CMMG STA has two forms, the HT variant and the VHT variant. The two forms differ in the format of the HT Control Middle subfield, described in 9.2.4.6.2 for the HT variant and in 9.2.4.6.3 for the VHT variant and in the value of the VHT subfield.

The VHT subfield of the HT Control field indicates whether the HT Control Middle subfield is the VHT variant or the HT variant. The VHT subfield is set to 1 to indicate that the HT Control Middle subfield is the VHT variant and is set to 0 to indicate that the HT Control Middle subfield is the HT variant.

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The HT Control field transmitted by a CMMG STA has one form, the CMMG variant HT Control. The format of the HT Control field transmitted by a CMMG STA is shown in Figure 9-20.

The AC Constraint subfield of the HT Control field indicates whether the mapped AC of an RD Data frame is constrained to a single AC, as defined in Table 9-14.

Table 9-14—AC Constraint subfield values

Value	Description
0	The response to a reverse direction grant (RDG) contains Data frames from any TID; see 10.29.4.
1	The response to an RDG contains Data frames only from the same AC as the last Data frame received from the RD initiator; see 10.29.4.

NOTE 2—The AC of the last Data frame received from the RD initiator is determined directly from the TID of the received frame if the TID is between 0 and 7 or from the UP field of the TSPEC identified by the TID of the received frame if the TID is between 8 and 15.

The RDG/More PPDU subfield of the HT Control field is interpreted differently depending on whether it is transmitted by an RD initiator or an RD responder, as defined in Table 9-15.

Table 9-15—RDG/More PPDU subfield values

Value	Role of transmitting STA	Interpretation of value
0	Not an RD responder	No reverse grant
	RD responder	The PPDU carrying the frame is the last transmission by the RD responder
1	RD initiator	An RDG is present
	RD responder	The PPDU carrying the frame is followed by another PPDU

9.2.4.6.2 HT variant

The format of the HT Control Middle subfield of the HT variant HT Control field is shown in Figure 9-12.

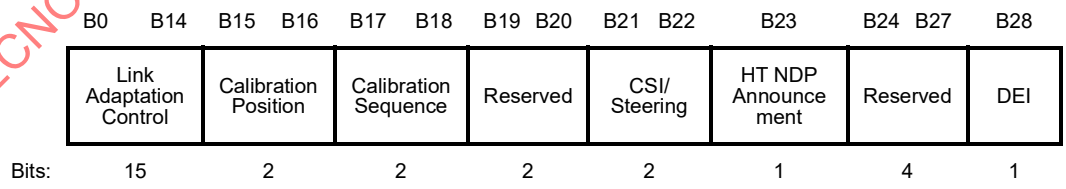

Figure 9-12—HT Control Middle subfield of the HT variant HT Control field format

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The format of the Link Adaptation Control subfield of the HT variant HT Control field is defined in Figure 9-13.

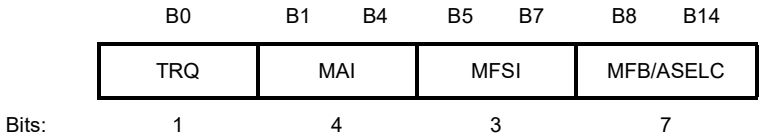

Figure 9-13—Link Adaptation Control subfield format

The subfields of the Link Adaptation Control subfield are defined in Table 9-16.

Table 9-16—Subfields of Link Adaptation Control subfield

Subfield	Meaning	Definition
TRQ	Training request	Set to 1 to request the responder to transmit a sounding PPDU. Set to 0 to indicate that the responder is not requested to transmit a sounding PPDU. See 10.34.2 and 10.36.2.
MAI	MCS request (MRQ) or ASEL indication	Set to 14 (indicating ASELI) to indicate that the MFB/ASELC subfield is interpreted as ASELC. Otherwise, the MAI subfield is interpreted as shown in Figure 9-14, and the MFB/ASELC subfield is interpreted as MCS feedback (MFB).
MFSI	MCS feedback sequence identifier	Set to the received value of MSI contained in the frame to which the MFB information refers. Set to 7 for unsolicited MFB.
MFB/ASELC	MCS feedback and antenna selection command/data	When the MAI subfield is equal to the value ASELI, this subfield is interpreted as defined in Figure 9-15 and Table 9-18. Otherwise, this subfield contains recommended MFB. Set to 127 to indicate that no feedback is present.

The structure of the MAI subfield of the Link Adaptation Control subfield is defined in Figure 9-14. The subfields of the MAI subfield are defined in Table 9-17.

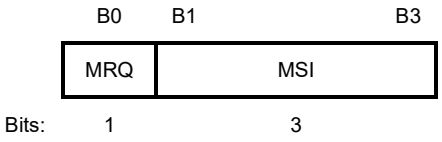

Figure 9-14—MAI subfield format

Table 9-17—Subfields of the MAI subfield

Subfield	Meaning	Definition
MRQ	MCS request	Set to 1 to indicate that MFB is requested. Set to 0 to indicate that no MFB is requested.
MSI	MRQ sequence identifier	When the MRQ subfield is equal to 1, the MSI subfield contains a sequence number in the range 0 to 6 that identifies the specific request. When the MRQ subfield is equal to 0, the MSI subfield is reserved.

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The ASELC subfield of the Link Adaptation Control subfield contains the ASEL Command and ASEL Data subfields, as shown in Figure 9-15. The encoding of these subfields is shown in Table 9-18.

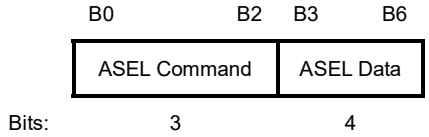

Figure 9-15—ASELC subfield format

Table 9-18—ASEL Command and ASEL Data subfields

ASEL Command	Interpretation of ASEL Command	ASEL Data
0	Transmit Antenna Selection Sounding Indication (TXASSI)	Number of remaining sounding PPDUs to be transmitted See NOTE
1	Transmit Antenna Selection Sounding Request (TXASSR) or Transmit ASEL Sounding Resumption	0 when the command is Transmit ASEL Sounding Request A number in the range 1 to 15, the number being the number of the first sounding PPDU to be transmitted when the command is Transmit ASEL Sounding Resumption, where 0 corresponds to the first sounding PPDU in the original ASEL training sequence
2	Receive Antenna Selection Sounding Indication (RXASSI)	Number of remaining sounding PPDUs to be received See NOTE
3	Receive Antenna Selection Sounding Request (RXASSR)	Number of sounding PPDUs required
4	Sounding Label	Sequence number of the sounding PPDU corresponding to a channel state information (CSI) frame in ASEL feedback
5	No Feedback Due to ASEL Training Failure or Stale Feedback	The number of the first sounding PPDU that was not received properly, where 0 corresponds to the first sounding PPDU in the ASEL training sequence, or 0 if no sounding PPDUs were received properly, or 0 if this is a request for a full retraining sequence
6	Transmit Antenna Selection Sounding Indication requesting feedback of explicit CSI (TXASSI-CSI)	Number of remaining sounding PPDUs to be transmitted See NOTE
7	Reserved	Reserved

NOTE—If the HT variant HT Control field is carried in a sounding PPDU, then the ASEL Data field contains the remaining number of sounding frames following the current one. If null data PPDU (NDP) sounding frame is used, then the ASEL Data field contains the number of NDPs following a non-NDP+HTC. The HT NDP Announcement subfield in the HT Control field is set to 1 to indicate NDP sounding.

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The Calibration Position and Calibration Sequence subfields of the HT variant HT Control field are defined in Table 9-19.

Table 9-19—Calibration control subfields

Subfield	Meaning	Definition
Calibration Position	Position in calibration sounding exchange sequence	Set to 0 indicates this is not a calibration frame. Set to 1 indicates calibration start. Set to 2 indicates sounding response. Set to 3 indicates sounding complete.
Calibration Sequence	Calibration sequence identifier	The field is included in each frame within the calibration procedure and its value is unchanged for the frame exchanges during one calibration procedure. See 10.34.2.4.3.

The Calibration Sequence subfield identifies an instance of the calibration procedure. The subfield is included in each frame within a calibration procedure, and its value is unchanged for frames within the same calibration procedure.

The CSI/Steering subfield of the HT variant HT Control field indicates the type of feedback, as shown in Table 9-20.

Table 9-20—CSI/Steering subfield values

Value	Definition
0	No feedback required
1	CSI
2	Noncompressed beamforming
3	Compressed beamforming

The HT NDP Announcement subfield of the HT variant HT Control field indicates that an NDP will be transmitted after the frame (according to the rules described in 10.36). It is set to 1 to indicate that an NDP will follow; otherwise, it is set to 0.

The DEI subfield of the HT Control field is set by the transmitting STA to indicate the suitability of the corresponding MSDU or A-MSDU to be discarded if there are insufficient resources at the receiving STA, per the value of the drop eligible parameter in the MA-UNITDATA.request. See 10.8 and 11.25.2. In a Management frame, the DEI subfield is reserved.

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9.2.4.6.3 VHT variant

In a non-S1G STA, the format of the HT Control Middle subfield of the VHT variant HT Control field is shown in Figure 9-16.

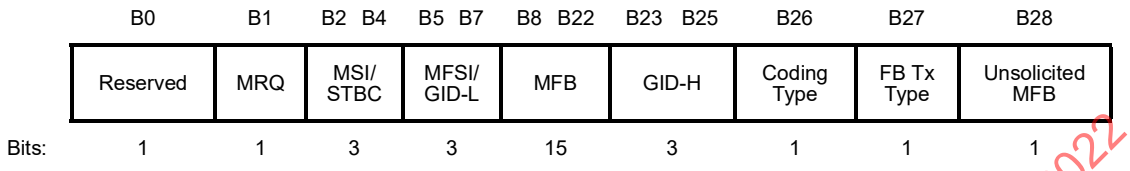

Figure 9-16—HT Control Middle subfield of the VHT variant HT Control field format

The subfields of VHT variant HT Control field are defined in Table 9-21.

Table 9-21—VHT variant HT Control field subfields

Subfield	Meaning	Definition
MRQ	VHT-MCS feedback request	Set to 1 to request VHT-MCS feedback (solicited MFB); otherwise, set to 0.
MSI/STBC	MRQ sequence identifier/STBC indication	If the Unsolicited MFB subfield is 0 and the MRQ subfield is 1, the MSI/STBC subfield contains a sequence number in the range 0 to 6 that identifies the specific MCS feedback request. If the Unsolicited MFB subfield is 0 and the MRQ subfield is 0, the MSI/STBC subfield is reserved. If the Unsolicited MFB subfield is 1 and the MFB does not contain the value representing "no feedback is present," the MSI/STBC field contains the Compressed MSI and STBC Indication subfields as shown in Figure 9-17. The STBC Indication subfield indicates whether the estimate in the MFB subfield is computed based on a PPDU using STBC encoding: Set to 0 if the PPDU was not STBC encoded Set to 1 if the PPDU was STBC encoded The Compressed MSI subfield contains a sequence number that identifies the specific MCS feedback request. It is in the range 0 to 3 if STBC Indication equals 0 or in the range 0 to 2 if STBC Indication equals 1. Otherwise, the MSI/STBC subfield is reserved.
MFSI/GID-L	MFB sequence identifier/LSBs of group ID	If the Unsolicited MFB subfield is 0, the MFSI/GID-L subfield contains the received value of MSI contained in the frame to which the MFB information refers. If the Unsolicited MFB subfield is 1, the MFB does not contain the value representing "no feedback is present," and the MFB is estimated from a VHT MU PPDU, then the MFSI/GID-L subfield contains the lowest 3 bits of group ID of that PPDU from which the MFB was estimated (bit 0 of the group ID appears in the lowest numbered bit of the field MFSI/GID-L). If the unsolicited MFB is estimated from an SU PPDU, the MFSI/GID-L subfield is set to all 1s. Otherwise, this subfield is reserved.
MFB	NUM_STS, VHT-MCS, BW and SNR feedback	MFB subfield is interpreted as defined in Table 9-22. This subfield contains the recommended MFB. The combination of VHT-MCS=15 and NUM_STS=7 indicates that no feedback is present.

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Table 9-21—VHT variant HT Control field subfields *(continued)*

Subfield	Meaning	Definition
GID-H	MSBs of group ID	If the Unsolicited MFB subfield is 1, the MFB does not contain the value representing "no feedback is present," and the unsolicited MFB is estimated from a VHT MU PPDU, then the GID-H subfield contains the highest 3 bits of group ID of the PPDU from which the unsolicited MFB was estimated (bit 3 of the group ID appears in the lowest numbered bit of the field GID-H). If the unsolicited MFB is estimated from an SU PPDU, the GID-H subfield is set to all 1s. Otherwise, this subfield is reserved.
Coding Type	Coding type of the measured PPDU	If the Unsolicited MFB subfield is 1 and the MFB does not contain the value representing "no feedback is present," the Coding Type subfield contains the Coding information (0 for BCC and 1 for LDPC) of the PPDU from which the unsolicited MFB was estimated. Otherwise, this subfield is reserved.
FB Tx Type	Transmission type of the measured PPDU	If the Unsolicited MFB subfield is 1, the MFB does not contain the value representing "no feedback is present," and FB Tx Type subfield is 0, then the unsolicited MFB is estimated from a VHT PPDU with the RXVECTOR parameter BEAMFORMED equal to 0. If the Unsolicited MFB subfield is 1, the MFB does not contain the value representing "no feedback is present," and the FB Tx Type subfield is 1, then the unsolicited MFB is estimated from a VHT PPDU with the RXVECTOR parameter BEAMFORMED equal to 1. Otherwise, this subfield is reserved.
Unsolicited MFB	Unsolicited VHT-MCS feedback indicator	Set to 1 if the MFB is not a response to an MRQ. Set to 0 if the MFB is a response to an MRQ.

The format of the MSI/STBC subfield when the Unsolicited subfield is 1 is shown in Figure 9-17.

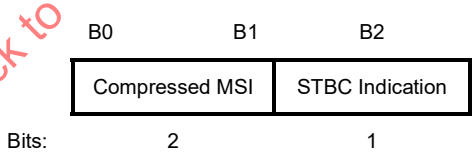

Figure 9-17—MSI/STBC subfield format when the Unsolicited MFB subfield is 1

The format of the MFB subfield in the VHT variant HT Control field is shown in Figure 9-18.

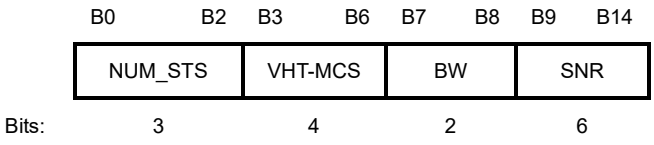

Figure 9-18—MFB subfield format in the VHT variant HT Control field

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In an S1G STA, the format of the MFB subfield in the VHT variant HT Control field is shown in Figure 9-19.

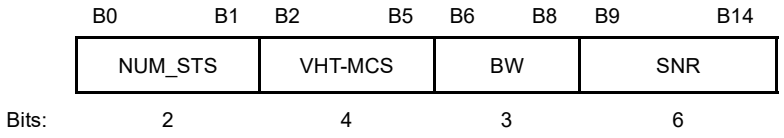

Figure 9-19—MFB subfield format in the VHT variant HT Control field when carried in S1G PPDU

The subfields of the MFB subfield in the VHT variant HT Control field are defined in Table 9-22.

Table 9-22—MFB subfield in the VHT variant HT Control field

Subfield	Meaning	Definition
NUM_STS	Recommended NUM_STS	Indicates the recommended NUM_STS as defined in 10.32.3. The NUM_STS subfield contains an unsigned integer representing the number of space-time streams minus 1.
VHT-MCS	Recommended VHT-MCS	Indicates the recommended VHT-MCS as defined in 10.32.3. The VHT-MCS subfield contains an unsigned integer in the range 0 to 9 representing a VHT-MCS Index value (defined in 21.5).
BW	Bandwidth of the recommended VHT-MCS or S1G-MCS	If the Unsolicited MFB subfield is 1, the BW subfield indicates the bandwidth for which the recommended VHT-MCS or S1G-MCS is intended, as defined in 10.32.3: For a VHT STA: Set to 0 for 20 MHz Set to 1 for 40 MHz Set to 2 for 80 MHz Set to 3 for 160 MHz and 80+80 MHz. For a TVHT STA: Set to 0 for TVHT_W Set to 1 for TVHT_2W and TVHT_W+W Set to 2 for TVHT_4W and TVHT_2W+2W The value 3 is reserved. In an S1G STA: Set to 0 for 1 MHz Set to 1 for 2 MHz Set to 2 for 4 MHz Set to 3 for 8 MHz. Set to 4 for 16 MHz. The values 5 to 7 are reserved. If the Unsolicited MFB subfield is 0, the BW subfield is reserved.
SNR	Average SNR	Indicates the average SNR, which is an SNR averaged over data subcarriers and space-time streams. The SNR is averaged over all of the space-time streams and data subcarriers and is encoded as a 6-bit 2s complement number of SNR_average – 22, where SNR_average is the sum of the values of SNR per frequency subcarrier (in decibels) per space-time stream divided by the product of the number of space-time streams, as indicated in the NUM_STS subfield, and the number of frequency subcarriers represented in the bandwidth in which the MFB was estimated. This encoding covers the SNR range from –10 dB to 53 dB in 1 dB steps.

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9.2.4.6.4 CMMG variant HT Control field

The format of the CMMG variant HT Control field is shown in Figure 9-20.

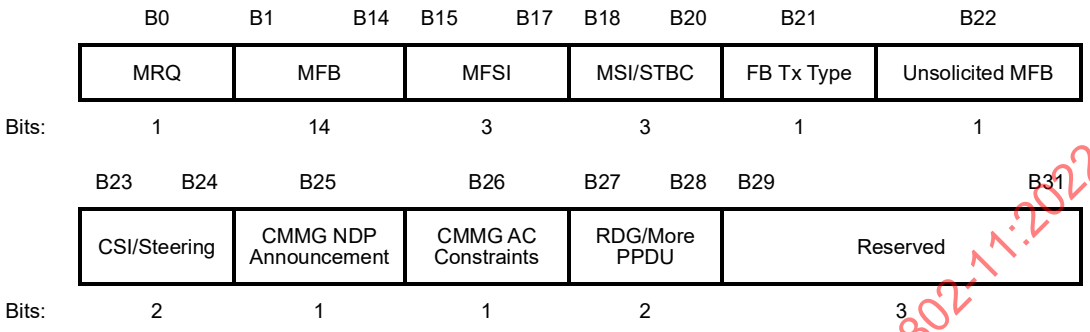

Figure 9-20—CMMG variant HT Control field format

The link adaptation related subfields including the first six subfields are defined in Table 9-23.

Table 9-23—Subfields corresponding to link adaptation

Subfield	Meaning	Definition
MRQ	CMMG-MCS Feedback request	Set to 1 to request CMMG-MCS feedback (solicited MFB); otherwise, set to 0.
MFB	NUM_STS, CMMG-MCS, BW and SNR feedback	MFB subfield is interpreted as defined in Table 9-24. This subfield contains the recommended MFB. The combination of CMMG-MCS=31 and NUM_STS=3 indicates that no feedback is present.
MFSI	MFB sequence identifier	Set to the received value of MSI contained in the frame to which the MFB information refers. Set to 7 for unsolicited MFB.
MSI/STBC	MSI/STBC	If the Unsolicited MFB subfield is 0 and the MRQ subfield is 1, the MSI/STBC subfield contains a sequence number in the range 0 to 6 that identifies the specific MCS feedback request. If the Unsolicited MFB subfield is 0 and the MRQ subfield is 0, the MSI/STBC subfield is reserved. If the Unsolicited MFB subfield is 1 and the MFB does not contain the value representing “no feedback is present,” the MSI/STBC field contains the Compressed MSI and STBC Indication subfields as shown in Figure 9-22. The STBC Indication subfield indicates whether the estimate in the MFB subfield is computed based on a PPDU using STBC encoding: Set to 0 if the PPDU was not STBC encoded. Set to 1 if the PPDU was STBC encoded. The Compressed MSI subfield contains a sequence number that identifies the specific MCS feedback request. It is in the range 0 to 3 if STBC Indication equals 0 or in the range 0 to 2 if STBC Indication equals 1. Otherwise, the MSI/STBC subfield is reserved.

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Table 9-23—Subfields corresponding to link adaptation *(continued)*

Subfield	Meaning	Definition
FB Tx Type	Transmission type of the measured PPDU	If the Unsolicited MFB subfield is 1 and FB Tx Type subfield is 0, then the unsolicited MFB is estimated from a CMMG PPDU with the RXVECTOR parameter BEAMFORMED equal to 0. If the Unsolicited MFB subfield is 1, the MFB does not contain the value representing "no feedback is present," and the FB Tx Type subfield is 1, then the unsolicited MFB is estimated from a CMMG PPDU with the RXVECTOR parameter BEAMFORMED equal to 1. Otherwise, this subfield is reserved.
Unsolicited MFB	Unsolicited CMMG-MCS feedback indicator	Set to 1 if the MFB is not a response to an MRQ. Set to 0 if the MFB is a response to an MRQ.

The format of the MFB subfield in the CMMG variant HT Control field is shown in Figure 9-21.

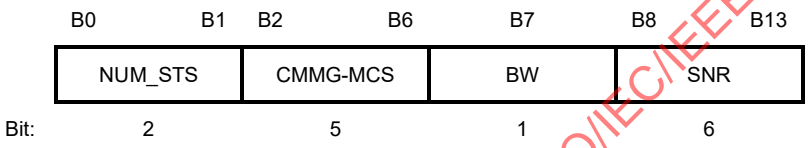

Figure 9-21—MFB subfield in the CMMG variant HT Control field format

The subfields of the MFB subfield in the CMMG variant HT Control field are defined in Table 9-24.

Table 9-24—MFB subfield in the CMMG variant HT Control field

Subfield	Meaning	Definition
NUM_STS	Recommended NUM_STS	Indicates the recommended NUM_STS as defined in 10.30.4. The NUM_STS subfield contains an unsigned integer representing the number of space-time streams minus 1.
CMMG-MCS	Recommended CMMG-MCS	Indicates the recommended CMMG-MCS as defined in 10.30.4. The CMMG-MCS subfield contains an unsigned integer representing a CMMG-MCS Index value (defined in 25.15).
BW	Bandwidth of the recommended CMMG-MCS	If the Unsolicited MFB subfield is 1, the BW subfield indicates the bandwidth for which the recommended CMMG-MCS is intended, as defined in 10.30.4: Set to 0 for 540 MHz. Set to 1 for 1080 MHz. If the Unsolicited MFB subfield is 0, the BW subfield is reserved.
SNR	Average SNR	The SNR subfield of the MFB subfield in the CMMG variant HT Control field is defined in Table 9-22.

The format of the MSI/STBC subfield when the Unsolicited MFB subfield is 1 is shown in Figure 9-22.

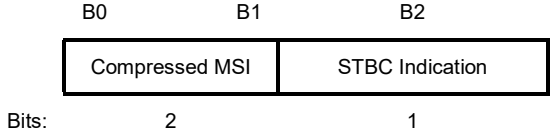

Figure 9-22—MSI/STBC subfield format when the Unsolicited MFB subfield is 1

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The CSI/Steering subfield of the CMMG variant HT Control field is defined in Table 9-20.

The CMMG NDP Announcement subfield of the CMMG variant HT Control field indicates that an NDP will be transmitted after the frame (according to the rules described in 10.33. It is set to 1 to indicate that an NDP follows; otherwise, it is set to 0.

The CMMG AC Constraint subfield of the CMMG variant HT Control field is the same as defined in Table 9-14.

The RDG/More PPDU subfield of the CMMG variant HT Control field is defined in Table 9-15.

9.2.4.7 Frame Body field

9.2.4.7.1 General

The Frame Body field is a variable length field that contains information specific to individual frame types and subtypes. The minimum length of the frame body is 0 octets. The maximum length of the frame body is constrained or affected by the following:

— The maximum MMPDU, MSDU, A-MSDU, and MPDU sizes supported by the recipient(s) for the PPDU format in use, as specified in Table 9-25.
— The maximum PPDU duration [e.g., HT_MF L-SIG L_LENGTH, HT_GF, VHT, TVHT, S1G, or DMG aPPDUMaxTime (see Table 9-25); any nonzero TXOP limit; any regulatory constraints (e.g., CS4-msBehavior)].
— The fields present in the MAC header (e.g., QoS Control, Address 4, HT Control).
— The presence of security encapsulation (e.g., TKIP, CCMP or GCMP header and MIC).
— The presence of Mesh Control fields (see 9.2.4.7.3).

NOTE 1—In an A-MSDU, the Mesh Control field is located in the A-MSDU Subframe Header (see Figure 9-70). In an MMPDU, the Mesh Control field is located within the MMPDU (see 9.6.17). Such Mesh Control fields need to be taken into account if a maximum A-MSDU or MMPDU size constraint applies as well as if a maximum MPDU size constraint applies.

NOTE 2—TKIP is not allowed with A-MSDUs (see 12.2.5) or MMPDUs (see 12.5.4.1) and, therefore, need not be taken into account if a maximum A-MSDU or MMPDU size constraint applies.

Table 9-25—Maximum data unit sizes (in octets) and durations (in microseconds)

	Non-HT non-VHT non-S1G non-DMG PPDU and non-HT duplicate PPDU	HT PPDU	VHT PPDU	S1G PPDU	DMG PPDU
MMPDU size	2304	2304	See NOTE 1	See NOTE 1	2304
MSDU size	2304	2304	2304	2304	7920
A-MSDU size	3839 or 4065 (see NOTE 2) (HT STA, see also Table 9-184), or N/A (non-HT STA, see also 10.11)	3839 or 7935 (see also Table 9-184)	See NOTE 3	See NOTE 3	7935

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Table 9-25—Maximum data unit sizes (in octets) and durations (in microseconds) *(continued)*

	Non-HT non-VHT non-S1G non-DMG PPDU and non-HT duplicate PPDU	HT PPDU	VHT PPDU	S1G PPDU	DMG PPDU
MPDU size	See NOTE 4	See NOTE 5	3895 or 7991 or 11 454 (see also Table 9-271)	3895 or 7991 (see also Table 9-300)	See NOTE 5
PSDU size	2^{12}–1 (see Table 15-5, Table 16-4, Table 17-21, Table 18-5)	2^{16}–1 (see Table 19-25)	4 692 480 (~$2^{22.16}$) (see Table 21-28)	797 160 (~$2^{19.60}$) (see Table 23-40)	2^{18}–1 (see Table 20-30)
PPDU duration	See NOTE 6	5484 (HT_MF; see 10.27.4) or 10 000 (HT_GF; see Table 19-25)	5484 (see Table 21-28)	27 840 (see Table 23-40)	2000 (see Table 20-30)

NOTE 1—No direct constraint on the maximum MMPDU size; indirectly constrained by the maximum MPDU size (see 9.3.3.1).

NOTE 2—Indirect constraint from the maximum PSDU size: 2^{12}–1 octets minus the minimum QoS Data frame overhead (26 octets for the MAC header and 4 octets for the FCS).

NOTE 3—No direct constraint on the maximum A-MSDU size; indirectly constrained by the maximum MPDU size.

NOTE 4—No direct constraint on the maximum MPDU size; indirectly constrained by the maximum MSDU/MMPDU or (for HT STAs only) A-MSDU size.

NOTE 5—No direct constraint on the maximum MPDU size; indirectly constrained by the maximum A-MSDU size.

NOTE 6—No direct constraint on the maximum duration, but an L_LENGTH value above 2332 might not be supported by some receivers (see NOTE 2 in 10.27.4).

9.2.4.7.2 Overhead for encryption

The overhead for encryption is described in Clause 12. When the Mesh Control field is present in the frame body, the Mesh Control field is encrypted as a part of data.

9.2.4.7.3 Mesh Control field

The Mesh Control field is present in a mesh Data frame containing an unfragmented MSDU or the first fragment of a fragmented MSDU and is present in a Multihop Action frame transmitted by a mesh STA.

In mesh Data frames, when the Mesh Control Present subfield in the QoS Control field is 1, the Mesh Control field is prepended to the MSDU and located as follows:

— When the frame body contains an MSDU (or a fragment thereof) and the frame is not encrypted, the Mesh Control field is located in the first octets of the frame body.

— When the frame body contains an MSDU (or a fragment thereof) and the frame is encrypted, the Mesh Control field is located in the first octets of the encrypted data portion.

— When the frame body contains an A-MSDU, the Mesh Control field is located in the A-MSDU subframe header as shown in Figure 9-70.

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In the Multihop Action frame, the Mesh Control field is present as specified in 9.6.17.

The Mesh Control field is of variable length (6, 12, or 18 octets). The structure of the Mesh Control field is defined in Figure 9-23.

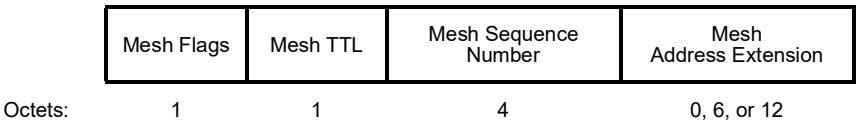

Figure 9-23—Mesh Control field format

The Mesh Flags subfield contains the Address Extension Mode subfield. The structure of the Mesh Flags subfield is shown in Figure 9-24.

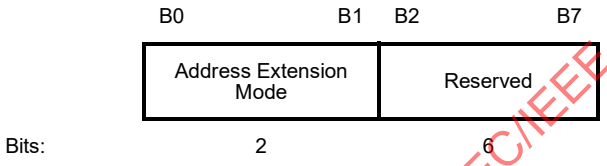

Figure 9-24—Mesh Flags subfield format

The Address Extension Mode subfield indicates the contents of the Mesh Address Extension subfield. Table 9-26 defines valid values for the Address Extension Mode and describes the corresponding contents of the Mesh Address Extension subfield.

Table 9-26—Valid values for the Address Extension Mode subfield

Address extension mode value	Address extension mode name	Address extension mode description	Mesh Address Extension subfield length (octets)	Applicable frame types
0	None	No Mesh Address Extension subfield	0	Data, Management (Multihop Action, group addressed)
1	Address4	Mesh Address Extension subfield contains Address 4	6	Management (Multihop Action, individually addressed), Data (proxied, group addressed)
2	Address5&6	Mesh Address Extension subfield contains Address 5 and Address 6	12	Data (proxied, individually addressed)
3		Reserved	—	—

The Mesh TTL subfield contains a nonzero unsigned integer corresponding to the remaining number of hops the MSDU/MMPDU is forwarded. How the Mesh TTL is used in both individually and group addressed frames is described in 10.38.3 and 10.38.4.

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The Mesh Sequence Number subfield contains an unsigned integer sequence number counter value. Source mesh STAs assign mesh sequence numbers from a single modulo 2^{32} counter, starting at 0 and incrementing by 1 for each MSDU or MMPDU that is transmitted with a Mesh Control field. Usage of the Mesh Sequence Number is described in 10.38.6.

NOTE 1—It is believed that a 32-bit sequence number is sufficient as the rollover would occur after a period of 5 days assuming a source continuously transmitting at a rate of 10^4 frames per second.

The Mesh Address Extension subfield, shown in Figure 9-25, is present only when the Address Extension Mode subfield of the Mesh Flags subfield is a nonzero nonreserved value. The Mesh Address Extension subfield provides additional address fields for mesh address extension as defined in Table 9-26. The interpretation of the extended Address fields is described in 9.3.5.

	Address 4	Address 5	Address 6
Octets:	0 or 6	0 or 6	0 or 6

Figure 9-25—Mesh Address Extension subfield format

The Address 4 subfield is present when the Address Extension Mode subfield in the Mesh Flags subfield is 1. It carries a fourth address that is not included as a part of the MAC header for these frames.

The Address 5 subfield and Address 6 subfield are present when the Address Extension Mode subfield in the Mesh Flags subfield is 2. It carries the addresses of source and destination end station of the end-to-end IEEE 802 communication if either (or both) of the end stations are not mesh STAs at the beginning or end of a single mesh path. (See Figure 9-81.)

NOTE 2—This is useful, for example, when the end stations of IEEE 802 communication are nonmesh, external STAs that communicate over a mesh BSS via proxy mesh gates.

Details on the usage of these optional address fields are given in 14.10.8.4.

9.2.4.8 FCS field

The FCS field contains a 32-bit CRC. The FCS field value is calculated over all of the fields of the MAC header and the Frame Body field. These are referred to as the *calculation fields*.

The FCS field value is calculated using the following standard generator polynomial of degree 32:

$$G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$$

The FCS field value is the 1s complement of the sum (modulo 2) of the following:

a) The remainder of $x^k \times (x^{31} + x^{30} + x^{29} + \ldots + x^2 + x + 1)$ divided (modulo 2) by $G(x)$, where k is the number of bits in the calculation fields, and

b) The remainder after multiplication of the contents (treated as a polynomial) of the calculation fields by x^{32} and then division by $G(x)$.

The FCS field is transmitted commencing with the coefficient of the highest-order term.

As a typical implementation, at the transmitter, the initial remainder of the division is preset to all 1s and is then modified by division of the calculation fields by the generator polynomial $G(x)$. The 1s complement of this remainder is transmitted, with the highest-order bit first, as the FCS field.

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At the receiver, the initial remainder is preset to all 1s and the serial incoming bits of the calculation fields and FCS, when divided by $G(x)$, results (in the absence of transmission errors) in a unique nonzero remainder value. The unique remainder value is the polynomial:

$$x^{31} + x^{30} + x^{26} + x^{25} + x^{24} + x^{18} + x^{15} + x^{14} + x^{12} + x^{11} + x^{10} + x^{8} + x^{6} + x^{5} + x^{4} + x^{3} + x + 1$$

9.2.5 Duration/ID field (QoS STA)

9.2.5.1 General

The value in the Duration/ID field within Poll, SPR, Grant, Grant Ack, DMG CTS, DMG DTS, SSW, SSW-Feedback, and SSW-Ack frames transmitted by a DMG STA are described in 9.3.1.10 to 9.3.1.18. The value in the Duration/ID field within DMG Beacon frames transmitted by a DMG STA is described in 9.3.4.2.

The value in the Duration/ID field in a frame transmitted by a QoS STA is defined in 9.2.5.2 to 9.2.5.8.

All times are calculated in microseconds. If a calculated duration includes a fractional microsecond, that value inserted in the Duration/ID field is rounded up to the next higher integer. If a calculated duration results in a negative value, the Duration/ID field is 0.

The value in the Duration field of NDP Ack, and NDP CTS frames transmitted by an S1G STA is defined in 9.2.5.7. Setting the Duration field is additionally constrained by the same rules that apply to the Duration/ID field of Ack, and CTS frames as described in 9.2.5.2 and 9.2.5.8.

The value in the Duration field for the NDP_1M Ack frame when the Idle Indication field is 0, the NDP_1M CTS frame and the NDP_1M CF-End frame is calculated in multiples of 40 μs. If a calculated duration is not a multiple of 40 μs, the value inserted in the Duration field is rounded up to the next higher integer so that the contained duration is a multiple of 40 μs. If a calculated duration results in a negative value, the Duration field is 0. See 23.3.12.2.4.2 (NDP_1M Ack) for the value in the Duration field for the NDP_1M Ack frame when the Idle Indication field is 1. See 23.3.12.2.5.2 for the value in the Duration field for the NDP_1M PS-Poll-Ack frame.

The value in the Duration field for the NDP_2M Ack frame when the Idle Indication field is 0, the NDP_2M PS-Poll-Ack frame when the Idle Indication field is 0, the NDP_2M CTS frame, and the NDP_2M CF-End frame is calculated in microseconds. If a calculated duration includes a fractional microsecond, the value inserted in the Duration field is rounded up to the next higher integer. If a calculated duration results in a negative value, the Duration field is 0. See 23.3.12.2.4.3 for the value in the Duration field for the NDP_2M Ack frame when the Idle Indication field is 1. See 23.3.12.2.5.3 for the value in the Duration field for the NDP_2M PS-Poll-Ack frame when the Idle Indication field is 1.

9.2.5.2 Setting for single and multiple protection under enhanced distributed channel access (EDCA)

In transmissions under EDCA by a STA that initiates a TXOP, there are two classes of duration settings: single protection and multiple protection. In single protection, the Duration/ID field of the frame can set a network allocation vector (NAV) value at receiving STAs that protects up to the end of any following Data, Management, or response frame plus any additional overhead frames as described below. In multiple protection, the Duration/ID field of the frame can set a NAV that protects up to the estimated end of a sequence of multiple frames.

The STA selects between single and multiple protection when it transmits the first frame of a TXOP. All subsequent frames transmitted by the STA in the same TXOP use the same class of duration settings. A STA always uses multiple protection in a TXOP that includes the following:

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— Frames that have the RDG/More PPDU subfield equal to 1
— PSMP frames
— VHT NDP Announcement frames or Beamforming Report Poll frames
— S1G Beacon frames
— Frames transmitted by an S1G STA with the TXVECTOR parameter RESPONSE INDICATION equal to Long Response

For S1G STAs, Duration/ID field determination rules are further specified in 10.3.2.15.

The Duration/ID field is set as follows:

a) Single protection settings.
   1) In an RTS frame that is not part of a dual clear-to-send (CTS) exchange and is not part of a BDT exchange, the Duration/ID field is set to the estimated time, in microseconds, required to transmit the pending frame, plus one CTS frame, plus one Ack or BlockAck frame if required, plus any NDPs required, plus explicit feedback if required, plus applicable IFSs.
   2) In all CTS frames sent by STAs as the first frame in the exchange under EDCA and with the receiver address (RA) matching the MAC address of the transmitting STA, the Duration/ID field is set to one of the following:
      i) If there is a response frame, the estimated time required to transmit the pending frame, plus one SIFS, plus the response frame (Ack or BlockAck), plus any NDPs required, plus explicit feedback if required, plus an additional SIFS
      ii) If there is no response frame, the time required to transmit the pending frame, plus one SIFS
   3) In a BlockAckReq frame, the Duration/ID field is set to the estimated time required to transmit one Ack or BlockAck frame, as applicable, plus one SIFS.
   4) In a BlockAck frame that is not sent in response to a BlockAckReq frame or an implicit block ack request, the Duration/ID field is set to the estimated time required to transmit an Ack frame plus a SIFS.
   5) In Management frames, non-QoS Data frames (i.e., with bit 7 of the Frame Control field equal to 0), and individually addressed Data frames with an ack policy other than No Ack or Block Ack, the Duration/ID field is set to one of the following:
      i) If the frame is the final frame of the TXOP, the estimated time required for the transmission of one Ack frame (including appropriate IFSs)
      ii) Otherwise, the estimated time required for the transmission of one Ack frame, plus the time required for the transmission of the following frame and its response if required, plus applicable IFSs.
   6) In individually addressed QoS Data frames with an ack policy of No Ack or Block Ack, for Action No Ack frames, and for group addressed frames, the Duration/ID field is set to one of the following:
      i) If the frame is the final frame of the TXOP, 0
      ii) Otherwise, the estimated time required for the transmission of the following frame and its response frame, if required (including appropriate IFSs)

b) Multiple protection settings. The Duration/ID field is set to a value D as follows:
   1) If $T_{TXOP} = 0$ and $T_{END\text{-}NAV} = 0$, then $D = T_{SINGLE\text{-}MSDU} - T_{\text{PPDU}}$
   2) Else if $T_{TXOP} = 0$ and $T_{END\text{-}NAV} > 0$, then $D = \max(0, T_{END\text{-}NAV} - T_{PPDU})$
   3) Else if $T_{END\text{-}NAV} = 0$, then $\min(T_{PENDING}, T_{TXOP} - T_{PPDU}) \le D \le T_{TXOP} - T_{PPDU}$
   4) Else $T_{END\text{-}NAV} - T_{PPDU} \le D \le T_{TXOP\text{-}REMAINING} - T_{PPDU}$

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where

$T_{SINGLE\text{-}MSDU}$ is the estimated time required for the transmission of the allowed frame exchange sequence defined in 10.23.2.9 (for a TXOP limit of 0), including applicable IFSs

$T_{PENDING}$ is the estimated time required for the transmission of

- Pending MPDUs of the same AC
- Any associated immediate response frames
- Any HT NDP, VHT NDP, or Beamforming Report Poll frame transmissions and explicit feedback response frames
- Applicable IFSs
- Any RDG
- Any BDT
- Any pending QoS Null frame exchanges by paged STAs
- Any pending PS-Poll or NDP PS-Poll frame exchanges by paged STAs

T_{TXOP} is the duration given by dot11EDCATableTXOPLimit (dot11QAPEDCATableTXOPLimit for the AP) for that AC

$T_{TXOP\text{-}REMAINING}$ is T_{TXOP} less the time already used within the TXOP

$T_{END\text{-}NAV}$ is the remaining duration of any NAV set by the TXOP holder, or 0 if no NAV has been established

T_{PPDU} is the time required for transmission of the current PPDU

The estimated time required for transmission of a VHT Compressed Beamforming frame response is determined by assuming the following:

- All feedback segments (as defined in 10.36.5.3) are transmitted, even if a Beamforming Report Poll frame is used and not all of the bits in the included Feedback Segment Retransmission Bitmap field are equal to 1.
- The subfield values of the VHT MIMO Control field are as follows:
  - The Feedback Type, Nr Index, and Channel Width fields are as specified in 10.36.5.
  - The Nc Index field is as specified in 10.36.5 if the Feedback Type field is MU, or to the greatest value allowed by 10.36.5 if the Feedback Type field is SU.
  - The Grouping field indicates no grouping.
  - The Codebook Information field has the value 1.

NOTE 1—Estimated times might prove to be inexact, if the TXOP responder has a choice of PHY options (e.g., BCC v. LDPC, use of STBC, use of short GI, PHY header/preamble format options) or MAC options (e.g., use of HT Control). Heuristics such as the TXOP responder's previous choices and channel conditions might be used to minimize the inexactitude.

NOTE 2—If a TXOP includes the transmission of a VHT Compressed Beamforming frame by the TXOP responder, the TXOP holder can, if the duration estimates prove excessive, indicate truncation of the TXOP by using a CF-End frame, provided that the remaining duration of the TXOP after the transmission of the last frame can accommodate the CF-End frame (see 10.23.2.10).

In a PS-Poll+BDT frame or an RTS frame generated by an S1G STA as part of a BDT exchange the Duration/ID field is set as follows:

- In a PS-Poll+BDT frame, the Duration/ID field is set to the estimated time required for the transmission of one Ack frame, plus the estimated time required for the transmission of its following MPDUs and their responses if required, plus applicable IFS durations.

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— In an RTS frame that is sent as a response to the PS-Poll+BDT frame, the Duration/ID field is set to a value D: min ($T_{END\text{-}NAV}$ +$T_{PENDING}$ − T_{PPDU}; $T_{TXOP\text{-}REMAINING}$ − T_{PPDU}) ≤ D ≤ $T_{TXOP\text{-}REMAINING}$ − T_{PPDU}.

In any frame that includes a Duration/ID field, transmitted by an S1G STA as a response to PV1 frames that are not part of a BDT exchange, the Duration/ID field of the frame is set to 0. For any frame transmitted by a BDT initiator that is the TXOP holder as a response to PV1 frames, the Duration/ID field of the frame is set to the value of the TXNAV timer minus the estimated time required to transmit the frame. In any frame transmitted by a BDT initiator that is not the TXOP holder as a response to PV1 frames, the Duration/ID field of the frame is set to the remaining duration of the TXOP.

9.2.5.3 Setting for QoS CF-Poll frames

Within a Data frame containing QoS CF-Poll, the Duration/ID field value is set to one of the following:

a) One SIFS plus the TXOP limit, if the TXOP limit is nonzero, or
b) The time required for the transmission of one MPDU of nominal MSDU size and the associated Ack frame plus two SIFSs, if the TXOP limit is 0.

9.2.5.4 Setting for frames sent by a TXOP holder under HCCA

Within a frame sent by a TXOP holder under hybrid coordination function (HCF) controlled channel access (HCCA), to provide NAV protection for the entire controlled access phase (CAP), the Duration/ID field is set to one of the following values:

a) In an RTS frame
    1) If the pending frame is the final frame, the time required to transmit the pending frame, plus one CTS frame, plus one Ack frame if required, plus three SIFSs
    2) If the pending frame is not the final frame in the TXOP, the remaining duration of the TXOP
b) In a CTS frame
    1) If the pending frame is the sole frame in the TXOP, one of the following:
        i) If there is a response frame, the time required to transmit the pending frame, plus one SIFS, plus the response frame (Ack or BlockAck), plus an additional SIFS
        ii) If there is no response frame, the time required to transmit the pending frame, plus one SIFS
    2) If the pending frame is not the final frame in the TXOP, the remaining duration of the TXOP
c) Otherwise
    1) If the frame is a nonfinal frame in a TXOP with multiple frame exchanges, the remaining duration of the TXOP
    2) If the frame is the sole or final frame in the TXOP, the actual remaining time needed for this frame exchange sequence

9.2.5.5 Settings within a PSMP sequence

Within a PSMP frame the Duration/ID field is set to a value that is no less than the time required to complete all PSMP-DTT and PSMP-UTT periods described in the frame.

Within the PSMP-DTT and PSMP-UTT of a PSMP sequence, the Duration/ID field is set to the Duration/ID value of the preceding PSMP frame minus the time between the end of the PSMP frame and the end of the PPDU carrying the frame.

NOTE—In other words, all frames transmitted within a PSMP sequence locate the same NAV endpoint.

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9.2.5.6 Settings within a dual CTS sequence

Within a frame ("Frame1") (excluding a second CTS (CTS2) transmission, as defined in 10.3.2.10) sent by a QoS STA that is not a TXOP holder in a PPDU that contains an immediate response or that is sent by an RD responder, the Duration/ID field is set to the Duration/ID value from the frame(s) ("Frames2") that elicited the response or that carried the RDG minus the time interval between the end of the PPDU that carried Frame1 and the end of the PPDU that carries Frames2.

Within a frame ("Frame1") (excluding a CTS2 transmission, as defined in 10.3.2.10) sent by a QoS STA that is a TXOP holder, the Duration/ID field is set according to the rules in the following subclauses:

— 9.2.5.2 rule b) for multiple protection if Frame1 is not a QoS +CF-Poll frame and the TXOP holder is not operating under HCCA or PSMP
— 9.2.5.3 if Frame1 is a QoS +CF-Poll frame and the TXOP holder is not operating under HCCA or PSMP
— 9.2.5.4 if the TXOP holder is operating under HCCA
— 9.2.5.5. if the TXOP holder is operating under PSMP

Within the CTS2 of a dual CTS exchange, defined in 10.3.2.10, the Duration/ID field is set to the value of the Duration/ID field of the RTS frame that initiated the exchange minus the time required to transmit the first clear-to-sent (CTS1), CTS2, and the applicable IFSs.

9.2.5.7 Setting for control response frames

This subclause describes how to set the Duration/ID field for CTS, Ack, and BlockAck frames transmitted by a QoS STA.

In a CTS frame that is not part of a dual CTS sequence transmitted in response to an RTS frame, the Duration/ID field is set to the value obtained from the Duration/ID field of the RTS frame that elicited the response minus the time, in microseconds, between the end of the PPDU carrying the RTS frame and the end of the PPDU carrying the CTS frame.

In an Ack frame, the Duration/ID field is set to the value obtained from the Duration/ID field of the frame that elicited the response minus the time, in microseconds between the end of the PPDU carrying the frame that elicited the response and the end of the PPDU carrying the Ack frame.

In a BlockAck frame transmitted in response to a BlockAckReq frame or transmitted in response to a frame containing an implicit block ack request, the Duration/ID field is set to the value obtained from the Duration/ID field of the frame that elicited the response minus the time, in microseconds between the end of the PPDU carrying the frame that elicited the response and the end of the PPDU carrying the BlockAck frame.

In an NDP CTS frame transmitted in response to an RTS frame, the Duration field is set to the value obtained from the Duration/ID field of the RTS frame that elicited the response minus the time, in microseconds, between the end of the PPDU carrying the RTS frame and the end of the NDP CTS frame except as described in 10.54.5.4.

In an NDP Ack frame with the Idle Indication field equal to 0, the Duration field is set to the value obtained from the Duration/ID field of the frame that elicited the response minus the time, in microseconds, between the end of the PPDU carrying the frame that elicited the response and the end of the NDP Ack frame except when the eliciting frame is a PS-Poll frame in which case the Duration field can be set as described in 10.3.2.15.

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In an NDP Ack frame with the Idle Indication field equal to 1, the Duration field is set to the duration of time, in milliseconds, during which an idle period is expected from the STA that elicited the response, starting from the end of NDP Ack frame response.

In a TACK frame, the Duration/ID field is set to the value obtained from the Duration/ID field of the frame that elicited the response minus the time, in microseconds, between the end of the PPDU carrying the frame that elicited the response and the end of the PPDU carrying the TACK frame.

9.2.5.8 Setting for other response frames

In any frame transmitted by a STA that is not the TXOP holder and is not specified by 9.2.5.1 to 9.2.5.7, the Duration/ID field is set to the value obtained from the Duration/ID field of the frame that elicited the response minus the time, in microseconds, between the end of the PPDU carrying the frame that elicited the response and the end of the PPDU carrying the frame.

9.3 Format of individual frame types

9.3.1 Control frames

9.3.1.1 Format of Control frames

In the following descriptions, “immediately previous” frame means a frame whose reception concluded within the SIFS preceding the start of the current frame.

The Frame Control, Duration and Address 1 (RA) fields are present in all control frame subtypes. The Address 2 (TA) field is present in some control frame subtypes.

The subfields within the Frame Control field of Control frames carried in a non-S1G PPDU are set as shown in Figure 9-26.

B0 B1	B2 B3	B4 B7	B8	B9	B10	B11	B12	B13	B14	B15
Protocol Version	Type (Control)	Subtype	To DS (0)	From DS (0)	More Frag (0)	Retry (0)	Power Man-age-ment	More Data	Protected Frame (0)	+HTC (0)
Bits: 2	2	4	1	1	1	1	1	1	1	1

Figure 9-26—Frame Control field subfield values within Control frames carried in a non-S1G PPDU

In a Control frame carried in an S1G PPDU, when the Subtype subfield is not equal to 3 and not equal to 10, the format of the Frame Control field is shown in Figure 9-27.

B0 B1	B2 B3	B4 B7	B8 B10	B11	B12	B13	B14	B15
Protocol Version	Type	Subtype	Bandwidth Indication	Dynamic Indication	Power Manageme nt	More Data	Protected Frame	+HTC
Bits: 2	2	4	3	1	1	1	1	1

Figure 9-27—Frame Control field format in Control frames carried in an S1G PPDU when Subtype subfield is not equal to 3 and not equal to 10

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In a Control frame carried in an S1G PPDU, when the Subtype subfield is equal to 3, the format of the Frame Control field is shown in Figure 9-28.

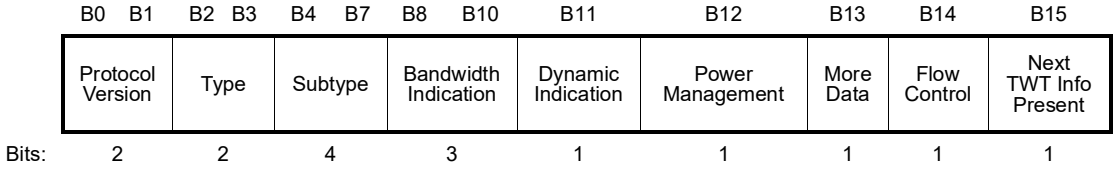

Figure 9-28—Frame Control field format in Control frames carried in an S1G PPDU when Subtype subfield is equal to 3

In a Control frame carried in an S1G PPDU, when the Subtype subfield is equal to 10, the format of the Frame Control field is shown in Figure 9-29.

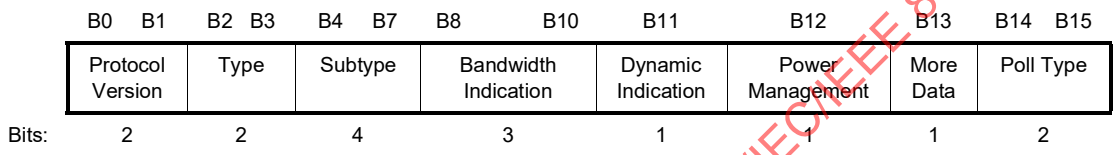

Figure 9-29—Frame Control field format in Control frames carried in an S1G PPDU when Subtype subfield is equal to 10

9.3.1.2 RTS frame format

The frame format for the RTS frame is defined in Figure 9-30.

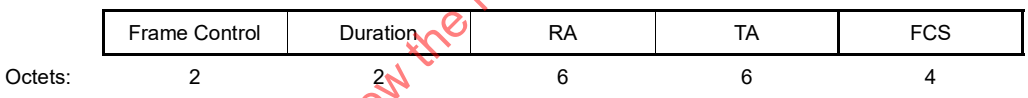

Figure 9-30—RTS frame format

The RA field of the RTS frame is the address of the STA that is the intended immediate recipient of a pending individually addressed frame.

The TA field is the address of the STA transmitting the RTS frame or the bandwidth signaling TA of the STA transmitting the RTS frame. In an RTS frame transmitted by a VHT STA in a non-HT or non-HT duplicate format to another VHT STA, the scrambling sequence carries the TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT (see 10.3.2.7) and the TA field is a bandwidth signaling TA.

For all RTS frames sent by non-QoS STAs, the Duration field is the time, in microseconds, required to transmit the pending Data or Management frame, plus one CTS frame, plus one Ack frame, plus three SIFSs. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer. For RTS frames sent by QoS STAs, see 9.2.5.

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9.3.1.3 CTS frame format

The frame format for the CTS frame is defined in Figure 9-31.

	Frame Control	Duration	RA	FCS
Octets:	2	2	6	4

Figure 9-31—CTS frame format

When the CTS frame is a response to an RTS frame, the RA field of the CTS frame is set to the address from the TA field of the RTS frame with the Individual/Group bit set to 0. When the CTS frame is the first frame in a frame exchange, the RA field is set to the MAC address of the transmitter.

For all CTS frames transmitted by a non-QoS STA in response to RTS frames, the Duration field is the value obtained from the Duration field of the immediately previous RTS frame, minus the time, in microseconds, required to transmit the CTS frame and its SIFS. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer.

At a non-QoS STA, if the CTS frame is the first frame in the exchange and the pending Data or Management frame requires acknowledgment, the Duration field is the time, in microseconds, required to transmit the pending Data or Management frame, plus two SIFSs plus one Ack frame. At a non-QoS STA, if the CTS frame is the first frame in the exchange and the pending Data or Management frame does not require immediate acknowledgment, the Duration field is the time, in microseconds, required to transmit the pending Data or Management frame, plus one SIFS. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer.

For other CTS frame transmissions by a QoS STA, the Duration field is set as defined in 9.2.5.

A CTS-to-self frame is a CTS frame in which the RA field is equal to the transmitter's MAC address.

A CTS-to-AP frame is a CTS frame that is not transmitted in response to an RTS frame and in which the RA field is equal to the MAC address of the AP with which the STA is associated.

9.3.1.4 Ack frame format

The frame format for the Ack frame is defined in Figure 9-32.

	Frame Control	Duration	RA	FCS
Octets:	2	2	6	4

Figure 9-32—Ack frame format

The RA field of the Ack frame is the nonbandwidth signaling TA from the Address 2 field of the immediately previous individually addressed Data, Management, BlockAckReq, BlockAck, or PS-Poll frames.

For Ack frames sent by non-QoS STAs, if the More Fragments bit was equal to 0 in the Frame Control field of the immediately previous individually addressed Data or Management frame, the Duration field is set to 0. In other Ack frames sent by non-QoS STAs, the Duration field is the value obtained from the Duration/ID field of the immediately previous Data, Management, BlockAckReq, or BlockAck frame minus the time, in microseconds, required to transmit the Ack frame and its SIFS. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer.

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In all other Ack frames, the Duration field is specified by 9.2.5.

9.3.1.5 PS-Poll frame format

9.3.1.5.1 General

The frame format for the PS-Poll frame is defined in Figure 9-33.

	Frame Control	Duration/ID	BSSID(RA)	TA	FCS
Octets:	2	2	6	6	4

Figure 9-33—PS-Poll frame format

The BSSID (RA) field is set to the address of the STA contained in the AP. The TA field value is the address of the STA transmitting the frame or a bandwidth signaling TA. In a PS-Poll frame transmitted by a VHT STA in a non-HT or non-HT duplicate format and where the scrambling sequence carries the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT, the TA field value is a bandwidth signaling TA.

9.3.1.5.2 Non-BDT variant of the PS-Poll frame format

The Duration/ID field contains the AID value assigned to the STA transmitting the frame by the AP in the (Re)Association Response frame that established that STA's current association, with the two MSBs set to 1.

9.3.1.5.3 BDT variant of the PS-Poll frame format

A PS-Poll frame with the Duration/ID field that contains a duration value as described in 9.2.5 is a BDT variant of the PS-Poll frame and is referred to as PS-Poll+BDT frame.

The Poll Type field in the Frame Control field of the PS-Poll+BDT frame is set to 0.

Bit 15 of the Duration/ID field of a PS-Poll+BDT frame is set to 0.

A non-S1G STA does not transmit PS-Poll+BDT frames.

9.3.1.6 CF-End frame format

The frame format for the CF-End frame is defined in Figure 9-34.

	Frame Control	Duration	RA	BSSID(TA)	FCS
Octets:	2	2	6	6	4

Figure 9-34—CF-End frame format

When transmitted by a non-DMG and non-S1G STA, the Duration field is set to 0. When transmitted by a DMG STA, the Duration field is set to the time required to complete the CF-End truncation sequence of which it is part (see 10.39.8): Duration = $(i - 1) \times$ (TXTIME(CF-End) + SIFS), where i is in the range 1 to 3 and indicates the order of the CF-End frame in the truncation sequence in the reverse direction (i.e., i=1 corresponds to the last CF-End frame in the sequence). When transmitted by an S1G STA, the Duration field is set to either 0 or a truncated time as described in 10.23.2.9.

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When transmitted by a non-DMG STA, the RA field is the broadcast address. When transmitted by a DMG STA, the RA field is the MAC address of the STA that is the intended immediate recipient of the individually addressed Data or Management frame, or the broadcast address.

When transmitted by a non-DMG STA, the BSSID (TA) field is the address of the STA contained in the AP except that the Individual/Group bit of the BSSID (TA) field is set to 1 in a CF-End frame transmitted by a VHT STA to a VHT AP in a non-HT or non-HT duplicate format to indicate that the scrambling sequence carries the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT. When transmitted by a DMG STA, the TA field is the MAC address of the STA transmitting the frame.

9.3.1.7 BlockAckReq frame format

9.3.1.7.1 Overview

The frame format of the BlockAckReq frame is defined in Figure 9-35.

	Frame Control	Duration	RA	TA	BAR Control	BAR Information	FCS
Octets:	2	2	6	6	2	variable	4

Figure 9-35—BlockAckReq frame format

The Duration field value is set as defined in 9.2.5.

The RA field of the BlockAckReq frame is the address of the recipient STA.

The TA field value is the address of the STA transmitting the BlockAckReq frame or a bandwidth signaling TA. In a BlockAckReq frame transmitted by a VHT STA in a non-HT or non-HT duplicate format and where the scrambling sequence carries the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT, the TA field value is a bandwidth signaling TA.

The BAR (for block acknowledgment request) Control field is shown in Figure 9-36.

	B0	B1	B2	B3	B4	B5	B11	B12	B15
	Reserved	Multi-TID	Compressed Bitmap	GCR Mode		Reserved		TID_INFO	
Bits:	1	1	1	2		7		4	

Figure 9-36—BAR Control field format

The values of the Multi-TID, Compressed Bitmap, and GCR Mode subfields indicate the BlockAckReq frame variants used, as indicated in Table 9-27.

DMG STAs use only the Compressed BlockAckReq variant and the Extended Compressed BlockAckReq variant.

The meaning of the TID_INFO subfield of the BAR Control field depends on the BlockAckReq frame variant type. The meaning of this subfield is explained within the subclause for each of the BlockAckReq frame variants.

The meaning of the BAR Information field of the BlockAckReq frame depends on the BlockAckReq frame variant type. The meaning of this field is explained within the subclause for each of the BlockAckReq frame variants.

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Table 9-27—BlockAckReq frame variant encoding

Multi-TID subfield value	Compressed Bitmap subfield value	GCR Mode subfield value (B3 B4)	BlockAckReq frame variant
0	0	00	Reserved
		01	Reserved
		10	Reserved
		11	Reserved
0	1	00	Compressed BlockAck
		01	GLK-GCR BlockAck
		10	GCR BlockAck
		11	Reserved
1	0	00	Extended Compressed BlockAck
		01	Reserved
		10	Reserved
		11	Reserved
1	1	00	Multi-TID BlockAck
		01	Reserved
		10	Reserved
		11	Reserved

NOTE—Reference to "a BlockAckReq" frame without any other qualification from other subclauses applies to any of the variants, unless specific exclusions are called out.

9.3.1.7.2 Compressed BlockAckReq variant

The TID_INFO subfield of the BAR Control field of the Compressed BlockAckReq frame contains the TID for which a BlockAck frame is requested.

The BAR Information field of the Compressed BlockAckReq frame contains the Block Ack Starting Sequence Control subfield, as shown in Figure 9-37. The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield contains the sequence number of the first MSDU or A-MSDU for which this BlockAckReq frame is sent. The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is set to 0.

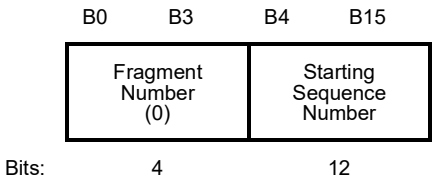

Figure 9-37—Block Ack Starting Sequence Control subfield format

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9.3.1.7.3 Extended Compressed BlockAckReq variant

The TID_INFO subfield of the BAR Control field of the Extended Compressed BlockAckReq frame contains the TID for which a BlockAck frame is requested.

The BAR Information field of the Extended Compressed BlockAckReq frame contains the Block Ack Starting Sequence Control subfield, as shown in Figure 9-37. The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield contains the sequence number of the first MSDU or A-MSDU for which this BlockAckReq frame is sent. The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is set to 0.

9.3.1.7.4 Multi-TID BlockAckReq variant

The TID_INFO subfield of the BAR Control field of the Multi-TID BlockAckReq frame determines the number of TIDs present in the Multi-TID BlockAckReq frame as given by TID_INFO + 1, e.g., a 2 in the TID_INFO subfield means that three TID values are present in the Multi-TID BlockAckReq frame's BAR Information field.

The BAR Information field of the Multi-TID BlockAckReq frame comprises multiple sets of Per TID Info subfields and Block Ack Starting Sequence Control subfields, as shown in Figure 9-38. The Per TID Info subfield is shown in Figure 9-39. The Block Ack Starting Sequence Control subfield is shown in Figure 9-37. The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield contains the sequence number of the first MSDU or A-MSDU for which this BlockAckReq frame is sent. The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is set to 0.

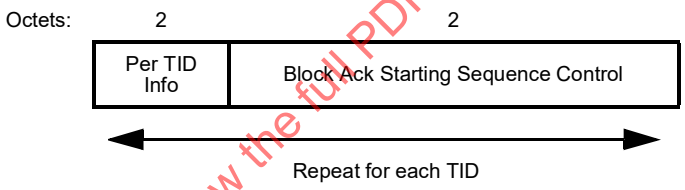

Figure 9-38—BAR Information field format (Multi-TID BlockAckReq)

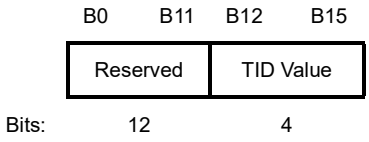

Figure 9-39—Per TID Info subfield format

9.3.1.7.5 GCR BlockAckReq variant

The TID_INFO subfield of the BAR Control field of the GCR BlockAckReq frame is set to 0.

The BAR Information field of the GCR BlockAckReq frame contains the Block Ack Starting Sequence Control subfield and GCR Group Address subfield, as shown in Figure 9-40. The Block Ack Starting Sequence Control subfield is shown in Figure 9-37. The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield contains the sequence number of the first MSDU or A-MSDU for which this BlockAckReq frame is sent. The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is set to 0.

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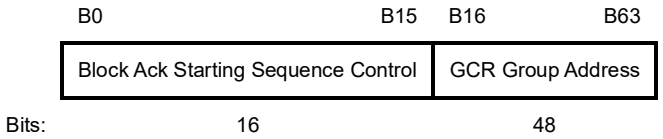

Figure 9-40—BAR Information field format (GCR BlockAckReq)

The GCR Group Address subfield contains the MAC address of the group for which reception status is being requested.

9.3.1.7.6 GLK-GCR BlockAckReq variant

For the BlockAcqReq variant, the TID_INFO subfield in the BAR Control field in the GLK-GCR BlockAckReq frame is 0.

The BAR Information field in the GLK-GCR BlockAckReq frame contains the Block Ack Starting Sequence Control subfield as shown in Figure 9-37. The Starting Sequence Number subfield in the Block Ack Starting Sequence Control subfield contains the sequence number of the first MSDU or A-MSDU for which this GLK-GCR BlockAckReq frame is sent. The Fragment Number subfield in the Block Ack Starting Sequence Control subfield is 0.

9.3.1.8 BlockAck frame format

9.3.1.8.1 Overview

The frame format of the BlockAck frame is defined in Figure 9-41.

	Frame Control	Duration	RA	TA	BA Control	BA Information	FCS
Octets:	2	2	6	6	2	variable	4

Figure 9-41—BlockAck frame format

The Duration field value is set as defined in 9.2.5.

The RA field of the BlockAck frame is the address of the recipient STA that requested the BlockAck frame.

The TA field value is the address of the STA transmitting the BlockAck frame.

The BA Control field is defined in Figure 9-42.

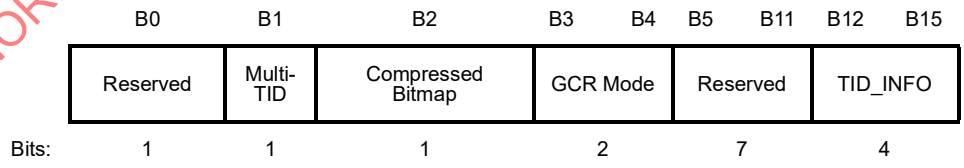

Figure 9-42—BA Control field format

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The values of the Multi-TID, Compressed Bitmap, and GCR Mode subfields of the BA Control field determine the BlockAck frame variants represented, as indicated in the Table 9-28.

Table 9-28—BlockAck frame variant encoding

Multi-TID subfield value	Compressed Bitmap subfield value	GCR Mode subfield value(B3 B4)	BlockAck frame variant
0	0	00	Reserved
		01	Reserved
		10	Reserved
		11	Reserved
0	1	00	Compressed BlockAck
		01	GLK-GCR BlockAck
		10	GCR BlockAck
		11	Reserved
1	0	00	Extended Compressed BlockAck
		01	Reserved
		10	Reserved
		11	Reserved
1	1	00	Multi-TID BlockAck
		01	Reserved
		10	Reserved
		11	Reserved

NOTE—Reference to “a BlockAck” frame without any other qualification from other subclauses applies to any of the variants, unless specific exclusions are called out.

The GCR Mode subfield indicates whether the BlockAck frame was sent in response to a GCR BlockAckReq or a GLK-GCR BlockAckReq frame.

The meaning of the TID_INFO subfield of the BA Control field depends on the BlockAck frame variant type. The meaning of this subfield is explained within the subclause for each of the BlockAck frame variants.

The meaning of the BA Information field depends on the BlockAck frame variant type. The meaning of this field is explained within the subclause for each of the BlockAck frame variants.

9.3.1.8.2 Compressed BlockAck variant

The TID_INFO subfield of the BA Control field of the Compressed BlockAck frame contains the TID for which this BlockAck frame is sent.

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The BA Information field of the Compressed BlockAck frame comprises the Block Ack Starting Sequence Control subfield and the Block Ack Bitmap subfield, as shown in Figure 9-43. The Block Ack Starting Sequence Control subfield is shown in Figure 9-37. The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield contains the sequence number of the first MSDU or A-MSDU for which this BlockAck frame is sent. This subfield is defined in 10.25.6.5. The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is set to 0.

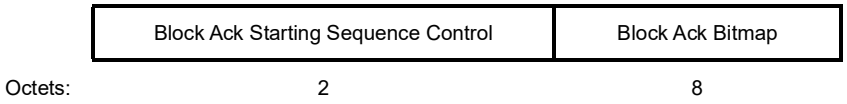

Figure 9-43—BA Information field format (Compressed BlockAck)

The Block Ack Bitmap subfield of the BA Information field of the Compressed BlockAck frame is used to indicate the received status of up to 64 entries, where each entry represents an MSDU or an A-MSDU. Each bit that is equal to 1 in the compressed Block Ack Bitmap field acknowledges the reception of a single MSDU or A-MSDU in the order of sequence number, with the first bit of the Block Ack Bitmap field corresponding to the MSDU or A-MSDU with the sequence number that matches the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield.

9.3.1.8.3 Multi-TID BlockAck variant

The TID_INFO subfield of the BA Control field of the Multi-TID BlockAck frame contains the number of TIDs, minus one, for which information is reported in the BA Information field.

The BA Information field of the Multi-TID BlockAck frame comprises one or more instances of the Per TID Info, Block Ack Starting Sequence Control, and the Block Ack Bitmap subfields, as shown in Figure 9-44. The Per TID Info subfield is shown in Figure 9-39, and the Block Ack Starting Sequence Control subfield is shown in Figure 9-37.

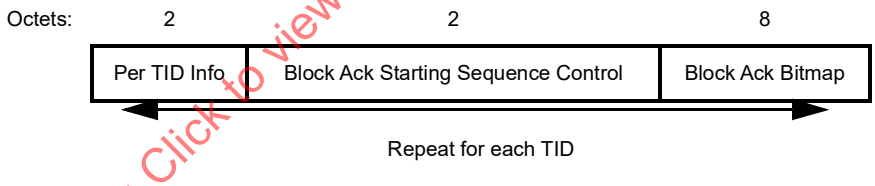

Figure 9-44—BA Information field format (Multi-TID BlockAck)

The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield is the sequence number of the first MSDU or A-MSDU for which this BlockAck frame is sent. This subfield is defined in 10.25.6.5. The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is set to 0. The first instance of the Per TID Info, Block Ack Starting Sequence Control, and Block Ack Bitmap subfields that is transmitted corresponds to the lowest TID value, with subsequent instances ordered by increasing values of the Per TID Info subfield.

The Block Ack Bitmap subfield of the BA Information field of the Multi-TID BlockAck frame contains an 8-octet block ack bitmap. Each bit that is equal to 1 in the Block Ack Bitmap subfield acknowledges the reception of a single MSDU or A-MSDU in the order of sequence number with the first bit of the Block Ack Bitmap subfield corresponding to the MSDU or A-MSDU with the sequence number that matches the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield.

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9.3.1.8.4 Extended Compressed BlockAck variant

The TID_INFO subfield of the BA Control field of the Compressed BlockAck frame contains the TID for which a BlockAck frame is requested.

The BA Information field of the Extended Compressed BlockAck frame is shown in Figure 9-45. The Block Ack Starting Sequence Control subfield is shown in Figure 9-37. The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield contains the sequence number of the first MSDU or A-MSDU for which this BlockAck frame is sent. This subfield is defined in 10.25.6.5. The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is set to 0.

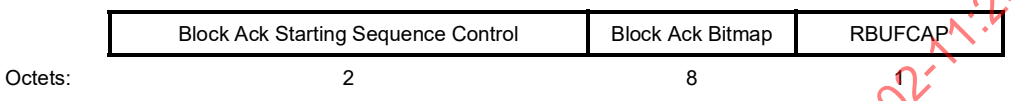

Figure 9-45—BA Information field format (Extended Compressed BlockAck)

The Block Ack Bitmap subfield of the BA Information field of the Extended Compressed BlockAck frame is used to indicate the received status of up to 64 entries, where each entry represents an MSDU or an A-MSDU. Each bit that is set to 1 in the Block Ack Bitmap subfield acknowledges the reception of a single MSDU or A-MSDU in the order of sequence number. The first bit of the Block Ack Bitmap subfield corresponds to the MSDU or A-MSDU with the sequence number that matches the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield.

The RBUFCAP field contains an unsigned integer that is the number of MPDU buffers available to store received MPDUs at the time of transmission of the Extended Compressed BlockAck frame (10.42.9).

9.3.1.8.5 GCR Block Ack variant

The TID_INFO subfield of the BA Control field of the GCR BlockAck frame contains the TID for which this BlockAck frame is sent.

The BA Information field of the GCR BlockAck frame comprises the Block Ack Starting Sequence Control, GCR Group Address, and the Block Ack Bitmap subfields, as shown in Figure 9-46. The Block Ack Starting Sequence Control subfield is shown in Figure 9-37. The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield contains the sequence number of the first A-MSDU for which this BlockAck frame is sent. This subfield is defined in 10.25.8. The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is set to 0.

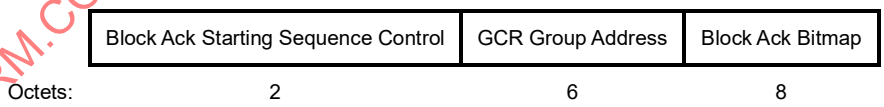

Figure 9-46—BA Information field format (GCR BlockAck)

The GCR Group Address subfield is set to the value from the Group Address subfield of the GCR BAR Information field in the BlockAckReq frame to which the BlockAck frame is sent in response.

The Block Ack Bitmap subfield is used to indicate the received status of up to 64 entries, where each entry represents an MSDU or an A-MSDU. Each bit that is equal to 1 in the Block Ack Bitmap subfield acknowledges the reception of a single MSDU or A-MSDU in the order of sequence number, with the first bit of the Block Ack Bitmap subfield corresponding to the MSDU or A-MSDU with the sequence number that matches the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield.

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9.3.1.8.6 GLK-GCR BlockAck variant

The TID_INFO subfield in the BA Control field in the GLK-GCR BlockAck frame contains the TID for which this BlockAck frame is sent.

The BA Information field in the GLK-GCR BlockAck frame comprises the Block Ack Starting Sequence Control and the Block Ack Bitmap subfields, as shown in Figure 9-47. The Block Ack Starting Sequence Control subfield is shown in Figure 9-47 The Starting Sequence Number subfield in the Block Ack Starting Sequence Control subfield contains the sequence number of the first A-MSDU for which this BlockAck frame is sent. This subfield is defined in 10.25.8. The Fragment Number subfield in the Block Ack Starting Sequence Control subfield is 0.

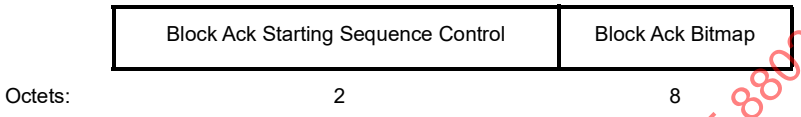

Figure 9-47—BA Information field format (GLK-GCR BlockAck)

The Block Ack Bitmap subfield is used to indicate the received status of up to 64 MSDUs and A-MSDUs. Each bit that is equal to 1 in the Block Ack Bitmap subfield acknowledges the reception of a single MSDU or A-MSDU in the order of sequence number, with the first bit of the Block Ack Bitmap subfield corresponding to the MSDU or A-MSDU with the sequence number that matches the Starting Sequence Number subfield in the Block Ack Starting Sequence Control subfield.

9.3.1.9 Control Wrapper frame format

The format of the Control Wrapper frame is shown in Figure 9-48.

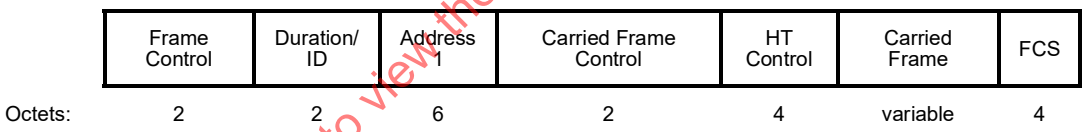

Figure 9-48—Control Wrapper frame format

The Control Wrapper frame is used to wrap any other Control frame (i.e., excluding the Control Wrapper frame) together with an HT Control field.

The Duration/ID field of the Control Wrapper frame is generated by following the rules for the Duration/ID field of the Control frame that is being wrapped.

The Address 1 field of the Control Wrapper frame is generated by following the rules for the Address 1 field of the Control frame that is being wrapped.

The Carried Frame Control field contains the value of the Frame Control field of the wrapped Control frame.

The HT Control field is defined in 9.2.4.6.

The Carried Frame field contains the fields that follow the Address 1 field of the Control frame that is being wrapped, excluding the FCS field.

The FCS field is defined in 9.2.4.8.

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9.3.1.10 Poll frame format

The format of the Poll frame is shown in Figure 9-49.

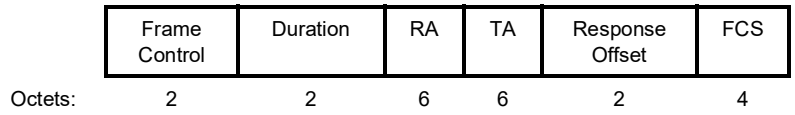

Figure 9-49—Poll frame format

The Duration field is set to include the duration, in microseconds, of the remaining Poll frame transmissions (see 10.39.7.2), plus all appropriate IFSs (10.3.2.3), plus the duration of the SPR frame transmissions.

The RA field contains the MAC address of the STA being polled.

The TA field contains the MAC address of the AP or PCP.

The Response Offset field indicates the offset, in units of 1 μs, beginning SIFS after the end of the Poll frame when the SPR frame in response to this Poll frame is transmitted.

9.3.1.11 Service period request (SPR) frame format

The format of the SPR frame is shown in Figure 9-50.

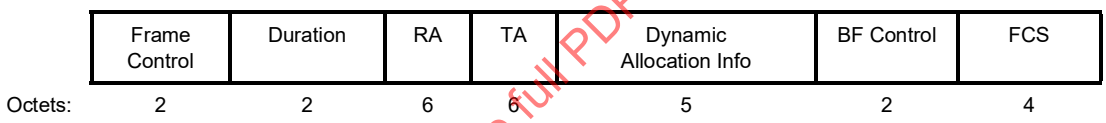

Figure 9-50—SPR frame format

When an SPR frame is sent in response to a Poll frame (see 10.39.7), the Duration field in the SPR frame is set to the value of the Duration field contained in the Poll frame, minus the value of the Response Offset field contained in the Poll frame multiplied by its unit as specified in 9.3.1.10, minus SIFS, minus the time taken to transmit the SPR frame. When the SPR frame is not sent in response to a Poll frame (see 10.39.9 and 11.4.13) and transmitted within an SP or a TXOP allocation, the Duration field is set to the time left in the allocation excluding the SPR transmission time. In all other cases, the Duration field is set to 0.

The RA field contains the MAC address of the AP or PCP.

The TA field contains the MAC address of the STA transmitting the SP request.

The Dynamic Allocation Info field is defined in 9.5.2.

The BF Control field is defined in 9.5.5.

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9.3.1.12 Grant frame format

The format of the Grant frame is shown in Figure 9-51.

	Frame Control	Duration	RA	TA	Dynamic Allocation Info	BF Control	FCS
Octets:	2	2	6	6	5	2	4

Figure 9-51—Grant frame format

For individually addressed Grant frames:

— If the Grant frame is used to obtain a TXOP, the Duration field is set to a value subject to the TXOP limit as described in 10.23.2.9. In all other cases within a CBAP, the Duration field is set to the Duration field of the immediately preceding frame minus TXTIME(Grant frame) minus aSIFSTime.

— If the Grant frame is sent within an SP, the Duration field is set according to the rules in 10.39.7, 10.39.8, and 10.39.9 as appropriate depending on the Grant frame usage.

— If the Grant frame is sent within an ATI, the Duration field is set according to the rules in 10.39.3.

For group addressed Grant frames, the Duration field is set to the time between PHY-TXEND.indication primitive of the Grant frame and the start of the allocation as indicated by the Allocation Duration subfield within the Dynamic Allocation Info field.

The RA field contains the MAC address of the STA receiving the SP grant.

The TA field contains the MAC address of the STA that has transmitted the Grant frame.

The Dynamic Allocation Info field is defined in 9.5.2.

The BF Control field is defined in 9.5.5.

9.3.1.13 DMG CTS frame format

The frame format for the DMG CTS frame is defined in Figure 9-52.

	Frame Control	Duration	RA	TA	FCS
Octets:	2	2	6	6	4

Figure 9-52—DMG CTS frame format

When the DMG CTS frame is a response to an RTS frame, the RA field of the DMG CTS frame is set to the address from the TA field of the RTS frame. When the DMG CTS frame is the first frame in a frame exchange, the RA field is set to the MAC address of the transmitter.

A DMG CTS-to-self frame is a DMG CTS frame in which the RA field is equal to the transmitter's MAC address.

For DMG CTS frames other than DMG CTS-to-self frames, the Duration field is set to the value of the Duration field of the immediately previous RTS frame, minus the time, in microseconds, required to transmit the DMG CTS frame and its SIFS. For DMG CTS-to-self frames, the Duration field is set to the remaining duration of the TXOP or SP. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer.

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For DMG CTS frames other than DMG CTS-to-self frames, the TA field is the MAC address of the STA transmitting the DMG CTS frame. For DMG CTS-to-self frames, the TA field is set to the individual address of the recipient or the group address of the recipients of the frame that the DMG STA intends to transmit after the DMG CTS-to-self frame.

9.3.1.14 DMG DTS frame format

The frame format for the DMG Denial to Send (DTS) frame is defined in Figure 9-53.

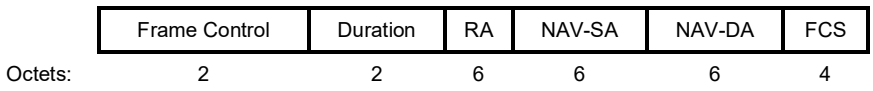

Figure 9-53—DMG DTS frame format

The Duration field is set to the value of the transmitting STA's NAV – (TXTIME(DMG DTS) + SIFS) or the remaining time in the SP at the end of the DMG DTS frame transmission, whichever is smaller. The transmitting STA's NAV is the value of its NAV at the start of the DMG DTS frame transmission.

The RA field of the frame is copied from the TA field of the immediately previous RTS frame to which the DMG DTS frame is a response.

The NAV-SA and the NAV-DA fields contain the MAC addresses of the source DMG STA and the destination DMG STA, respectively, whose exchange of an RTS and DMG CTS frame caused the last update to the NAV at the transmitting STA.

9.3.1.15 Sector sweep (SSW) frame format

The frame format for the SSW frame is defined in Figure 9-54.

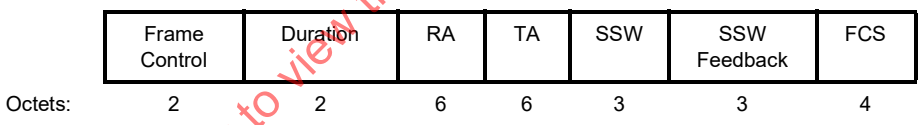

Figure 9-54—SSW frame format

The Duration field is set to the time until the end of the current SSW slot when the SSW frame is transmitted within an association beamforming training (A-BFT). Otherwise, it is set to the time until the end of the SSW frame transmission that has the CDOWN subfield within the SSW field equal to 0, plus MBIFS, or until the end of the current allocation (see 10.42), whichever comes first.

The RA field contains the MAC address of the STA that is the intended receiver of the sector sweep.

The TA field contains the MAC address of the transmitter STA of the sector sweep frame.

The SSW field is defined in 9.5.1.

The SSW Feedback field is defined in 9.5.3.

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9.3.1.16 Sector sweep feedback (SSW-Feedback) frame format

The format of the SSW-Feedback frame is shown in Figure 9-55.

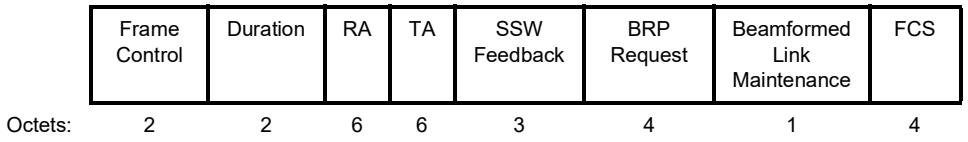

Figure 9-55—SSW-Feedback frame format

The Duration field is set to 0 when the SSW-Feedback frame is transmitted within an association beamforming training (A-BFT). When transmitted within a DTI, the Duration field is set to one of the following:

a) If a BRP phase is requested through the BRP Request field, the Duration field is set to the time, in microseconds, required to transmit an SSW-Ack frame plus 2×MBIFS (10.42.3.1).

b) If a BRP phase is not requested, the Duration field is set to the time, in microseconds, required to transmit an SSW-Ack frame, plus MBIFS (10.42.3.1) or the time until the end of the current allocation, whichever comes earlier.

The RA field contains the MAC address of the STA that is the intended destination of the SSW-Feedback frame.

The TA field contains the MAC address of the STA transmitting the SSW-Feedback frame.

The SSW Feedback field is defined in 9.5.3.

The BRP Request field is defined in 9.5.4.

The Beamformed Link Maintenance field is defined in 9.5.6.

9.3.1.17 Sector sweep Ack (SSW-Ack) frame format

The format of the SSW-Ack frame is shown in Figure 9-56.

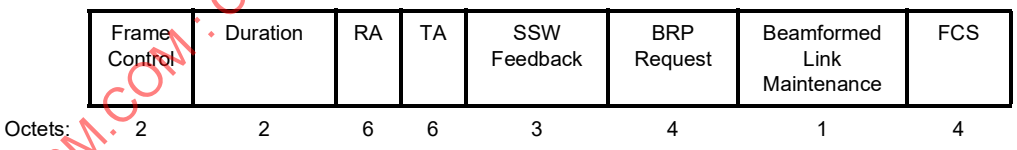

Figure 9-56—SSW-Ack frame format

The Duration field is set to the value of the Duration field of the immediately preceding SSW-Feedback frame, minus MBIFS, minus the time required to transmit the SSW-Ack frame.

The RA field contains the MAC address of the STA that is the intended destination of the SSW-Ack frame.

The TA field contains the MAC address of the STA transmitting the SSW-Ack frame.

The SSW Feedback field is defined in 9.5.3.

The BRP Request field is defined in 9.5.4.

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The Beamformed Link Maintenance field is defined in 9.5.6.

9.3.1.18 Grant Ack frame format

The format of the Grant Ack frame is shown in Figure 9-57. The Grant Ack frame is sent as a response to the reception of a Grant frame.

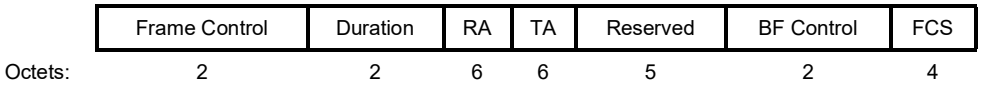

Figure 9-57—Grant Ack frame format

The Duration field is set to the value obtained from the Duration field of the immediately previous Grant frame minus the time, in microseconds, required to transmit the Grant Ack frame and its SIFS.

The RA field of the Grant Ack frame is copied from the Address 2 field of the immediately previous Grant frame.

The TA field contains the MAC address of the STA that has transmitted the Grant Ack frame.

The BF Control field is defined in 9.5.5.

9.3.1.19 VHT NDP Announcement frame format

The frame format of the VHT NDP Announcement frame is shown in Figure 9-58.

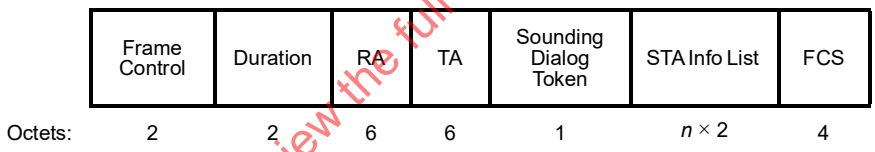

Figure 9-58—VHT NDP Announcement frame format

The Duration field is set as defined in 9.2.5.

The VHT NDP Announcement frame contains at least one STA Info field. If the VHT NDP Announcement frame contains only one STA Info field, then the RA field is set to the address of the STA that can provide feedback (see 10.36.5.2). If the VHT NDP Announcement frame contains more than one STA Info field, then the RA field is set to the broadcast address.

The TA field is set to the address of the STA transmitting the VHT NDP Announcement frame or the bandwidth signaling TA of the STA transmitting the VHT NDP Announcement frame. In a VHT NDP Announcement frame transmitted by a VHT STA in a non-HT or non-HT duplicate format and where the scrambling sequence carries the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT, the TA field is set to a bandwidth signaling TA.

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The format of the Sounding Dialog Token field is shown in Figure 9-59.

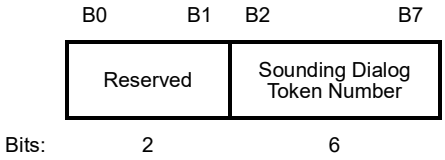

Figure 9-59—Sounding Dialog Token field format

The Sounding Dialog Token Number subfield in the Sounding Dialog Token field contains a value selected by the beamformer to identify the VHT NDP Announcement frame.

The STA Info List field contains one or more (*n*) STA Info fields.

If the VHT NDP Announcement frame is transmitted by a non-S1G STA, then the format of the STA Info field is shown in Figure 9-60.

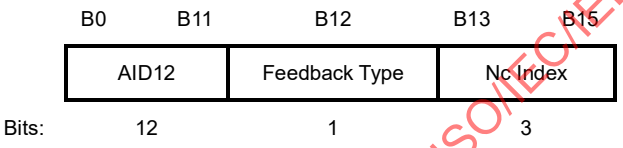

Figure 9-60—STA Info field format in a non-S1G STA

The subfields in the STA Info field are described in Table 9-29.

Table 9-29—STA Info subfields

Subfield	Description
AID12	Contains the 12 least significant bits of the AID of a STA expected to process the following VHT NDP and prepare the sounding feedback. Equal to 0 if the STA is an AP, mesh STA, or IBSS STA.
Feedback Type	Indicates the type of feedback requested. Set to 0 for SU. Set to 1 for MU.
Nc Index	If the Feedback Type field indicates MU, then Nc Index indicates the number of columns minus 1, (*Nc* – *1*), in the compressed beamforming feedback matrix. Reserved if the Feedback Type field indicates SU.

If the VHT NDP Announcement frame is transmitted in an S1G PPDU, the frame is referred to as an S1G NDP Announcement frame, and the format of the STA Info field is shown in Figure 9-61. The Feedback Type and Nc Index subfields are defined in Table 9-29, wherein the Nc Index field does not indicate a value that is more than 4. The AID13 subfield contains the least significant bits of the AID of the STA that could process the following S1G NDP and prepare sounding feedback. The AID13 subfield is equal to 0 if the STA is an AP or is in an IBSS.

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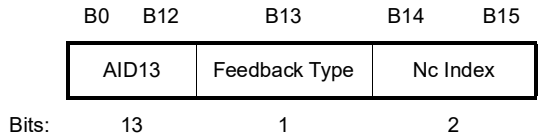

Figure 9-61—STA Info field format in an S1G STA

9.3.1.20 Beamforming Report Poll frame format

The Beamforming Report Poll frame is shown in Figure 9-62.

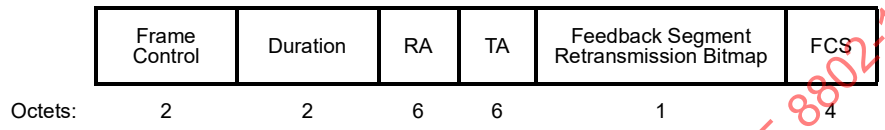

Figure 9-62—Beamforming Report Poll frame format

The Duration field is set as defined in 9.2.5.

The RA field is set to the address of the intended recipient.

The TA field is set to the address of the STA transmitting the Beamforming Report Poll or a bandwidth signaling TA. In a Beamforming Report Poll frame transmitted by a VHT STA in a non-HT or non-HT duplicate format and where the scrambling sequence carries the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT, the TA field is set to a bandwidth signaling TA.

The Feedback Segment Retransmission Bitmap field indicates the requested feedback segments of a VHT Compressed Beamforming report (see 10.36.5.3). If the bit in position *n* (*n=0* for LSB and *n=7* for MSB) is 1, then the feedback segment with the Remaining Feedback Segments subfield in the VHT MIMO Control field equal to *n* is requested. If the bit in position *n* is 0, then the feedback segment with the Remaining Feedback Segments subfield in the VHT MIMO Control field equal to *n* is not requested.

9.3.1.21 TACK frame format

The frame format of the TACK frame is defined in Figure 9-63.

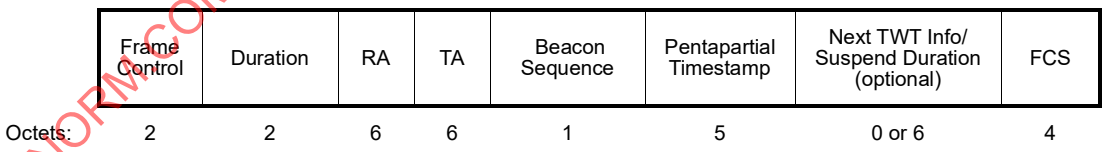

Figure 9-63—TACK frame format

The Duration field is described in 9.2.5.7.

The RA field contains the address of the intended recipient of the frame.

The TA field contains the address of the transmitter sending the frame.

The Beacon Sequence field contains the value of the Change Sequence field from the most recently transmitted S1G Beacon frame.

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The Pentapartial Timestamp field contains the value of the 5 least significant octets of the STA's TSF timer at the time that the start of the data symbol containing the first bit of the Pentapartial Timestamp field appears at the transmit antenna connector.

The format for the optional Next TWT Info/Suspend Duration field is defined in Figure 9-64.

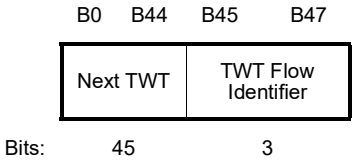

Figure 9-64—Next TWT Info/Suspend Duration field format

If the Next TWT Info Present field of the Frame Control field is equal to 1 and the Flow Control field of the Frame Control field is equal to 0, then the Next TWT Info/Suspend Duration field is present and is set to 0 or contains the 45 MSBs of the value of the 6 least significant octets of the TSF timer corresponding to the next scheduled TWT SP for the TWT agreement identified by the TWT Flow Identifier subfield for the STA that is the intended recipient of the frame. If the Next TWT Info/Suspend Duration field is 0, the transmitter does not currently have a Next TWT value available for transmission for the TWT agreement identified by the TWT Flow Identifier subfield for the STA that is the intended recipient of the frame.

If the Next TWT Info Present field of the Frame Control field is equal to 1 and the Flow Control field of the Frame Control field is equal to 1, then the Next TWT Info/Suspend Duration field is present and contains a flow suspension duration in microseconds during which the intended recipient TWT STA is not allowed to transmit Data frames to the STA identified by the TA field of the TACK frame.

If the Next TWT Info Present field is equal to 0 in the Frame Control field, the Next TWT Info/Suspend Duration field is not present in the TACK frame.

9.3.2 Data frames

9.3.2.1 Format of Data frames

9.3.2.1.1 General

The format of a Data frame is defined in Figure 9-65. The Frame Control, Duration, Address 1, Address 2, Address 3, and Sequence Control fields are present in all data frame subtypes. The presence of the Address 4 field is determined by the setting of the To DS and From DS subfields of the Frame Control field (see below). The presence of the QoS Control field is determined by the setting of the QoS subfield of the Subtype subfield (see 9.2.4.1.3 of the Frame Control field. The presence of the HT Control field is determined by the setting of the +HTC subfield of the Frame Control field (see 9.2.4.1.10).

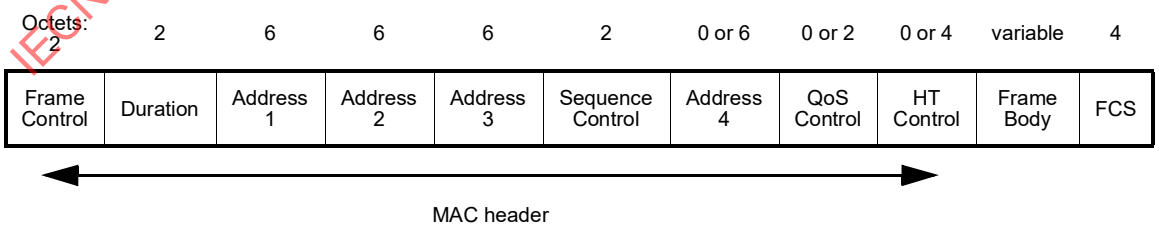

Figure 9-65—Data frame format

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NOTE—The maximum frame body size shown in Figure 9-65 is for GCMP encryption of a maximum-size A-MSDU (note that TKIP encryption is not allowed in this case and any Mesh Control fields are part of the A-MSDU subframes). The corresponding maximum for CCMP encryption is 7951 octets. The maximum frame body size if A-MSDUs are not used is 2346 octets for GCMP encryption of a maximum-size MSDU, 2338 octets for CCMP encryption of a maximum-size MSDU and 2342 octets for TKIP encryption of a maximum-size MSDU, including in both cases an 18-octet Mesh Control field. The frame body size might in all cases be greater if a vendor-specific cipher suite is used.

Data frames with the QoS subfield of the Subtype subfield (see 9.2.4.1.3) set to 1 contain *QoS* in their names and contain a QoS Control field in the MAC header. Depending on the context, *QoS Data frame* either refers to any such frame, or refers specifically to the Data frame with subtype 1000. References nearby to other specific Data frames with *QoS* in their name (e.g., QoS Null or QoS Data +CF-Poll) typically suggest the latter interpretation.

A QoS STA always uses QoS Data frames for data transmissions to other QoS STAs. A QoS STA uses frames with the QoS subfield of the Subtype subfield set to 0 for data transmissions to non-QoS STAs. A non-QoS STA always uses frames with the QoS subfield of the Subtype subfield set to 0 for data transmissions to other STAs. All STAs use frames with the QoS subfield of the Subtype subfield set to 0 for nonconcealed GCR broadcast Data frames unless a transmitting STA knows that all STAs in a BSS have QoS capability, in which case the transmitting STAs use QoS Data frames. All STAs use frames with the QoS subfield of the Subtype subfield set to 0 for nonconcealed GCR group addressed Data frames unless it is known to the transmitter that all STAs in the BSS that are members of the multicast group have QoS capability, in which case STAs use QoS Data frames. APs where dot11RobustAVStreamingImplemented is true or mesh STAs where dot11MeshGCRImplemented is true use frames with the QoS subfield of the Subtype subfield set to 1 for concealed GCR frames, as described in 11.21.16.3.5.

9.3.2.1.2 Address and BSSID fields

The content of the address fields of Data frames is dependent upon the values of the To DS and From DS subfields in the Frame Control field and whether the Frame Body field contains either an MSDU (or fragment thereof) or an entire A-MSDU, as determined by the A-MSDU Present subfield of the QoS Control field (see 9.2.4.5.9). The content of the address fields transmitted by nonmesh STAs is defined in Table 9-30. The content of the address fields transmitted by mesh STAs is defined in 9.3.5, and the content of the fields transmitted by GLK STAs is defined in 10.65. Where the content of a field is shown as not applicable (N/A), the field is omitted. Note that Address 1 always holds the receiver address of the intended receiver (or, in the case of group addressed frames, receivers) and that Address 2 always holds the address of the STA that is transmitting the frame.

A STA uses the contents of the Address 2 field to direct the acknowledgment if an acknowledgment is necessary.

The DA field contains the destination of the MSDU (or fragment thereof) or A-MSDU in the Frame Body field.

NOTE 1—A SYNRA is never the DA. When a GLK AP uses a SYNRA as the RA, the actual DA is carried in another field. See 10.65.

The SA field contains the address of the MAC entity that initiated the MSDU (or fragment thereof) or A-MSDU in the Frame Body field.

When a Data frame carries an MSDU (or fragment thereof), the DA and SA values related to that MSDU are carried in the Address 1, Address 2, Address 3, and Address 4 fields (according to the setting of the To DS and From DS subfields) as defined in Table 9-30.

When a Data frame carries a basic A-MSDU, the DA and SA values related to each MSDU carried by the A-MSDU are carried within the A-MSDU subframe header. Zero, one, or both of these fields are present in the Address 1 and Address 2 fields as indicated in Table 9-30.

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Table 9-30—Address field contents

To DS	From DS	Address 1	Address 2	Address 3		Address 4	
				MSDU and Short A-MSDU case	Basic A-MSDU and Dynamic A-MSDU case	MSDU and Short A-MSDU case	Basic A-MSDU and Dynamic A-MSDU case
0	0	RA = DA	TA = SA	BSSID	BSSID	N/A	N/A
0	1	RA (see NOTE 1)	TA = BSSID	SA	BSSID	N/A	N/A
1	0	RA = BSSID	TA (see NOTE 2)	DA	BSSID	N/A	N/A
1	1	RA	TA	DA	BSSID	SA	BSSID

NOTE 1—Address 1 field of a frame with To DS equal to 0 and From DS equal to 1 is equal to the DA, except when an individually addressed A-MSDU frame is used in DMS and S1G relay, in which case, the destination address of the frame is included in the DA field of the A-MSDU subframe (see 11.21.16 and 10.54).

NOTE 2—Address 2 field of a frame with To DS equal to 1 and From DS equal to 0 is equal to the SA, except when an individually addressed A-MSDU frame is used in S1G relay, in which case, the source address of the frame is included in the SA field of the A-MSDU subframe (see 10.54).

The RA field is the individual address of the STA that is the immediate intended receiver of the frame or the group address of the STAs that are the immediate intended receivers of the frame.

When a GLK AP Data frame is sent with a four-address MAC header with a groupcast RA, the RA is a SYNRA (see 10.65). A SYNRA is also used when the DA is not known by the corresponding IEEE 802.1Q bridge. The format of the RA field when it carries a SYNRA is shown in Figure 9-66.

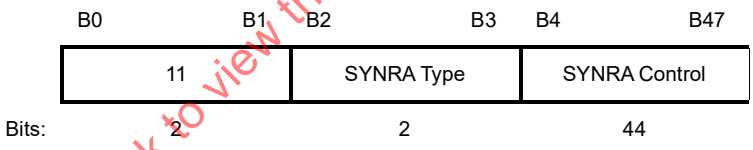

Figure 9-66—Format of an RA field carrying a SYNRA

NOTE 2—IEEE Std 802 and IEEE Std 802.1CQ define groupcast MAC addresses with a similar format to a SYNRA, but groupcast MAC addresses are DAs in the context of IEEE Std 802.11. Since SYNRAs only occur in the RA field, the similar formats are disambiguated by virtue of being used within an RA or DA.

The SYNRA Type subfield is used to select between multiple possible SYNRA formats. The SYNRA types and the format of the SYNRA Control subfield for each type are listed in Table 9-31.

The SYNRA Control subfield format is specified separately for each SYNRA type, as defined in Table 9-31.

Table 9-31—SYNRA Type field encoding

Value	Description	SYNRA Control subfield format
0	Basic SYNRA	See Figure 9-67.
1–3	Reserved	—

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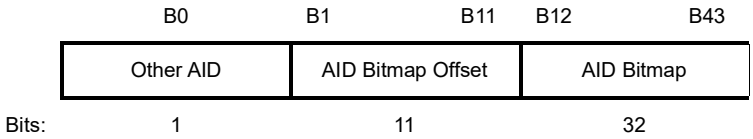

Figure 9-67—Basic SYNRA Control subfield format

The AID Bitmap Offset subfield in a Basic SYNRA Control subfield is used to indicate the starting AID value, which is associated with bit 0 of the AID Bitmap subfield. Its value is multiplied by 4 to find the starting AID value, and it has a value from 0 to 494 for a non-S1G STA, or 0 to 2040 for an S1G STA. Other values are reserved.

NOTE 3—These match the maximum AID values of 2007 (for non-S1G STAs) and 8191 (for S1G STAs).

The AID Bitmap subfield in a Basic SYNRA Control subfield provides the accept/discard indication for a range of 32 consecutive AIDs. Bits B12 to B43 represent AID values in the range AID Bitmap Offset × 4 + 1 to AID Bitmap Offset × 4 + 32, respectively. For each bit in the AID Bitmap subfield, a 1 indicates acceptance, and a 0 indicates discarding.

The Other AID subfield in a Basic SYNRA Control subfield provides the accept/discard indication for AIDs outside the range of values covered by the AID Bitmap subfield. A 1 indicates acceptance, and a 0 indicates discarding.

The TA field is the address of the STA that is transmitting the frame.

The BSSID field of the Data frame is set as follows:

a) If the STA is contained within an AP or is associated with an AP, the BSSID is the address currently in use by the STA contained in the AP.
b) If the STA is an IBSS STA, the BSSID is that selected by the STA that started the IBSS.
c) If the STA is transmitting a Data frame when dot11OCBActivated is true, the BSSID is the wildcard BSSID.
d) If the STA is a member of an MBSS, the BSSID is the address of the transmitter and is equal to the Data frame's TA.
e) If the STA participates in a PBSS, the BSSID is the address of the STA contained in the PCP.

9.3.2.1.3 Other MAC Header fields

The Sequence Control field is defined in 9.2.4.4.

The QoS Control field is defined in 9.2.4.5. The presence of the QoS Control field is determined by the Subtype subfield of the Frame Control field, as specified in 9.2.4.1.3.

The HT Control field is defined in 9.2.4.6. The presence of the HT Control field is determined by the +HTC subfield of the Frame Control field, as specified in 9.2.4.1.10.

9.3.2.1.4 The frame body

The frame body consists of either of the following:

— The MSDU (or a fragment thereof), the Mesh Control field (present if the frame is transmitted by a mesh STA and the Mesh Control Present subfield of the QoS Control field is 1, otherwise absent), and a security header and trailer (present if the Protected Frame subfield in the Frame Control field is 1, otherwise absent)

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— The A-MSDU and a security header and trailer (present if the Protected Frame subfield in the Frame Control field is 1, otherwise absent)

The presence of an A-MSDU in the frame body is indicated by setting the A-MSDU Present subfield of the QoS Control field to 1, as shown in Table 9-10.

For Data frames of subtype Null, QoS Null, QoS CF-Ack, QoS CF-Poll, and QoS CF-Ack +CF-Poll, the Frame Body field is null (i.e., has a length of 0 octets); these subtypes are used for MAC control purposes. For Data frames of subtype Data, the Frame Body field contains all of, or a fragment of, an MSDU after any encapsulation for security. For Data frames of subtypes QoS Data, QoS Data +CF-Ack, QoS Data +CF-Poll, and QoS Data +CF-Ack +CF-Poll, the Frame Body field contains an MSDU (or fragment thereof) or A-MSDU after any encapsulation for security. For Data frames of subtype QoS Data that are transmitted by a mesh STA, the Frame Body field also contains a Mesh Control field, as described in 9.2.4.7.3.

The maximum length of the Frame Body field can be determined from the maximum MSDU length plus the length of the Mesh Control field (if present) plus any overhead from encapsulation for encryption (i.e., it is always possible to send a maximum length MSDU, with any encapsulations provided by the MAC layer within a single Data frame). When the frame body carries an A-MSDU, the size of the Frame Body field is limited by:

— The PHY's maximum PHY service data unit (PSDU) length
— If A-MPDU aggregation is used by a non-VHT and non-DMG STA, a maximum MPDU length of 4095 octets (see 9.7)

9.3.2.1.5 Duration field

Within all Data frames sent by the QoS STA, the Duration field contains a duration value as defined in 9.2.5. Within all Data frames sent by non-QoS STAs, the Duration field is set according to the following rules:

— If the Address 1 field contains a group address, the Duration field is set to 0.
— If the More Fragments bit is 0 in the Frame Control field of a frame and the Address 1 field contains an individual address, the Duration field is set to the time, in microseconds, required to transmit one Ack frame, plus one SIFS.
— If the More Fragments bit is 1 in the Frame Control field of a frame and the Address 1 field contains an individual address, the Duration field is set to the time, in microseconds, required to transmit the next fragment of this Data frame, plus two Ack frames, plus three SIFSs.

The Duration field calculation for the Data frame is based on the rules in 10.6 that determine the data rate at which the Control frames in the frame exchange sequence are transmitted. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer. All STAs process Duration field values less than or equal to 32 767 from valid Data frames (without regard for the RA, DA, and/or BSSID address values that might be present in these frames) to update their NAV settings as appropriate under the coordination function rules.

NOTE 1—The QoS Data and QoS Null subtypes are the only Data subtypes transmitted by a DMG STA.

NOTE 2—The HT Control field is not present in frames transmitted by a DMG STA.

9.3.2.2 Aggregate MSDU (A-MSDU) format

9.3.2.2.1 General

An A-MSDU is a sequence of A-MSDU subframes as shown in Figure 9-68. Each A-MSDU subframe consists of an A-MSDU subframe header followed by an MSDU and 0 to 3 octets of padding as shown in Figure 9-69 (in 9.3.2.2.2), Figure 9-71 (in 9.3.2.2.3), and Figure 9-72 (in 9.3.2.2.4).

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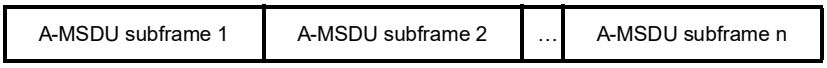

Figure 9-68—A-MSDU structure

Three A-MSDU subframe formats are defined: the Basic A-MSDU subframe described in 9.3.2.2.2, the Short A-MSDU subframe described in 9.3.2.2.3, and the Dynamic A-MSDU subframe described in 9.3.2.2.4. Unless otherwise noted, in this standard, the term A-MSDU applies to any of the Basic A-MSDU, the Short A-MSDU, and the Dynamic A-MSDU. The Basic A-MSDU uses only the Basic A-MSDU subframe format, the Short A-MSDU uses only the Short A-MSDU subframe format, and the Dynamic A-MSDU uses only the Dynamic A-MSDU subframe format.

9.3.2.2.2 Basic A-MSDU subframe format

The structure of a Basic A-MSDU subframe is shown in Figure 9-69.

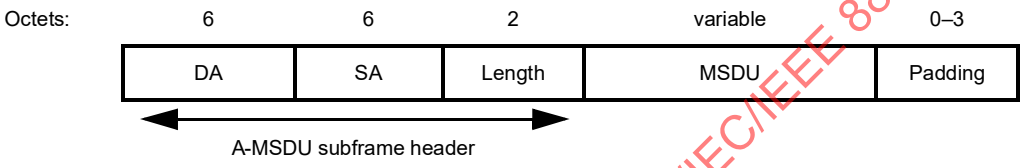

Figure 9-69—Basic A-MSDU subframe structure

In the Basic A-MSDU subframe, each A-MSDU subframe (except the last) is padded so that its length is a multiple of 4 octets. The last A-MSDU subframe has no padding.

The A-MSDU subframe header contains three fields: DA, SA, and Length. The order of these fields and the bits within these fields are the same as the IEEE 802.3™ frame format. The DA and SA fields of the A-MSDU subframe header contain the values passed in the MA-UNITDATA.request and MA-UNITDATA.indication primitives. The Length field contains the length in octets of the MSDU.

An A-MSDU contains only MSDUs whose DA and SA parameter values map to the same receiver address (RA) and transmitter address (TA) values. The rules for determining RA and TA are independent of whether the frame body carries an A-MSDU.

NOTE 1—It is possible to have different DA and SA parameter values in A-MSDU subframe headers of the same A-MSDU as long as they all map to the same Address 1 and Address 2 parameter values.

The MPDU containing the A-MSDU is carried in any of the following data frame subtypes: QoS Data, QoS Data +CF-Ack, QoS Data +CF-Poll, QoS Data +CF-Ack +CF-Poll. The A-MSDU structure is contained in the frame body of a single MPDU. If encrypted, the MPDU is encrypted as a single unit.

NOTE 2—The TID present in the QoS Control field of the MPDU carrying the A-MSDU indicates the TID for all MSDUs in the A-MSDU. Because this TID is common to all MSDUs in the A-MSDU, only MSDUs delivered to the MAC by an MA-UNITDATA.request primitive with an integer priority parameter that maps to the same TID can be aggregated together using A-MSDU.

When mesh Data frames are aggregated, the A-MSDU subframe header includes Mesh DA, Mesh SA, Length, and Mesh Control. The A-MSDU subframe structure for Mesh Data is defined in Figure 9-70.

The Mesh DA and Mesh SA fields contain the addresses of the destination mesh STA and the source mesh STA, respectively, determined in 9.3.5.

The Length field contains the length in octets of the MSDU.

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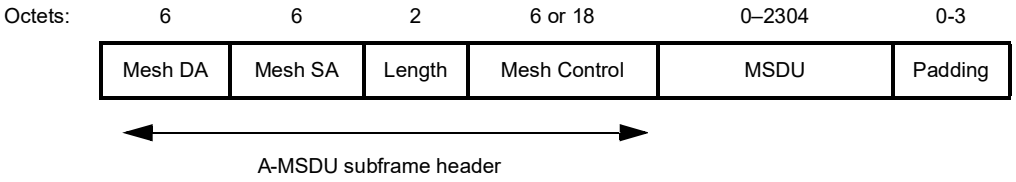

Figure 9-70—A-MSDU subframe structure for Mesh Data

The format of the Mesh Control field is described in 9.2.4.7.3.

NOTE 3—It is possible to have different Mesh DA, Mesh SA, and Mesh Control in subframe headers of the same A-MSDU as long as they all map to the same Address 1 and Address 2 values.

9.3.2.2.3 Short A-MSDU subframe format

The Short A-MSDU subframe is shown in Figure 9-71. In the Short A-MSDU subframe, each A-MSDU subframe (except the last) is padded so that its length excluding the A-MSDU subframe header is a multiple of 4 octets. The last A-MSDU subframe has no padding.

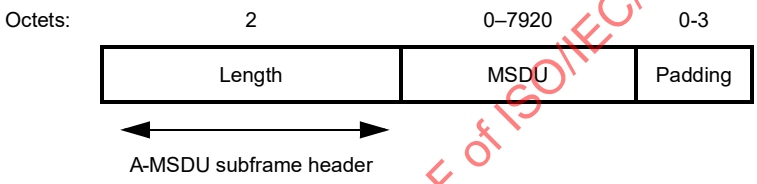

Figure 9-71—Short A-MSDU subframe structure

The Short A-MSDU subframe header consists of a Length field that contains the length in octets of the MSDU.

NOTE—The Short A-MSDU subframe format is not transmitted by non-DMG STAs.

9.3.2.2.4 Dynamic A-MSDU format

The structure of a Dynamic A-MSDU subframe is shown in Figure 9-72. In the Dynamic A-MSDU subframe, each A-MSDU subframe (except the last) is padded, so that its length is a multiple of 4 octets. The last A-MSDU subframe has no padding.

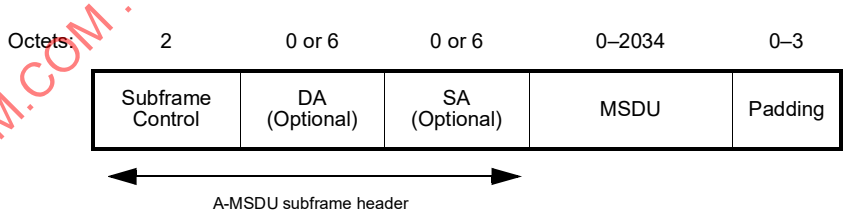

Figure 9-72—Dynamic A-MSDU subframe structure

The A-MSDU subframe header contains the Subframe Control field and optionally the DA and SA fields. A Dynamic A-MSDU subframe has 0, 1, or 2 addresses associated with it, as governed by the Subframe Control field.

The Subframe Control field is defined in Figure 9-73 and contains the Length, DA Present, and SA Present subfields.

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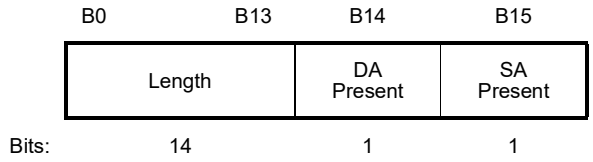

Figure 9-73—Subframe Control field format

The Length subfield contains the length in octets of the MSDU.

The DA Present field is set to 1 when the DA field is present in the Dynamic A-MSDU subframe header and is set to 0 when the DA field is not present.

The SA Present field is set to 1 when the SA field is present in the Dynamic A-MSDU subframe header and is set to 0 when the SA field is not present.

If present, the DA field of the Dynamic A-MSDU subframe header contains the destination address of the MSDU. When the DA field is not present, the DA of the MSDU is defined by the rules in 10.11.

If present, the SA field of the Dynamic A-MSDU subframe header contains the source address of the MSDU. When the SA field is not present in a Dynamic A-MSDU subframe, the SA is defined by the rules in 10.11.

The MSDU field contains the MSDU that is carried in the Dynamic A-MSDU subframe.

The Padding field contains 0 to 3 octets of padding, so that the length of the Dynamic A-MSDU subframe is a multiple of 4 octets, except for the last Dynamic A-MSDU subframe in a Dynamic A-MSDU, which has no padding.

9.3.3 (PV0) Management frames

9.3.3.1 Format of (PV0) Management frames

The format of a Management frame is defined in Figure 9-74. The Frame Control, Duration, Address 1, Address 2, Address 3, and Sequence Control fields are present in all management frame subtypes. In an MMPDU carried in one or more non-VHT PPDUs, the maximum MMPDU size is specified in Table 9-25. The presence of the HT Control field is determined by the setting of the +HTC subfield of the Frame Control field (see 9.2.4.1.10). In an MMPDU carried in one or more PPDU(s), all of which are VHT or S1G PPDU(s), the maximum MMPDU size specified in Table 9-25 is the maximum MPDU size supported by the recipient(s) less the shortest management frame MAC header and FCS.

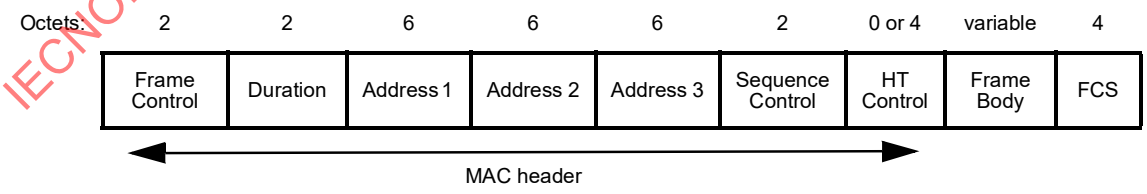

Figure 9-74—Management frame format

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NOTE 1—In an MMPDU carried in one or more PPDUs, all of which are VHT or S1G PPDUs, the presence of encryption overhead (i.e., the MMPDU is transmitted in protected robust Management frames) or an HT Control field might cause an MMPDU to be fragmented that would not otherwise need to be fragmented.

A STA uses the contents of the Address 1 field to perform the address matching for receive decisions. In the case where the Address 1 field contains a group address and the frame subtype is other than Beacon or the frame subtype Action, Category Multihop Action (Multihop Action frame), the Address 3 field also is validated to verify that the group addressed frame originated from a STA in the BSS of which the receiving STA is a member or from a mesh STA to which mesh peering is maintained. Details of addressing and forwarding of the group addressed frame in an MBSS are defined in 10.38.4. When the Address 1 field contains a group address and the frame subtype is either Probe Request or Action with Category Public, a wildcard BSSID value matches all receiving STA's BSSIDs. If the frame subtype is Beacon, other address matching rules apply, as specified in 11.1.3.7. Frames of subtype Probe Request are additionally processed as described in 11.1.4.3.2 for non-DMG STAs and 11.1.4.3.3 for DMG STAs. If the frame subtype is Action, the Category is Public, and the Action is 20/40 BSS Coexistence Management, then additional address matching rules for receive decisions apply as specified in 11.15 and 11.16.

The address fields for all Management frames except Multihop Action frames are as follows:

a) The Address 1 field of the Management frame is the RA (=DA) and is the destination of the frame.

b) The Address 2 field of the Management frame is the TA (=SA) and is the address of the STA transmitting the frame.

   1) If the STA is an AP with dot11MultiBSSDImplemented set to false, then this address is the BSSID.

   2) If the STA is an AP with dot11MultiBSSIDImplemented set to true and the Address 1 field is not set to the broadcast address, then this address is the BSSID of the AP's BSS (which is either the transmitted BSSID or a nontransmitted BSSID).

   3) If the STA is an AP with dot11MultiBSSIDImplemented set to true and the Address 1 field is set to the broadcast address, then this address is the transmitted BSSID.

c) The Address 3 field of the Management frame is set and determined as follows:

   1) In Probe Request frames, the Address 3 field can be the wildcard BSSID as defined in the procedures specified in 11.1.4. If Address 3 is not the wildcard BSSID, then it is (for a nonmesh STA) the BSSID of the BSS of the intended recipient(s), or (for a mesh STA) the MAC address of the intended recipient.

   NOTE 2—Per 11.1.4.3.4, a mesh STA does not examine the Address 3 field in Probe Request frames it receives. Using an individual address, however, might prevent unwanted responses from other STAs.

   2) In Public Action frames, the Address 3 field is the BSSID. The BSSID value is set according to 11.17.

   3) If dot11OCBActivated is true, the Address 3 field is the wildcard BSSID.

   4) Otherwise:

      i) If the STA is an AP or PCP, the Address 3 field is the same as the Address 2 field.

      ii) If the STA is transmitting the Management frame to an AP that is not in a multiple BSSID set or to a PCP, the Address 3 field is the BSSID, irrespective of whether the STA is associated with that AP or PCP.

      iii) If the STA is transmitting the Management frame to an AP that is in a multiple BSSID set, the Address 3 field is the BSSID of the AP's BSS (which is either the transmitted BSSID or a nontransmitted BSSID), irrespective of whether the STA is associated with that AP.

      iv) If the STA is transmitting the Management frame to one or more IBSS STAs, the Address 3 field is the BSSID.

      v) If the STA is a mesh STA, the Address 3 field is the TA.

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vi) If the STA is a TDLS STA transmitting the Management frame to a TDLS peer STA, and the AP to which they are associated is not in a multiple BSSID set, the Address 3 field is the BSSID.

vii) If the STA is a TDLS STA transmitting the Management frame to a TDLS peer STA, and the AP to which they are associated is in a multiple BSSID set, the Address 3 field is the BSSID of the AP's BSS (which is either the transmitted BSSID or a nontransmitted BSSID).

The address fields for)Multihop Action frames are described in 9.3.5.

Within all Management frames sent by the QoS STA, the Duration field contains a duration value as defined in 9.2.5. Within all Management frames sent by non-QoS STAs, the Duration field is set according to the following rules:

— If the DA field contains a group address, the Duration field is set to 0.

— If the More Fragments bit is 0 in the Frame Control field of a frame and the DA field contains an individual address, the Duration field is set to the time, in microseconds, required to transmit one Ack frame, plus one SIFS.

— If the More Fragments bit is 1 in the Frame Control field of a frame, and the DA field contains an individual address, the Duration field is set to the time, in microseconds, required to transmit the next fragment of this Management frame, plus two Ack frames, plus three SIFSs.

The Duration field calculation for the Management frame is based on the rules in 10.6 that determine the data rate at which the Control frames in the frame exchange sequence are transmitted. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer. All STAs process Duration field values less than or equal to 32 767 from valid Management frames to update their NAV settings as appropriate under the coordination function rules.

The HT Control field is defined in 9.2.4.6. The presence of the HT Control field is determined by the +HTC subfield of the Frame Control field, as specified in 9.2.4.1.10.

A Management frame is an IQMF when both

— The RA of the Management frame corresponds to an individual MAC address; and

— The To DS subfield is set to 1 and the From DS subfield of the Frame Control field is set to 0.

A Management frame is a GQMF when both

— The RA of the Management frame corresponds to a group MAC address; and

— The To DS subfield is set to 1 and the From DS subfield of the Frame Control field is set to 0.

The frame body consists of fields and elements as defined for each management frame subtype. All fields and elements are mandatory unless stated otherwise. Fields and elements appear in the specified, relative order, skipping fields or elements that are not present. STAs that encounter an element ID they do not recognize in the frame body of a received Management frame ignore that element and continue to parse the remainder of the management frame body (if any) for additional elements with recognizable element IDs. See 10.28.7.

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9.3.3.2 Beacon frame format

The frame body of a Beacon frame contains the information shown in Table 9-32.

Table 9-32—Beacon frame body

Order	Information	Notes
1	Timestamp	See 9.4.1.10 for Timestamp field format.
2	Beacon Interval	See 9.4.1.3 for Beacon Interval field format.
3	Capability Information	See 9.4.1.4 for Capability Information field format.
4	Service Set Identifier (SSID)	If dot11MeshActivated is true, the SSID element is the wildcard value as described in 9.4.2.2.
5	Supported Rates and BSS Membership Selectors	
6	DSSS Parameter Set	The element is optionally present. The DSSS Parameter Set element is present within Beacon frames generated by STAs using Clause 15, Clause 16, and Clause 18 PHYs. The element is present within Beacon frames generated by STAs using a Clause 19 PHY in the 2.4 GHz band.
7	IBSS Parameter Set	The IBSS Parameter Set element is present only within Beacon frames generated by IBSS STAs.
8	Traffic indication map (TIM)	The TIM element is present only within Beacon frames generated by APs or mesh STAs.
9	Country	The Country element is present if dot11MultiDomainCapabilityActivated is true or dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true.
10	Power Constraint	The Power Constraint element is present if dot11SpectrumManagementRequired is true and is optionally present if dot11RadioMeasurementActivated is true.
11	Channel Switch Announcement	Channel Switch Announcement element is optionally present if dot11SpectrumManagementRequired is true.
12	Quiet	The Quiet element is optionally present if dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true.
13	IBSS DFS	IBSS DFS element is present if dot11SpectrumManagementRequired is true in an IBSS.
14	TPC Report	The TPC Report element is present if dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true.
15	ERP	The ERP element is present within Beacon frames generated by STAs using extended rate PHYs (ERPs) defined in Clause 18 and is optionally present in other cases.
16	Extended Supported Rates and BSS Membership Selectors	The Extended Supported Rates and BSS Membership Selectors element is present if there are more than eight supported rates, and it is optional otherwise.
17	RSN	The RSNE is present within Beacon frames generated by STAs that have dot11RSNAActivated equal to true.

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Table 9-32—Beacon frame body *(continued)*

Order	Information	Notes
18	BSS Load	The BSS Load element is present if dot11QosOptionImplemented and dot11QBSSLoadImplemented are both true.
19	EDCA Parameter Set	The EDCA Parameter Set element is present if dot11QosOptionImplemented is true, and dot11MeshActivated is false, and the QoS Capability element is not present.
20	QoS Capability	The QoS Capability element is present if dot11QosOptionImplemented is true, and dot11MeshActivated is false, and EDCA Parameter Set element is not present.
21	AP Channel Report	If dot11RMAPChannelReportActivated is true, one AP Channel Report element is present for each operating class that has at least 1 channel to report.
22	BSS Average Access Delay	The BSS Average Access Delay element is present if dot11RMBSSAverageAccessDelayActivated is true and the AP Average Access Delay field is not equal to 255 (measurement not available); otherwise, the BSS Average Access Delay element is optionally present if dot11RMBSSAverageAccessDelayActivated is true.
23	Antenna	The Antenna element is present if dot11RMAntennaInformationActivated is true and the Antenna ID field is not equal to 0 (unknown antenna); otherwise, the Antenna element is optionally present if dot11RMAntennaInformationActivated is true.
24	BSS Available Admission Capacity	The BSS Available Admission Capacity element is present if dot11RMBSSAvailableAdmissionCapacityActivated is true with the following exceptions: 1) when Available Admission Capacity Bitmask equals 0 (Available Admission Capacity List contains no entries), or 2) when the BSS Load element is present and the Available Admission Capacity Bitmask states that only AC_VO is present in the Available Admission Capacity List field.
25	BSS AC Access Delay	The BSS AC Access Delay element is present if dot11RMBSSAverageAccessDelayActivated is true and at least one field of the element is not equal to 255 (measurement not available); otherwise, the BSS AC Access Delay element is optionally present if dot11RMBSSAverageAccessDelayActivated is true.
26	Measurement Pilot Transmission	The Measurement Pilot Transmission element is present if dot11RMMeasurementPilotActivated is a value between 2 and 7.
27	Multiple BSSID	One or more Multiple BSSID elements are present if dot11RMMeasurementPilotActivated is a value between 2 and 7 and the AP is a member of a multiple BSSID set (see 11.10.14) with two or more members, or if dot11MultiBSSIDImplemented is true, or if dot11InterworkingServiceActivated is true and the AP is a member of a multiple BSSID set with two or more members and at least one dot11GASAdvertisementID exists.
28	RM Enabled Capabilities	RM Enabled Capabilities element is present if dot11RadioMeasurementActivated is true.
29	Mobility Domain	The Mobility Domain element (MDE) is present if dot11FastBSSTransitionActivated is true.
30	DSE registered location	The DSE Registered Location element is present if dot11LCIDSERequired is true.
31	Extended Channel Switch Announcement	The Extended Channel Switch Announcement element is optionally present if dot11ExtendedChannelSwitchActivated is true.

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Table 9-32—Beacon frame body *(continued)*

Order	Information	Notes
32	Supported Operating Classes	The Supported Operating Classes element is present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true. The Supported Operating Classes element is optionally present if dot11TVHTOptionImplemented is true.
33	HT Capabilities	The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true.
34	HT Operation	The HT Operation element is included by an AP and a mesh STA when dot11HighThroughputOptionImplemented is true.
35	20/40 BSS Coexistence	The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true.
36	Overlapping BSS Scan Parameters	The Overlapping BSS Scan Parameters element is optionally present if dot11FortyMHzOptionImplemented is true.
37	Extended Capabilities	The Extended Capabilities element is present if any of the fields in this element are nonzero.
38	FMS Descriptor	The FMS Descriptor element is present if dot11FMSActivated is true.
39	QoS Traffic Capability	The QoS Traffic Capability element is optionally present if dot11ACStationCountActivated is true.
40	Time Advertisement	The Time Advertisement element is present every dot11TimeAdvertisementDTIMInterval if dot11UTCTSFOffsetActivated is true.
41	Interworking	The Interworking element is present if dot11InterworkingServiceActivated is true.
42	Advertisement Protocol	Advertisement Protocol element is present if dot11InterworkingServiceActivated is true and at least one dot11GASAdvertisementID MIB attribute exists.
43	Roaming Consortium	The Roaming Consortium element is present if dot11InterworkingServiceActivated is true and the dot11RoamingConsortiumTable has at least one entry.
44	Emergency Alert Identifier	One or more Emergency Alert Identifier elements are present if dot11EASActivated is true and there are one or more EAS message(s) active in the network.
45	Mesh ID	The Mesh ID element is present if dot11MeshActivated is true.
46	Mesh Configuration	The Mesh Configuration element is present if dot11MeshActivated is true.
47	Mesh Awake Window	The Mesh Awake Window element is optionally present if dot11MeshActivated is true.
48	Beacon Timing	The Beacon Timing element is optionally present if both dot11MeshActivated and dot11MBCAActivated are true.
49	MCCAOP Advertisement Overview	The MCCAOP Advertisement Overview element is optionally present if both dot11MeshActivated and dot11MCCAActivated are true.
50	MCCAOP Advertisement	One or more MCCAOP Advertisement elements are optionally present if both dot11MeshActivated and dot11MCCAActivated are true.
51	Mesh Channel Switch Parameters	The Mesh Channel Switch Parameters element is present when dot11MeshActivated is true and either Channel Switch Announcement element or Extended Channel Switch Announcement element is present.

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Table 9-32—Beacon frame body *(continued)*

Order	Information	Notes
52	QMF Policy	Indicates the QMF policy parameters of the transmitting STA. The QMF Policy element is present when dot11QMFActivated is true and the transmitting STA is an AP or a mesh STA. This element is not present otherwise.
53	QLoad Report	The QLoad Report element is present every dot11QLoadReportIntervalDTIM DTIMs if dot11QLoadReportActivated is true.
54	HCCA TXOP Update Count	The HCCA TXOP Update Count element is present if both dot11PublicHCCATXOPNegotiationActivated is true and an HC is collocated with the AP.
55	Multi-band	The Multi-band element is optionally present if dot11MultibandImplemented is true.
56	VHT Capabilities	The VHT Capabilities element is present when dot11VHTOptionImplemented is true.
57	VHT Operation	The VHT Operation element is present when dot11VHTOptionImplemented is true; otherwise, it is not present.
58	Transmit Power Envelope element	One Transmit Power Envelope element is present for each distinct value of the Local Maximum Transmit Power Unit Interpretation subfield that is supported for the BSS if both of the following conditions are met: — dot11VHTOptionImplemented or dot11ExtendedSpectrumManagementImplemented is true; — Either dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true. Otherwise, this element is not present.
59	Channel Switch Wrapper element	The Channel Switch Wrapper element is optionally present if dot11VHTOptionImplemented or dot11ExtendedSpectrumManagementImplemented is true and at least one of a Channel Switch Announcement element or an Extended Channel Switch Announcement element is also present in the Beacon frame and the Channel Switch Wrapper element contains at least one subelement.
60	Extended BSS Load element	The Extended BSS Load element is optionally present if dot11QosOptionImplemented, dot11QBSSLoadImplemented, and dot11VHTOptionImplemented are true.
61	Quiet Channel	Either one Quiet Channel element containing an AP Quiet Mode field equal to 0 or, in an infrastructure BSS, one or more Quiet Channel elements each containing an AP Quiet Mode field equal to 1 are optionally present if dot11VHTOptionImplemented is true, and either dot11SpectrumManagementRequired or dot11RadioMeasurementActivated is true.
62	Operating Mode Notification	The Operating Mode Notification element is optionally present if dot11OperatingModeNotificationImplemented is true.
63	Reduced Neighbor Report	The Reduced Neighbor Report element is optionally present if dot11TVHTOptionImplemented or dot11FILSActivated is true; otherwise not present.
64	TVHT Operation	The TVHT Operation element is present for a TVHT STA when dot11TVHTOptionImplemented is true; otherwise it is not present.
65	Estimated Service Parameters Inbound	The Estimated Service Parameters Inbound element is present if dot11EstimatedServiceParametersInboundOptionImplemented is true.
66	Future Channel Guidance	The Future Channel Guidance element is optionally present if dot11FutureChannelGuidanceActivated is true.

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Table 9-32—Beacon frame body *(continued)*

Order	Information	Notes
67	Common Advertisement Group (CAG) Number	The CAG Number element is optionally present if dot11FILSActivated is true; otherwise not present.
68	FILS Indication	The FILS Indication element is present if dot11FILSActivated is true; otherwise not present.
69	AP-CSN	The AP Configuration Sequence Number (AP-CSN) element is optionally present if dot11FILSActivated is true; otherwise not present.
70	DILS	The DILS element is optionally present if dot11FILSActivated is true; otherwise not present.
71	Max Channel Switch Time	The Max Channel Switch Time element is optionally present when a Channel Switch Announcement or an Extended Channel Switch Announcement element is also present.
72	Estimated Services Parameters Outbound	The Estimated Service Parameters Outbound element is optionally present if dot11EstimatedServiceParametersOutboundOptionImplemented is true.
73	Service Hint	The Service Hint element is optionally present if dot11UnsolicitedPADActivated is true.
74	Service Hash	The Service Hash element is optionally present if dot11UnsolicitedPADActivated is true.
75	RSN Extension	The RSNXE is present if any subfield of the Extended RSN Capabilities field in this element is nonzero, except the Field Length subfield.
Last -1	Vendor Specific	One or more Vendor Specific elements are optionally present. These elements follow all other elements.
Last	MME	The MME is present if dot11BeaconProtectionEnabled is true at the AP.
NOTE—The MME appears after all fields that it protects. Therefore, it appears last in the frame body to protect the frames as specified in 12.5.4.		

9.3.3.3 ATIM frame format

The frame body of an ATIM frame is null.

9.3.3.4 Disassociation frame format

The frame body of a Disassociation frame contains the information shown in Table 9-33.

Table 9-33—Disassociation frame body

Order	Information
1	Reason code
Last – 1	One or more Vendor Specific elements are optionally present.
Last	The MME is present when management frame protection is enabled at the AP and the frame is a group addressed frame.
NOTE—The MME appears after all fields that it protects. Therefore, it appears last in the frame body to protect the frames as specified in 12.5.4.	

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9.3.3.5 Association Request frame format

The frame body of an Association Request frame contains the information shown in Table 9-34.

Table 9-34—Association Request frame body

Order	Information	Notes
1	Capability Information	See 9.4.1.4 for Capability Information field format.
2	Listen Interval	
3	SSID	
4	Supported Rates and BSS Membership Selectors	This element is not present if dot11DMGOptionImplemented is true.
5	Extended Supported Rates and BSS Membership Selectors	The Extended Supported Rates and BSS Membership Selectors element is present if there are more than eight supported rates, and it is optional otherwise. This element is not present if dot11DMGOptionImplemented is true.
6	Power Capability	The Power Capability element is present if dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true.
7	Supported Channels	The Supported Channels element is present if dot11SpectrumManagementRequired is true and dot11ExtendedChannelSwitchActivated is false.
8	RSN	The RSNE is present if dot11RSNAActivated is true.
9	QoS Capability	The QoS Capability element is present if dot11QosOptionImplemented is true.
10	RM Enabled Capabilities	RM Enabled Capabilities element is present if dot11RadioMeasurementActivated is true.
11	Mobility Domain	The Mobility Domain element (MDE) is present in an Association Request frame if dot11FastBSSTransitionActivated is true and if the frame is being sent to an AP that advertised its FT capability in the MDE in its Beacon or Probe Response frame (i.e., AP also has dot11FastBSSTransitionActivated equal to true).
12	Supported Operating Classes	The Supported Operating Classes element is present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true.
13	HT Capabilities	The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true.
14	20/40 BSS Coexistence	The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true.
15	Extended Capabilities	The Extended Capabilities element is present if any of the fields in this element are nonzero.
16	QoS Traffic Capability	The QoS Traffic Capability element is present if dot11QoSTrafficCapabilityActivated is true.
17	TIM Broadcast Request	The TIM Broadcast Request element is present if dot11TIMBroadcastActivated is true.
18	Interworking	The Interworking element is present if dot11InterworkingServiceActivated is true and the non-AP STA is requesting unauthenticated access to emergency services (see 11.3.5).

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Table 9-34—Association Request frame body *(continued)*

Order	Information	Notes
19	Multi-band	The Multi-band element is optionally present if dot11MultibandImplemented is true.
20	DMG Capabilities	The DMG Capabilities element is present if dot11DMGOptionImplemented is true.
21	Multiple MAC Sublayers	The Multiple MAC Sublayers element is present if dot11MultipleMACActivated is true.
22	VHT Capabilities	The VHT Capabilities element is present when dot11VHTOptionImplemented is true.
23	Operating Mode Notification	The Operating Mode Notification element is optionally present if dot11OperatingModeNotificationImplemented is true.
24	FILS Session	The FILS Session element is optionally present if dot11FILSActivated is true; otherwise not present.
25	FILS Public Key	The FILS Public Key element is present if dot11FILSActivated is true and FILS Public Key authentication is used; otherwise not present.
26	FILS Key Confirmation	The FILS Key Confirmation element is present if dot11FILSActivated is true and FILS authentication is used; otherwise not present.
27	FILS HLP Container	One or more FILS HLP Container elements are optionally present if dot11FILSActivated is true; otherwise not present.
28	FILS IP Address Assignment	The FILS IP Address Assignment element is optionally present if dot11FILSActivated is true; otherwise not present.
29	TWT	The TWT element is optionally present if dot11TWTOptionActivated is true; otherwise not present.
30	AID Request	The AID Request element is optionally present if dot11S1GOptionImplemented is true; otherwise not present.
31	S1G Capabilities	The S1G Capabilities element is present if dot11S1GOptionImplemented is true; otherwise not present.
32	EL Operation	The EL Operation element is optionally present if dot11S1GELOperationActivated is true; otherwise not present.
33	S1G Relay	The S1G Relay element is present if dot11RelaySTAImplemented is true; otherwise not present.
34	BSS Max Idle Period	The BSS Max Idle Period element is optionally present if dot11WirelessManagementImplemented and dot11BSSMaxIdlePeriodIndicationByNonAPSTA are true, or if dot11S1GOptionImplemented is true; otherwise not present.
35	Header Compression	The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true.
36	MAD	The MAD element is optionally present if dot11S1GOptionImplemented is true; otherwise not present.
37	Reachable Address	The Reachable Address element is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
38	S1G Relay Activation	The S1G Relay Activation element is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
39	CDMG Capabilities	The CDMG Capabilities element is present if dot11CDMGOptionImplemented is true; otherwise not present.

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Table 9-34—Association Request frame body *(continued)*

Order	Information	Notes
40	CMMG Capabilities	The CMMG Capabilities element is present when dot11CMMGOptionImplemented is true; otherwise not present.
41	GLK-GCR Parameter Set	The GLK-GCR Parameter Set element is present if dot11GLKImplemented is true to indicate the number of reorder buffers the STA has to support GLK-GCR with GCR block ack and respond to corresponding GLK-GCR BlockAckReq frames. Otherwise this element is not present.
42	Fast BSS Transition	An FTE is present in an Association Request frame if dot11FastBSSTransitionActivated is true, dot11RSNAAuthenticationSuiteSelected is 00-0F-AC:16 or 00-0F-AC:17, and FT initial mobility domain association over FILS in an RSN is being performed.
43	RSN Extension	The RSNXE is present if any subfield of the Extended RSN Capabilities field in this element is nonzero, except the Field Length subfield.
44	Supplemental Class 2 Capabilities	The Supplemental Class 2 Capabilities element is present when dot11Class2CapabilitiesOptionImplemented is true; otherwise not present.
45	MSCS Descriptor	The MSCS Descriptor element is optionally present if dot11MSCSActivated is true; otherwise not present.
Last	Vendor Specific	One or more Vendor Specific elements are optionally present. These elements follow all other elements.

9.3.3.6 Association Response frame format

The frame body of an Association Response frame contains the information shown in Table 9-35.

Table 9-35—Association Response frame body

Order	Information	Notes
1	Capability Information	See 9.4.1.4 for Capability Information field format.
2	Status code	
3	AID	This field is not present when dot11S1GOptionImplemented is true.
4	Supported Rates and BSS Membership Selectors	This field is not present if dot11DMGOptionImplemented is true.
5	Extended Supported Rates and BSS Membership Selectors	The Extended Supported Rates and BSS Membership Selectors element is present if there are more than eight supported rates and is optionally present otherwise. This element is not present if dot11DMGOptionImplemented is true.
6	EDCA Parameter Set	The EDCA Parameter Set element is present if dot11QosOptionImplemented is true; otherwise not present.
7	RCPI	The RCPI element is present if dot11RMRCPIMeasurementActivated is true.
8	RSNI	The RSNI element is present if dot11RMRSNIMeasurementActivated is true.

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Table 9-35—Association Response frame body *(continued)*

Order	Information	Notes
9	RM Enabled Capabilities	RM Enabled Capabilities element is present if dot11RadioMeasurementActivated is true.
10	RSN	The RSNE is present if dot11FILSActivated is true; otherwise not present.
11	Mobility Domain	An MDE is present in an Association Response frame when dot11FastBSSTransitionActivated is true and this frame is a response to an Association Request frame that contained an MDE (i.e., an FT initial mobility domain association exchange).
12	Fast BSS Transition	A Fast BSS Transition element (FTE) is present in an Association Response frame when dot11FastBSSTransitionActivated is true, dot11RSNAActivated is true, and this frame is a response to an Association Request frame that contained an MDE (i.e., an FT initial mobility domain association exchange in an RSN).
13	DSE registered location	The DSE Registered Location element is present if dot11LCIDSERequired is true.
14	Timeout Interval (Association Comeback time)	A Timeout Interval element (TIE) containing the Association Comeback time is present when dot11RSNAActivated is true, dot11RSNAProtectedManagementFramesActivated is true, and either the association request is rejected with a status code REFUSED_TEMPORARILY or the association request is accepted with a status code 0 and when dot11S1GOptionImplemented is true.
15	HT Capabilities	The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true.
16	HT Operation	The HT Operation element is included by an AP when dot11HighThroughputOptionImplemented is true.
17	20/40 BSS Coexistence	The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true.
18	Overlapping BSS Scan Parameters	The Overlapping BSS Scan Parameters element is optionally present if dot11FortyMHzOptionImplemented is true.
19	Extended Capabilities	The Extended Capabilities element is present if any of the fields in this element are nonzero.
20	BSS Max Idle Period	The BSS Max Idle Period element is present if dot11WirelessManagementImplemented is true or optionally present if dot11S1GOptionImplemented is true.
21	TIM Broadcast Response	The TIM Broadcast Response element is present if dot11TIMBroadcastActivated is true and the TIM Broadcast Request element is present in the Association Request frame that elicited this Association Response frame.
22	QoS Map	The QoS Map element is present if dot11QosMapActivated is true and the QoS Map field in the Extended Capabilities element of the corresponding Association Request frame is 1.
23	QMF Policy	The QMF Policy element is present if dot11QMFActivated is true and the QMFActivated subfield is 1 in the Extended Capabilities element in the Association Request frame that elicited this Association Response frame.
24	Multi-band	The Multi-band element is optionally present if dot11MultibandImplemented is true.

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Table 9-35—Association Response frame body *(continued)*

Order	Information	Notes
25	DMG Capabilities	The DMG Capabilities element is present if dot11DMGOptionImplemented is true.
26	DMG Operation	The DMG Operation element is present if dot11DMGOptionImplemented is true.
27	Multiple MAC Sublayers	The Multiple MAC Sublayers element is present if dot11MultipleMACActivated is true.
28	Neighbor Report	One or more Neighbor Report elements is present if the Status Code field is REJECTED_WITH_SUGGESTED_BSS_TRANSITION.
29	VHT Capabilities	The VHT Capabilities element is present when dot11VHTOptionImplemented is true.
30	VHT Operation	The VHT Operation element is present when dot11VHTOptionImplemented is true; otherwise, it is not present.
31	Operating Mode Notification	The Operating Mode Notification element is optionally present if dot11OperatingModeNotificationImplemented is true.
32	Future Channel Guidance	The Future Channel Guidance element is optionally present if dot11FutureChannelGuidanceActivated is true.
33	FILS Session	The FILS Session element is present if dot11FILSActivated is true; otherwise not present.
34	FILS Public Key	The FILS Public Key element is present if dot11FILSActivated is true and FILS Public Key authentication is used; otherwise not present.
35	FILS Key Confirmation	The FILS Key Confirmation element is present if dot11FILSActivated is true and FILS authentication is used; otherwise not present.
36	FILS HLP Container	One or more FILS HLP Container elements are optionally present if dot11FILSActivated is true; otherwise not present.
37	FILS IP Address Assignment	The FILS IP Address Assignment element is optionally present if dot11FILSActivated is true; otherwise not present.
38	Key Delivery	The Key Delivery element is present if dot11FILSActivated is true; otherwise not present.
39	S1G Sector Operation	The S1G Sector Operation element is optionally present if dot11S1GSectorizationActivated is true; otherwise not present.
40	TWT	The TWT element is present if dot11TWTOptionActivated is true and the TWT element is present in the Association Request frame that elicited this Association Response frame.
41	TSF Timer Accuracy	The TSF Timer Accuracy element is optionally present when dot11TSFTimerAccuracyImplemented is true; otherwise not present.
42	S1G Capabilities	The S1G Capabilities element is present if dot11S1GOptionImplemented is true; otherwise not present.
43	S1G Operation	The S1G Operation element is present if dot11S1GOptionImplemented is true; otherwise not present.
44	AID Response	The AID Response element is present when dot11S1GOptionImplemented is true.

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Table 9-35—Association Response frame body *(continued)*

Order	Information	Notes
45	Sectorized Group ID List	The Sectorized Group ID List element is optionally present when dot11S1GSectorizationActivated is true; otherwise not present.
46	S1G Relay	The S1G Relay element is optionally present if dot11RelayAPImplemented is true; otherwise not present.
47	Header Compression	The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true.
48	SST Operation	The SST Operation element is present if dot11SelectiveSubchannelTransmissionPermitted is true.
49	MAD	The MAD element is optionally present if dot11S1GOptionImplemented is true; otherwise not present.
50	S1G Relay Activation	The S1G Relay Activation element is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
51	CDMG Capabilities	The CDMG Capabilities element is present if dot11CDMGOptionImplemented is true; otherwise not present.
52	CMMG Capabilities	The CMMG Capabilities element is present when dot11CMMGOptionImplemented is true; otherwise not present.
53	CMMG Operation	The CMMG Operation element is present when dot11CMMGOptionImplemented is true; otherwise not present.
54	GLK-GCR Parameter Set	The GLK-GCR Parameter Set element is present if dot11GLKimplemented is true and the AP has set up a GLK-GCR for groupcast transmissions over the underlying general link. Otherwise this element is not present.
55	RSN Extension	The RSNXE is present if any subfield of the Extended RSN Capabilities field in this element is nonzero, except the Field Length subfield.
56	MSCS Descriptor	The MSCS Descriptor element is optionally present if dot11MSCSActivated is true; otherwise not present.
Last	Vendor Specific	One or more Vendor Specific elements are optionally present. These elements follow all other elements.

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9.3.3.7 Reassociation Request frame format

The frame body of a Reassociation Request frame contains the information shown in Table 9-36.

Table 9-36—Reassociation Request frame body

Order	Information	Notes
1	Capability Information	See 9.4.1.4 for Capability Information field format.
2	Listen Interval	
3	Current AP address	
4	SSID	
5	Supported Rates and BSS Membership Selectors	This field is not present if dot11DMGOptionImplemented is true.

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Table 9-36—Reassociation Request frame body *(continued)*

Order	Information	Notes
6	Extended Supported Rates and BSS Membership Selectors	The Extended Supported Rates and BSS Membership Selectors element is present if there are more than eight supported rates, and it is optional otherwise. This element is not present if dot11DMGOptionImplemented is true.
7	Power Capability	The Power Capability element is present if dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true.
8	Supported Channels	The Supported Channels element is present if dot11SpectrumManagementRequired is true and dot11ExtendedChannelSwitchActivated is false.
9	RSN	The RSNE is present if dot11RSNAActivated is true; otherwise not present.
10	QoS Capability	The QoS Capability element is present if dot11QosOptionImplemented is true.
11	RM Enabled Capabilities	RM Enabled Capabilities element is present if dot11RadioMeasurementActivated is true.
12	Mobility Domain	The MDE is present in a Reassociation Request frame if dot11FastBSSTransitionActivated is true and the frame is being sent to an AP that advertised its FT Capability in the MDE in its Beacon or Probe Response frame (i.e., AP also has dot11FastBSSTransitionActivated is true).
13	Fast BSS Transition	An FTE is present in a Reassociation Request frame if dot11FastBSSTransitionActivated is true and dot11RSNAAuthenticationSuiteSelected is equal to an AKM suite selector value for which the Authentication type column indicates FT authentication. See Table 9-151 (i.e., part of a fast BSS transition in an RSN).
14	Resource information container (RIC)	The set of elements that formulate a RIC-Request is optionally present in a Reassociation Request frame if — dot11FastBSSTransitionActivated is true, — The FT resource request protocol is not used, — The frame is being sent to an AP that advertised its FT capability in the MDE in its Beacon or Probe Response frame (i.e., AP also has dot11FastBSSTransitionActivated is true), and — Either dot11RSNAAuthenticationSuiteSelected is 00-0F-AC:3, 00-0F-AC:4, 00-0F-AC:9, 00-0F-AC:13, 00-0F-AC:16, or 00-0F-AC:17 (i.e., part of a fast BSS transition in an RSN) or dot11RSNAActivated is false (i.e., not in an RSN).
15	Supported Operating Classes	The Supported Operating Classes element is present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true.
16	HT Capabilities	The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true.
17	20/40 BSS Coexistence	The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true.
18	Extended Capabilities	The Extended Capabilities element is present if any of the fields in this element are nonzero.

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Table 9-36—Reassociation Request frame body *(continued)*

Order	Information	Notes
19	QoS Traffic Capability	The QoS Traffic Capability element is present if dot11QoSTrafficCapabilityActivated is true.
20	TIM Broadcast Request	The TIM Broadcast Request element is present if dot11TIMBroadcastActivated is true.
21	FMS Request	The FMS Request element is optionally present if dot11FMSActivated is true.
22	DMS Request	The DMS Request element is optionally present if dot11DMSActivated is true.
23	Interworking	The Interworking element is present if dot11InterworkingServiceActivated is true and the non-AP STA is requesting unauthenticated access to emergency services (see 11.3.5).
24	Multi-band	The Multi-band element is optionally present if dot11MultibandImplemented is true.
25	DMG Capabilities	The DMG Capabilities element is present if dot11DMGOptionImplemented is true.
26	Multiple MAC Sublayers	The Multiple MAC Sublayers element is present if dot11MultipleMACActivated is true.
27	VHT Capabilities	The VHT Capabilities element is present when dot11VHTOptionImplemented is true.
28	Operating Mode Notification	The Operating Mode Notification element is optionally present if dot11OperatingModeNotificationImplemented is true.
29	FILS Session	The FILS Session element is optionally present if dot11FILSActivated is true; otherwise not present.
30	FILS Public Key	The FILS Public Key element is present if dot11FILSActivated is true and FILS Public Key authentication is used; otherwise not present.
31	FILS Key Confirmation	The FILS Key Confirmation element is present if dot11FILSActivated is true and FILS authentication is used; otherwise not present.
32	FILS HLP Container	One or more FILS HLP Container elements are optionally present if dot11FILSActivated is true; otherwise not present.
33	FILS IP Address Assignment	The FILS IP Address Assignment element is optionally present if dot11FILSActivated is true; otherwise not present.
34	TWT	The TWT element is optionally present if dot11TWTOptionActivated is true; otherwise not present.
35	AID Request	The AID Request element is present when dot11S1GOptionImplemented is true.
36	S1G Capabilities	The S1G Capabilities element is present if dot11S1GOptionImplemented is true; otherwise not present.
37	EL Operation	The EL Operation element is present if dot11S1GELOperationActivated is true.
38	BSS Max Idle Period	The BSS Max Idle Period element is optionally present if dot11WirelessManagementImplemented and dot11BSSMaxIdlePeriodIndicationByNonAPSTA are true, or if dot11S1GOptionImplemented is true; otherwise not present.

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Table 9-36—Reassociation Request frame body *(continued)*

Order	Information	Notes
39	S1G Relay	The S1G Relay element is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
40	Header Compression	The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true.
41	MAD	The MAD element is optionally present if dot11S1GOptionImplemented is true; otherwise not present.
42	Reachable Address	The Reachable Address element is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
43	S1G Relay Activation element	The S1G Relay Activation element is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
44	CDMG Capabilities	The CDMG Capabilities element is present if dot11CDMGOptionImplemented is true; otherwise not present.
45	CMMG Capabilities	The CMMG Capabilities element is present when dot11CMMGOptionImplemented is true; otherwise not present.
46	OCI	OCI element is present if dot11FILSActivated and dot11RSNAOperatingChannelValidationActivated are both true; otherwise not present.
47	GLK-GCR Parameter Set	The GLK-GCR Parameter Set element is present if dot11GLKImplemented is true to indicate the number of reorder buffers the STA has to support GLK-GCR with GCR block ack and respond to corresponding GLK-GCR BlockAckReq frames. Otherwise this element is not present.
48	RSN Extension	The RSNXE is present if any subfield of the Extended RSN Capabilities field in this element is nonzero, except the Field Length subfield and, in the case of FT reassociation, the rules for FT reassociation in Table 13-1 do not omit the RSNXE from the third message.
49	Supplemental Class 2 Capabilities	The Supplemental Class 2 Capabilities element is present when dot11Class2CapabilitiesOptionImplemented is true; otherwise not present.
50	MSCS Descriptor	The MSCS Descriptor element is optionally present if dot11MSCSActivated is true; otherwise not present.
Last	Vendor Specific	One or more Vendor Specific elements are optionally present. These elements follow all other elements.

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9.3.3.8 Reassociation Response frame format

The frame body of a Reassociation Response frame contains the information shown in Table 9-37.

Table 9-37—Reassociation Response frame body

Order	Information	Notes
1	Capability Information	See 9.4.1.4 for Capability Information field format.
2	Status code	
3	AID	This field is not present when dot11S1GOptionImplemented is true.
4	Supported Rates and BSS Membership Selectors	This field is not present if dot11DMGOptionImplemented is true.
5	Extended Supported Rates and BSS Membership Selectors	The Extended Supported Rates and BSS Membership Selectors element is present if there are more than eight supported rates, and it is optional otherwise. This element is not present if dot11DMGOptionImplemented is true.
6	EDCA Parameter Set	The EDCA Parameter Set element is present if dot11QosOptionImplemented is true; otherwise not present.
7	RCPI	The RCPI element is present if dot11RMRCPIMeasurementActivated is true.
8	RSNI	The RSNI element is present if dot11RMRSNIMeasurementActivated is true.
9	RM Enabled Capabilities	RM Enabled Capabilities element is present if dot11RadioMeasurementActivated is true.
10	RSN	An RSNE is present in a Reassociation Response frame if dot11FastBSSTransitionActivated is true, dot11RSNAActivated is true, and this frame is a response to a Reassociation Request frame that contained an FTE (i.e., part of a fast BSS transition in an RSN); or if dot11FILSActivated is true. Otherwise, not present.
11	Mobility Domain	An MDE is present in a Reassociation Response frame if dot11FastBSSTransitionActivated is true and this frame is a response to a Reassociation Request frame that contained an MDE (i.e., either an FT initial mobility domain association exchange or part of a fast BSS transition).
12	Fast BSS Transition	An FTE is present in a Reassociation Response frame if dot11FastBSSTransitionActivated is true, dot11RSNAActivated is true, and this frame is a response to a Reassociation Request frame that contained an MDE (i.e., either an FT initial mobility domain association exchange or part of a fast BSS transition in an RSN).
13	RIC	The set of elements that formulate a RIC-Response is present in a Reassociation Response frame if dot11FastBSSTransitionActivated is true and this frame is a response to a Reassociation Request frame that contained a RIC-Request.
14	DSE registered location	The DSE Registered Location element is present if dot11LCIDSERequired is true.

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Table 9-37—Reassociation Response frame body *(continued)*

Order	Information	Notes
15	Timeout Interval (Association Comeback time)	A TIE containing the Association Comeback time is present when dot11RSNAActivated is true, dot11RSNAProtectedManagementFramesActivated is true, and either the reassociation is rejected with status code REFUSED_TEMPORARILY or the reassociation request is accepted with a status code 0 and when dot11S1GOptionImplemented is true.
16	HT Capabilities	The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true.
17	HT Operation	The HT Operation element is included by an AP when dot11HighThroughputOptionImplemented is true.
18	20/40 BSS Coexistence	The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true.
19	Overlapping BSS Scan Parameters	The Overlapping BSS Scan Parameters element is optionally present if dot11FortyMHzOptionImplemented is true.
20	Extended Capabilities	The Extended Capabilities element is present if any of the fields in this element are nonzero.
21	BSS Max Idle Period	The BSS Max Idle Period element is present if dot11WirelessManagementImplemented is true or optionally present if dot11S1GOptionImplemented is true.
22	TIM Broadcast Response	The TIM Broadcast Response element is present if dot11TIMBroadcastActivated is true and the TIM Broadcast Request element is present in the Reassociation Request frame that elicited this Reassociation Response frame.
23	FMS Response	The FMS Response element is present if dot11FMSActivated is true and the FMS Request element is present in the Reassociation Request frame that elicited this Reassociation Response frame.
24	DMS Response	The DMS Response element is present if dot11DMSActivated is true and the DMS Request element is present in the Reassociation Request frame that elicited this Reassociation Response frame.
25	QoS Map	The QoS Map element is present if dot11QosMapActivated is true and the QoS Map field in the Extended Capabilities element of the corresponding Reassociation Request frame is 1.
26	QMF Policy	The QMF Policy element is present if dot11QMFActivated is true and the QMFActivated subfield is 1 in the Extended Capabilities element in the Reassociation Request that elicited this Reassociation Response frame.
27	Multi-band	The Multi-band element is optionally present if dot11MultibandImplemented is true.
28	DMG Capabilities	The DMG Capabilities element is present if dot11DMGOptionImplemented is true.
29	DMG Operation	The DMG Operation element is present if dot11DMGOptionImplemented is true.
30	Multiple MAC Sublayers	The Multiple MAC Sublayers element is present if dot11MultipleMACActivated is true.
31	Neighbor Report	One or more Neighbor Report elements is present if the Status Code field is REJECTED_WITH_SUGGESTED_BSS_TRANSITION.

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Table 9-37—Reassociation Response frame body *(continued)*

Order	Information	Notes
32	VHT Capabilities	The VHT Capabilities element is present when dot11VHTOptionImplemented is true.
33	VHT Operation	The VHT Operation element is present when dot11VHTOptionImplemented is true; otherwise, it is not present.
34	Operating Mode Notification	The Operating Mode Notification element is optionally present if dot11OperatingModeNotificationImplemented is true.
35	Future Channel Guidance	The Future Channel Guidance element is optionally present if dot11FutureChannelGuidanceActivated is true.
36	FILS Session	The FILS Session element is present if dot11FILSActivated is true and FILS authentication is used; otherwise not present.
37	FILS Public Key	The FILS Public Key element is present if dot11FILSActivated is true and FILS Public Key authentication is used; otherwise not present.
38	FILS Key Confirmation	The FILS Key Confirmation element is present if dot11FILSActivated is true and FILS authentication is used; otherwise not present.
39	FILS HLP Container	One or more FILS HLP Container elements are optionally present if dot11FILSActivated is true; otherwise not present.
40	FILS IP Address Assignment	The FILS IP Address Assignment element is optionally present if dot11FILSActivated is true; otherwise not present.
41	Key Delivery	The Key Delivery element is present if dot11FILSActivated is true and FILS authentication is used; otherwise not present.
42	S1G Sector Operation	The S1G Sector Operation element is optionally present if dot11S1GSectorizationActivated is true; otherwise not present.
43	TWT	The TWT element is present if dot11TWTOptionActivated is true and the TWT element is present in the Reassociation Request frame that elicited this Reassociation Response frame.
44	TSF Timer Accuracy	The TSF Timer Accuracy element is optionally present when dot11TSFTimerAccuracyImplemented is true; otherwise not present.
45	S1G Capabilities	The S1G Capabilities element is present if dot11S1GOptionImplemented is true; otherwise not present.
46	S1G Operation	The S1G Operation element is present when dot11S1GOptionImplemented is true; otherwise not present.
47	AID Response	The AID Response element is present when dot11S1GOptionImplemented is true.
48	Sectorized Group ID List	The Sectorized Group ID List element is optionally present when dot11S1GSectorizationActivated is true; otherwise not present.
49	S1G Relay	The S1G Relay element is optionally present if dot11RelayAPImplemented is true; otherwise not present.

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Table 9-37—Reassociation Response frame body *(continued)*

Order	Information	Notes
50	Header Compression	The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true.
51	SST Operation	The SST Operation element is present if dot11SelectiveSubchannelTransmissionPermitted is true.
52	MAD	The MAD element is optionally present if dot11S1GOptionImplemented is true; otherwise not present.
53	S1G Relay Activation	The S1G Relay Activation element is optionally present if dot11RelaySTAImplemented is true; otherwise not present.
54	CDMG Capabilities	The CDMG Capabilities element is present if dot11CDMGOptionImplemented is true; otherwise not present.
55	CMMG Capabilities	The CMMG Capabilities element is present when dot11CMMGOptionImplemented is true; otherwise not present.
56	CMMG Operation	The CMMG Operation element is present when dot11CMMGOptionImplemented is true; otherwise not present.
56	OCI	The OCI element is present if dot11FILSActivated and dot11RSNAOperatingChannelValidationActivated are both true; otherwise not present.
58	GLK-GCR Parameter Set	The GLK-GCR Parameter Set element is present if dot11GLKimplemented is true and the AP has set up a GLK-GCR for groupcast transmissions over the underlying general link. Otherwise this element is not present.
59	RSN Extension	The RSNXE is present if any subfield of the Extended RSN Capabilities field in this element is nonzero, except the Field Length subfield and, in the case of FT reassociation, the rules for FT reassociation in Table 13-1 do not omit the RSNXE from the fourth message.
60	MSCS Descriptor	The MSCS Descriptor element is optionally present if dot11MSCSActivated is true; otherwise not present.
Last	Vendor Specific	One or more Vendor Specific elements are optionally present. These elements follow all other elements.

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9.3.3.9 Probe Request frame format

The frame body of a Probe Request frame contains the information shown in Table 9-38.

Table 9-38—Probe Request frame body

Order	Information	Notes
1	SSID	If dot11MeshActivated is true, the SSID element is the wildcard value as described in 9.4.2.2.
2	Supported Rates and BSS Membership Selectors	This field is not present if dot11DMGOptionImplemented is true.
3	Request	The Request element is optionally present if dot11RadioMeasurementActivated is true. The Request element is optionally present if dot11MultiDomainCapabilityActivated is true or if dot11EstimatedServiceParametersInboundOptionImplemented is true.
4	Extended Supported Rates and BSS Membership Selectors	The Extended Supported Rates and BSS Membership Selectors element is present if there are more than eight supported rates and is optionally present otherwise. This element is not present if dot11DMGOptionImplemented is true.
5	DSSS Parameter Set	The element is optionally present. The DSSS Parameter Set element is present within Probe Request frames generated by STAs using Clause 15, Clause 16, or Clause 18 PHYs if dot11RadioMeasurementActivated is true. The DSSS Parameter Set element is present within Probe Request frames generated by STAs using a Clause 19 PHY in the 2.4 GHz band if dot11RadioMeasurementActivated is true. The DSSS Parameter Set element is optionally present within Probe Request frames generated by STAs using Clause 15, Clause 16, or Clause 18 PHYs if dot11RadioMeasurementActivated is false. The DSSS Parameter Set element is optionally present within Probe Request frames generated by STAs using a Clause 19 PHY in the 2.4 GHz band if dot11RadioMeasurementActivated is false.
6	Supported Operating Classes	The Supported Operating Classes element is present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true. The Supported Operating Classes element is optionally present if dot11TVHTOptionImplemented is true.
7	HT Capabilities	The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true.
8	20/40 BSS Coexistence	The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true.
9	Extended Capabilities	The Extended Capabilities element is present if any of the fields in this element are nonzero.
10	SSID List	The SSID List element is optionally present if dot11SSIDListActivated is true.
11	Channel Usage	The Channel Usage element is optionally present if dot11ChannelUsageActivated is true.

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Table 9-38—Probe Request frame body *(continued)*

Order	Information	Notes
12	Interworking	The Interworking element is present if dot11InterworkingServiceActivated is true.
13	Mesh ID	The Mesh ID element is present if dot11MeshActivated is true.
14	Multi-band	The Multi-band element is optionally present if dot11MultibandImplemented is true.
15	DMG Capabilities	The DMG Capabilities element is present if dot11DMGOptionImplemented is true.
16	Multiple MAC Sublayers	The Multiple MAC Sublayers element is present if dot11MultipleMACActivated is true.
17	VHT Capabilities	The VHT Capabilities element is present when dot11VHTOptionImplemented is true.
18	Estimated Service Parameters Inbound	The Estimated Service Parameters Inbound element is optionally present if dot11EstimatedServiceParametersInboundOptionImplemented is true.
19	Extended Request	The Extended Request element is optionally present if dot11RadioMeasurementActivated is true.
20	FILS Request Parameters	The FILS Request Parameters element is optionally present if dot11FILSActivated is true; otherwise not present.
21	AP-CSN	The AP-CSN element is optionally present if dot11FILSActivated is true; otherwise not present.
22	Change Sequence	The Change Sequence element is optionally present if dot11S1GOptionImplemented is true; otherwise not present.
23	S1G Relay Discovery	The S1G Relay Discovery element is optionally present if dot11RelayDiscoveryOptionImplemented is true; otherwise not present.
24	PV1 Probe Response Option	The PV1 Probe Response Option element is optionally present if dot11PV1ProbeResponseOptionImplemented is true; otherwise not present.
25	S1G Capabilities	The S1G Capabilities element is present if dot11S1GOptionImplemented is true; otherwise not present.
26	EL Operation	The EL Operation element is present if dot11S1GELOperationActivated is true.
27	MAD	The MAD element is optionally present if dot11S1GOptionImplemented is true; otherwise not present.
28	Vendor Specific Request	The Vendor Specific Request element is optionally present.
29	CDMG Capabilities	The CDMG Capabilities element is present if dot11CDMGOptionImplemented is true; otherwise not present.
30	Cluster Probe	The Cluster Probe element is optionally present if dot11ClusteringActivated is true; otherwise not present.
31	CMMG Capabilities	The CMMG Capabilities element is present when dot11CMMGOptionImplemented is true; otherwise not present.

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Table 9-38—Probe Request frame body *(continued)*

Order	Information	Notes
32	Estimated Services Parameters Outbound	The Estimated Service Parameters Outbound element is optionally present if dot11EstimatedServiceParametersOutboundOptionImplemented is true.
33	Supplemental Class 2 Capabilities	The Supplemental Class 2 Capabilities element is present when dot11Class2CapabilitiesOptionImplemented is true; otherwise not present.
Last	Vendor Specific	One or more Vendor Specific elements are optionally present. These elements follow all other elements.

9.3.3.10 Probe Response frame format

The frame body of a Probe Response frame contains the information shown in Table 9-39. See additional details and procedures in 11.1.4.

Table 9-39—Probe Response frame body

Order	Information	Notes
1	Timestamp	See 9.4.1.10 for Timestamp field format.
2	Beacon Interval	See 9.4.1.3 for Beacon Interval field format.
3	Capability Information	See 9.4.1.4 for Capability Information field format.
4	SSID	If dot11MeshActivated is true, the SSID element is the wildcard value as described in 9.4.2.2.
5	Supported Rates and BSS Membership Selectors	This field is not present if dot11DMGOptionImplemented is true.
6	DSSS Parameter Set	The element is optionally present. The DSSS Parameter Set element is present within Probe Response frames generated by STAs using Clause 15, Clause 16, and Clause 18 PHYs. The DSSS Parameter Set element is present within Probe Response frames generated by STAs using a Clause 19 PHY in the 2.4 GHz band.
7	IBSS Parameter Set	The IBSS Parameter Set element is present only within Probe Response frames generated by IBSS STAs.
8	Country	The Country element is present if dot11MultiDomainCapabilityActivated is true or dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true.
9	Power Constraint	The Power Constraint element is present if dot11SpectrumManagementRequired is true and is optionally present if dot11RadioMeasurementActivated is true.
10	Channel Switch Announcement	The Channel Switch Announcement element is optionally present for non-DMG STAs if dot11SpectrumManagementRequired is true.
11	Quiet	The Quiet element is optionally present if dot11SpectrumManagementRequired is true or if dot11RadioMeasurementActivated is true.

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Table 9-39—Probe Response frame body *(continued)*

Order	Information	Notes
12	IBSS DFS	The IBSS DFS element is present if dot11SpectrumManagementRequired is true in an IBSS.
13	TPC Report	The TPC Report element is present if dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true.
14	ERP	The ERP element is present within Probe Response frames generated by STAs using ERPs and is optionally present otherwise.
15	Extended Supported Rates and BSS Membership Selectors	The Extended Supported Rates and BSS Membership Selectors element is present if there are more than eight supported rates, and it is optionally present otherwise. This element is not present if dot11DMGOptionImplemented is true.
16	RSN	The RSNE is present if dot11RSNAActivated is true; otherwise not present.
17	BSS Load	The BSS Load element is present if dot11QosOptionImplemented and dot11QBSSLoadImplemented are both true.
18	EDCA Parameter Set	The EDCA Parameter Set element is present if dot11QosOptionImplemented is true and dot11MeshActivated is false.
19	Measurement Pilot Transmission	The Measurement Pilot Transmission element is present if dot11RMMeasurementPilotActivated is between 2 and 7.
20	Multiple BSSID	One or more Multiple BSSID elements are present if dot11RMMeasurementPilotActivated is between 2 and 7 and the AP is a member of a multiple BSSID set (see 11.10.14) with two or more members, or if dot11MultiBSSIDImplemented is true, or if dot11InterworkingServiceActivated is true and the AP is a member of a multiple BSSID set with two or more members and at least one dot11GASAdvertisementID MIB attribute exists.
21	RM Enabled Capabilities	The RM Enabled Capabilities element is present if dot11RadioMeasurementActivated is true.
22	AP Channel Report	If dot11RMAPChannelReportActivated is true, one AP Channel Report element is optionally present for each operating class that has at least 1 channel to report.
23	BSS Average Access Delay	The BSS Average Access Delay element is optionally present if dot11RMBSSAverageAccessDelayActivated is true and the AP Average Access Delay field is not equal to 255 (measurement not available).
24	Antenna	The Antenna element is optionally present if dot11RMAntennaInformationActivated is true and the Antenna ID field is not equal to 0 (unknown antenna).
25	BSS Available Admission Capacity	The BSS Available Admission Capacity element is optionally present if dot11RMBSSAvailableAdmissionCapacityActivated is true with the following exceptions: 1) when Available Admission Capacity Bitmask equals 0 (Available Admission Capacity List contains no entries), or 2) when the BSS Load element is present and the Available Capacity Bitmask equals 256 (Available Admission Capacity List contains only the AC_VO entry).
26	BSS AC Access Delay	The BSS AC Access Delay element is optionally present if dot11RMBSSAverageAccessDelayActivated is true and at least one field of the element is not equal to 255 (measurement not available).

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Table 9-39—Probe Response frame body *(continued)*

Order	Information	Notes
27	Mobility Domain	The MDE is present if dot11FastBSSTransitionActivated is true.
28	DSE registered location	The DSE Registered Location element is present if dot11LCIDSERequired is true.
29	Extended Channel Switch Announcement	The Extended Channel Switch Announcement element is optionally present if dot11ExtendedChannelSwitchActivated is true.
30	Supported Operating Classes	The Supported Operating Classes element is present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true. The Supported Operating Classes element is optionally present if dot11TVHTOptionImplemented is true.
31	HT Capabilities	The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true.
32	HT Operation	The HT Operation element is included by an AP and a mesh STA when dot11HighThroughputOptionImplemented is true.
33	20/40 BSS Coexistence	The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true.
34	Overlapping BSS Scan Parameters	The Overlapping BSS Scan Parameters element is optionally present if dot11FortyMHzOptionImplemented is true.
35	Extended Capabilities	The Extended Capabilities element is present if any of the fields in this element are nonzero.
36	QoS Traffic Capability	The QoS Traffic Capability element is optionally present if dot11ACStationCountActivated is true.
37	Channel Usage	The Channel Usage element is present if the Channel Usage element is present in the Probe Request frame and dot11ChannelUsageActivated is true.
38	Time Advertisement	The Time Advertisement element is present if dot11UTCTSFOffsetActivated is true.
39	Time Zone	The Time Zone element is present if dot11UTCTSFOffsetActivated is true.
40	Interworking	The Interworking element is present if dot11InterworkingServiceActivated is true.
41	Advertisement Protocol	Advertisement Protocol element is present if dot11InterworkingServiceActivated is true and at least one dot11GASAdvertisementID exists.
42	Roaming Consortium	The Roaming Consortium element is present if dot11InterworkingServiceActivated is true and the dot11RoamingConsortiumTable has at least one entry.
43	Emergency Alert Identifier	One or more Emergency Alert Identifier elements are present if dot11EASActivated is true and there are one or more EAS message(s) active in the network.
44	Mesh ID	The Mesh ID element is present if dot11MeshActivated is true.
45	Mesh Configuration	The Mesh Configuration element is present if dot11MeshActivated is true.
46	Mesh Awake Window	The Mesh Awake Window element is optionally present if dot11MeshActivated is true.

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Table 9-39—Probe Response frame body *(continued)*

Order	Information	Notes
47	Beacon Timing	The Beacon Timing element is optionally present if both dot11MeshActivated and dot11MBCAActivated are true.
48	MCCAOP Advertisement Overview	The MCCAOP Advertisement Overview element is optionally present if both dot11MeshActivated and dot11MCCAActivated are true.
49	MCCAOP Advertisement	One or more MCCAOP Advertisement elements are optionally present if both dot11MeshActivated and dot11MCCAActivated are true.
50	Mesh Channel Switch Parameters	The Mesh Channel Switch Parameters element is present if dot11MeshActivated is true and either Channel Switch Announcement element or Extended Channel Switch Announcement element is present.
51	QMF Policy	The QMF Policy element is present if dot11QMFActivated is true and the QMFActivated subfield is 1 in the Extended Capabilities element in the Probe Request that elicited this Probe Response frame.
52	QLoad Report	The QLoad Report element is present if dot11QLoadReportActivated is true.
53	Multi-band	The Multi-band element is optionally present if dot11MultibandImplemented is true.
54	DMG Capabilities	The DMG Capabilities element is present if dot11DMGOptionImplemented is true.
55	DMG Operation	The DMG Operation element is present if dot11DMGOptionImplemented is true.
56	Multiple MAC Sublayers	The Multiple MAC Sublayers element is present if dot11MultipleMACActivated is true.
57	Antenna Sector ID Pattern	The Antenna Sector ID Pattern element is optionally present if dot11DMGOptionImplemented is true.
58	VHT Capabilities	The VHT Capabilities element is present when dot11VHTOptionImplemented is true.
59	VHT Operation	The VHT Operation element is present when dot11VHTOptionImplemented is true; otherwise, it is not present.
60	Transmit Power Envelope element	One Transmit Power Envelope element is present for each distinct value of the Local Maximum Transmit Power Unit Interpretation subfield that is supported for the BSS if both of the following conditions are met: — dot11VHTOptionImplemented or dot11ExtendedSpectrumManagementImplemented is true; — Either dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true. Otherwise, this element is not present.
61	Channel Switch Wrapper element	The Channel Switch Wrapper element is optionally present if dot11VHTOptionImplemented or dot11ExtendedSpectrumManagementImplemented is true and at least one of a Channel Switch Announcement element or an Extended Channel Switch Announcement element is also present in the Probe Response frame and the Channel Switch Wrapper element contains at least one subelement. The Channel Switch Wrapper element is optionally present if dot11S1GOptionImplemented is true and Extended Channel Switch Announcement element is present in the Probe Response frame.

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Table 9-39—Probe Response frame body *(continued)*

Order	Information	Notes
62	Extended BSS Load element	The Extended BSS Load element is optionally present if dot11QosOptionImplemented, dot11QBSSLoadImplemented and dot11VHTOptionImplemented are true.
63	Quiet Channel	Either one Quiet Channel element containing an AP Quiet Mode field equal to 0 or, in an infrastructure BSS, one or more Quiet Channel elements each containing an AP Quiet Mode field equal to 1 are optionally present if dot11VHTOptionImplemented is true, and either dot11SpectrumManagementRequired or dot11RadioMeasurementActivated is true.
64	Operating Mode Notification	The Operating Mode Notification element is optionally present if dot11OperatingModeNotificationImplemented is true.
65	Reduced Neighbor Report	The Reduced Neighbor Report element is optionally present if dot11TVHTOptionImplemented or dot11FILSActivated is true; otherwise not present.
66	TVHT Operation	The TVHT Operation element is present for a TVHT STA when dot11TVHTOptionImplemented is true; otherwise it is not present.
67	Estimated Service Parameters Inbound	The Estimated Service Parameters Inbound element is optionally present if dot11EstimatedServiceParametersInboundOptionImplemented is true.
68	Relay Capabilities	The Relay Capabilities element is present if dot11RelayActivated is true; otherwise not present.
69	CAG Number	The CAG Number element is optionally present if dot11FILSActivated is true; otherwise not present.
70	FILS Indication	The FILS Indication element is present if dot11FILSActivated is true; otherwise not present.
71	AP-CSN	The AP-CSN element is optionally present if dot11FILSActivated is true; otherwise not present.
72	DILS	The DILS element is optionally present if dot11FILSActivated is true; otherwise not present.
73	RPS	The RPS element is optionally present if dot11RAWOperationActivated is true; otherwise not present.
74	Page Slice	The Page Slice element is optionally present if dot11PageSlicingActivated is true; otherwise not present.
75	Change Sequence	The Change Sequence element is optionally present if dot11S1GOptionImplemented is true; otherwise not present.
76	TSF Timer Accuracy	The TSF Timer Accuracy element is optionally present when dot11TSFTimerAccuracyImplemented is true; otherwise not present.
77	S1G Relay Discovery	The S1G Relay Discovery element is optionally present if dot11RelayDiscoveryOptionImplemented is true; otherwise not present.
78	S1G Capabilities	The S1G Capabilities element is present if dot11S1GOptionImplemented is true; otherwise not present.
79	S1G Operation	The S1G Operation element is present when dot11S1GOptionImplemented is true; otherwise not present.
80	MAD	The MAD element is optionally present if dot11S1GOptionImplemented is true; otherwise not present.

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Table 9-39—Probe Response frame body *(continued)*

Order	Information	Notes
81	Short Beacon Interval	The Short Beacon Interval element is present if dot11ShortBeaconInterval is true.
82	S1G Open-Loop Link Margin Index	The S1G Open-Loop Link Margin Index element is optionally present if dot11S1GOptionImplemented is true; otherwise not present.
83	S1G Relay	The S1G Relay element is optionally present if dot11RelayAPImplemented is true; otherwise not present.
84	Max Channel Switch Time	The Max Channel Switch Time element is optionally present when a Channel Switch Announcement or an Extended Channel Switch Announcement element is also present.
85	CDMG Capabilities	The CDMG Capabilities element is present if dot11CDMGOptionImplemented is true; otherwise not present.
86	Extended Cluster Report	The Extended Cluster Report element is optionally present if dot11ClusteringActivated is true; otherwise not present.
87	CMMG Capabilities	The CMMG Capabilities element is present when dot11CMMGOptionImplemented is true; otherwise not present.
88	CMMG Operation	The CMMG Operation element is present when dot11CMMGOptionImplemented is true; otherwise not present.
89	Estimated Services Parameters Outbound	The Estimated Service Parameters Outbound element is optionally present if dot11EstimatedServiceParametersOutboundOptionImplemented is true.
90	Service Hint	The Service Hint element is optionally present if dot11UnsolicitedPADActivated is true.
91	Service Hash	The Service Hash element is optionally present if dot11UnsolicitedPADActivated is true.
91	RSN Extension	The RSNXE is present if any subfield of the Extended RSN Capabilities field in this element is nonzero, except the Field Length subfield.
Last–1	Vendor Specific	One or more Vendor Specific elements are optionally present. These elements follow all other elements, except the Requested elements.
Last	Requested elements	Elements requested by the Request element or Extended Request element(s) of the Probe Request frame are present if dot11MultiDomainCapabilityActivated or dot11EstimatedServiceParametersInboundOptionImplemented is true. See 11.1.4.3.2 and 11.44.

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9.3.3.11 Authentication frame format

The frame body of an Authentication frame contains the information shown in Table 9-40. FT authentication is used when FT support is advertised by the AP and dot11FastBSSTransitionActivated is true in the STA. SAE authentication is used when dot11MeshActiveAuthenticationProtocol is sae (1). FILS authentication is used if support for FILS authentication is advertised by the AP and dot11FILSActivated is true in the STA.

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Table 9-40—Authentication frame body

Order	Information	Notes
1	Authentication algorithm number	
2	Authentication transaction sequence number	
3	Status code	The status code information is reserved in certain Authentication frames as defined in Table 9-41.
4	Finite Cyclic Group	An unsigned integer indicating a finite cyclic group as described in 9.4.1.42. This is present only in certain Authentication frames as defined in Table 9-41.
5	Anti-Clogging Token	A random bit string used for anti-clogging purposes as described in 12.4.6. This is present only in certain Authentication frames as defined in Table 9-41.
6	Send-Confirm	A binary encoding of an integer used for anti-replay purposes as described in 12.4.7.5. This is present only in certain Authentication frames as defined in Table 9-41.
7	Scalar	An unsigned integer encoded as described in 12.4.7.4. This is present only in certain Authentication frames as defined in Table 9-41.
8	FFE field	An element in a finite field encoded as described in 12.4.7.4. This is present only in certain Authentication frames as defined in Table 9-41.
9	Confirm	An unsigned integer encoded as described in 12.4.7.5. This is present only in certain Authentication frames as defined in Table 9-41.
10	Challenge text	A Challenge Text element is present only in certain Authentication frames as defined in Table 9-41.
11	RSN	An RSNE is present only in certain Authentication frames as defined in Table 9-41.
12	Mobility Domain	An MDE is present only in certain Authentication frames as defined in Table 9-41.
13	Fast BSS Transition	An FTE is present only in certain Authentication frames as defined in Table 9-41.
14	Timeout Interval (reassociation deadline)	A TIE containing the reassociation deadline interval is present only in certain Authentication frames as defined in Table 9-41.
15	RIC	A resource information container, containing a variable number of elements, is present only in certain Authentication frames as defined in Table 9-41.
16	Multi-band	The Multi-band element is optionally present if dot11MultibandImplemented is true.
17	Neighbor Report	One or more Neighbor Report elements are present only in certain Authentication frames as defined in Table 9-41.
18	FILS Nonce	The FILS Nonce element is present in FILS Authentication frames as defined in Table 9-41.
19	FILS Session	The FILS Session element is present in FILS Authentication frames as defined in Table 9-41.
20	FILS Wrapped Data	The FILS Wrapped Data element is present in FILS Authentication frames as defined in Table 9-41.

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Table 9-40—Authentication frame body *(continued)*

Order	Information	Notes
21	Association Delay Info	The Association Delay Info element is present in FILS Authentication frames as defined in Table 9-41.
22	Password Identifier	The Password Identifier element is optionally present in certain Authentication frames as defined in Table 9-41.
23	Rejected Groups	The Rejected Groups element is present only in certain Authentication frames as defined in Table 9-41.
24	Anti-Clogging Token Container	The Anti-Clogging Token Container element is present only in certain Authentication frames as defined in Table 9-41.
Last	Vendor Specific	One or more Vendor Specific elements are optionally present. These elements follow all other elements.

Table 9-41—Presence of fields and elements in Authentication frames

Authentication algorithm	Authentication transaction sequence number	Status code	Presence of fields and elements from order 4 onward
Open System	1	Reserved	Not present
Open System	2	Not REJECTED_WITH_SUGGESTED_BSS_TRANSITION	Not present
Open System	2	REJECTED_WITH_SUGGESTED_BSS_TRANSITION	One or more Neighbor Report element(s) is present
Shared Key	1	Reserved	Not present
Shared Key	2	Any	The Challenge Text element is present
Shared Key	3	Reserved	The Challenge Text element is present
Shared Key	4	Any	Not present
FT	1	Reserved	The Mobility Domain element is present. The Fast BSS Transition element and RSNEs are present if dot11RSNAActivated is true.
FT	2	Not REJECTED_WITH_SUGGESTED_BSS_TRANSITION	The Mobility Domain element is present if the Status Code field is 0. The Fast BSS Transition element and RSNEs are present if the Status Code field is 0 and dot11RSNAActivated is true.
FT	2	REJECTED_WITH_SUGGESTED_BSS_TRANSITION	One or more Neighbor Report element(s) is present

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Table 9-41—Presence of fields and elements in Authentication frames *(continued)*

Authentication algorithm	Authentication transaction sequence number	Status code	Presence of fields and elements from order 4 onward
FT	3	Reserved	The Mobility Domain element is present. The Fast BSS Transition element and RSNEs are present if dot11RSNAActivated is true. The RIC element is optionally present.
FT	4	Any	The Mobility Domain element is present if the Status Code field is 0. The Fast BSS Transition element and RSNEs are present if dot11RSNAActivated is true. The RIC element is optionally present if the Status Code field is 0. The TIE (reassociation deadline) is present if a RIC element is present.
SAE	1	Any	The Scalar field is present if the Status Code field is zero or 126. The FFE field is present if the Status Code field is zero or 126. When the hunting-and-pecking method is used to drive the PWE, the Anti-Clogging Token field is present if the Status Code field is ANTI_CLOGGING_TOKEN_REQUIRED or if the Authentication frame is in response to a previous rejection with the Status Code field equal to ANTI_CLOGGING_TOKEN_REQUIRED. The Finite Cyclic Group field is present if the Status Code field is zero, ANTI_CLOGGING_TOKEN_REQUIRED, 77 or 126. The Password Identifier element is optionally present if the Status Code field is zero, 123 or 126. The Rejected Groups element is conditionally present if the Status Code field is 126, as described in 12.4.7.4. When the hash-to-element method is used to derive the PWE, the Anti-Clogging Token Container element is present if the Status Code field is ANTI_CLOGGING_TOKEN_REQUIRED or if the Authentication frame is in response to a previous rejection with the Status Code field equal to ANTI_CLOGGING_TOKEN_REQUIRED.
SAE	2	Not REJECTED_WITH_SUGGESTED_BSS_TRANSITION	The Send-Confirm field is present. The Confirm field is present.
SAE	2	REJECTED_WITH_SUGGESTED_BSS_TRANSITION	One or more Neighbor Report element(s) are present

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Table 9-41—Presence of fields and elements in Authentication frames *(continued)*

Authentication algorithm	Authentication transaction sequence number	Status code	Presence of fields and elements from order 4 onward
FILS Shared Key authentication without PFS	1	Reserved	The RSNE is present. The MDE is present if the FILS authentication is used for FT initial mobility domain association. The FILS Nonce element is present. The FILS Session element is present. The FILS Wrapped Data element is present.
FILS Shared Key authentication without PFS	2	Status	The RSNE is present. The MDE and the FTE are present if the Status Code field is 0 and FILS authentication is used for FT initial mobility domain association. The FILS Nonce element is present if the Status Code field is 0. The FILS Session element is present if the Status Code field is 0. The FILS Wrapped Data element is present if the Status Code field is 0. The Association Delay Info element is present if the Status Code field is 0 and the AP expects that the (Re)Association Response frame will be transmitted more than 1 TU after the (Re)Association Request frame.
FILS Shared Key authentication with PFS	1	Reserved	The Finite Cyclic Group field is present. The FFE field is present. The RSNE is present. The MDE is present if the FILS authentication is used for FT initial mobility domain association. The FILS Nonce element is present. The FILS Session element is present. The FILS Wrapped Data element is present.

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Table 9-41—Presence of fields and elements in Authentication frames *(continued)*

Authentication algorithm	Authentication transaction sequence number	Status code	Presence of fields and elements from order 4 onward
FILS Shared Key authentication with PFS	2	Status	The Finite Cyclic Group is present if the Status Code field is 0. The FFE field is present if the Status Code field is 0. The RSNE is present. The MDE and the FTE are present if the Status Code field is 0 and FILS authentication is used for FT initial mobility domain association. The FILS Nonce element is present if the Status Code field is 0. The FILS Session element is present if the Status Code field is 0. The FILS Wrapped Data element is present if the Status Code field is 0. The Association Delay Info element is present if the Status Code field is 0 and the AP expects that the (Re)Association Response frame will be transmitted more than 1 TU after the (Re)Association Request frame.
FILS Public Key authentication	1	Reserved	The Finite Cyclic Group field is present. The FFE field is present. The RSNE is present. The MDE is present if the FILS authentication is used for FT initial mobility domain association. The FILS Nonce element is present. The FILS Session element is present.
FILS Public Key authentication	2	Status	The Finite Cyclic Group is present if the Status Code field is 0. The FFE field is present if the Status Code field is 0. The RSNE is present. The MDE and the FTE are present if the Status Code field is 0 and FILS authentication is used for FT initial mobility domain association. The FILS Nonce element is present if the Status Code field is 0. The FILS Session element is present if the Status Code field is 0. The Association Delay Info element is present if the Status Code field is 0 and the AP expects that the (Re)Association Response frame will be transmitted more than 1 TU after the (Re)Association Request frame.

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9.3.3.12 Deauthentication

The frame body of a Deauthentication frame contains the information shown in Table 9-42.

Table 9-42—Deauthentication frame body

Order	Information
1	Reason code
Last – 1	One or more Vendor Specific elements are optionally present.
Last	The MME is present when management frame protection is enabled at the AP and the frame is a group addressed frame.
NOTE—The MME appears after all fields that it protects. Therefore, it appears last in the frame body to protect the frames as specified in 12.5.4.	

9.3.3.13 Action frame format

The frame body of an Action frame contains the information shown in Table 9-43.

Table 9-43—Action frame body and Action No Ack frame body

Order	Information
1	Action
Last – 2	One or more Vendor Specific elements are optionally present. These elements are absent when the Category subfield of the Action field is Vendor-Specific, Vendor-Specific Protected, or Self-protected or when the Category subfield of the Action field is VHT and the VHT Action subfield of the Action field is VHT Compressed Beamforming.
Last – 1	The MME is present when management frame protection is enabled at the AP, the frame is a group addressed robust Action frame, and the category of the Action frame does not support group addressed privacy as indicated by Table 9-51.
Last	The Authenticated Mesh Peering Exchange element is present in a Self-protected Action frame if dot11MeshSecurityActivated, dot11ProtectedQLoadReportActivated, or dot11ProtectedTXOPNegotiationActivated is true and a PMK exists between the sender and recipient of this frame; otherwise not present.
NOTE—The MME appears after any fields that it protects. Therefore, it appears last in the frame body to protect the frames as specified in 12.5.4.	

9.3.3.14 Action No Ack frame format

The frame body of an Action No Ack frame contains the information shown in Table 9-43.

NOTE—The selection of Action or Action No Ack is made per frame that uses these formats.

Unless specified as allowing the use of the Action No Ack management frame subtype, a frame described as an “Action frame” uses only the Action subtype.

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9.3.3.15 Timing Advertisement frame format

The frame body of a Timing Advertisement frame contains the information shown in Table 9-44.

Table 9-44—Timing Advertisement frame body

Order	Information	Notes
1	Timestamp	See 9.4.1.10 for Timestamp field format.
2	Capability Information	See 9.4.1.4 for Capability Information field format.
3	Country	The Country element is present if dot11MultiDomainCapabilityActivated is true or dot11SpectrumManagementRequired is true.
4	Power Constraint	The Power Constraint element is optionally present if the Country element is present; otherwise not present.
5	Time Advertisement	The Time Advertisement element is optionally present. See 9.4.2.60.
6	Extended Capabilities	The Extended Capabilities element is present.
Last	Vendor specific	One or more Vendor Specific elements are optionally present. These elements follow all other elements.

9.3.4 Extension frames

9.3.4.1 Format of Extension frames

The format of Extension frames is defined in Figure 9-75. The MAC header of an Extension frame starts with the Frame Control field followed by the Duration field. The MAC header of different Extension frames can have different number and types of fields following the Duration field.

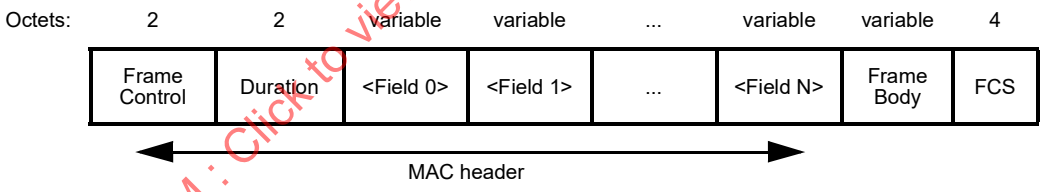

Figure 9-75—Extension frame format

9.3.4.2 DMG Beacon

The format of the DMG Beacon frame is shown in Figure 9-76.

In addition to supporting functions such as network synchronization (see 11.1), the DMG Beacon frame can also be used as a training frame for beamforming (see 10.42).

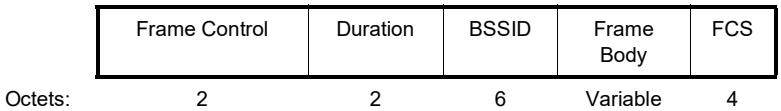

Figure 9-76—DMG Beacon frame format

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The Duration field is set to the time remaining until the end of the beacon transmission interval (BTI).

The BSSID field contains the BSSID.

The Frame Body field of the DMG Beacon frame contains the elements listed in Table 9-45.

Table 9-45—DMG Beacon frame body

Order	Information	Notes
1	Timestamp	See 9.4.1.10
2	Sector Sweep	See 9.5.1
3	Beacon Interval	See 9.4.1.3
4	Beacon Interval Control	See Figure 9-77.
5	DMG Parameters	See 9.4.1.46
6	Clustering Control	Optional. See Figure 9-78 and Figure 9-79.
7	DMG Capabilities	The DMG Capabilities element is optionally present.
8	Extended Schedule	The Extended Schedule element is optionally present.
9	RSN	The RSNE is optionally present if dot11RSNAActivated is true.
10	Multiple BSSID	One or more Multiple BSSID elements are optionally present if dot11MultiBSSIDImplemented is true.
11	DMG Operation	The DMG Operation element is optionally present.
12	Next DMG ATI	The Next DMG ATI element is optionally present.
13	DMG BSS Parameter Change	The DMG BSS Parameter Change element is optionally present.
14	Multi-band	Zero or more Multi-band elements are present if dot11MultibandImplemented is true.
15	Awake Window	The Awake Window element is optionally present. If present, this element specifies the characteristics of the awake window of a CBAP (see 11.2.7).
16	DMG Wakeup Schedule	The DMG Wakeup Schedule element is optionally present (see 11.2.7.3.3.
17	UPSIM	The UPSIM element is optionally present (see 11.2.7.2.2).
18	SSID	The SSID element is optionally present.
19	IBSS Parameter Set	The IBSS Parameter Set element is present only within DMG Beacon frames generated by IBSS STAs.
20	Country	The Country element is optionally present if dot11MultiDomainCapabilityActivated is true or dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true.
21	BSS Load	The BSS Load element is optionally present if dot11QosOptionImplemented and dot11QBSSLoadImplemented are both true.
22	EDCA Parameter Set	The EDCA Parameter Set element is optionally present.

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Table 9-45—DMG Beacon frame body *(continued)*

Order	Information	Notes
23	Power Constraint	The Power Constraint element is optionally present if dot11SpectrumManagementRequired is true and is optionally present if dot11RadioMeasurementActivated is true.
24	Neighbor Report	The Neighbor Report element is optionally present.
25	Quiet	The Quiet element is optionally present if dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true.
26	QoS Capability	The QoS Capability element is optionally present.
27	Extended Channel Switch Announcement	The Extended Channel Switch Announcement element is optionally present if dot11ExtendedChannelSwitchActivated is true.
28	BSS Average Access Delay	The BSS Average Access Delay element is optionally present.
29	RM Enabled Capabilities	The RM Enabled Capabilities element is optionally present if dot11RadioMeasurementActivated is true.
30	Nontransmitted BSSID Capability	The Nontransmitted BSSID Capability element is optionally present.
31	Interworking	The Interworking element is optionally present if dot11InterworkingServiceActivated is true.
32	Advertisement Protocol	The Advertisement Protocol element is optionally present if dot11InterworkingServiceActivated is true and at least one dot11GASAdvertisementID exists.
33	Roaming Consortium	The Roaming Consortium element is optionally present if dot11InterworkingServiceActivated is true and the dot11RoamingConsortiumTable has at least one entry.
34	STA Availability	The STA Availability element is optionally present.
35	Next PCP List	The Next PCP List element is optionally present.
36	PCP Handover	The PCP Handover element is optionally present.
37	Antenna Sector ID Pattern	The Antenna Sector ID Pattern element is optionally present.
38	CDMG Capabilities	The CDMG Capabilities element is present if dot11CDMGOptionImplemented is true; otherwise not present.
39	Dynamic Bandwidth Control	The Dynamic Bandwidth Control element is optionally present if a STA operates as an AP or PCP and dot11CDMGOptionImplemented is true; otherwise not present.
40	Cluster Probe	The Cluster Probe element is optionally present if dot11ClusteringActivated is true; otherwise not present.
41	Extended Cluster Report	The Extended Cluster Report element is optionally present if dot11ClusteringActivated is true; otherwise not present.
42	Cluster Switch Announcement	The Cluster Switch Announcement element is optionally present if dot11ClusteringActivated is true; otherwise not present.
43	Extended Cluster Report	The Extended Cluster Report element is optionally present if dot11ClusteringActivated is true; otherwise not present.

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Table 9-45—DMG Beacon frame body *(continued)*

Order	Information	Notes
44	Cluster Switch Announcement	The Cluster Switch Announcement element is optionally present if dot11ClusteringActivated is true; otherwise not present.
45	SPSH Report	The SPSH Report element is optionally present if dot11ClusteringActivated is true; otherwise not present.
46	Clustering Interference Assessment	The Clustering Interference Assessment element is optionally present if dot11ClusteringActivated is true; otherwise not present.
47	CMMG Capabilities	The CMMG Capabilities element is present when dot11CMMGOptionImplemented is true; otherwise not present.
48	CMMG Operation	The CMMG Operation element is present if dot11CMMGOptionImplemented is true; otherwise not present.
49	Power Constraint	The Power Constraint element is present if dot11SpectrumManagementRequired is true and is optionally present if dot11RadioMeasurementActivated is true; otherwise not present.
50	TPC Report	The TPC Report element is present if dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true; otherwise not present.
51	BSS Load	The BSS Load element is present if dot11QosOptionImplemented and dot11QBSSLoadImplemented are both true; otherwise not present.
52	CDMG Extended Schedule	The CDMG Extended Schedule element is optionally present.
53	Service Hint	The Service Hint element is optionally present if dot11UnsolicitedPADActivated is true.
54	Service Hash	The Service Hash element is optionally present if dot11UnsolicitedPADActivated is true.
Last	Vendor Specific	One or more Vendor Specific elements are optionally present. These elements follow all other elements.

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The format of the Beacon Interval Control field is shown in Figure 9-77.

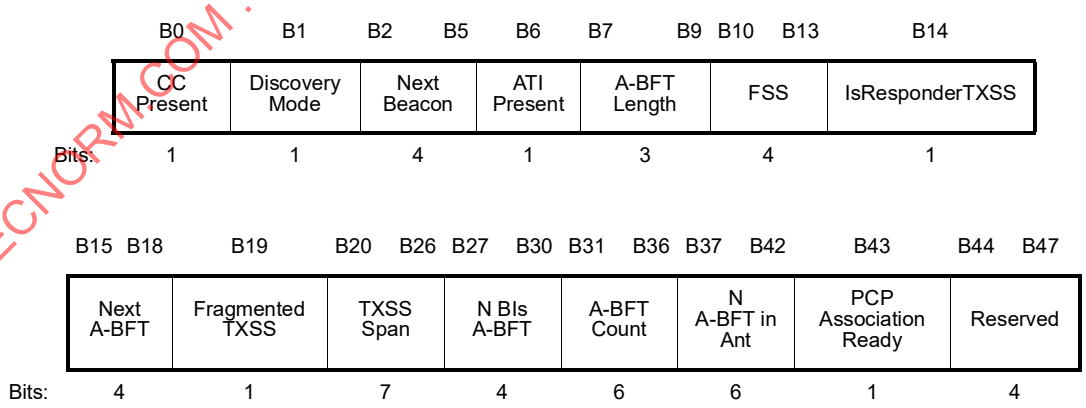

Figure 9-77—Beacon Interval Control field format

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The CC Present subfield is set to 1 to indicate that the Clustering Control field is present in the DMG Beacon frame. Otherwise, the Clustering Control field is not present.

The Discovery Mode subfield is set to 1 if the STA is generating the DMG Beacon frame following the procedure described in 11.1.3.4. Otherwise, this subfield is set to 0.

The Next Beacon subfield indicates the number of beacon intervals following the current beacon interval during which the DMG Beacon frame will not be transmitted.

The ATI Present subfield is set to 1 to indicate that the announcement transmission interval (ATI) is present in the current beacon interval. Otherwise, the ATI is not present.

The A-BFT Length subfield indicates the number of sector sweep slots (10.42.5) in the A-BFT following the BTI, minus 1.

The FSS subfield indicates the number of SSW frames allowed per sector sweep slot (10.42.5). The subfield contains the number of SSW frames allowed minus one. The range of this subfield is 0 to 15.

The IsResponderTXSS subfield is set to 1 to indicate the A-BFT following the BTI is used for responder transmit sector sweep (TXSS). This field is set to 0 to indicate responder receive sector sweep (RXSS). When this subfield is set to 0, the FSS subfield specifies the length of a complete receive sector sweep by the STA sending the DMG Beacon frame.

The Next A-BFT subfield indicates the number of beacon intervals during which the A-BFT is not present. This subfield is set to 0 if the A-BFT immediately follows this BTI.

The Fragmented TXSS subfield is set to 1 to indicate the TXSS is a fragmented sector sweep and is set to 0 to indicate the TXSS is a complete sector sweep.

The TXSS Span subfield indicates the number of beacon intervals it takes for the STA sending the DMG Beacon frame to complete the TXSS phase. This subfield is always greater than or equal to 1.

The N BIs A-BFT subfield indicates the interval, in number of beacon intervals, at which the STA sending the DMG Beacon frame allocates an A-BFT. The subfield is set to 1 if every beacon interval contains an A-BFT.

The A-BFT Count subfield indicates the number of A-BFTs since the STA sending the DMG Beacon frame last switched RX DMG antennas for an A-BFT. The subfield is set to 0 if the DMG antenna used in the forthcoming A-BFT differs from the DMG antenna used in the last A-BFT. This subfield is reserved if the Number of RX DMG Antennas field within the STA's DMG Capabilities element is 1.

The N A-BFT in Ant subfield indicates how many A-BFTs the STA sending the DMG Beacon frame receives from each DMG antenna in the DMG antenna receive rotation. This subfield is reserved if the Number of RX DMG Antennas field within the STA's DMG Capabilities element is 1.

The PCP Association Ready subfield is set to 1 to indicate that the PCP is ready to receive Association Request frames from non-PCP STAs and is set to 0 otherwise. This subfield is reserved when transmitted by a non-PCP STA.

The DMG Parameters field is defined in 9.4.1.46.

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If the Discovery Mode field is 0, the Clustering Control field is formatted as shown in Figure 9-78. If the Discovery Mode field is 1, the Clustering Control field is formatted as shown in Figure 9-79.

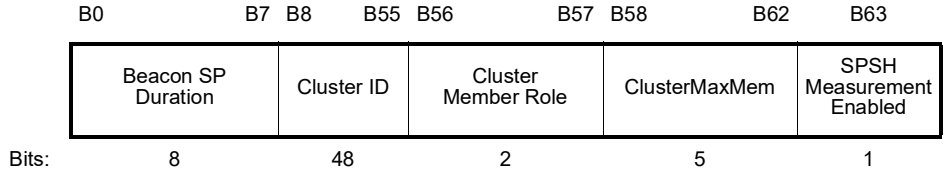

Figure 9-78—Clustering Control field format if the Discovery Mode field is 0

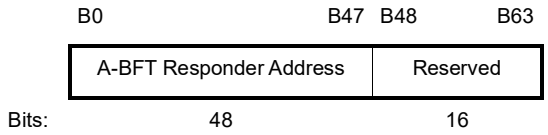

Figure 9-79—Clustering Control field format if the Discovery Mode field is 1

If ECAPC Policy Enforced field is set to 0, the Beacon SP Duration subfield indicates the duration, in units of 8 μs, of the Beacon SPs in the cluster. If ECAPC Policy Enforced field is set to 1, the Beacon SP Duration subfield indicates the maximum duration, in units of 8 μs, of the beacon header interval (BHI) of the BSS, and the minimum duration of Beacon SPs in the cluster (see 10.40.2.2).

The cluster to which the transmitter of the Clustering Control field belongs is identified by the Cluster ID subfield. The MAC address of the S-AP or synchronization PCP (S-PCP) is the Cluster ID of the cluster.

The Cluster Member Role subfield identifies the role that the transmitting STA assumes within the cluster. A 0 means that the STA is currently not participating in clustering. A 1 means that the STA acts as the S-AP or S-PCP of the cluster. A 2 means that the STA participates in the cluster, but not as the S-AP or S-PCP. The value 3 is reserved.

The ClusterMaxMem subfield defines the maximum number of PCPs and/or APs, including the S-AP or S-PCP, that can participate in the cluster. The ClusterMaxMem subfield is computed in relation to the beacon interval value (10.42.2). The value 0 is reserved. Values 8 and above are reserved if the ECAPC Policy Enforced field is set to 0. The value 1 is assigned to the S-AP or S-PCP.

The SPSH Measurement Enabled subfield is used by a CDMG S-AP or S-PCP to indicate whether the member APs or member PCPs in an AP or PCP cluster are allowed to perform channel measurement to achieve spatial sharing. If the SPSH Measurement Enabled subfield is 1, a SPSH measurement period starts. In this period, the member APs or member PCPs in an AP or PCP cluster can perform channel measurement in its BSS and spatial reuse is not allowed. If the SPSH Measurement Enabled subfield is 0, SPSH measurement terminates and SP reuse is conducted in the following time interval, i.e., APs or PCPs of the AP or PCP cluster are allowed to allocate time-overlapping SPs among different BSSs. In a DMG Beacon frame transmitted by a non-CDMG S-AP or S-PCP, the SPSH Measurement Enabled subfield is reserved.

The A-BFT Responder Address subfield contains the MAC address of the STA that is allowed to transmit during the A-BFT, if present, that follows the BTI.

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9.3.4.3 S1G Beacon frame format

The format of the S1G Beacon is shown in Figure 9-80.

	Frame Control	Duration	SA	Time-stamp	Change Sequence	Next TBTT (optional)	Compressed SSID (optional)	Access Network Options (optional)	Frame Body	FCS
Octets:	2	2	6	4	1	0 or 3	0 or 4	0 or 1	variable	4

Figure 9-80—S1G Beacon frame format

The Duration field is set to the duration of time, in microseconds, required by the paged STAs to transmit any pending QoS Null, PS-Poll or NDP PS-Poll frames as specified in 9.2.5.2.

The SA field is the address of the STA transmitting the S1G Beacon frame.

The Timestamp field contains the value of the 4 least significant octets of the STA's TSF timer at the time that the start of the data symbol containing the first bit of the Timestamp field appears at the transmit antenna connector.

The Change Sequence field is defined as an unsigned integer, initialized to 0, that increments when a critical update to the Beacon frame has occurred (see 10.46.2).

The Next TBTT field is present if the Next TBTT Present field in the Frame Control field is 1 and indicates the most significant 3 octets of the 4 least significant octets of the next TBTT. Otherwise, it is not present.

The Compressed SSID field is present if the Compressed SSID Present field in the Frame Control is 1 and indicates a 32-bit CRC calculated over the SSID contained in the S1G Beacon frame (calculation is performed as defined in 9.2.4.8 where the SSID is the calculation fields). Otherwise, it is not present.

The Access Network Options field is present if the ANO field in the Frame Control field is 1 and it is defined in 9.4.2.91 (see Figure 9-484). Otherwise, it is not present.

The Frame Body field contains the optional elements listed in Table 9-46. The minimum set of optional elements is included in an S1G Beacon frame transmitted at a TSBTT that is not a TBTT and the full set of optional elements is included in an S1G Beacon frame that is transmitted at a TBTT (see 11.1.3.10.1). See 10.28.6 on the parsing of the elements.

Table 9-46—Minimum and full set of optional elements

Order	Information	Notes	Allowed in minimum set	Allowed in full set
1	S1G Beacon Compatibility	The S1G Beacon Compatibility element is present within S1G Beacon frames generated at TBTTs.	No	Yes
2	Traffic indication map (TIM)	The TIM element is present within S1G Beacon frames generated by APs at TBTTs and is optionally present otherwise.	Yes	Yes

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Table 9-46—Minimum and full set of optional elements

Order	Information	Notes	Allowed in minimum set	Allowed in full set
3	FMS Descriptor	The FMS Descriptor element is present if dot11FMSActivated is true.	Yes	Yes
4	RPS	The RPS element is optionally present if dot11RAWOperationActivated is true.	Yes	Yes
5	SST Operation	The SST Operation element is present if dot11SelectiveSubchannelTransmissionPermitted is true.	No	Yes
6	Subchannel Selective Transmission	The Subchannel Selective Transmission element is optionally present if dot11SubchannelSelectiveTransmissionActivated is true.	Yes	Yes
7	S1G Relay	The S1G Relay element is optionally present if dot11RelayAPImplemented is true.	Yes	Yes
8	Page Slice	The Page Slice element is optionally present if dot11PageSlicingActivated is true.	No	Yes
9	S1G Sector Operation	The S1G Sector Operation element is optionally present if dot11S1GSectorizationActivated is true.	No	Yes
10	Authentication Control	The Authentication Control element is optionally present when dot11S1GCentralizedAuthenticationControlActivated is true or dot11S1GDistributedAuthenticationControlActivated is true.	No	Yes
11	TSF Timer Accuracy	The TSF Timer Accuracy element is optionally present when dot11TSFTimerAccuracyImplemented is true.	No	Yes
12	S1G Relay Discovery	The S1G Relay Discovery element is optionally present if dot11RelayDiscoveryOptionImplemented is true.	No	Yes
13	S1G Capabilities	The S1G Capabilities element is present if dot11S1GOptionImplemented is true; otherwise not present.	No	Yes
14	S1G Operation	The S1G Operation element is present when dot11S1GOptionImplemented is true; otherwise not present.	No	Yes
15	Short Beacon Interval	The Short Beacon Interval element is present if dot11ShortBeaconInterval is true.	No	Yes
16	Multiple BSSID	One or more Multiple BSSID elements are present if dot11MultiBSSIDImplemented is true; otherwise not present.	No	Yes

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Table 9-46—Minimum and full set of optional elements

Order	Information	Notes	Allowed in minimum set	Allowed in full set
Last–1	One or more elements can appear in this frame.	These elements are optionally present and follow all other elements that are not Vendor Specific elements and precede all other elements that are Vendor Specific elements that are part of the Last field in the frame.	No	Yes
Last	Vendor Specific	One or more Vendor Specific elements are optionally present. These elements follow all other elements.	No	Yes

9.3.5 Frame addressing in an MBSS

Mesh Data frames and Multihop Action frames enable multihop MSDU and MMPDU forwarding in an MBSS using the Mesh Control field described in 9.2.4.7.3.

Table 9-47 shows the valid combinations of address fields in mesh Data frames and Multihop Action frames along with the corresponding value of the Address Extension Mode subfield in the Mesh Control field.

Table 9-47—Valid address field usage for Mesh Data and Multihop Action frames

Supported frames	To DS	From DS	Address extension mode	Address 1	Address 2	Address 3	Address 4	Address 5	Address 6
Mesh Data (individually addressed)	1	1	None	RA	TA	DA = Mesh DA	SA = Mesh SA	*Not Present*	*Not Present*
Mesh Data (group addressed)	0	1	None	DA	TA	SA = Mesh SA	*Not Present*	*Not Present*	*Not Present*
Mesh Data (proxied, individually addressed)	1	1	Address5&6	RA	TA	Mesh DA	Mesh SA	DA	SA
Mesh Data (proxied, group addressed)	0	1	Address4	DA	TA	Mesh SA	SA	*Not Present*	*Not Present*
Multihop Action (individually addressed)	0	0	Address4	RA	TA	DA = Mesh DA	SA = Mesh SA	*Not Present*	*Not Present*
Multihop Action (group addressed)	0	0	None	DA	TA	SA = Mesh SA	*Not Present*	*Not Present*	*Not Present*

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NOTE 1—To DS and From DS subfields are located in the Frame Control field (see 9.2.4.1.4). The Address Extension Mode subfield is located in the Mesh Flags subfield in the Mesh Control field (see 9.2.4.7.3). Address 1, Address 2, and Address 3 fields are located in the MAC header (see 9.2.3). The Address 4 field is located in the MAC header if both To DS and From DS subfields are 1; otherwise, the Address 4 field is located in the Mesh Address Extension subfield of the Mesh Control field (see 9.2.3 and 9.2.4.7.3). Address 5 and Address 6 fields are located in the Mesh Control field if they are present (see 9.2.4.7.3).

NOTE 2—Values for the Address Extension Mode subfield are defined in see Table 9-26.

In individually addressed Mesh Data and Multihop Action frames, Address 1 and Address 2 correspond to the mesh STA receiver address (RA) and the mesh STA transmitter address (TA) for a particular mesh link. Address 3 and Address 4 correspond to the destination mesh STA and the source mesh STA of a mesh path. The Address Extension Mode subfield in the Mesh Control field indicates the presence of an optional Mesh Address Extension subfield in the Mesh Control field. When the Extension Mode subfield equals "Address5&6" (see Table 9-26), the Mesh Control field includes Address 5 and Address 6 that correspond to the end-to-end destination address (DA) and source address (SA) of STAs that communicate over the mesh path, for instance, external STAs that communicate over the mesh BSS via proxy mesh gates (see Figure 9-81).

NOTE 3—The forwarding of individually addressed mesh Data frames uses only mesh STA addresses in fields Address 1, Address 2, Address 3, and Address 4. This allows intermediate mesh STAs to forward mesh Data frames without necessarily having any knowledge of the addresses of the source and destination end stations, which might be external addresses. Thus, proxy information only needs to be maintained by proxy mesh gates and by source mesh STAs.

The term source mesh STA refers to the first mesh STA on a mesh path. A source mesh STA is either a mesh STA that is the initial source of an MSDU/MMPDU or a mesh STA that receives an MSDU/MMPDU from a mesh path or from a STA outside the mesh BSS and translates and forwards the MSDU/MMPDU on the mesh path. The address of the source mesh STA is referred to as the *Mesh SA*.

The term destination mesh STA refers to the final mesh STA on a mesh path. A destination mesh STA is either a mesh STA that is the final destination of an MSDU/MMPDU or a mesh STA that receives an MSDU/MMPDU from a mesh path and translates and forwards the MSDU/MMPDU on another mesh path or to a STA outside of the mesh BSS. The address of the destination mesh STA is referred to as the *Mesh DA*.

In group addressed mesh Data frames, Address 1 and Address 2 correspond to the group address and the mesh STA transmitter address (TA). Address 3 corresponds to the mesh source address (mesh SA) of the group addressed mesh Data frame. The Address Extension Mode indicates the presence of an optional address extension field Address 4 in the Mesh Control field that corresponds to the source address (SA) of external STAs that communicate over the mesh BSS via proxy mesh gates.

NOTE 4—The reason for not using the four-address MAC header format for group addressed traffic is to avoid interactions with existing implementations. Earlier revisions of this standard defined the four-address MAC header format without defining procedures for its use. As a result there is a large number of deployed devices that use the four-address frame format in ways that would affect and be affected by mesh traffic if four-address group addressed frames were to be used.

Figure 9-81 illustrates the addressing of a mesh Data frame that contains an MSDU transmitted and forwarded on a mesh path from a mesh STA collocated with a portal (STA 1) to a mesh STA collocated with an AP (STA 2) where the source is a STA outside of the mesh BSS (STA 33) that is reachable via the portal and the destination is an IEEE 802.11 STA associated with the AP (STA 22).

Details on how these address mappings work in forwarding processing are described in 10.38.3 and 10.38.4.

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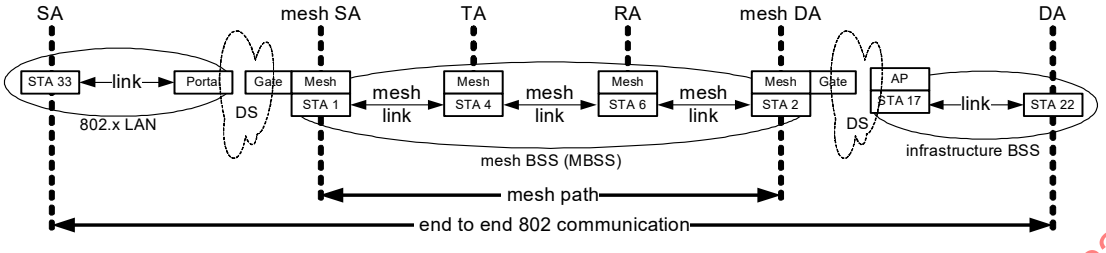

Figure 9-81—Example addressing for a mesh Data frame

9.4 Management and Extension frame body components

9.4.1 Fields that are not elements

9.4.1.1 Authentication Algorithm Number field

The Authentication Algorithm Number field indicates a single authentication algorithm. The length of the Authentication Algorithm Number field is 2 octets. The Authentication Algorithm Number field is shown in Figure 9-82. The following values are defined for authentication algorithm number:

Authentication algorithm number = 0: Open System
Authentication algorithm number = 1: Shared Key
Authentication algorithm number = 2: Fast BSS Transition
Authentication algorithm number = 3: Simultaneous Authentication of Equals (SAE)
Authentication algorithm number = 4: FILS Shared Key authentication without PFS
Authentication algorithm number = 5: FILS Shared Key authentication with PFS
Authentication algorithm number = 6: FILS Public Key authentication
Authentication algorithm number = 65 535: vendor specific use

NOTE—The use of this value implies that a Vendor Specific element is included with more information.

All other values of authentication algorithm number are reserved.

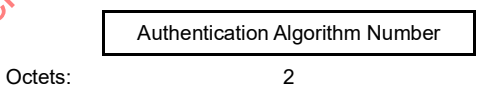

Figure 9-82—Authentication Algorithm Number field format

9.4.1.2 Authentication Transaction Sequence Number field

The Authentication Transaction Sequence Number field indicates the current state of progress through a multistep transaction. The length of the Authentication Transaction Sequence Number field is 2 octets. The Authentication Transaction Sequence Number field is shown in Figure 9-83.

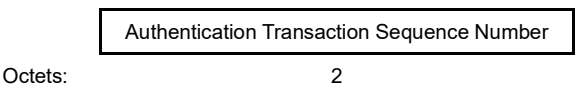

Figure 9-83—Authentication Transaction Sequence Number field format

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9.4.1.3 Beacon Interval field

The Beacon Interval field represents the number of time units (TUs) between target beacon transmission times (TBTTs). The length of the Beacon Interval field is 2 octets. The Beacon Interval field is shown in Figure 9-84.

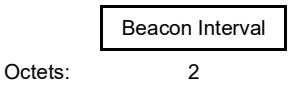

Figure 9-84—Beacon Interval field format

A 0 in the Beacon Interval field transmitted by a DMG STA indicates that the TBTT of the next BTI is unknown.

9.4.1.4 Capability Information field

The Capability Information field contains a number of subfields that are used to indicate requested or advertised optional capabilities.

The length of the Capability Information field is 2 octets. The format of the Capability Information field is defined in Figure 9-85 when transmitted by a non-DMG STA and in Figure 9-86 when transmitted by a DMG STA.

B0	B1	B2	B3	B4	B5	B6	B7
ESS	IBSS	Reserved	Reserved	Privacy	Short Preamble	Reserved	Reserved

B8	B9	B10	B11	B12	B13	B14	B15
Spectrum Management	QoS	Short Slot Time	APSD	Radio Measurement	EPD	Reserved	Reserved

Figure 9-85—Capability Information field format (non-DMG STA)

B0	B7	B8	B9	B10 B11	B12	B13	B14 B15
DMG Parameters		Spectrum Management	Triggered Unscheduled PS	Reserved	Radio Measurement	EPD	Reserved
Bits:	8	1	1	2	1	1	2

Figure 9-86—Capability Information field format (DMG STA)

A DMG STA sets the Triggered Unscheduled PS subfield to 1 within the Capability Information field when it transmits a Capability Information field in which the Reverse Direction subfield is equal to 1 and is capable of delivering a BU as an RD responder on receipt of a PPDU containing an RDG MPDU with the Power Management subfield set to 1 and sets it to 0 otherwise.

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Each Capability Information subfield is interpreted according to the management frame subtype, as defined in this subclause.

An AP sets the ESS subfield to 1 and the IBSS subfield to 0 within transmitted Beacon or Probe Response frames. An IBSS STA sets the ESS subfield to 0 and the IBSS subfield to 1 in transmitted Beacon or Probe Response frames. A mesh STA sets the ESS and IBSS subfields to 0 in transmitted Beacon or Probe Response frames. Otherwise, the ESS and IBSS subfields are reserved.

An AP sets the Privacy subfield to 1 within transmitted Beacon, Probe Response, (Re)Association Response frames if data confidentiality is required for all Data frames exchanged within the BSS. If data confidentiality is not required, the Privacy subfield is set to 0.

In an RSNA, a non-AP STA in an infrastructure BSS sets the Privacy subfield to 0 within transmitted (Re)Association Request frames. The Privacy subfield is reserved in (Re)Association Request frames.

An IBSS STA sets the Privacy subfield to 1 in transmitted Beacon or Probe Response frames if data confidentiality is required for all Data frames exchanged within the IBSS. If data confidentiality is not required, An IBSS STA sets the Privacy subfield to 0 within these Management frames.

A mesh STA sets the Privacy subfield to 1 in transmitted Beacon or Probe Response frames if data confidentiality is required for all Data frames exchanged within the MBSS. If data confidentiality is not required, a mesh STA sets the Privacy subfield to 0 within these Management frames.

A STA that includes the RSNE in Beacon and Probe Response frames sets the Privacy subfield to 1 in any frame that includes the RSNE.

An AP sets the Short Preamble subfield to 1 in transmitted Beacon, Probe Response, Association Response, and Reassociation Response frames to indicate that the use of the short preamble, as described in 16.2.2.3, is allowed within this BSS; an IBSS STA sets the Short Preamble subfield to 1 in transmitted Beacon when dot11ShortPreambleOptionImplemented is true. Otherwise an AP or an IBSS STA sets the Short Preamble subfield to 0.

A mesh STA sets the Short Preamble subfield to 1 when dot11ShortPreambleOptionImplemented is true. Otherwise, a mesh STA sets the Short Preamble subfield to 0.

An ERP STA sets dot11ShortPreambleOptionImplemented to true as all ERP STAs support both long and short preamble formats.

A STA sets the Spectrum Management subfield in the Capability Information field to 1 if dot11SpectrumManagementRequired is true; otherwise, it is set to 0.

A STA sets the QoS subfield to 1 within the Capability Information field when dot11QosOptionImplemented is true and sets it to 0 otherwise.

A STA sets the Short Slot Time subfield to 1 in transmitted Association Request, and Reassociation Request frames when dot11ShortSlotTimeOptionImplemented and dot11ShortSlotTimeOptionActivated are true. Otherwise, the STA sets the Short Slot Time subfield to 0.

An AP sets the Short Slot Time subfield in transmitted Beacon, Probe Response, Association Response, and Reassociation Response frames to indicate the currently used slot time value within this BSS. See 11.1.3.2.

See 10.3.2.16 for the operation of aSlotTime.

For IBSS and MBSS, the Short Slot Time subfield is set to 0.

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An AP sets the APSD subfield to 1 within the Capability Information field when dot11APSDOptionImplemented is true and sets it to 0 otherwise. A non-AP STA always sets this subfield to 0.

A STA sets the Radio Measurement subfield in the Capability Information field to 1 when dot11RadioMeasurementActivated is true and sets it to 0 otherwise.

A STA sets the EPD subfield in the Capability Information field to 1 when dot11EPDImplemented is true and sets it to 0 otherwise.

The DMG Parameters field is defined in 9.4.1.46.

9.4.1.5 Current AP Address field

The Current AP Address field is the MAC address of the AP with which the STA is currently associated. The length of the Current AP Address field is 6 octets. The Current AP Address field is shown in Figure 9-87.

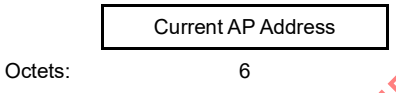

Figure 9-87—Current AP Address field format

9.4.1.6 Listen Interval field

The Listen Interval field is used to indicate to the AP how often an S1G STA with dot11NonTIMModeActivated equal to false or a non-S1G STA in power save mode wakes to listen to Beacon frames. It is also used to indicate to an AP the duration during which an S1G STA with dot11NonTIMModeActivated equal to true is required to transmit at least one frame that is addressed to the associated AP. This field is derived from the ListenInterval parameter when present as a parameter of an MLME primitive. The value is in units of beacon interval if dot11ShortBeaconInterval is false and in units of short beacon interval if dot11ShortBeaconInterval is true (see 11.1.3.10.2). The length of the Listen Interval field is 2 octets. The Listen Interval field is shown in Figure 9-88.

NOTE—The value 0 might be used by a STA that never enters power save mode.

Figure 9-88—Listen Interval field format carried in a non-S1G PPDU

The Listen Interval field carried in an S1G PPDU is shown in Figure 9-89.

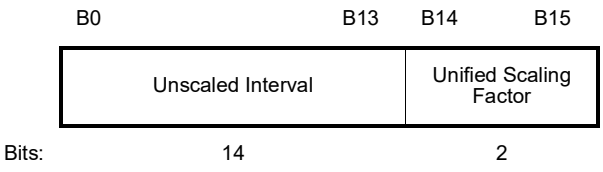

Figure 9-89—Listen Interval field format carried in an S1G PPDU

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In an S1G STA, the ListenInterval parameter used by the MLME primitives is equal to the Unscaled Interval subfield multiplied by the scaling factor that corresponds to the value indicated in the Unified Scaling Factor subfield. The Unified Scaling Factor subfield encoding is defined in Table 9-48.

Table 9-48—Unified Scaling Factor subfield encoding

Unified Scaling Factor	Scaling factor
0	1
1	10
2	1000
3	10 000

An AP uses the listen interval in determining the lifetime of frames that it buffers for a STA.

9.4.1.7 Reason Code field

This Reason Code field is used to indicate the reason that an unsolicited notification Management frame of type Disassociation, Deauthentication, DELTS, DELBA,)or Mesh Peering Close was generated. It is contained in the Mesh Channel Switch Parameters element to indicate the reason for the channel switch. It is contained in the PERR element to indicate the reason for the path error. The length of the Reason Code field is 2 octets. The Reason Code field is shown in Figure 9-90.

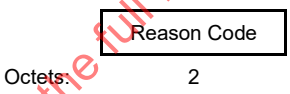

Figure 9-90—Reason Code field format

The reason codes are defined in Table 9-49.

Table 9-49—Reason codes

Reason code	Name	Meaning
0		Reserved
1	UNSPECIFIED_REASON	Unspecified reason
2	INVALID_AUTHENTICATION	Previous authentication no longer valid
3	LEAVING_NETWORK_DEAUTH	Deauthenticated because sending STA is leaving (or has left) the BSS
4	REASON_INACTIVITY	Disassociated due to inactivity
5	NO_MORE_STAS	Disassociated because AP is unable to handle all currently associated STAs
6	INVALID_CLASS2_FRAME	Class 2 frame received from nonauthenticated STA
7	INVALID_CLASS3_FRAME	Class 3 frame received from nonassociated STA

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Table 9-49—Reason codes *(continued)*

Reason code	Name	Meaning
8	LEAVING_NETWORK_DISASSOC	Disassociated because sending STA is leaving (or has left) BSS
9	NOT_AUTHENTICATED	STA requesting (re)association is not authenticated with responding STA
10	UNACCEPTABLE_POWER_CAPABILITY	Disassociated because the information in the Power Capability element is unacceptable
11	UNACCEPTABLE_SUPPORTED_CHANNELS	Disassociated because the information in the Supported Channels element is unacceptable
12	BSS_TRANSITION_DISASSOC	Disassociated due to BSS transition management
13	REASON_INVALID_ELEMENT	Invalid element, i.e., an element defined in this standard for which the content does not meet the specifications in Clause 9
14	MIC_FAILURE	Message integrity code (MIC) failure
15	4WAY_HANDSHAKE_TIMEOUT	4-way handshake timeout
16	GK_HANDSHAKE_TIMEOUT	Group key handshake timeout
17	HANDSHAKE_ELEMENT_MISMATCH	Element in 4-way handshake different from (Re)Association Request/Probe Response/Beacon frame
18	REASON_INVALID_GROUP_CIPHER	Invalid group cipher
19	REASON_INVALID_PAIRWISE_CIPHER	Invalid pairwise cipher
20	REASON_INVALID_AKMP	Invalid AKMP
21	UNSUPPORTED_RSNE_VERSION	Unsupported RSNE version
22	INVALID_RSNE_CAPABILITIES	Invalid RSNE capabilities
23	802_1_X_AUTH_FAILED	IEEE 802.1X authentication failed
24	REASON_CIPHER_OUT_OF_POLICY	Cipher suite rejected because of the security policy
25	TDLS_PEER_UNREACHABLE	TDLS direct-link teardown due to TDLS peer STA unreachable via the TDLS direct link
26	TDLS_UNSPECIFIED_REASON	TDLS direct-link teardown for unspecified reason
27	SSP_REQUESTED_DISASSOC	Disassociated because session terminated by SSP request
28	NO_SSP_ROAMING_AGREEMENT	Disassociated because of lack of SSP roaming agreement
29	BAD_CIPHER_OR_AKM	Requested service rejected because of SSP cipher suite or AKM requirement
30	NOT_AUTHORIZED_THIS_LOCATION	Requested service not authorized in this location
31	SERVICE_CHANGE_PRECLUDES_TS	TS deleted because QoS AP lacks sufficient bandwidth for this QoS STA due to a change in BSS service characteristics or operational mode (e.g., an HT BSS change from 40 MHz channel to 20 MHz channel)

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Table 9-49—Reason codes *(continued)*

Reason code	Name	Meaning
32	UNSPECIFIED_QOS_REASON	Disassociated for unspecified, QoS-related reason
33	NOT_ENOUGH_BANDWIDTH	Disassociated because QoS AP lacks sufficient bandwidth for this QoS STA
34	MISSING_ACKS	Disassociated because excessive number of frames need to be acknowledged, but are not acknowledged due to AP transmissions and/or poor channel conditions
35	EXCEEDED_TXOP	Disassociated because STA is transmitting outside the limits of its TXOPs
36	STA_LEAVING	Requesting STA is leaving the BSS (or resetting)
37	END_TS END_BA	Requesting STA is no longer using the stream or session
38	UNKNOWN_TS UNKNOWN_BA	Requesting STA received frames using a mechanism for which a setup has not been completed
39	TIMEOUT	Requested from peer STA due to timeout
40–45	Reserved	
46	PEER_INITIATED	In a Disassociation frame: Disassociated because authorized access limit reached
47	AP_INITIATED	In a Disassociation frame: Disassociated due to external service requirements
48	REASON_INVALID_FT_ACTION_FRAME_COUNT	Invalid FT Action frame count
49	REASON_INVALID_PMKID	Invalid pairwise master key identifier (PMKID)
50	REASON_INVALID_MDE	Invalid MDE
51	REASON_INVALID_FTE	Invalid FTE
52	MESH-PEERING-CANCELED	Mesh peering canceled for unknown reasons
53	MESH-MAX-PEERS	The mesh STA has reached the supported maximum number of peer mesh STAs
54	MESH-CONFIGURATION-POLICY-VIOLATION	The received information violates the Mesh Configuration policy configured in the mesh STA profile
55	MESH-CLOSE-RCVD	The mesh STA has received a Mesh Peering Close frame requesting to close the mesh peering.
56	MESH-MAX-RETRIES	The mesh STA has resent dot11MeshMaxRetries Mesh Peering Open frames, without receiving a Mesh Peering Confirm frame.
57	MESH-CONFIRM-TIMEOUT	The confirmTimer for the mesh peering instance times out.
58	MESH-INVALID-GTK	The mesh STA fails to unwrap the GTK or the values in the wrapped contents do not match
59	MESH-INCONSISTENT-PARAMETERS	The mesh STA receives inconsistent information about the mesh parameters between mesh peering Management frames
60	MESH-INVALID-SECURITY-CAPABILITY	The mesh STA fails the authenticated mesh peering exchange because due to failure in selecting either the pairwise ciphersuite or group ciphersuite

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Table 9-49—Reason codes *(continued)*

Reason code	Name	Meaning
61	MESH-PATH-ERROR-NO-PROXY-INFORMATION	The mesh STA does not have proxy information for this external destination.
62	MESH-PATH-ERROR-NO-FORWARDING-INFORMATION	The mesh STA does not have forwarding information for this destination.
63	MESH-PATH-ERROR-DESTINATION-UNREACHABLE	The mesh STA determines that the link to the next hop of an active path in its forwarding information is no longer usable.
64	MAC-ADDRESS-ALREADY-EXISTS-IN-MBSS	The Deauthentication frame was sent because the MAC address of the STA already exists in the mesh BSS. See 11.3.6.
65	MESH-CHANNEL-SWITCH-REGULATORY-REQUIREMENTS	The mesh STA performs channel switch to meet regulatory requirements.
66	MESH-CHANNEL-SWITCH-UNSPECIFIED	The mesh STA performs channel switching with unspecified reason.
67	TRANSMISSION_LINK_ESTABLISHMENT_ FAILED	Transmission link establishment in alternative channel failed.
68	ALTERATIVE_ CHANNEL_OCCUPIED	The alternative channel is occupied.
69–65 535		Reserved

9.4.1.8 AID field

In infrastructure BSS operation, the AID field contains a value assigned by an AP or PCP during association. The field represents the 16-bit ID of a STA. In mesh BSS operation, the AID field is a value that represents the 16-bit ID of a neighbor peer mesh STA, assigned during mesh peering. The length of the AID field is 2 octets. The AID field is shown in Figure 9-91.

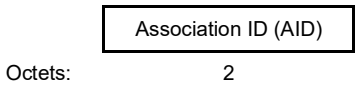

Figure 9-91—AID field format

The AID field for a non-DMG and non-S1G STA is in the range of 1 to 2007. This value is placed in the 14 LSBs of the AID field, with the two MSBs of the AID field set to 1.

The AID field for an S1G STA is in the range of 1 to 8191, and the 3 MSBs of the AID field are reserved.

The AID field for a DMG STA is in the range 1 to 254. The value 255 is reserved as the broadcast AID, and the value 0 corresponds to the AP or PCP. The 8 MSBs of the AID field are reserved.

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9.4.1.9 Status Code field

The Status Code field is used in a response Management frame to indicate the success or failure of a requested operation. The Status Code field is shown in Figure 9-92.

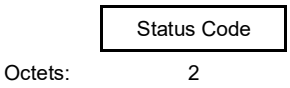

Figure 9-92—Status Code field format

If an operation is successful, then the status code is set to SUCCESS (0). A status code of SUCCESS_POWER_SAVE_MODE also indicates a successful operation. If an operation results in failure, the status code indicates a failure cause. The failure cause codes are defined in Table 9-50.

Table 9-50—Status codes

Status code	Name	Meaning
0	SUCCESS	Successful.
1	REFUSED, REFUSED_REASON_UNSPECIFIED	Unspecified failure.
2	TDLS_REJECTED_ALTERNATIVE_PROVIDED	TDLS wakeup schedule rejected but alternative schedule provided.
3	TDLS_REJECTED	TDLS wakeup schedule rejected.
4		Reserved.
5	SECURITY_DISABLED	Security disabled.
6	UNACCEPTABLE_LIFETIME	Unacceptable lifetime.
7	NOT_IN_SAME_BSS	Not in same BSS.
8–9		Reserved.
10	REFUSED_CAPABILITIES_MISMATCH	Cannot support all requested capabilities in the Capability Information field.
11	DENIED_NO_ASSOCIATION_EXISTS	Reassociation denied due to inability to confirm that association exists.
12	DENIED_OTHER_REASON	Association denied due to reason outside the scope of this standard.
13	UNSUPPORTED_AUTH_ALGORITHM	Responding STA does not support the specified authentication algorithm.
14	TRANSACTION_SEQUENCE_ERROR	Received an Authentication frame with authentication transaction sequence number out of expected sequence.
15	CHALLENGE_FAILURE	Authentication rejected because of challenge failure.
16	REJECTED_SEQUENCE_TIMEOUT	Authentication rejected due to timeout waiting for next frame in sequence.
17	DENIED_NO_MORE_STAS	Association denied because AP is unable to handle additional associated STAs.

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Table 9-50—Status codes *(continued)*

Status code	Name	Meaning
18	REFUSED_BASIC_RATES_ MISMATCH	Association denied due to requesting STA not supporting all of the data rates in the BSSBasicRateSet parameter, the Basic HT-MCS Set field of the HT Operation parameter, or the Basic VHT-MCS And NSS Set field in the VHT Operation parameter.
19	DENIED_NO_SHORT_PREAMBLE_ SUPPORT	Association denied due to requesting STA not supporting the short preamble option.
20		Reserved.
21		Reserved.
22	REJECTED_SPECTRUM_MANAGE MENT_REQUIRED	Association request rejected because spectrum management capability is required.
23	REJECTED_BAD_POWER_CAPABI LITY	Association request rejected because the information in the Power Capability element is unacceptable.
24	REJECTED_BAD_SUPPORTED_CH ANNELS	Association request rejected because the information in the Supported Channels element is unacceptable.
25	DENIED_NO_SHORT_SLOT_TIME_ SUPPORT	Association denied due to requesting STA not supporting short slot time.
26		Reserved.
27	DENIED_NO_HT_SUPPORT	Association denied because the requesting STA does not support HT features.
28	R0KH_UNREACHABLE	R0KH unreachable.
29		Reserved
30	REFUSED_TEMPORARILY	Association request rejected temporarily; try again later.
31	ROBUST_MANAGEMENT_POLICY _VIOLATION	Robust management frame policy violation.
32	UNSPECIFIED_QOS_FAILURE	Unspecified, QoS-related failure.
33	DENIED_INSUFFICIENT_BANDWI DTH	Association denied because QoS AP or PCP has insufficient bandwidth to handle another QoS STA.
34	DENIED_POOR_CHANNEL_CONDI TIONS	Association denied due to excessive frame loss rates and/ or poor conditions on current operating channel.
35	DENIED_QOS_NOT_SUPPORTED	Association (with QoS BSS) denied because the requesting STA does not support the QoS facility.
36		Reserved.
37	REQUEST_DECLINED	The request has been declined.
38	INVALID_PARAMETERS	The request has not been successful as one or more parameters have invalid values.
39	REJECTED_WITH_SUGGESTED_ CHANGES	The allocation or TS has not been created because the request cannot be honored; however, a suggested TSPEC/DMG TSPEC is provided so that the initiating STA can attempt to set another allocation or TS with the suggested changes to the TSPEC/DMG TSPEC.
40	STATUS_INVALID_ELEMENT	Invalid element, i.e., an element defined in this standard for which the content does not meet the specifications in Clause 9.

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Table 9-50—Status codes *(continued)*

Status code	Name	Meaning
41	STATUS_INVALID_GROUP_CIPHER	Invalid group cipher.
42	STATUS_INVALID_PAIRWISE_CIPHER	Invalid pairwise cipher.
43	STATUS_INVALID_AKMP	Invalid AKMP.
44	UNSUPPORTED_RSNE_VERSION	Unsupported RSNE version.
45	INVALID_RSNE_CAPABILITIES	Invalid RSNE capabilities.
46	STATUS_CIPHER_OUT_OF_POLICY	Cipher suite rejected because of security policy.
47	REJECTED_FOR_DELAY_PERIOD	The TS or allocation has not been created; however, the HC or PCP might be capable of creating a TS or allocation, in response to a request, after the time indicated in the TS Delay element.
48		Reserved.
49	NOT_PRESENT	The Destination STA is not present within this BSS.
50	NOT_QOS_STA	The Destination STA is not a QoS STA.
51	DENIED_LISTEN_INTERVAL_TOO_LARGE	Association denied because the listen interval is too large.
52	STATUS_INVALID_FT_ACTION_FRAME_COUNT	Invalid FT Action frame count.
53	STATUS_INVALID_PMKID	Invalid pairwise master key identifier (PMKID).
54	STATUS_INVALID_MDE	Invalid MDE.
55	STATUS_INVALID_FTE	Invalid FTE.
56	REQUESTED_TCLAS_NOT_SUPPORTED	Requested TCLAS processing is not supported by the AP or PCP.
57	INSUFFICIENT_TCLAS_PROCESSING_RESOURCES	The AP or PCP has insufficient TCLAS processing resources to satisfy the request.
58	TRY_ANOTHER_BSS	The TS has not been created because the request cannot be honored; however, the HC or PCP suggests that the STA transition to a different BSS to set up the TS.
59	GAS_ADVERTISEMENT_PROTOCOL_NOT_SUPPORTED	GAS advertisement protocol not supported.
60	NO_OUTSTANDING_GAS_REQUEST	No outstanding GAS request.
61	GAS_RESPONSE_NOT_RECEIVED_FROM _SERVER	GAS response not received from the advertisement server.
62	GAS_QUERY_TIMEOUT	STA timed out waiting for GAS query response.
63	GAS_QUERY_RESPONSE_TOO_ LARGE	GAS response is larger than query response length limit.
64	REJECTED_HOME_WITH_SUGGESTED_CHANGES	Request refused because home network does not support request.
65	SERVER_UNREACHABLE	Advertisement server in the network is not currently reachable.

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Table 9-50—Status codes *(continued)*

Status code	Name	Meaning
66		Reserved.
67	REJECTED_FOR_SSP_PERMISSIONS	Request refused due to permissions received via SSPN interface.
68	REFUSED_UNAUTHENTICATED_ACCESS_NOT_SUPPORTED	Request refused because the AP or PCP does not support unauthenticated access.
69–71		Reserved.
72	INVALID_RSNE	Invalid contents of RSNE, other than unsupported RSNE version or invalid RSNE capabilities, AKMP or pairwise cipher.
73	U_APSD_COEXISTENCE_NOT_SUPPORTED	U-APSD coexistence is not supported.
74	U_APSD_COEX_MODE_NOT_SUPPORTED	Requested U-APSD coexistence mode is not supported.
75	BAD_INTERVAL_WITH_U_APSD_COEX	Requested interval/duration value cannot be supported with U-APSD coexistence.
76	ANTI_CLOGGING_TOKEN_REQUIRED	Authentication is rejected because an anti-clogging token is required.
77	UNSUPPORTED_FINITE_CYCLIC_GROUP	Authentication is rejected because the offered finite cyclic group is not supported.
78	CANNOT_FIND_ALTERNATIVE_TBTT	The TBTT adjustment request has not been successful because the STA could not find an alternative TBTT.
79	TRANSMISSION_FAILURE	Transmission failure.
80	REQUESTED_TCLAS_NOT_SUPPORTED	Requested TCLAS not supported.
81	TCLAS_RESOURCES_EXHAUSTED	TCLAS resources exhausted.
82	REJECTED_WITH_SUGGESTED_BSS_TRANSITION	Rejected with suggested BSS transition.
83	REJECT_WITH_SCHEDULE	Reject with recommended schedule.
84	REJECT_NO_WAKEUP_SPECIFIED	Reject because no wakeup schedule specified.
85	SUCCESS_POWER_SAVE_MODE	Success, the destination STA is in power save mode.
86	PENDING_ADMITTING_FST_SESSION	FST pending, in process of admitting FST session.
87	PERFORMING_FST_NOW	Performing FST now.
88	PENDING_GAP_IN_BA_WINDOW	FST pending, gap(s) in block ack window.
89	REJECT_U-PID_SETTING	Reject because of U-PID setting.
90–91		Reserved.
92	REFUSED_EXTERNAL_REASON	(Re)Association refused for some external reason.
93	REFUSED_AP_OUT_OF_MEMORY	(Re)Association refused because of memory limits at the AP.
94	REJECTED_EMERGENCY_SERVICES_NOT_SUPPORTED	(Re)Association refused because emergency services are not supported at the AP.

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Table 9-50—Status codes *(continued)*

Status code	Name	Meaning
95	QUERY_RESPONSE_ OUTSTANDING	GAS query response not yet received.
96	REJECT_DSE_BAND	Reject since the request is for transition to a frequency band subject to DSE procedures and FST Initiator is a dependent STA.
97	TCLAS_PROCESSING_ TERMINATED	Requested TCLAS processing has been terminated by the AP.
98	TS_SCHEDULE_CONFLICT	The TS schedule conflicts with an existing schedule; an alternative schedule is provided.
99	DENIED_WITH_SUGGESTED_BAN D_AND_CHANNEL	The association has been denied; however, one or more Multi-band elements are included that can be used by the receiving STA to join the BSS.
100	MCCAOP_RESERVATION_ CONFLICT	The request failed due to a reservation conflict.
101	MAF_LIMIT_EXCEEDED	The request failed due to exceeded MAF limit.
102	MCCA_TRACK_LIMIT_EXCEEDED	The request failed due to exceeded MCCA track limit.
103	DENIED_DUE_TO_SPECTRUM_MA NAGEMENT	Association denied because the information in the Spectrum Management field is unacceptable.
104	DENIED_VHT_NOT_SUPPORTED	Association denied because the requesting STA does not support VHT features.
105	ENABLEMENT DENIED	Enablement denied.
106	RESTRICTION FROM AUTHORIZED GDB	Enablement denied due to restriction from an authorized GDB.
107	AUTHORIZATION DEENABLED	Authorization deenabled.
108	ENERGY_LIMITED_OPERATION_N OT_SUPPORTED	Re(association) refused or disassociated because energy limited operation is not supported at the AP.
109	REJECTED_NDP_BLOCK_ACK_SU GGESTED	BlockAck negotiation refused because, due to buffer constraints and other unspecified reasons, the recipient prefers to generate only NDP BlockAck frames.
110	REJECTED_MAX_AWAY_DURATIO N_UNACCEPTABLE	Association denied/disassociated because the suggested value for max away duration is unacceptable.
111	FLOW_CONTROL_OPERATION_SU PPORTED	Re(association) refused or disassociated because flow control operation is not supported by the non-AP STA.
112	FILS_AUTHENTICATION_FAILURE	Authentication rejected due to FILS authentication failure.
113	UNKNOWN_AUTHENTICATION_ SERVER	Authentication rejected due to unknown Authentication Server.
114–115		Reserved.
116	DENIED_NOTIFICATION_PERIOD_ ALLOCATION	Request denied because the allocation of notification period is failed.
117	DENIED_CHANNEL_SPLITTING	Request denied because the request of channel splitting is failed.
118	DENIED_ALLOCATION	Request denied because the allocation request is failed.

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Table 9-50—Status codes *(continued)*

Status code	Name	Meaning
119	CMMG_FEATURES_NOT_SUPPORTED	Association denied because the requesting STA does not support CMMG features.
120	GAS_FRAGMENT_NOT_AVAILABLE	The requested GAS fragment is not available.
121	SUCCESS_CAG_VERSIONS_MATCH	Success, the CAG Version provided by the requesting STA is the same as the latest CAG Version provided by the relevant server.
122	GLK_NOT_AUTHORIZED	The STA is not authorized to use GLK per local policy.
123	UNKNOWN_PASSWORD_IDENTIFIER	Authentication rejected because the password identifier is unknown.
124		Reserved.
125	DENIED_LOCAL_MAC_ADDRESS_POLICY_VIOLATION	Request denied because source address of request is inconsistent with local MAC address policy.
126	SAE_HASH_TO_ELEMENT	SAE authentication uses direct hashing, instead of looping, to obtain the PWE.
127		Reserved.
128	TCLAS_PROCESSING_TERMINATED_INSUFFICIENT_QOS	Requested TCLAS processing has been terminated by the AP due to insufficient QoS capacity.
129	TCLAS_PROCESSING_TERMINATED_POLICY_CONFLICT	Requested TCLAS processing has been terminated by the AP due to conflict with higher layer QoS policies.
130–65 535		Reserved.

9.4.1.10 Timestamp field

This field represents the timing synchronization function (TSF) timer (see 11.1 and 11.19) of a frame's source. The length of the Timestamp field is 8 octets. The Timestamp field is shown in Figure 9-93.

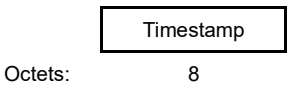

Figure 9-93—Timestamp field format

9.4.1.11 Action field

The Action field provides a mechanism for specifying extended management actions. The format of the Action field is shown in Figure 9-94.

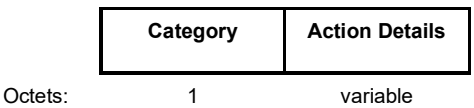

Figure 9-94—Action field format

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The Category field is set to one of the nonreserved values shown in the Code column of Table 9-51. Action frames of a given category are referred to as <*category name*> *Action frames*. For example, frames in the QoS category are called *QoS Action frames*. Action frames of a given category and further identified by a subfield in the Action Details field are referred to as <*subfield name*> *frames*. For example, frames in the QoS category with a QoS Action subfield of ADDTS Request are called *ADDTS Request frames*.

The Action Details field contains the details of the action. The details of the actions allowed in each category are described in the appropriate subclause referenced in Table 9-51.

Table 9-51—Category values

Code	Meaning	See subclause	Robust	Group addressed privacy
0	Spectrum Management	9.6.2	Yes	No
1	QoS	9.6.3	Yes	No
2	Reserved			
3	Block Ack	9.6.4	Yes	No
4	Public	9.6.7	No	No
5	Radio Measurement	9.6.6	Yes	No
6	Fast BSS Transition	9.6.8	Yes	No
7	HT	9.6.11	No	No
8	SA Query	9.6.9	Yes	No
9	Protected Dual of Public Action	9.6.10	Yes	No
10	WNM	9.6.13	Yes	No
11	Unprotected WNM	9.6.14	No	No
12	TDLS	9.6.12	See NOTE	No
13	Mesh	9.6.16	Yes	Yes
14	Multihop	9.6.17	Yes	Yes
15	Self-protected	9.6.15	No	No
16	DMG	9.6.19	Yes	No
17	Reserved (used by the Wi-Fi Alliance® [a])			
18	Fast Session Transfer	9.6.20	Yes	No
19	Robust AV Streaming	9.6.18	Yes	No
20	Unprotected DMG	9.6.21	No	No
21	VHT	9.6.22	No	No
22	Unprotected S1G	9.6.24	No	No
23	S1G	9.6.25	Yes	No
24	Flow control	9.6.26	Yes	No
25	Control Response MCS Negotiation	9.6.27	Yes	No
26	FILS	9.6.23	Yes	No

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Table 9-51—Category values *(continued)*

Code	Meaning	See subclause	Robust	Group addressed privacy
27	CDMG	9.6.28	Yes	No
28	CMMG	9.6.29	Yes	No
29	GLK	9.6.30	Yes	Yes
30–125	Reserved			
126	Vendor-specific Protected	9.6.5	Yes	No
127	Vendor-specific	9.6.5	No	No
128–255	Error			
NOTE—TDLS Action fields are always transported encapsulated within a Data frame (see 11.20.1), so the question of whether these frames are robust is not applicable.				

[a] See http://www.wi-fi.org.

9.4.1.12 Dialog Token field

The Dialog Token field is used for matching action responses with action requests when there are multiple, concurrent action requests. The length of the Dialog Token field is 1 octet. The Dialog Token field is shown in Figure 9-95. See 10.28.5.

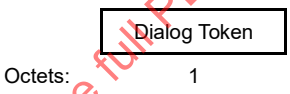

Figure 9-95—Dialog Token field format

9.4.1.13 Block Ack Parameter Set field

The Block Ack Parameter Set field is used in ADDBA Request and ADDBA Response frames to signal the parameters for setting up a block ack agreement. The length of the Block Ack Parameter Set field is 2 octets. The Block Ack Parameter Set field is shown in Figure 9-96.

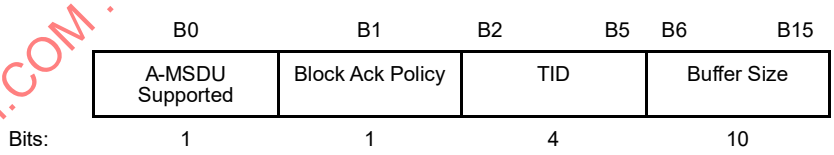

Figure 9-96—Block Ack Parameter Set field format

The A-MSDU Supported subfield is set to 1 by a STA to indicate that it supports an A-MSDU carried in a QoS Data frame sent under this block ack agreement. It is set to 0 otherwise.

The Block Ack Policy subfield is set to 1 for immediate or HT-immediate block ack.

The TID subfield contains the TC or TS for which the BlockAck frame is being requested.

The Buffer Size subfield indicates the number of buffers available for this particular TID.[23] When the A-MSDU Supported field is equal to 0 as indicated by the STA transmitting the Block Ack Parameter Set

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field, each buffer is capable of holding a number of octets equal to the maximum size of an MSDU. When the A-MSDU Supported field is equal to 1 as indicated by the STA, each buffer is capable of holding a number of octets equal to the maximum size of an A-MSDU that is supported by the STA.

In an ADDBA Request frame, the Buffer Size subfield provides guidance for the frame receiver to decide its reordering buffer size. If the Buffer Size subfield is equal to 0, it implies that the originator of the block ack has no information to specify its value.

In an ADDBA Response frame, when the Status Code field is equal to SUCCESS, the Buffer Size subfield is set to at least 1.

9.4.1.14 Block Ack Timeout Value field

The Block Ack Timeout Value field is used in the ADDBA Request and Response frames to indicate the timeout value for a block ack agreement. The length of the Block Ack Timeout Value field is 2 octets. The Block Ack Timeout Value field is shown in Figure 9-97.

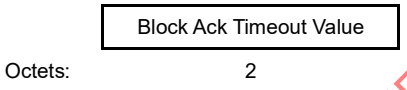

Figure 9-97—Block Ack Timeout Value field format

The Block Ack Timeout Value field contains the duration, in TUs, after which the block ack setup is terminated, if there are no frame exchanges (see 11.5.4) within this duration using this block ack agreement. The field is set to 0 to disable the timeout.

9.4.1.15 Originator Preferred MCS field

The Originator Preferred MCS field is used in ADDBA Response frame to signal the preferred MCS used for eliciting A-MPDUs from the data originator. The length of the Originator Preferred MCS field is 2 octets. The Originator Preferred MCS field is shown in Figure 9-98.

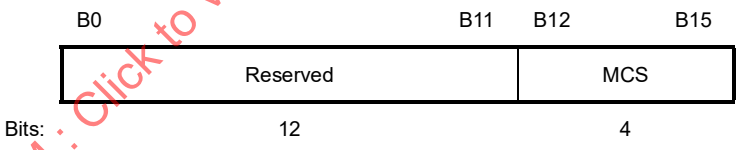

Figure 9-98—Originator Preferred MCS field format

The MCS subfield of the Originator Preferred MCS field is defined in Table 9-52.

Table 9-52—MCS subfield of the Originator Preferred MCS field

MCS subfield value	S1G-MCS Index	Description
0–10	0–10	The value represents the preferred S1G-MCS level

[23] For buffer size, the recipient of data advertises a single scalar number that is the number of fragment buffers of the maximum MSDU or A-MSDU size (indicated by the A-MSDU Supported field) available for the block ack agreement that is being negotiated. Every buffered MPDU that is associated with this block ack agreement consumes one of these buffers regardless of whether the frame contains a whole MSDU (or a fragment thereof) or an A-MSDU. For example, ten maximum-size unfragmented MSDUs consumes the same amount of buffer space at the recipient as ten smaller fragments of a single MSDU of maximum size.

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Table 9-52—MCS subfield of the Originator Preferred MCS field

11–14		Reserved
15		The value represents that the asymmetric BA is not supported by either the originator or the intended recipient of the ADDBA Response that contains this value in the MCS subfield of the Originator Preferred MCS field. See 10.25.1 for asymmetric BA and 11.5.2.3 on how to set the MCS subfield of the Originator Preferred MCS field in the ADDBA Response.

9.4.1.16 DELBA Parameter Set field

The DELBA Parameter Set field is used in a DELBA frame to terminate an already set up block ack agreement. The length of the DELBA Parameter Set field is 2 octets. The DELBA Parameter Set field is shown in Figure 9-99.

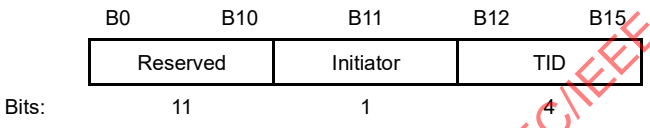

Figure 9-99—DELBA Parameter Set field format

The Initiator subfield indicates if the originator or the recipient of the data is sending this frame. It is set to 1 to indicate the originator and is set to 0 to indicate the recipient. The TID subfield indicates the TSID or the UP for which the block ack has been originally set up.

9.4.1.17 QoS Info field

The QoS Info field contains capability information bits. The contents of the field are dependent on whether the STA is contained within an AP.

The format of the QoS Info field, when sent by the AP, is defined in Figure 9-100.

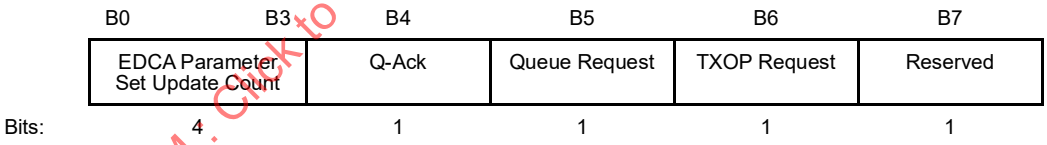

Figure 9-100—QoS Info field format when sent by an AP

The EDCA Parameter Set Update Count subfield is described in 10.2.3.2.

APs set the Q-Ack subfield to 1 when dot11QAckOptionImplemented is true and set it to 0 otherwise.

APs set the Queue Request subfield to 1 if they can process a nonzero Queue Size subfield in the QoS Control field in QoS Data frames and set it to 0 otherwise.

APs set the TXOP Request subfield to 1 if they can process a nonzero TXOP Duration Requested subfield in the QoS Control field in QoS Data frames and set it to 0 otherwise.

The format of the QoS Info field, when sent by the non-AP STA, is defined in Figure 9-101.

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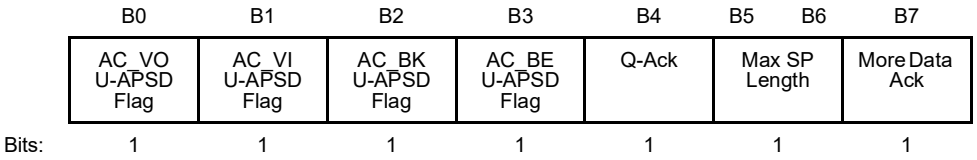

Figure 9-101—QoS Info field format when set by a non-AP STA

Each of the ACs U-APSD Flag subfields set to 1 in (Re)Association Request frames to indicate that the corresponding AC (AC_BE, AC_BK, AC_VI, or AC_VO) is both trigger-enabled and delivery-enabled. It is set to 0 in (Re)Association Request frames to indicate that the corresponding AC is neither trigger-enabled nor delivery-enabled. A TSPEC as described in 11.2.3.5 is to be used to make a particular AC exclusively either trigger-enabled or delivery-enabled. These subfields are set to 0 when the APSD subfield in the Capability Information field received from the AP with which the non-AP STA is associating is equal to 0.

Non-AP STAs set the Q-Ack subfield to 1 when dot11QAckOptionImplemented is true and set it to 0 otherwise.

The Max SP Length subfield indicates the maximum number of buffered BUs the STA is prepared to receive during any SP triggered by the STA. This subfield is reserved when the APSD subfield in the Capability Information field is equal to 0. If the APSD subfield in the Capability Information field is equal to 1, the settings of the values in the Max SP Length subfield are defined in Table 9-53.

Table 9-53—Settings of the Max SP Length subfield

Bit 5	Bit 6	Usage
0	0	The STA is prepared to receive all buffered BUs.
1	0	The STA is prepared to receive a maximum of two BUs per SP.
0	1	The STA is prepared to receive a maximum of four BUs per SP.
1	1	The STA is prepared to receive a maximum of six BUs per SP.

Non-AP STAs set the More Data Ack subfield to 1 to indicate that they can process Ack frames with the More Data bit in the Frame Control field equal to 1 and remain in the awake state. Non-AP STAs set the More Data Ack subfield to 0 otherwise. For APs, the More Data Ack subfield is reserved.

9.4.1.18 Measurement Pilot Interval field

The Measurement Pilot Interval field represents the number of time units (TUs) between target measurement pilot transmission times (TMPTTs). The length of the Measurement Pilot Interval field is 1 octet. The Measurement Pilot Interval field is shown in Figure 9-102.

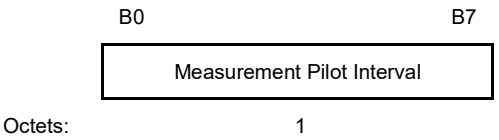

Figure 9-102—Measurement Pilot Interval field format

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9.4.1.19 Max Transmit Power field

The Max Transmit Power field is a 2s complement signed integer. It provides an upper limit, in units of dBm, on the transmit power as measured at the antenna connector to be used by the transmitting STA on the current channel. The Max Transmit Power value has a tolerance of ± 5 dB. See 11.10.13. The Max Transmit Power field is shown in Figure 9-103.

Figure 9-103—Max Transmit Power field format

9.4.1.20 Transmit Power Used field

The Transmit Power Used field is a 2s complement signed integer. It is less than or equal to the Max Transmit Power and indicates the actual power used as measured at the antenna connector, in units of dBm, by a STA when transmitting the frame containing the Transmit Power Used field. The Transmit Power Used value is determined any time prior to sending the frame in which it is contained and has a tolerance of ± 5 dB. The Transmit Power Used field is shown in Figure 9-104.

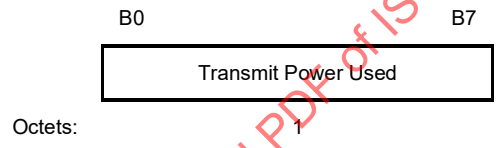

Figure 9-104—Transmit Power Used field format

9.4.1.21 Channel Width field

The Channel Width field is used in a Notify Channel Width frame (see 9.6.11.2) to indicate the channel width on which the sending STA is able to receive. The length of the field is 1 octet. The Channel Width field is shown in Figure 9-105.

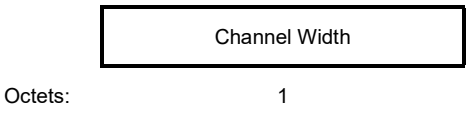

Figure 9-105—Channel Width field

If a STA transmitting or receiving this field is operating in an operating class that includes a value of PrimaryChannelLowerBehavior or PrimaryChannelUpperBehavior in the behavior limits set as specified in Annex E, then the Channel Width field is defined in Table 9-54. If a STA transmitting or receiving this field

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is operating in an operating class that does not include a value of PrimaryChannelLowerBehavior or PrimaryChannelUpperBehavior in the behavior limits set as specified in Annex E, then this field is reserved.

Table 9-54—Settings of the Channel Width field

Value	Meaning
0	20 MHz channel width
1	Any channel width in the STA's Supported Channel Width Set subfield
2–255	Reserved

9.4.1.22 Operating Class and Channel field

The Operating Class and Channel field is used in the Location Indication Channels subelement of the Location Parameters element and in the Channel Usage element. The Operating Class and Channel field indicates an operating class and channel. The format of the field is defined in Figure 9-106.

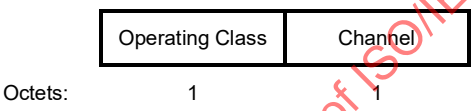

Figure 9-106—Operating Class and Channel field format

The Operating Class field indicates an operating class value as defined in Annex E. The operating class is interpreted in the context of the country specified in the Beacon frame.

The Channel field indicates a channel number, which is interpreted in the context of the indicated operating class. Channel numbers are defined in Annex E.

9.4.1.23 SM Power Control field

The SM Power Control field is used in an SM Power Save frame (see 9.6.11.3) by a STA to communicate changes in its SM power saving state. The field is shown in Figure 9-107.

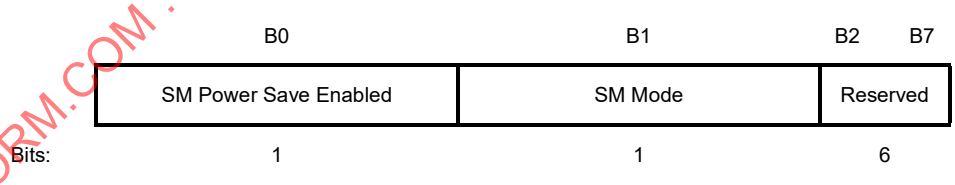

Figure 9-107—SM Power Control field format

The SM Power Save Enabled subfield indicates whether SM power saving is enabled at the STA. A 1 indicates enabled, and a 0 indicates disabled.

The SM Mode subfield indicates the mode of operation. A 1 indicates dynamic SM power save mode, a 0 indicates static SM power save mode. The modes are described in 11.2.6.

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9.4.1.24 PSMP Parameter Set field

PSMP is obsolete. Support for this mechanism might be removed in a later revision of the standard.

The PSMP Parameter Set field is used in a PSMP frame (see 9.6.11.4) to define the number of PSMP STA Info fields held in the PSMP frame, to indicate whether the PSMP sequence is to be followed by another PSMP sequence, and to indicate the duration of the PSMP sequence.

The structure of the PSMP Parameter Set field is defined in Figure 9-108.

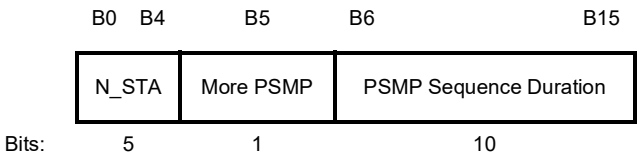

Figure 9-108—PSMP Parameter Set field format

The N_STA subfield indicates the number of STA Info fields present in the PSMP frame that contains the PSMP Parameter Set field.

The More PSMP subfield, when set to 1, indicates that the current PSMP sequence will be followed by another PSMP sequence. The subfield is set to 0 to indicate that there will be no PSMP sequence following the current PSMP sequence.

The PSMP Sequence Duration subfield indicates the duration of the current PSMP sequence that is described by the PSMP frame, in units of 8 μs, relative to the end of the PSMP frame. Therefore, this field can describe a PSMP sequence with a duration of up to 8.184 ms. The next PSMP sequence within the current PSMP burst starts a SIFS after the indicated duration.

9.4.1.25 PSMP STA Info field

PSMP is obsolete. Support for this mechanism might be removed in a later revision of the standard.

The PSMP STA Info field is used by the PSMP frame (see 9.6.11.4). The PSMP STA Info field defines the allocation of time to the downlink (PSMP-DTT) and/or uplink (PSMP-UTT) associated with a single RA. There are two variants of the structure for the individually addressed and group addressed cases. The length of the PSMP STA Info field is 8 octets.

The structure of the STA Info field is defined in Figure 9-109 and Figure 9-110.

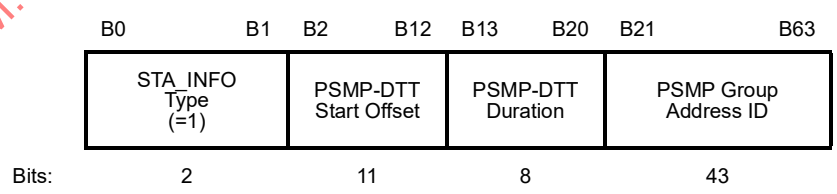

Figure 9-109—PSMP STA Info field format (group addressed)

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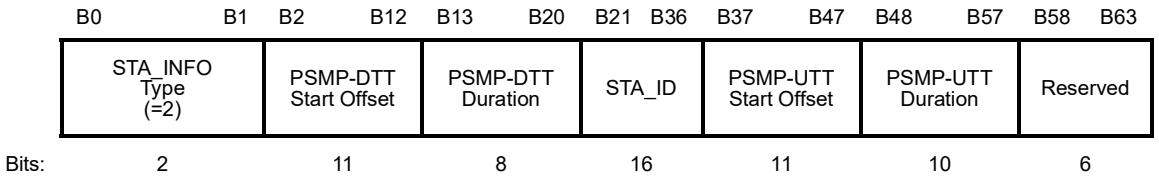

Figure 9-110—PSMP STA Info field format (individually addressed)

The STA_INFO Type subfield indicates the format of the remainder of the structure. When the STA_INFO Type subfield is equal to 1, the PSMP STA Info field is structured as defined in Figure 9-109 and supports the transmission of group addressed data by the AP. When the STA_INFO Type subfield is equal to 2, the PSMP STA Info field is structured as defined in Figure 9-110 and supports the exchange of data with a single STA. STA_INFO Type subfield values 0 and 3 are reserved.

The PSMP-DTT Start Offset subfield indicates the start of the PSMP-DTT for the destination identified by the PSMP STA Info field, relative to the end of the PSMP frame, in units of 4 μs. This subfield locates the start of the first PPDU containing downlink data for this destination.

The PSMP-DTT Duration subfield indicates the duration of the PSMP-DTT for the destination identified by the PSMP STA Info field, in units of 16 μs. This subfield locates the end of the last PPDU containing downlink data for this destination relative to the PDMP-DTT start offset.

If no PSMP-DTT is scheduled for a STA, but a PSMP-UTT is scheduled for that STA, the PSMP-DTT Duration subfield is set to 0, and the PSMP-DTT Start Offset subfield is reserved.

The PSMP Group Address ID (B21 to B63) subfield contains MAC_ADDR[5:47] of a 48 bit MAC address. Use of this subfield is described in 10.30.2.8. B63 contains bit 47 of the group address.

The STA_ID subfield contains the AID of the STA to which the PSMP STA Info field is directed.

The PSMP-UTT Start Offset subfield indicates the start of the PSMP-UTT. The offset is specified relative to the end of the PSMP frame. It is specified in units of 4 μs. The first PSMP-UTT is scheduled to begin after a SIFS from the end of the last PSMP-DTT described in the PSMP.

The PSMP-UTT Duration subfield indicates the maximum length of a PSMP-UTT for a STA. PSMP-UTT duration is specified in units of 4 μs. All transmissions by the STA within the current PSMP sequence lie within the indicated PSMP-UTT.

If no PSMP-UTT is scheduled for a STA, but a PSMP-DTT is scheduled for that STA, the PSMP-UTT Start Offset and PSMP-UTT Duration subfields are both set to 0.

9.4.1.26 MIMO Control field

The MIMO Control field is used to manage the exchange of MIMO channel state or transmit beamforming feedback information. It is used in the CSI (see 9.6.11.5), Noncompressed Beamforming (see 9.6.11.6), and Compressed Beamforming (see 9.6.11.7) frames.

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The MIMO Control field is defined in Figure 9-111.

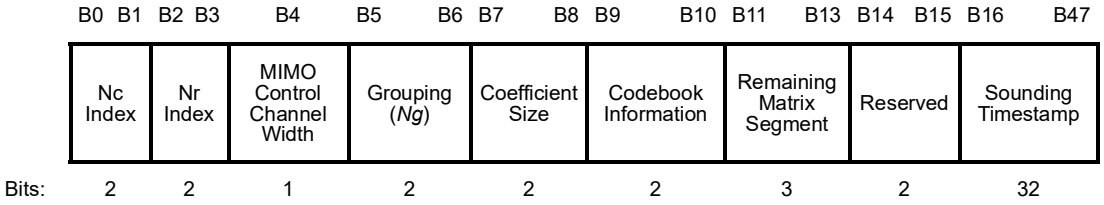

Figure 9-111—MIMO Control field format

The subfields of the MIMO Control field are defined in Table 9-55.

Table 9-55—Subfields of the MIMO Control field

Subfield	Description
Nc Index	Indicates the number of columns in the compressed beamforming feedback matrix minus one.
Nr Index	Indicates the number of rows in the compressed beamforming feedback matrix minus one. The value 0 is reserved.
MIMO Control Channel Width	Indicates the width of the channel in which a measurement was made: Set to 0 for 20 MHz Set to 1 for 40 MHz
Grouping (*Ng*)	Number of carriers grouped into one: Set to 0 for *Ng* = 1 (No grouping) Set to 1 for *Ng* = 2 Set to 2 for *Ng* = 4 The value 3 is reserved
Coefficient Size	Indicates the number of bits in the representation of the real and imaginary parts of each element in the matrix. For CSI feedback: Set to 0 for *Nb* = 4 Set to 1 for *Nb* = 5 Set to 2 for *Nb* = 6 Set to 3 for *Nb* = 8 For noncompressed beamforming feedback: Set 0 for *Nb* = 4 Set 1 for *Nb* = 2 Set 2 for *Nb* = 6 Set 3 for *Nb* = 8
Codebook Information	Indicates the size of codebook entries: Set to 0 for 1 bit for ψ , 3 bits for ϕ Set to 1 for 2 bits for ψ , 4 bits for ϕ Set to 2 for 3 bits for ψ , 5 bits for ϕ Set to 3 for 4 bits for ψ , 6 bits for ϕ

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Table 9-55—Subfields of the MIMO Control field *(continued)*

Subfield	Description
Remaining Matrix Segment	Contains the remaining segment number for the associated measurement report. Set to 0 for the last segment of a segmented report or the only segment of an unsegmented report.
Sounding Timestamp	Contains the lower 4 octets of the TSF timer sampled at the instant that the MAC received the PHY-CCA.indication(IDLE) primitive that corresponds to the end of the reception of the sounding PPDU that was used to generate feedback information contained in the frame.

9.4.1.27 CSI Report field

The CSI Report field is used by the CSI frame (see 9.6.11.5) to carry explicit channel state information to a transmit HT beamformer, as described in 10.34.3.

The CSI Matrix subfields in the CSI Report field shown in Table 9-56 and Table 9-57 are matrices whose elements are taken from the CHAN_MAT parameter of RXVECTOR (see Table 19-1).

Table 9-56—CSI Report field (20 MHz)

Field	Size (bits)	Meaning
SNR in receive chain 1	8	Signal-to-noise ratio in the first receive chain of the STA sending the report.
...		
SNR in receive chain *Nr*	8	Signal-to-noise ratio in the *Nr*'th receive chain of the STA sending the report.
CSI Matrix for carrier –28	3+2× *Nb*×*Nc*×*Nr*	CSI matrix (see Figure 9-112)
...		
CSI Matrix for carrier –1	3+2× *Nb*×*Nc*×*Nr*	CSI matrix
CSI Matrix for carrier 1	3+2× *Nb*×*Nc*×*Nr*	CSI matrix
...		
CSI Matrix for carrier 28	3+2× *Nb*×*Nc*×*Nr*	CSI matrix

The structure of the field depends on the value of the MIMO Control Channel Width subfield. The CSI Report field for 20 MHz has the structure defined in Table 9-56 where

Nb is the number of bits determined by the Coefficients Size field of the MIMO Control field
Nc is the number of columns in a CSI matrix determined by the Nc Index field of the MIMO Control field
Nr is the number of rows in a CSI matrix determined by the Nr Index field of the MIMO Control field

The CSI Report field for 40 MHz has the structure defined in Table 9-57.

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Table 9-57—CSI Report field (40 MHz)

Field	Size (bits)	Meaning
SNR in receive chain 1	8	Signal-to-noise ratio in the first receive chain of the STA sending the report.
...		
SNR in receive chain *Nr*	8	Signal-to-noise ratio in the *Nr*'th receive chain of the STA sending the report.
CSI Matrix for carrier –58	3+2× *Nb*×*Nc*×*Nr*	CSI matrix (see Figure 9-112)
...		
CSI Matrix for carrier –2	3+2× *Nb*×*Nc*×*Nr*	CSI matrix
CSI Matrix for carrier 2	3+2× *Nb*×*Nc*×*Nr*	CSI matrix
...		
CSI Matrix for carrier 58	3+2× *Nb*×*Nc*×*Nr*	CSI matrix

The signal-to-noise ratio (SNR) values in Table 9-56 and Table 9-57 are encoded as an 8-bit 2s complement value of 4 × (SNR_average – 22), where SNR_average is the decibel representation of linearly averaged values over the subcarriers represented. This encoding covers the SNR range from –10 dB to 53.75 dB in 0.25 dB steps.

Grouping is a method that reduces the size of the CSI Report field by reporting a single value for each group of *Ng* adjacent subcarriers. With grouping, the size of the CSI Report field is *Nr*×8+*Ns*×(3+2×*Nb*×*Nc*×*Nr)* bits, where the number of subcarriers sent, *Ns*, is a function of *Ng* and whether matrices for 40 MHz or 20 MHz are sent. The value of *Ns* and the specific carriers for which matrices are sent are shown in Table 9-58. If the size of the CSI Report field is not an integer multiple of 8 bits, up to 7 0s are appended to the end of the report to make its size an integer multiple of 8 bits.

Table 9-58—Number of matrices and carrier grouping

BW	Grouping *Ng*	*Ns*	Carriers for which matrices are sent
20 MHz	1	56	All data and pilot carriers: –28, –27,…–2, –1, 1, 2,…27, 28
	2	30	–28,–26,–24,–22,–20,–18,–16,–14,–12,–10,–8,–6,–4,–2,–1, 1,3,5,7,9,11,13,15,17,19,21,23,25,27,28
	4	16	–28,–24,–20,–16,–12,–8,–4,–1,1,5,9,13,17,21,25,28
40 MHz	1	114	All data and pilot carriers: –58, –57, …, –3, –2, 2, 3,…, 57, 58
	2	58	–58,–56,–54,–52,–50,–48,–46,–44,–42,–40,–38,–36,–34,–32,–30,–28,–26,–24, –22,–20,–18,–16,–14,–12,–10,–8,–6,–4,–2, 2,4,6,8,10,12,14,16,18,20,22,24,26,28,30,32,34,36,38,40,42,44,46,48,50,52,54, 56,58
	4	30	–58,–54,–50,–46,–42,–38,–34,–30,–26,–22,–18,–14,–10,–6, –2, 2,6,10,14,18,22,26,30,34,38,42,46,50,54,58

The CSI matrix H_{eff} for a single carrier has the structure defined in Figure 9-112. The encoding rules for the elements of the H_{eff} matrix are given in 19.3.12.3.2.

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```
For each subcarrier include
{
    Carrier Matrix Amplitude of 3 bits
    For each of Nr rows in each CSI matrix in order: (1, …, Nr)
    {
        Include Nc complex coefficients of CSI matrix H_eff in order: (1, …, Nc);
        each element of H_eff includes the real part of the element (Nb bits) and
        imaginary part of the element (Nb bits) in that order
    }

}
```

Figure 9-112—CSI matrix coding

When operating with a 40 MHz channel width, CSI feedback with a bandwidth of 20 MHz corresponds to the subcarriers in the primary 20 MHz channel.

9.4.1.28 Noncompressed Beamforming Report field

The Noncompressed Beamforming Report field is used by the Noncompressed Beamforming frame to carry explicit feedback in the form of noncompressed beamforming feedback matrices *V* for use by a transmit HT beamformer to determine steering matrices Q, as described in 10.34.3 and 19.3.12.3.

The structure of the field is dependent on the value of the MIMO Control Channel Width subfield. The Noncompressed Beamforming Report field for 20 MHz has the structure defined in Table 9-59 where

Nb is the number of bits determined by the Coefficients Size field of the MIMO Control field

Nc is the number of columns in a beamforming feedback matrix determined by the Nc Index field of the MIMO Control field

Nr is the number of rows in a beamforming feedback matrix determined by the Nr Index field of the MIMO Control field

Table 9-59—Noncompressed Beamforming Report field (20 MHz)

Field	Size (bits)	Meaning
SNR for space-time stream 1	8	Average signal-to-noise ratio in the STA sending the report for space-time stream 1.
...		
SNR for space-time stream *Nc*	8	Average signal-to-noise ratio in the STA sending the report for space-time stream *Nc*.
Beamforming Feedback Matrix for carrier –28	2× *Nb*×*Nc*×*Nr*	Beamforming feedback matrix *V* (see Figure 9-113)
...		
Beamforming Feedback Matrix for carrier –1	2× *Nb*×*Nc*×*Nr*	Beamforming feedback matrix *V*
Beamforming Feedback Matrix for carrier 1	2× *Nb*×*Nc*×*Nr*	Beamforming feedback matrix *V*
...		
Beamforming Feedback Matrix for carrier 28	2× *Nb*×*Nc*×*Nr*	Beamforming feedback matrix *V*

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The Noncompressed Beamforming Report field for 40 MHz has the structure defined in Table 9-60.

Table 9-60—Noncompressed Beamforming Report field (40 MHz)

Field	Size (bits)	Meaning
SNR for space-time stream 1	8	Average signal-to-noise ratio in the STA sending the report for space-time stream 1.
...		
SNR for space-time stream *Nc*	8	Average signal-to-noise ratio in the STA sending the report for space-time stream *Nc*.
Beamforming Feedback Matrix for carrier –58	2× *Nb*×*Nc*×*Nr*	Beamforming feedback matrix *V* (see Figure 9-113).
...		
Beamforming Feedback Matrix for carrier –2	2× *Nb*×*Nc*×*Nr*	Beamforming feedback matrix *V*.
Beamforming Feedback Matrix for carrier 2	2× *Nb*×*Nc*×*Nr*	Beamforming feedback matrix *V*.
...		
Beamforming Feedback Matrix for carrier 58	+2× *Nb*×*Nc*×*Nr*	Beamforming feedback matrix *V*.

The SNR values in Table 9-59 and Table 9-60 are encoded as an 8-bit 2s complement value of 4 × (SNR_average – 22), where SNR_average is the sum of the values of SNR per subcarrier (in decibels) divided by the number of subcarriers represented. This encoding covers the SNR range from –10 dB to 53.75 dB in 0.25 dB steps. The SNR in space-time stream *i* corresponds to the SNR associated with the column *i* of the beamforming feedback matrix *V*. Each SNR corresponds to the predicted SNR at the HT beamformee when the HT beamformer applies the matrix *V*.

Grouping is a method that reduces the size of the Noncompressed Beamforming Report field by reporting a single value for each group of *Ng* adjacent subcarriers. With grouping, the size of the Noncompressed Beamforming Report field is *Nc*×8+*Ns*×(2×*Nb*×*Nc*×*Nr*) bits. The number of subcarriers sent, *Ns*, is a function of *Ng* and whether matrices for 40 MHz or 20 MHz are sent. The value of *Ns* and the specific carriers for which matrices are sent is shown in Table 9-58. If the size of the Noncompressed Beamforming Report field is not an integer multiple of 8 bits, up to 7 0s are appended to the end of the report to make its size an integer multiple of 8 bits.

A beamforming feedback matrix *V* for a single carrier has the structure defined in Figure 9-113.

Encoding rules for elements of the *V* matrix are given in 19.3.12.3.5.

When operating with a 40 MHz channel width, noncompressed feedback with a bandwidth of 20 MHz corresponds to the subcarriers in the primary 20 MHz channel.

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```
For each subcarrier include
{
For each of Nr rows in the
        Noncompressed beamforming feedback matrix in order: (1, …, Nr)
    {
        Include Nc complex coefficients of the Noncompressed beamforming feedback
        matrix V in order: (1, …, Nc );  each element of V includes the real
        part of the element (Nb bits) and imaginary part of the element (Nb bits)
        in that order
    }
}
```

Figure 9-113—*V* matrix coding (noncompressed beamforming)

9.4.1.29 Compressed Beamforming Report field

The Compressed Beamforming Report field is used by the Compressed Beamforming frame (see 9.6.11.7) to carry explicit feedback information in the form of angles representing compressed beamforming feedback matrices *V* for use by a transmit HT beamformer to determine steering matrices Q, as described in 10.34.3 and 19.3.12.3.

The size of the Compressed Beamforming Report field depends on the values in the MIMO Control field.

The Compressed Beamforming Report field contains the channel matrix elements indexed, first, by matrix angles in the order shown in Table 9-61 and, second, by data subcarrier index from lowest frequency to highest frequency. The explanation on how these angles are generated from the beamforming feedback matrix *V* is given in 19.3.12.3.6.

Table 9-61—Order of angles in the Compressed Beamforming Report field

Size of *V* (*Nr* × *Nc*)	Number of angles (*Na*)	The order of angles in the Quantized Beamforming Feedback Matrices Information field
2×1	2	ϕ_{11}, ψ_{21}
2×2	2	ϕ_{11}, ψ_{21}
3×1	4	ϕ_{11}, ϕ_{21}, ψ_{21}, ψ_{31}
3×2	6	ϕ_{11}, ϕ_{21}, ψ_{21}, ψ_{31}, ϕ_{22}, ψ_{32}
3×3	6	ϕ_{11}, ϕ_{21}, ψ_{21}, ψ_{31}, ϕ_{22}, ψ_{32}
4×1	6	ϕ_{11}, ϕ_{21}, ϕ_{31}, ψ_{21}, ψ_{31}, ψ_{41}
4×2	10	ϕ_{11}, ϕ_{21}, ϕ_{31}, ψ_{21}, ψ_{31}, ψ_{41}, ϕ_{22}, ϕ_{32}, ψ_{32}, ψ_{42}
4×3	12	ϕ_{11}, ϕ_{21}, ϕ_{31}, ψ_{21}, ψ_{31}, ψ_{41}, ϕ_{22}, ϕ_{32}, ψ_{32}, ψ_{42}, ϕ_{33}, ψ_{43}
4×4	12	ϕ_{11}, ϕ_{21}, ϕ_{31}, ψ_{21}, ψ_{31}, ψ_{41}, ϕ_{22}, ϕ_{32}, ψ_{32}, ψ_{42}, ϕ_{33}, ψ_{43}

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The angles are quantized as defined in Table 9-62. All angles are transmitted LSB to MSB.

Table 9-62—Quantization of angles

Quantized ψ	Quantized ϕ
$\psi = \frac{k\pi}{2^{b_\psi+1}} + \frac{\pi}{2^{b_\psi+2}}$ radians where $k = 0, 1, \ldots, 2^{b_\psi} - 1$ b_ψ is the number of bits used to quantize ψ (defined by the Codebook Information field of the MIMO Control field; see 9.4.1.26);	$\phi = \frac{k\pi}{2^{b_\phi-1}} + \frac{\pi}{2^{b_\phi}}$ radians where $k = 0, 1, \ldots, 2^{b_\phi} - 1$ b_ϕ is the number of bits used to quantize ϕ (defined by the Codebook Information field of the MIMO Control field; see 9.4.1.26)

The Compressed Beamforming Report field for 20 MHz has the structure defined in Table 9-63, where *Na* is the number of angles used for beamforming feedback matrix *V* (see Table 9-61).

Table 9-63—Compressed Beamforming Report field (20 MHz)

Field	Size (bits)	Meaning
SNR in space-time stream 1	8	Average signal-to-noise ratio in the STA sending the report for space-time stream 1.
...		
SNR in space-time stream *Nc*	8	Average signal-to-noise ratio in the STA sending the report for space-time stream *Nc*.
Beamforming Feedback Matrix *V* for carrier –28	$Na \times (b_\psi + b_\phi)/2$	Beamforming feedback matrix *V*.
...		
Beamforming Feedback Matrix *V* for carrier –1	$Na \times (b_\psi + b_\phi)/2$	Beamforming feedback matrix *V*.
Beamforming Feedback Matrix *V* for carrier 1	$Na \times (b_\psi + b_\phi)/2$	Beamforming feedback matrix *V*.
...		
Beamforming Feedback Matrix *V* for carrier 28	$Na \times (b_\psi + b_\phi)/2$	Beamforming feedback matrix *V*.

The Compressed Beamforming Report field for 40 MHz has the structure defined in Table 9-64, where *Na* is the number of angles used for beamforming feedback matrix *V* (see Table 9-61).

The SNR values in Table 9-63 and Table 9-64 are encoded as an 8-bit 2s complement value of 4 × (SNR_average – 22), where SNR_average is the sum of the values of SNR per subcarrier (in decibels) divided by the number of subcarriers represented. This encoding covers the SNR range from –10 dB to 53.75 dB in 0.25 dB steps. Each SNR value per subcarrier in stream *i* (before being averaged) corresponds to the SNR associated with the column *i* of the beamforming feedback matrix *V* determined at the HT beamformee. Each SNR corresponds to the predicted SNR at the HT beamformee when the HT beamformer applies the matrix *V*.

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Table 9-64—Compressed Beamforming Report field (40 MHz)

Field	Size (bit)	Meaning
SNR in space-time stream 1	8	Average signal-to-noise ratio in the STA sending the report for space-time stream 1.
...		
SNR in space-time stream *Nc*	8	Average signal-to-noise ratio in the STA sending the report for space-time stream *Nc*.
Beamforming Feedback Matrix *V* for carrier –58	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*.
Beamforming Feedback Matrix *V* for carrier –58 + *Ng*	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*.
...		
Beamforming Feedback Matrix *V* for carrier –2	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*.
Beamforming Feedback Matrix *V* for carrier 2	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*.
Beamforming Feedback Matrix *V* for carrier 2 + *Ng*	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*.
...		
Beamforming Feedback Matrix *V* for carrier 58	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*.

Grouping is a method that reduces the size of the Compressed Beamforming Report field by reporting a single value for each group of *Ng* adjacent subcarriers. With grouping, the size of the Compressed Beamforming Report field is $Nc\times 8+Ns\times(Na\times(b_\psi+b_\phi)/2)$ bits, where the number of subcarriers sent, *Ns*, is a function of *Ng* and whether matrices for 40 MHz or 20 MHz are sent. The value of *Ns* and the specific carriers for which matrices are sent is defined in Table 9-58. If the size of the Compressed Beamforming Report field is not an integer multiple of 8 bits, up to 7 0s are appended to the end of the report to make its size an integer multiple of 8 bits.

See Figure 9-114 and Figure 9-115 for examples of this encoding.

Bits	b0..b4	b5..b7	b8..b12	b13..b15	…	b440..b444	b445..b447
Data	$\phi_{11}(-28)$	$\psi_{21}(-28)$	$\phi_{11}(-27)$	$\psi_{21}(-27)$	…	$\phi_{11}(28)$	$\psi_{21}(28)$

Conditions:
- 2 × 2 V
- $b_\psi = 3$, $b_\phi = 5$
- No grouping
- 20 MHz width
- The matrix *V* is encoded using 8 bits per subcarrier.

Figure 9-114—First example of Compressed Beamforming Report field encoding

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Bits	b0..b3	b4..b7	…	b26..b27	b28..b29	b30..b33	…	b58..b59	…	b870..b873	…	b898..b899
Data	$\phi_{11}(-58)$	$\phi_{21}(-58)$	…	$\psi_{32}(-58)$	$\psi_{42}(-58)$	$\phi_{11}(-54)$	…	$\psi_{42}(-54)$	…	$\phi_{11}(58)$	…	$\psi_{42}(58)$

Conditions:
- 4 × 2 V
- $b_\psi = 2$, $b_\phi = 4$
- 4 subcarrier grouping
- 40 MHz width
- The matrix *V* is encoded using 30 bits per subcarrier .

Figure 9-115—Second example of Compressed Beamforming Report field encoding

When operating with a 40 MHz channel width, compressed feedback with a bandwidth of 20 MHz corresponds to the subcarriers in the primary 20 MHz channel.

9.4.1.30 Antenna Selection Indices field

The Antenna Selection Indices field is used within the Antenna Selection Indices Feedback frame to carry ASEL feedback, as described in 10.35.

The Antenna Selection Indices field is shown in Figure 9-116.

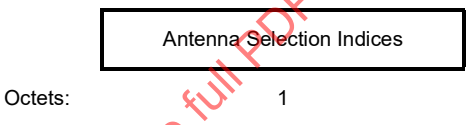

Figure 9-116—Antenna Selection Indices field format

Bits 0 to 7 in the Antenna Selection Indices field correspond to antennas with indices 0 to 7, respectively. A 1 in a bit indicates the corresponding antenna is selected, and a 0 indicates the corresponding antenna is not selected.

9.4.1.31 Organization Identifier field

The Organization Identifier field contains a public unique identifier assigned by the IEEE Registration Authority as a 24-bit OUI, a 24-bit CID, or a 36-bit OUI-36, see IEEE Registration Authority [B15] and [B16]. The order of the Organization Identifier field is described in 9.2.2.

The length of the Organization Identifier field (*j*) is the minimum number of octets required to contain the entire IEEE-assigned identifier (see Figure 9-117). Thus, the Organization Identifier field is 3 octets in length if the IEEE-assigned identifier is an OUI or CID, or 5 octets in length if the IEEE-assigned identifier is an OUI-36.

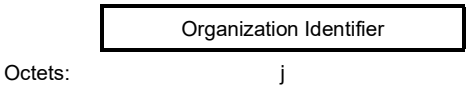

Figure 9-117—Organization Identifier field format

If the length of the IEEE-assigned identifier is not an integer number of octets, the least significant bits of the last octet are specified by the organization identified.

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NOTE—For example, for the IEEE-assigned identifier 0x0050C24A4, the Organization Identifier field would contain 0x0050C24A4*y* where *y* represents the four least significant bits of the fifth octet of the field. The value of *y* is specified by the organization whose identifier is 0x0050C24A4.

9.4.1.32 Rate Identification field

The Rate Identification field contains the rate identification information for a frame that is not the current frame transmitted or received by a STA. This information allows services to exchange frame rate information prior to use of the frames that use the rate specified by the Rate Identification field. The contents of the field is defined in Figure 9-118.

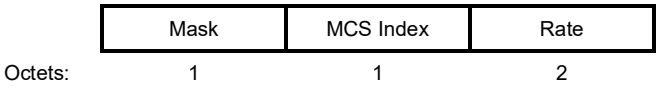

Figure 9-118—Identification field format

The Mask field specifies the other fields in the Rate Identification field that are used by a STA. The format of the Mask field is shown in Figure 9-119.

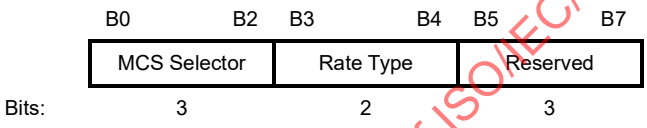

Figure 9-119—Mask field format

The MCS Selector field value 0 indicates that the MCS Index field is reserved. The MCS Selector field value 1 indicates the MCS Index field specifies an index value that is taken from Table 19-27 to Table 19-30 and Table 19-36 to Table 19-38 in 19.5.

The MCS Selector field value 2 indicates that the MCS Index field specifies:

— Values that are taken from Table 19-31 to Table 19-35 and Table 19-40 to Table 19-41 in 19.5, when carried in frames transmitted by a non-S1G STA.

— Values that are taken from Table 23-41 to Table 23-44, indicating an S1G-MCS for a 1 MHz channel width, when carried in frames transmitted by an S1G STA.

The MCS Selector field value 3 indicates that the MCS Index field specifies:

— Values that are taken from Table 21-29 to Table 21-36, indicating a VHT-MCS for a 20 MHz channel width, when carried in frames transmitted by a non-S1G STA.

— Values that are taken from Table 23-45 to Table 23-48, indicating an S1G-MCS for a 2 MHz channel width, when carried in frames transmitted by an S1G STA.

The MCS Selector field value 4 indicates that the MCS Index field specifies

— Values that are taken from Table 21-37 to Table 21-44, indicating a VHT-MCS for a 40 MHz channel width, when carried in frames transmitted by a non-TVHT and non-S1G STA.

— Values that are taken from Table 22-26 to Table 22-29, indicating a TVHT-MCS for a TVHT_W channel width, when carried in frames transmitted by a TVHT STA.

— Values that are taken from Table 23-49 to Table 23-52, indicating an S1G-MCS for a 4 MHz channel width, when carried in frames transmitted by an S1G STA.

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The MCS Selector field value 5 indicates that the MCS Index field specifies

— Values that are taken from Table 21-45 to Table 21-52, indicating a VHT-MCS for an 80 MHz channel width, when carried in frames transmitted by a non-TVHT and non-S1G STA.
— Values that are taken from Table 22-30 to Table 22-33, indicating a TVHT-MCS for a TVHT_2W or TVHT_W+W channel width, when carried in frames transmitted by a TVHT STA.
— Values that are taken from Table 23-53 to Table 23-56, indicating an S1G-MCS for an 8 MHz channel width, when carried in frames transmitted by an S1G STA.

The MCS Selector field value 6 indicates that the MCS Index field specifies

— Values that are taken from Table 21-53 to Table 21-60, indicating a VHT-MCS for a 160 MHz or 80+80 MHz channel width, when carried in frames transmitted by a non-TVHT and non-S1G STA.
— Values that are taken from Table 22-34 to Table 22-37, indicating a TVHT-MCS for a TVHT_4W or TVHT_2W+2W channel width, when carried in frames transmitted by a TVHT STA.
— Values that are taken from Table 23-57 to Table 23-60, indicating an S1G-MCS for a 16 MHz channel width, when carried in frames transmitted by an S1G STA.

The MCS Selector field value 7 is reserved.

The Rate Type field set to 0 indicates the Rate field is reserved. The Rate Type field set to 1 indicates the Rate field specifies a data rate that is in the basic rate set. The Rate Type field set to 2 indicates the Rate field specifies a data rate that is not in the basic rate set.

If MCS Selector is 1 or 2, the MCS Index field is a 1 octet unsigned integer that specifies the row index for one of the MCS parameter tables in 19.5.

If MCS Selector field is 3, 4, 5, or 6, the MCS Index field format is as shown in Figure 9-120. In frames transmitted by an S1G STA, the MCS Index field format is also valid when MCS Selector field is 2. The NSS subfield indicates the number of spatial streams, and the VHT-MCS Index Row subfield indicates a value from the VHT-MCS Index column of Table 21-29 to Table 21-60 in 21.5 or from the MCS Index column of Table 22-26 to Table 22-37 in 22.5 that corresponds to the channel width and N_{SS} values, or from the MCS Idx column of Table 23-41 to Table 23-60 that corresponds to the channel width and NSS values.

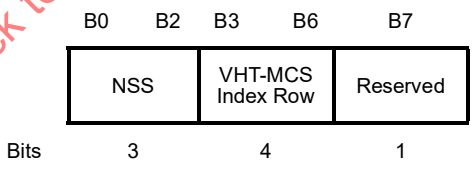

Figure 9-120—MCS Index field format when the MCS Selector field is 3, 4, 5, or 6

For non-S1G STAs, the Rate field contains an unsigned integer that specifies the PHY rate in 0.5 Mb/s units. For S1G STAs, it is reserved.

9.4.1.33 GAS Query Response Fragment ID field

A GAS Query Fragment Response ID field is used by the STA to indicate when a GAS Query Response spans multiple MMPDUs. STAs responding to GAS request use this field to inform the requesting STA of the GAS fragment number of the transmitted frames as well as identifying the last GAS fragment of the Query Response. Requesting STAs use this field to determine if any fragments of the Query Response are missing. The maximum value permitted in the GAS Query Response Fragment ID is 127. The More GAS Fragments field is set to 1 in GAS Query Response fragments of GAS Comeback Response frames that have

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another GAS fragment of the current query response to follow; otherwise, it is set to 0. The format of GAS Query Response Fragment ID is shown in Figure 9-121.

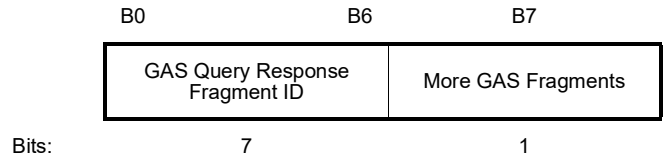

Figure 9-121—GAS Query Response Fragment ID field format

9.4.1.34 Venue Info field

The Venue Info field contains Venue Group and Venue Type subfields. The format of Venue Info subfield is shown in Figure 9-122.

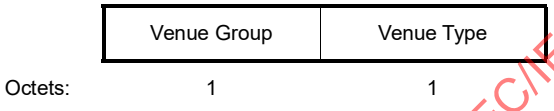

Figure 9-122—Venue Info field format

The Venue Group and Venue Type subfields are selected from Table 9-65 and Table 9-66, respectively. The entries in Table 9-65 and Table 9-66 are drawn from the *International Building Code*'s Use and Occupancy Classifications [B49].

Table 9-65—Venue group codes and descriptions

Venue group code	Venue group description
0	Unspecified
1	Assembly
2	Business
3	Educational
4	Factory and Industrial
5	Institutional
6	Mercantile
7	Residential
8	Storage
9	Utility and Miscellaneous
10	Vehicular
11	Outdoor
12–255	Reserved

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Table 9-66—Venue type assignments

Venue group code	Venue type code	Venue description
0	0	Unspecified
0	1–255	Reserved
1	0	Unspecified Assembly
1	1	Arena
1	2	Stadium
1	3	Passenger Terminal (e.g., airport, bus, ferry, train station)
1	4	Amphitheater
1	5	Amusement Park
1	6	Place of Worship
1	7	Convention Center
1	8	Library
1	9	Museum
1	10	Restaurant
1	11	Theater
1	12	Bar
1	13	Coffee Shop
1	14	Zoo or Aquarium
1	15	Emergency Coordination Center
1	16–255	Reserved
2	0	Unspecified Business
2	1	Doctor or Dentist office
2	2	Bank
2	3	Fire Station
2	4	Police Station
2	6	Post Office
2	7	Professional Office
2	8	Research and Development Facility
2	9	Attorney Office
2	10–255	Reserved
3	0	Unspecified Educational
3	1	School, Primary
3	2	School, Secondary
3	3	University or College
3	4–255	Reserved
4	0	Unspecified Factory and Industrial
4	1	Factory
4	2–255	Reserved

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Table 9-66—Venue type assignments *(continued)*

Venue group code	Venue type code	Venue description
5	0	Unspecified Institutional
5	1	Hospital
5	2	Long-Term Care Facility (e.g., Nursing home, Hospice, etc.)
5	3	Alcohol and Drug Rehabilitation Center
5	4	Group Home
5	5	Prison or Jail
5	6–255	Reserved
6	0	Unspecified Mercantile
6	1	Retail Store
6	2	Grocery Market
6	3	Automotive Service Station
6	4	Shopping Mall
6	5	Gas Station
6	6–255	Reserved
7	0	Unspecified Residential
7	1	Private Residence
7	2	Hotel or Motel
7	3	Dormitory
7	4	Boarding House
7	5–255	Reserved
8	0	Unspecified Storage
8	1–255	Reserved
9	0	Unspecified Utility and Miscellaneous
9	1–255	Reserved
10	0	Unspecified Vehicular
10	1	Automobile or Truck
10	2	Airplane
10	3	Bus
10	4	Ferry
10	5	Ship or Boat
10	6	Train
10	7	Motor Bike
10	8–255	Reserved
11	0	Unspecified Outdoor
11	1	Muni-mesh Network
11	2	City Park
11	3	Rest Area

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Table 9-66—Venue type assignments *(continued)*

Venue group code	Venue type code	Venue description
11	4	Traffic Control
11	5	Bus Stop
11	6	Kiosk
11	7–255	Reserved

9.4.1.35 Target Channel

The Target Channel field specifies the channel number of the target channel. The length of the Target Channel field is 1 octet. The Target Channel field is shown in Figure 9-123.

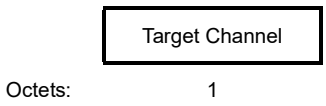

Figure 9-123—Target Channel field format

9.4.1.36 Operating Class

The Operating Class field specifies the operating class for the channel field included in the same frame. The length of the Operating Class field is 1 octet. Operating classes are defined in Annex E. The Operating Class field is shown in Figure 9-124.

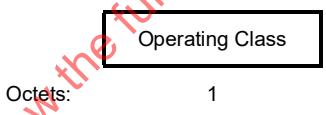

Figure 9-124—Operating Class field format

9.4.1.37 Send-Confirm field

The Send-Confirm field is used with SAE authentication as an anti-replay counter as specified in 12.4. See Figure 9-125.

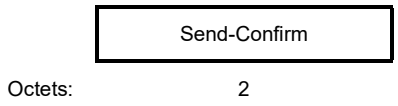

Figure 9-125—Send-Confirm field format

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9.4.1.38 Anti-Clogging Token field

The Anti-Clogging Token field is used with SAE authentication for denial-of-service protection as specified in 12.4. See Figure 9-126.

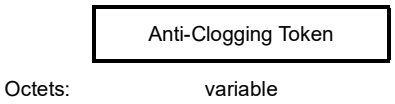

Figure 9-126—Anti-Clogging Token field format

9.4.1.39 Scalar field

The Scalar field is used with SAE authentication to communicate cryptographic material as specified in 12.4. See Figure 9-127.

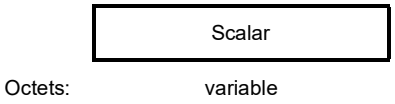

Figure 9-127—Scalar field format

9.4.1.40 FFE field

The FFE field is used with SAE authentication and FILS authentication to communicate an element in a finite field as specified in 12.4. See Figure 9-128.

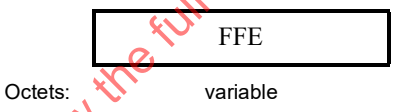

Figure 9-128—FFE field format

9.4.1.41 Confirm field

The Confirm field is used with SAE authentication to authenticate and prove possession of a cryptographic key as specified in 12.4. See Figure 9-129.

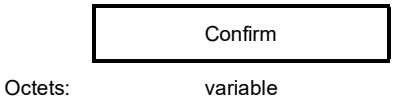

Figure 9-129—Confirm field format

9.4.1.42 Finite Cyclic Group field

The Finite Cyclic Group field is used as specified in Clause 12 to indicate an unsigned integer, from a repository maintained by IANA as “Group Description” attributes for IETF RFC 2409 (IKE) [B14][B30] that specifies the cryptographic group to use in a cryptographic exchange. See Figure 9-130.

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The Finite Cyclic Group field is used in SAE to indicate the cryptographic group to use in the SAE authentication as specified in 12.4. This field is also used in FILS to indicate the cryptographic group to use in FILS authentication as specified in 12.11 . See Figure 9-130.

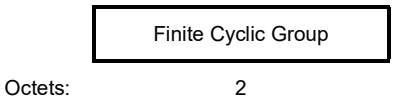

Figure 9-130—Finite Cyclic Group field format

9.4.1.43 TXOP Reservation field

The format of the TXOP Reservation field is shown in Figure 9-131.

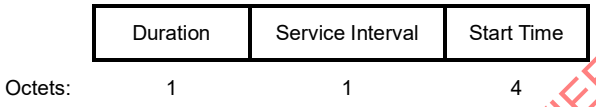

Figure 9-131—TXOP Reservation field format

The Duration subfield specifies the duration of the TXOP in units of 32 μs.

The Service Interval subfield contains an unsigned integer that specifies the service interval (SI) of the reservation in units of milliseconds.

The Start Time subfield is the offset from the next TBTT to the start of the first SP and indicates the anticipated start time, expressed in microseconds, of the first TXOP after the TBTT.

9.4.1.44 Relay Capable STA Info field

The format of the Relay Capable STA Info field is defined in Figure 9-132.

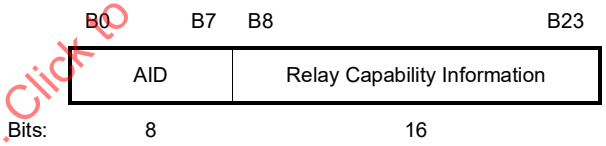

Figure 9-132—Relay Capable STA Info field format

The AID subfield contains the AID of the relay capable STA that is associated with the AP or PCP.

The Relay Capability Information subfield is defined in 9.4.2.147.

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9.4.1.45 Band ID field

The Band ID field is defined in Table 9-67.

Table 9-67—Band ID field

Band ID value	Meaning
0	TV white spaces
1	Sub-1 GHz (excluding TV white spaces)
2	2.4 GHz
3	3.6 GHz
4	4.9 and 5 GHz
5	60 GHz
6	45 GHz
7–255	Reserved

9.4.1.46 DMG Parameters field

The format of the DMG Parameters field is shown in Figure 9-133.

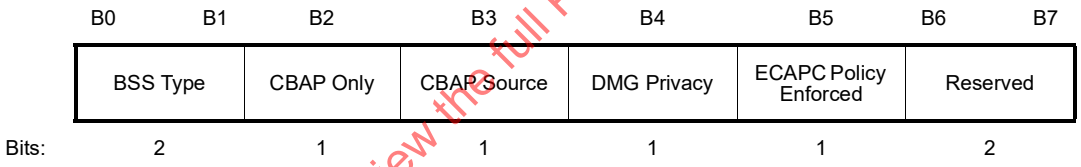

Figure 9-133—DMG Parameters

If the BSS Type field is transmitted as part of a DMG Beacon frame that has the Discovery Mode field within the Beacon Interval Control field (see Figure 9-77) equal to 0, then the BSS Type subfield is defined in Table 9-68 for specific types of frame cited below. An AP sets the BSS Type subfield to 3 within transmitted DMG Beacon, Probe Response, or (Re)Association Response frames. A PCP sets the BSS Type subfield to 2 within transmitted DMG Beacon, Probe Response, or (Re)Association Response frames. An IBSS STA or a STA that is not a member of a BSS sets the BSS Type subfield to 1 within transmitted DMG Beacon or Probe Response frames. The BSS Type subfield is reserved for all other types of frame.

Table 9-68—The BSS Type subfield when the Discovery mode field is 0

Subfield value	BSS Type	Transmitted by DMG STA
3	Infrastructure BSS	AP
2	PBSS	PCP
1	IBSS	Any non-AP and non-PCP DMG STA
0	Reserved	

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If the BSS Type field is transmitted as part of a DMG Beacon frame that has the Discovery Mode field within the Beacon Interval Control field (see Figure 9-77) equal to 1, the BSS Type subfield is defined in Table 9-69. Depending on the role of the STA that responds to the DMG Beacon frame (identified by the Responding STA role column of Table 9-69), the behavior is different and is defined in 10.42.5.2.

Table 9-69—The BSS Type subfield when the Discovery mode field is 1

Subfield value	Responding STA role	Applicable BSS types
3	AP	Infrastructure BSS
2	PCP	PBSS
1	Non-AP STA	PBSS, IBSS
0	Any	Infrastructure BSS, PBSS, IBSS

The CBAP Only, CBAP Source, and ECAPC Policy Enforced subfields are valid only when transmitted within a DMG Beacon, Probe Response, or (Re)Association Response frames and are set as follows:

— The CBAP Only subfield indicates the type of link access provided by the STA sending the DMG Beacon frame in the data transfer interval (DTI) (see 10.39.2) of the beacon interval. The CBAP Only subfield is set to 1 when the entirety of the DTI portion of the beacon interval is allocated as a CBAP. The CBAP Only subfield is set to 0 when the allocation of the DTI portion of the beacon interval is provided through the Extended Schedule element.

— The CBAP Source subfield is valid only if the CBAP Only subfield is 1. The CBAP Source subfield is set to 1 to indicate that the AP or PCP has higher priority to transmit during the CBAP than non-AP and non-PCP STAs. The CBAP Source subfield is set to 0 otherwise.

— The ECAPC Policy Enforced subfield is set to 1 to indicate that medium access policies specific to the centralized AP or PCP cluster are required as defined in 10.40.3.4. The ECAPC Policy Enforced subfield is set to 0 to indicate that medium access policies specific to the centralized AP or PCP cluster are not required.

The DMG Privacy subfield is set to 1 if dot11RSNAActivated is true. Otherwise, this subfield is set to 0.

9.4.1.47 CMMG Parameters field

The definition of the CMMG parameters field is the same as the definition of the DMG parameters field (see 9.4.1.46).

9.4.1.48 VHT MIMO Control field

The VHT MIMO Control field is included in every VHT Compressed Beamforming frame (see 9.6.22.2). The VHT MIMO Control field is defined in Figure 9-134.

B0B2	B3B5	B6B7	B8B9	B10	B11	B12B14	B15	B16B17	B18B23
Nc Index	Nr Index	Channel Width	Grouping	Codebook Information	Feedback Type	Remaining Feedback Segments	First Feedback Segment	Reserved	Sounding Dialog Token Number
Bits: 3	3	2	2	1	1	3	1	2	6

Figure 9-134—VHT MIMO Control field format

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The subfields of the VHT MIMO Control field are defined in Table 9-70.

Table 9-70—Subfields of the VHT MIMO Control field

Subfield	Description
Nc Index	Indicates the number of columns, *Nc*, in the compressed beamforming feedback matrix minus 1. In an S1G PPDU, the Nc Index field does not indicate an *Nc* that is greater than 4.
Nr Index	Indicates the number of rows, *Nr*, in the compressed beamforming feedback matrix minus 1. The value 0 is reserved. In an S1G PPDU, the Nr Index field does not indicate an *Nr* that is greater than 4.
Channel Width	Indicates the width of the channel in which the measurement to create the compressed beamforming feedback matrix was made: In a non-S1G PPDU: Set to 0 for 20 MHz Set to 1 for 40 MHz Set to 2 for 80 MHz Set to 3 for 160 MHz or 80+80 MHz In an S1G PPDU: Set to 0 for 2MHz Set to 1 for 4 MHz Set to 2 for 8 MHz Set to 3 for 16 MHz
Grouping	Indicates the subcarrier grouping, *Ng*, used for the compressed beamforming feedback matrix: Set to 0 for *Ng* = 1 (No grouping) Set to 1 for *Ng* = 2 Set to 2 for *Ng* = 4 The value 3 is reserved.
Codebook Information	Indicates the size of codebook entries: If Feedback Type is SU in a VHT PPDU: Set to 0 for 2 bits for ψ, 4 bits for ϕ Set to 1 for 4 bits for ψ, 6 bits for ϕ If Feedback Type is SU in an S1G PPDU with Nc Index field equal to 0: Set to 0 for 2 bits for ϕ, and ψ is not fed back Set to 1 for 2 bits for ψ, and 4 bits for ϕ If Feedback Type is MU in a VHT PPDU: Set to 0 for 5 bits for ψ, 7 bits for ϕ Set to 1 for 7 bits for ψ, 9 bits for ϕ If Feedback Type is MU in an S1G PPDU: Set to 0 for 5 bits for ψ, 7 bits for ϕ Set to 1 for 7 bits for ψ, 9 bits for ϕ
Feedback Type	Indicates the feedback type: Set to 0 for SU Set to 1 for MU
Remaining Feedback Segments	Indicates the number of remaining feedback segments for the associated VHT Compressed Beamforming frame: Set to 0 for the last feedback segment of a segmented report or the only feedback segment of an unsegmented report. Set to a value between 1 and 6 for a feedback segment that is neither the first nor the last of a segmented report. Set to a value between 1 and 7 for a feedback segment that is not the last feedback segment of a segmented report. In a retransmitted feedback segment, the field is set to the same value associated with the feedback segment in the original transmission.

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Table 9-70—Subfields of the VHT MIMO Control field *(continued)*

Subfield	Description
First Feedback Segment	Set to 1 for the first feedback segment of a segmented report or the only feedback segment of an unsegmented report; set to 0 if it is not the first feedback segment or if the VHT Compressed Beamforming Report field and MU Exclusive Beamforming Report field are not present in the frame. In a retransmitted feedback segment, the field is set to the same value associated with the feedback segment in the original transmission.
Sounding Dialog Token Number	The sounding dialog token from the VHT NDP Announcement frame soliciting feedback.

In a VHT Compressed Beamforming frame not carrying all or part of a VHT Compressed Beamforming report (see 10.36.5 for a description of such a case), the Nc Index, Nr Index, Channel Width, Grouping, Codebook Information, Feedback Type and Sounding Dialog Token Number subfields are reserved, the First Feedback Segment subfield is set to 0 and the Remaining Feedback Segments subfield is set to 7.

9.4.1.49 VHT Compressed Beamforming Report field

The VHT Compressed Beamforming Report field is used by the VHT compressed beamforming feedback (see 9.6.22.2) to carry explicit feedback information in the form of angles representing compressed beamforming feedback matrices V for use by a transmit beamformer to determine steering matrices Q, as described in 10.34.3 and 19.3.12.3.

The size of the VHT Compressed Beamforming Report field depends on the values in the VHT MIMO Control field. The VHT Compressed Beamforming Report field contains VHT Compressed Beamforming Report information or successive (possibly zero-length) portions thereof in the case of segmented VHT compressed beamforming feedback (see 10.36.5). VHT Compressed Beamforming Report information is always included in the VHT compressed beamforming feedback.

The VHT Compressed Beamforming Report information contains the channel matrix elements for each subcarrier from lowest frequency to highest frequency. For each subcarrier, the channel matrix element is represented by a sequence of angles. The order of the angles within each subcarrier when used in a non-S1G band is shown in Table 9-71. The order of the angles within each subcarrier when used in an S1G band for SU and MU type feedback are shown in Table 9-72 and Table 9-73, respectively. Explanation on how these angles are generated from the beamforming feedback matrix V is given in 19.3.12.3.6.

In Table 9-71,

Nc is the number of columns in a compressed beamforming feedback matrix determined by the Nc Index field of the VHT MIMO Control field,

Nr is the number of rows in a compressed beamforming feedback matrix determined by the Nr Index field of the VHT MIMO Control field.

The beamforming feedback matrix V is formed by the beamformee as follows. The beamformer transmits an NDP with $N_{STS,NDP}$ space-time streams, where $N_{STS,NDP}$ takes a value between 2 and 8. Based on this NDP, the beamformee estimates the $N_{RX,BFEE} \times N_{STS,NDP}$ channel, and based on that channel it determines a $Nr \times Nc$ orthonormal matrix V, where Nr and Nc satisfy Equation (9-1).

$$Nr = N_{STS,NDP}, Nc \leq min(N_{STS,NDP}, N_{RX,BFEE}) \quad (9\text{-}1)$$

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Table 9-71—Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band

Size of *V* (*Nr* × *Nc*)	Number of angles (*Na*)	The order of angles in the compressed beamforming feedback matrix
2×1	2	ϕ11, ψ21
2×2	2	ϕ11, ψ21
3×1	4	ϕ11, ϕ21, ψ21, ψ31
3×2	6	ϕ11, ϕ21, ψ21, ψ31, ϕ22, ψ32
3×3	6	ϕ11, ϕ21, ψ21, ψ31, ϕ22, ψ32
4×1	6	ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41
4×2	10	ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41, ϕ22, ϕ32, ψ32, ψ42
4×3	12	ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41, ϕ22, ϕ32, ψ32, ψ42, ϕ33, ψ43
4×4	12	ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41, ϕ22, ϕ32, ψ32, ψ42, ϕ33, ψ43
5×1	8	ϕ11, ϕ21, ϕ31, ϕ41, ψ21, ψ31, ψ41, ψ51
5×2	14	ϕ11, ϕ21, ϕ31, ϕ41, ψ21, ψ31, ψ41, ψ51, ϕ22, ϕ32, ϕ42, ψ32, ψ42, ψ52
5×3	18	ϕ11, ϕ21, ϕ31, ϕ41, ψ21, ψ31, ψ41, ψ51, ϕ22, ϕ32, ϕ42, ψ32, ψ42, ψ52, ϕ33, ϕ43, ψ43, ψ53
5×4	20	ϕ11, ϕ21, ϕ31, ϕ41, ψ21, ψ31, ψ41, ψ51, ϕ22, ϕ32, ϕ42, ψ32, ψ42, ψ52, ϕ33, ϕ43, ψ43, ψ53, ϕ44, ψ54
5×5	20	ϕ11, ϕ21, ϕ31, ϕ41, ψ21, ψ31, ψ41, ψ51, ϕ22, ϕ32, ϕ42, ψ32, ψ42, ψ52, ϕ33, ϕ43, ψ43, ψ53, ϕ44, ψ54
6×1	10	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ψ21, ψ31, ψ41, ψ51, ψ61
6×2	18	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ψ21, ψ31, ψ41, ψ51, ψ61, ϕ22, ϕ32, ϕ42, ϕ52, ψ32, ψ42, ψ52, ψ62
6×3	24	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ψ21, ψ31, ψ41, ψ51, ψ61, ϕ22, ϕ32, ϕ42, ϕ52, ψ32, ψ42, ψ52, ψ62, ϕ33, ϕ43, ϕ53, ψ43, ψ53, ψ63
6×4	28	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ψ21, ψ31, ψ41, ψ51, ψ61, ϕ22, ϕ32, ϕ42, ϕ52, ψ32, ψ42, ψ52, ψ62, ϕ33, ϕ43, ϕ53, ψ43, ψ53, ψ63, ϕ44, ϕ54, ψ54, ψ64
6×5	30	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ψ21, ψ31, ψ41, ψ51, ψ61, ϕ22, ϕ32, ϕ42, ϕ52, ψ32, ψ42, ψ52, ψ62, ϕ33, ϕ43, ϕ53, ψ43, ψ53, ψ63, ϕ44, ϕ54, ψ54, ψ64, ϕ55, ψ65
6×6	30	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ψ21, ψ31, ψ41, ψ51, ψ61, ϕ22, ϕ32, ϕ42, ϕ52, ψ32, ψ42, ψ52, ψ62, ϕ33, ϕ43, ϕ53, ψ43, ψ53, ψ63, ϕ44, ϕ54, ψ54, ψ64, ϕ55, ψ65
7×1	12	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71
7×2	22	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ψ32, ψ42, ψ52, ψ62, ψ72
7×3	30	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ψ32, ψ42, ψ52, ψ62, ψ72, ϕ33, ϕ43, ϕ53, ϕ63, ψ43, ψ53, ψ63, ψ73
7×4	36	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ψ32, ψ42, ψ52, ψ62, ψ72, ϕ33, ϕ43, ϕ53, ϕ63, ψ43, ψ53, ψ63, ψ73, ϕ44, ϕ54, ϕ64, ψ54, ψ64, ψ74

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Table 9-71—Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band *(continued)*

Size of *V* (*Nr* × *Nc*)	Number of angles (*Na*)	The order of angles in the compressed beamforming feedback matrix
7×5	40	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ψ32, ψ42, ψ52, ψ62, ψ72, ϕ33, ϕ43, ϕ53, ϕ63, ψ43, ψ53, ψ63, ψ73, ϕ44, ϕ54, ϕ64, ψ54, ψ64, ψ74, ϕ55, ϕ65, ψ65, ψ75
7×6	42	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ψ32, ψ42, ψ52, ψ62, ψ72, ϕ33, ϕ43, ϕ53, ϕ63, ψ43, ψ53, ψ63, ψ73, ϕ44, ϕ54, ϕ64, ψ54, ψ64, ψ74, ϕ55, ϕ65, ψ65, ψ75, ϕ66, ψ76
7×7	42	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ψ32, ψ42, ψ52, ψ62, ψ72, ϕ33, ϕ43, ϕ53, ϕ63, ψ43, ψ53, ψ63, ψ73, ϕ44, ϕ54, ϕ64, ψ54, ψ64, ψ74, ϕ55, ϕ65, ψ65, ψ75, ϕ66, ψ76
8×1	14	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81
8×2	26	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ϕ72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82
8×3	36	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ϕ72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, ϕ33, ϕ43, ϕ53, φ63, ϕ73, ψ43, ψ53, ψ63, ψ73, ψ83
8×4	44	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ϕ72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, ϕ33, ϕ43, ϕ53, ϕ63, ϕ73, ψ43, ψ53, ψ63, ψ73, ψ83, ϕ44, ϕ54, ϕ64, ϕ74, ψ54, ψ64, ψ74, ψ84
8×5	50	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ϕ72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, ϕ33, ϕ43, ϕ53, ϕ63, ϕ73, ψ43, ψ53, ψ63, ψ73, ψ83, ϕ44, ϕ54, ϕ64, ϕ74, ψ54, ψ64, ψ74, ψ84, ϕ55, ϕ65, ϕ75, ψ65, ψ75, ψ85
8×6	54	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ϕ72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, ϕ33, ϕ43, ϕ53, ϕ63, ϕ73, ψ43, ψ53, ψ63, ψ73, ψ83, ϕ44, ϕ54, ϕ64, ϕ74, ψ54, ψ64, ψ74, ψ84, ϕ55, ϕ65, ϕ75, ψ65, ψ75, ψ85, ϕ66, ϕ76, ψ76, ψ86
8×7	56	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ϕ72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, ϕ33, ϕ43, ϕ53, ϕ63, ϕ73, ψ43, ψ53, ψ63, ψ73, ψ83, ϕ44, ϕ54, ϕ64, ϕ74, ψ54, ψ64, ψ74, ψ84, ϕ55, ϕ65, ϕ75, ψ65, ψ75, ψ85, ϕ66, ϕ76, ψ76, ψ86, ϕ77, ψ87
8×8	56	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ϕ72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, ϕ33, ϕ43, ϕ53, ϕ63, ϕ73, ψ43, ψ53, ψ63, ψ73, ψ83, ϕ44, ϕ54, ϕ64, ϕ74, ψ54, ψ64, ψ74, ψ84, ϕ55, ϕ65, ϕ75, ψ65, ψ75, ψ85, ϕ66, ϕ76, ψ76, ψ86, ϕ77, ψ87

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Table 9-72—Order of angles in the compressed beamforming feedback matrix for SU type feedback when used in an S1G band

Size of *V* (*Nr* × *Nc*)	Codebook Information field	Number of angles (*Na*)	The order of angles in the compressed beamforming feedback matrix
2×1	0	1	$\phi 11$
2×1	1	2	$\phi 11, \psi 21$
2×2	0 or 1	2	$\phi 11, \psi 21$
3×1	0	2	$\phi 11, \phi 21$
3×1	1	4	$\phi 11, \phi 21, \psi 21, \psi 31$
3×2	0 or 1	6	$\phi 11, \phi 21, \psi 21, \psi 31, \phi 22, \psi 32$
3×3	0 or 1	6	$\phi 11, \phi 21, \psi 21, \psi 31, \phi 22, \psi 32$
4×1	0	3	$\phi 11, \phi 21, \phi 31$
4×1	1	6	$\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41$
4×2	0 or 1	10	$\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41, \phi 22, \phi 32, \psi 32, \psi 42$
4×3	0 or 1	12	$\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41, \phi 22, \phi 32, \psi 32, \psi 42, \phi 33, \psi 43$
4×4	0 or 1	12	$\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41, \phi 22, \phi 32, \psi 32, \psi 42, \phi 33, \psi 43$

Table 9-73—Order of angles in the compressed beamforming feedback matrix for MU type feedback when used in an S1G band

Size of *V* (*Nr* × *Nc*)	Codebook Information field	Number of angles (*Na*)	The order of angles in the compressed beamforming feedback matrix
2×1	0 or 1	2	$\phi 11, \psi 21$
2×2	0 or 1	2	$\phi 11, \psi 21$
3×1	0 or 1	4	$\phi 11, \phi 21, \psi 21, \psi 31$
3×2	0 or 1	6	$\phi 11, \phi 21, \psi 21, \psi 31, \phi 22, \psi 32$
3×3	0 or 1	6	$\phi 11, \phi 21, \psi 21, \psi 31, \phi 22, \psi 32$
4×1	0 or 1	6	$\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41$
4×2	0 or 1	10	$\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41, \phi 22, \phi 32, \psi 32, \psi 42$
4×3	0 or 1	12	$\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41, \phi 22, \phi 32, \psi 32, \psi 42, \phi 33, \psi 43$
4×4	0 or 1	12	$\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41, \phi 22, \phi 32, \psi 32, \psi 42, \phi 33, \psi 43$

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Further restrictions on *Nc* are described in 10.36.5.

The angles are quantized as defined in Table 9-74.

Table 9-74—Quantization of angles

Quantized ψ	Quantized ϕ
$\psi = \frac{k\pi}{2^{b_\psi+1}} + \frac{\pi}{2^{b_\psi+2}}$ radians where $k = 0, 1, \ldots, 2^{b_\psi} - 1$ b_ψ is the number of bits used to quantize ψ (defined by the Codebook Information field of the VHT MIMO Control field (see 9.4.1.48)	$\phi = \frac{k\pi}{2^{b_\phi-1}} + \frac{\pi}{2^{b_\phi}}$ radians where $k = 0, 1, \ldots, 2^{b_\phi} - 1$ b_ϕ is the number of bits used to quantize ϕ (defined by the Codebook Information field of the VHT MIMO Control field (see 9.4.1.48)

The VHT Compressed Beamforming Report information has the structure defined in Table 9-75, where *Na* is the number of angles used for the compressed beamforming feedback matrix (see Table 9-71, Table 9-72, and Table 9-73).

Table 9-75—VHT Compressed Beamforming Report information

Field	Size (bits)	Meaning
Average SNR of Space-Time Stream 1	8	Signal-to-noise ratio at the beamformee for space-time stream 1 averaged over all data subcarriers. See Table 9-77.
...	…	…
Average SNR of Space-Time Stream *Nc*	8	Signal-to-noise ratio at the beamformee for space-time stream *Nc* averaged over all data subcarriers. See Table 9-77.
Compressed Beamforming Feedback Matrix *V* for subcarrier $k = scidx(0)$	$Na \times (b_\psi + b_\phi)/2$	Compressed beamforming feedback matrix as defined in Table 9-71, Table 9-72, or Table 9-73
Compressed Beamforming Feedback Matrix *V* for subcarrier $k = scidx(1)$	$Na \times (b_\psi + b_\phi)/2$	Compressed beamforming feedback matrix as defined in Table 9-71, Table 9-72, or Table 9-73

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Table 9-75—VHT Compressed Beamforming Report information *(continued)*

Field	Size (bits)	Meaning
Compressed Beamforming Feedback Matrix V for subcarrier $k = scidx(2)$	$Na \times (b_{\psi} + b_{\phi})/2$	Compressed beamforming feedback matrix as defined in Table 9-71, Table 9-72, or Table 9-73
...	…	…
Compressed Beamforming Feedback Matrix V for subcarrier $k = scidx(Ns - 1)$	$Na \times (b_{\psi} + b_{\phi})/2$	Compressed beamforming feedback matrix as defined in Table 9-71, Table 9-72, or Table 9-73
NOTE—*scidx()* is defined in Table 9-76.		

Ns is the number of subcarriers for which the compressed beamforming feedback matrix is sent back to the beamformer. A beamformee might choose to reduce *Ns* by using a method referred to as grouping, in which only a single Compressed Beamforming Feedback Matrix is reported for each group of *Ng* adjacent subcarriers. *Ns* is a function of the Channel Width and Grouping subfields in the VHT MIMO Control field (see 9.4.1.48). Table 9-76 lists *Ns*, the exact subcarrier indices and their order for which the compressed beamforming feedback matrix is sent back. No padding is present between angles in the VHT Compressed Beamforming Report information, even if they correspond to different subcarriers. If the size of the VHT Compressed Beamforming Report information is not an integer multiple of 8 bits, up to seven zeros are appended to the end of the field to make its size an integer multiple of 8 bits.

Table 9-76—Subcarrier indices for which a compressed beamforming feedback matrix is sent back

Channel Width	*Ng*	*Ns*	Subcarrier indices for which Compressed Beamforming Feedback Matrix subfield is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*-1)
20 MHz in a non-S1G band or 2 MHz in an S1G band	1	52	–28, –27, –26, –25, –24, –23, –22, –20, –19, –18, –17, –16, –15, –14, –13, –12, –11, –10, –9, –8, –6, –5, –4, –3, –2, –1, 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28 NOTE—Pilot subcarriers (± 21, ± 7) and DC subcarrier (0) are skipped
	2	30	–28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, –1, 1, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28
	4	16	–28, –24, –20, –16, –12, –8, –4, –1, 1, 4, 8, 12, 16, 20, 24, 28

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Table 9-76—Subcarrier indices for which a compressed beamforming feedback matrix is sent back *(continued)*

Channel Width	*Ng*	*Ns*	Subcarrier indices for which Compressed Beamforming Feedback Matrix subfield is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*-1)
40 MHz in a non-S1G band or 4 MHz in an S1G band	1	108	–58, –57, –56, –55, –54, –52, –51, –50, –49, –48, –47, –46, –45, –44, –43, –42, –41, –40, –39, –38, –37, –36, –35, –34, –33, –32, –31, –30, –29, –28, –27, –26, –24, –23, –22, –21, –20, –19, –18, –17, –16, –15, –14, –13, –12, –10, –9, –8, –7, –6, –5, –4, –3, –2, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 54, 55, 56, 57, 58 NOTE—Pilot subcarriers (± 53, ± 25, ± 11) and DC subcarriers (0, ± 1) are skipped.
	2	58	–58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, -22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58
	4	30	–58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6, –2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58
80 MHz in a non-S1G band or 8 MHz in an S1G band	1	234	–122, –121, –120, –119, –118, –117, –116, –115, –114, –113, –112, –111, –110, –109, –108, –107, –106, –105, –104, –102, –101, –100, –99, –98, –97, –96, –95, –94, –93, –92, –91, –90, –89, –88, –87, –86, –85, –84, –83, –82, –81, –80, –79, –78, –77, –76, –74, –73, –72, –71, –70, –69, –68, –67, –66, –65, –64, –63, –62, –61, –60, –59, –58, –57, –56, –55, –54, –53, –52, –51, –50, –49, –48, –47, –46, –45, –44, –43, –42, –41, –40, –38, –37, –36, –35, –34, –33, –32, –31, –30, –29, –28, –27, –26, –25, –24, –23, –22, –21, –20, –19, –18, –17, –16, –15, –14, –13, –12, –10, –9, –8, –7, –6, –5, –4, –3, –2, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122 NOTE—Pilot subcarriers (± 103, ± 75, ± 39, ± 11) and DC subcarriers (0, ± 1) are skipped.
80 MHz in a non-S1G band or 8 MHz in an S1G band	2	122	–122, –120, –118, –116, –114, –112, –110, –108, –106, –104, –102, –100, –98, –96, –94, –92, –90, –88, –86, –84, –82, –80, –78, –76, –74, –72, –70, –68, –66, –64, –62, –60, –58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122
	4	62	–122, –118, –114, –110, –106, –102, –98, –94, –90, –86, –82, –78, –74, –70, –66, –62, –58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6, –2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62, 66, 70, 74, 78, 82, 86, 90, 94, 98, 102, 106, 110, 114, 118, 122

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Table 9-76—Subcarrier indices for which a compressed beamforming feedback matrix is sent back *(continued)*

Channel Width	*Ng*	*Ns*	Subcarrier indices for which Compressed Beamforming Feedback Matrix subfield is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*-1)
160 MHz in a non-S1G band or 16 MHz in an S1G band	1	468	–250, –249, –248, –247, –246, –245, –244, –243, –242, –241, –240, –239, –238, –237, –236, –235, –234, –233, –232, –230, –229, –228, –227, –226, –225, –224, –223, –222, –221, –220, –219, –218, –217, –216, –215, –214, –213, –212, –211, –210, –209, –208, –207, –206, –205, –204, –202, –201, –200, –199, –198, –197, –196, –195, –194, –193, –192, –191, –190, –189, –188, –187, –186, –185, –184, –183, –182, –181, –180, –179, –178, –177, –176, –175, –174, –173, –172, –171, –170, –169, –168, –166, –165, –164, –163, –162, –161, –160, –159, –158, –157, –156, –155, –154, –153, –152, –151, –150, –149, –148, –147, –146, –145, –144, –143, –142, –141, –140, –138, –137, –136, –135, –134, –133, –132, –131, –130, –126, –125, –124, –123, –122, –121, –120, –119, –118, –116, –115, –114, –113, –112, –111, –110, –109, –108, –107, –106, –105, –104, -103, –102, –101, –100, –99, –98, –97, –96, –95, –94, –93, –92, –91, –90, –88, –87, –86, –85, –84, –83, –82, –81, –80, –79, –78, –77, –76, –75, –74, –73, –72, –71, –70, –69, –68, –67, –66, –65, –64, –63, –62, –61, –60, –59, –58, –57, –56, –55, –54, –52, –51, –50, –49, –48, –47, –46, –45, –44, –43, –42, –41, –40, –39, –38, –37, –36, –35, –34, –33, –32, –31, –30, –29, –28, –27, –26, –24, –23, –22, –21, –20, –19, –18, –17, –16, –15, –14, –13, –12, –11, –10, –9, –8, –7, –6, –5, –4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 118, 119, 120, 121, 122, 123, 124, 125, 126, 130, 131, 132, 133, 134, 135, 136, 137, 138, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250 NOTE—Pilot subcarriers (± 231, ± 203, ± 167, ± 139, ± 117, ± 89, ± 53, ± 25), DC subcarriers (0, ± 1, ± 2, ± 3, ± 4, ± 5) and subcarriers ± 127, ± 128, ± 129 are skipped.

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Table 9-76—Subcarrier indices for which a compressed beamforming feedback matrix is sent back *(continued)*

Channel Width	*Ng*	*Ns*	Subcarrier indices for which Compressed Beamforming Feedback Matrix subfield is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*-1)
160 MHz in a non-S1G band or 16 MHz in an S1G band	2	244	–250, –248, –246, –244, –242, –240, –238, –236, –234, –232, –230, –228, –226, –224, –222, –220, –218, –216, –214, –212, –210, –208, –206, –204, –202, –200, –198, –196, –194, –192, –190, –188, –186, –184, –182, –180, –178, –176, –174, –172, –170, –168, –166, –164, –162, –160, –158, –156, –154, –152, –150, –148, –146, –144, –142, –140, –138, –136, –134, –132, –130, –126, –124, –122, –120, –118, –116, –114, –112, –110, -108, –106, –104, –102, –100, –98, –96, –94, –92, –90, –88, –86, –84, –82, –80, –78, –76, –74, –72, –70, –68, –66, –64, –62, –60, –58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166, 168, 170, 172, 174, 176, 178, 180, 182, 184, 186, 188, 190, 192, 194, 196, 198, 200, 202, 204, 206, 208, 210, 212, 214, 216, 218, 220, 222, 224, 226, 228, 230, 232, 234, 236, 238, 240, 242, 244, 246, 248, 250 NOTE—DC subcarriers 0, ± 2, ± 4, and ± 128 are skipped.
	4	124	–250, –246, –242, –238, –234, –230, –226, –222, –218, –214, –210, –206, –202, –198, –194, –190, –186, –182, –178, –174, –170, –166, –162, –158, –154, –150, –146, –142, –138, –134, –130, –126, –122, –118, –114, –110, –106, –102, –98, –94, –90, –86, –82, –78, –74, –70, –66, –62, –58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62, 66, 70, 74, 78, 82, 86, 90, 94, 98, 102, 106, 110, 114, 118, 122, 126, 130, 134, 138, 142, 146, 150, 154, 158, 162, 166, 170, 174, 178, 182, 186, 190, 194, 198, 202, 206, 210, 214, 218, 222, 226, 230, 234, 238, 242, 246, 250 NOTE—DC subcarriers ± 2 are skipped.

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Table 9-76—Subcarrier indices for which a compressed beamforming feedback matrix is sent back *(continued)*

Channel Width	*Ng*	*Ns*	Subcarrier indices for which Compressed Beamforming Feedback Matrix subfield is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*-1)
80+80 MHz	1	468	–122(L), –121(L), –120(L), –119(L), –118(L), –117(L), –116(L), –115(L), –114(L), –113(L), –112(L), –111(L), –110(L), –109(L), –108(L), –107(L), –106(L), –105(L), -104(L), –102(L), –101(L), –100(L), –99(L), –98(L), –97(L), –96(L), –95(L), –94(L), –93(L), –92(L), –91(L), –90(L), –89(L), –88(L), –87(L), –86(L), –85(L), –84(L), –83(L), –82(L), –81(L), –80(L), –79(L), –78(L), –77(L), –76(L), –74(L), –73(L), –72(L), –71(L), –70(L), –69(L), –68(L), –67(L), –66(L), –65(L), –64(L), –63(L), –62(L), –61(L), –60(L), –59(L), –58(L), –57(L), –56(L), –55(L), –54(L), –53(L), –52(L), –51(L), –50(L), –49(L), –48(L), –47(L), –46(L), –45(L), –44(L), –43(L), –42(L), –41(L), –40(L), –38(L), –37(L), –36(L), –35(L), –34(L), –33(L), –32(L), –31(L), –30(L), –29(L), –28(L), –27(L), –26(L), –25(L), –24(L), –23(L), –22(L), –21(L), –20(L), –19(L), –18(L), –17(L), –16(L), –15(L), –14(L), –13(L), –12(L), –10(L), –9(L), –8(L), –7(L), –6(L), –5(L), –4(L), –3(L), –2(L), 2(L), 3(L), 4(L), 5(L), 6(L), 7(L), 8(L), 9(L), 10(L), 12(L), 13(L), 14(L), 15(L), 16(L), 17(L), 18(L), 19(L), 20(L), 21(L), 22(L), 23(L), 24(L), 25(L), 26(L), 27(L), 28(L), 29(L), 30(L), 31(L), 32(L), 33(L), 34(L), 35(L), 36(L), 37(L), 38(L), 40(L), 41(L), 42(L), 43(L), 44(L), 45(L), 46(L), 47(L), 48(L), 49(L), 50(L), 51(L), 52(L), 53(L), 54(L), 55(L), 56(L), 57(L), 58(L), 59(L), 60(L), 61(L), 62(L), 63(L), 64(L), 65(L), 66(L), 67(L), 68(L), 69(L), 70(L), 71(L), 72(L), 73(L), 74(L), 76(L), 77(L), 78(L), 79(L), 80(L), 81(L), 82(L), 83(L), 84(L), 85(L), 86(L), 87(L), 88(L), 89(L), 90(L), 91(L), 92(L), 93(L), 94(L), 95(L), 96(L), 97(L), 98(L), 99(L), 100(L), 101(L), 102(L), 104(L), 105(L), 106(L), 107(L), 108(L), 109(L), 110(L), 111(L), 112(L), 113(L), 114(L), 115(L), 116(L), 117(L), 118(L), 119(L), 120(L), 121(L), 122(L), –122(H), –121(H), –120(H), –119(H), –118(H), –117(H), –116(H), –115(H), –114(H), –113(H), –112(H), –111(H), –110(H), –109(H), –108(H), –107(H), –106(H), –105(H), –104(H), -102(H), -101(H), –100(H), –99(H), –98(H), –97(H), –96(H), –95(H), –94(H), –93(H), –92(H), –91(H), –90(H), –89(H), –88(H), –87(H), –86(H), –85(H), –84(H), –83(H), -82(H), –81(H), –80(H), –79(H), –78(H), –77(H), –76(H), –74(H), –73(H), –72(H), –71(H), –70(H), –69(H), –68(H), –67(H), –66(H), –65(H), –64(H), –63(H), –62(H), –61(H), –60(H), –59(H), –58(H), –57(H), –56(H), –55(H), –54(H), –53(H), –52(H), –51(H), –50(H), –49(H), –48(H), –47(H), –46(H), –45(H), –44(H), –43(H), –42(H), –41(H), –40(H), –38(H), –37(H), –36(H), –35(H), –34(H), –33(H), –32(H), –31(H), –30(H), –29(H), –28(H), –27(H), –26(H), –25(H), –24(H), –23(H), –22(H), –21(H), –20(H), –19(H), –18(H), –17(H), –16(H), –15(H), –14(H), –13(H), –12(H), –10(H), –9(H), –8(H), –7(H), –6(H), –5(H), –4(H), –3(H), –2(H), 2(H), 3(H), 4(H), 5(H), 6(H), 7(H), 8(H), 9(H), 10(H), 12(H), 13(H), 14(H), 15(H), 16(H), 17(H), 18(H), 19(H), 20(H), 21(H), 22(H), 23(H), 24(H), 25(H), 26(H), 27(H), 28(H), 29(H), 30(H), 31(H), 32(H), 33(H), 34(H), 35(H), 36(H), 37(H), 38(H), 40(H), 41(H), 42(H), 43(H), 44(H), 45(H), 46(H), 47(H), 48(H), 49(H), 50(H), 51(H), 52(H), 53(H), 54(H), 55(H), 56(H), 57(H), 58(H), 59(H), 60(H), 61(H), 62(H), 63(H), 64(H), 65(H), 66(H), 67(H), 68(H), 69(H), 70(H), 71(H), 72(H), 73(H), 74(H), 76(H), 77(H), 78(H), 79(H), 80(H), 81(H), 82(H), 83(H), 84(H), 85(H), 86(H), 87(H), 88(H), 89(H), 90(H), 91(H), 92(H), 93(H), 94(H), 95(H), 96(H), 97(H), 98(H), 99(H), 100(H), 101(H), 102(H), 104(H), 105(H), 106(H), 107(H), 108(H), 109(H), 110(H), 111(H), 112(H), 113(H), 114(H), 115(H), 116(H), 117(H), 118(H), 119(H), 120(H), 121(H), 122(H) NOTE 1— *x*(L) denotes subcarrier index *x* in the frequency segment lower in frequency, and *x*(H) denotes subcarrier index *x* in the frequency segment higher in frequency. NOTE 2—Pilot subcarriers (± 103, ± 75, ± 39, ± 11) and DC subcarriers (0, ± 1) are skipped in each frequency segment.

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Table 9-76—Subcarrier indices for which a compressed beamforming feedback matrix is sent back *(continued)*

Channel Width	*Ng*	*Ns*	Subcarrier indices for which Compressed Beamforming Feedback Matrix subfield is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*-1)
80+80 MHz	2	244	–122(L), –120(L), –118(L), –116(L), –114(L), –112(L), –110(L), –108(L), –106(L), -104(L), –102(L), –100(L), –98(L), –96(L), –94(L), –92(L), –90(L), –88(L), –86(L), –84(L), –82(L), –80(L), –78(L), –76(L), –74(L), –72(L), –70(L), –68(L), –66(L), –64(L), –62(L), –60(L), –58(L), –56(L), –54(L), –52(L), –50(L), –48(L), –46(L), –44(L), –42(L), –40(L), –38(L), –36(L), –34(L), –32(L), –30(L), –28(L), –26(L), –24(L), –22(L), –20(L), –18(L), –16(L), –14(L), –12(L), –10(L), –8(L), –6(L), –4(L), –2(L), 2(L), 4(L), 6(L), 8(L), 10(L), 12(L), 14(L), 16(L), 18(L), 20(L), 22(L), 24(L), 26(L), 28(L), 30(L), 32(L), 34(L), 36(L), 38(L), 40(L), 42(L), 44(L), 46(L), 48(L), 50(L), 52(L), 54(L), 56(L), 58(L), 60(L), 62(L), 64(L), 66(L), 68(L), 70(L), 72(L), 74(L), 76(L), 78(L), 80(L), 82(L), 84(L), 86(L), 88(L), 90(L), 92(L), 94(L), 96(L), 98(L), 100(L), 102(L), 104(L), 106(L), 108(L), 110(L), 112(L), 114(L), 116(L), 118(L), 120(L), 122(L), –122(H), –120(H), –118(H), –116(H), –114(H), –112(H), –110(H), –108(H), –106(H), –104(H), –102(H), –100(H), –98(H), –96(H), –94(H), –92(H), –90(H), –88(H), –86(H), –84(H), –82(H), –80(H), –78(H), –76(H), –74(H), –72(H), –70(H), –68(H), –66(H), –64(H), –62(H), –60(H), –58(H), –56(H), –54(H), –52(H), –50(H), –48(H), –46(H), –44(H), –42(H), –40(H), –38(H), –36(H), –34(H), –32(H), –30(H), –28(H), –26(H), –24(H), –22(H), –20(H), –18(H), –16(H), –14(H), –12(H), –10(H), –8(H), –6(H), -4(H), –2(H), 2(H), 4(H), 6(H), 8(H), 10(H), 12(H), 14(H), 16(H), 18(H), 20(H), 22(H), 24(H), 26(H), 28(H), 30(H), 32(H), 34(H), 36(H), 38(H), 40(H), 42(H), 44(H), 46(H), 48(H), 50(H), 52(H), 54(H), 56(H), 58(H), 60(H), 62(H), 64(H), 66(H), 68(H), 70(H), 72(H), 74(H), 76(H), 78(H), 80(H), 82(H), 84(H), 86(H), 88(H), 90(H), 92(H), 94(H), 96(H), 98(H), 100(H), 102(H), 104(H), 106(H), 108(H), 110(H), 112(H), 114(H), 116(H), 118(H), 120(H), 122(H)
	4	124	–122(L), –118(L), –114(L), –110(L), –106(L), –102(L), –98(L), –94(L), –90(L), –86(L), –82(L), –78(L), –74(L), –70(L), –66(L), –62(L), –58(L), –54(L), –50(L), –46(L), –42(L), –38(L), –34(L), –30(L), –26(L), –22(L), –18(L), –14(L), –10(L), –6(L), –2(L), 2(L), 6(L), 10(L), 14(L), 18(L), 22(L), 26(L), 30(L), 34(L), 38(L), 42(L), 46(L), 50(L), 54(L), 58(L), 62(L), 66(L), 70(L), 74(L), 78(L), 82(L), 86(L), 90(L), 94(L), 98(L), 102(L), 106(L), 110(L), 114(L), 118(L), 122(L), –122(H), –118(H), –114(H), –110(H), –106(H), –102(H), –98(H), –94(H), –90(H), -86(H), –82(H), –78(H), –74(H), –70(H), –66(H), –62(H), –58(H), –54(H), –50(H), –46(H), –42(H), –38(H), –34(H), –30(H), –26(H), –22(H), –18(H), –14(H), –10(H), –6(H), –2(H), 2(H), 6(H), 10(H), 14(H), 18(H), 22(H), 26(H), 30(H), 34(H), 38(H), 42(H), 46(H), 50(H), 54(H), 58(H), 62(H), 66(H), 70(H), 74(H), 78(H), 82(H), 86(H), 90(H), 94(H), 98(H), 102(H), 106(H), 110(H), 114(H), 118(H), 122(H)

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The Average SNR of Space-Time Stream *i* subfield in the Table 9-75 is an 8-bit 2s complement integer whose definition is shown in Table 9-77.

Table 9-77—Average SNR of Space-Time Stream *i* subfield

Average SNR of Space-Time Stream *i* subfield	$AvgSNR_i$
–128	≤ –10 dB
–127	–9.75 dB
–126	–9.5 dB
…	…
+126	53.5 dB
+127	≥ 53.75 dB

The $AvgSNR_i$ in Table 9-77 is found by computing the SNR per subcarrier in decibels for the subcarriers identified in Table 9-76, and then computing the arithmetic mean of those values. Each SNR value per subcarrier in stream *i* (before being averaged) corresponds to the SNR associated with the column *i* of the beamforming feedback matrix *V* determined at the beamformee. Each SNR corresponds to the predicted SNR at the beamformee when the beamformer applies all columns of the matrix *V*.

A STA with a 40 MHz, 80 MHz, or 160 MHz operating channel width and sending feedback for a 20 MHz channel width includes only subcarriers corresponding to the primary 20 MHz channel in the Compressed Beamforming Feedback Matrix subfield.

A STA with an 80 MHz or 160 MHz operating channel width and sending feedback for a 40 MHz channel width includes only subcarriers corresponding to the primary 40 MHz channel in the Compressed Beamforming Feedback Matrix subfield.

A STA with a 160 MHz or 80+80 MHz operating channel width and sending feedback for an 80 MHz channel width includes only subcarriers corresponding to the primary 80 MHz channel in the Compressed Beamforming Feedback Matrix subfield.

9.4.1.50 TVHT Compressed Beamforming Report field

The format of the TVHT Compressed Beamforming Report field is the same as the VHT Compressed Beamforming Report field in 9.4.1.49 except for the following modifications.

The subcarriers for which Compressed Beamforming Feedback Matrix subfield is sent in Table 9-76 for 40 MHz are used for each basic channel unit (BCU) in TVHT_MODE_1 and TVHT_MODE_2N. See subcarrier location description in Table 22-9.

For TVHT_MODE_2C with 6 MHz and 8 MHz channelization, the subcarriers for which Compressed Beamforming Feedback Matrix subfield is sent in the Lower BCU are based on subtracting 72 from the values shown in Table 9-76 and for the Upper BCU by adding 72.

For TVHT_MODE_2C with 7 MHz channelization, the subcarriers for which Compressed Beamforming Feedback Matrix subfield is sent in the Lower BCU are based on subtracting 84 from the values shown in Table 9-76 and for the Upper BCU by adding 84.

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For TVHT_MODE_4C with 6 MHz and 8 MHz channelization, the subcarriers for which Compressed Beamforming Feedback Matrix subfield is sent in the lowest, second to lowest, second to highest, and highest BCUs are based on subtracting 216, subtracting 72, adding 72, and adding 216 from the values shown in Table 9-76, respectively.

For TVHT_MODE_4C with 7 MHz channelization, the subcarriers for which Compressed Beamforming Feedback Matrix subfield is sent in the lowest, second to lowest, second to highest, and highest BCUs are based on subtracting 252, subtracting 84, adding 84, and adding 252 from the values shown in Table 9-76, respectively.

For TVHT_MODE_4N channelization, the subcarriers for which Compressed Beamforming Feedback Matrix subfield is sent in each of the two noncontiguous frequency segments are as described for TVHT_MODE_2C.

A STA with a TVHT_2W, TVHT_4W, TVHT_W+W, or TVHT_2W+2W operating channel width and sending feedback for a TVHT_W channel width includes a representation of the compressed beamforming feedback matrices of the subcarriers corresponding to the primary TVHT_W channel in the Compressed Beamforming Feedback Matrix subfield.

A STA with a TVHT_4W or TVHT_2W+2W operating channel width and sending feedback for a TVHT_2W channel width includes a representation of the compressed beamforming feedback matrices of the subcarriers corresponding to the primary TVHT_2W channel in the Compressed Beamforming Feedback Matrix subfield.

9.4.1.51 MU Exclusive Beamforming Report field

The MU Exclusive Beamforming Report field is used by the VHT compressed beamforming feedback (see 9.6.22.2) to carry explicit feedback information in the form of delta SNRs. The information in the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field can be used by the transmit MU beamformer to determine steering matrices Q, as described in 10.34.3, 19.3.12.3, and 21.3.11.

The size of the MU Exclusive Beamforming Report field depends on the values in the VHT MIMO Control field. The MU Exclusive Beamforming Report field contains MU Exclusive Beamforming Report information or successive (possibly zero-length) portions thereof in the case of segmented VHT compressed beamforming feedback (see 10.36.5). The MU Exclusive Beamforming Report information is included in the VHT compressed beamforming feedback if the Feedback Type subfield in the VHT MIMO Control field indicates MU (see 9.4.1.48).

The MU Exclusive Beamforming Report information consists of Delta SNR subfields for each space-time stream (1 to Nc) of a subset of the subcarriers typically spaced $2Ng$ apart, where Ng is signaled in the Grouping subfield of the VHT MIMO Control field, starting from the lowest frequency subcarrier and continuing to the highest frequency subcarrier. No padding is present between $\Delta SNR_{k,i}$ in the MU Exclusive Beamforming Report field, even if they correspond to different subcarriers. The subset of subcarriers included is determined by the values of the Channel Width and Grouping subfields of the VHT MIMO Control field as listed in Table 9-79. For each subcarrier included, the deviation in dB of the SNR of that subcarrier for each column of V relative to the average SNR of the corresponding space-time stream is computed using Equation (9-2).

$$\Delta SNR_{k,i} = min(max(\text{Round}(10\log_{10}\left(\frac{\left\|H_k V_{k,i}\right\|^2}{N}\right) - \overline{SNR_i}), -8), 7) \quad (9\text{-}2)$$

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where

k is the subcarrier index in the range $scidx(0)$, …, $scidx(Ns'–1)$
i is the space-time stream index in the range 1, …, Nc
H_k is the estimated MIMO channel for subcarrier k
$V_{k,i}$ is column i of the beamforming matrix V for subcarrier k
N is the average noise plus interference power, measured at the beamformee, that was used to calculate $\overline{SNR_i}$
$\overline{SNR_i}$ is the average SNR of space-time stream i reported in the VHT Compressed Beamforming Report information (Average SNR of Space-Time Stream i field)

Each Delta SNR subfield contains the $\Delta SNR_{k,i}$ computed using Equation (9-2) and quantized to 4 bits in the range –8 dB to 7 dB with 1 dB granularity. The structure of the MU Exclusive Beamforming Report field is shown in Table 9-78.

Table 9-78—MU Exclusive Beamforming Report information

Field	Size (bits)	Meaning
Delta SNR for space-time stream 1 for subcarrier k = *scidx(0)*	4	$\Delta SNR_{scidx(0),1}$ as defined in Equation (9-2)
…	…	…
Delta SNR for space-time stream Nc for subcarrier k = *scidx(0)*	4	$\Delta SNR_{scidx(0),Nc}$ as defined in Equation (9-2)
Delta SNR for space-time stream 1 for subcarrier k = *scidx(1)*	4	$\Delta SNR_{scidx(1),1}$ as defined in Equation (9-2)
…	…	…
Delta SNR for space-time stream Nc for subcarrier k = *scidx(1)*	4	$\Delta SNR_{scidx(1),Nc}$ as defined in Equation (9-2)
…	…	…
Delta SNR for space-time stream 1 for subcarrier k = *scidx(Ns'–1)*	4	$\Delta SNR_{scidx(Ns'-1),1}$ as defined in Equation (9-2)
…	…	…
Delta SNR for space-time stream Nc for subcarrier k = *scidx(Ns'–1)*	4	$\Delta SNR_{scidx(Ns'-1),Nc}$ as defined in Equation (9-2)
NOTE—*scidx*() is defined in Table 9-79.		

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In Table 9-78, *Ns*' is the number of subcarriers for which the Delta SNR subfield is sent back to the beamformer. Table 9-79 shows *Ns*', the exact subcarrier indices and their order for which the Delta SNR is sent back.

Table 9-79—Number of subcarriers and subcarrier mapping

Channel Width	*Ng*	*Ns*'	Subcarrier indices for which the Delta SNR subfield is sent: *scidx*(0), *scidx*(1), … *scidx*(*Ns*'–1)
20 MHz	1	30	–28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, –1, 1, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28
	2	16	–28, –24, –20, –16, –12, –8, –4, –1, 1, 4, 8, 12, 16, 20, 24, 28
	4	10	–28, –20, –12, –4, –1, 1, 4, 12, 20, 28
40 MHz	1	58	–58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58
	2	30	–58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6, –2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58
	4	16	–58, –50, –42, –34, –26, –18, –10, –2, 2, 10, 18, 26, 34, 42, 50, 58
80 MHz	1	122	–122, –120, –118, –116, –114, –112, –110, –108, –106, –104, –102, –100, –98, –96, –94, –92, –90, –88, –86, –84, –82, –80, –78, –76, –74, –72, –70, –68, –66, –64, –62, –60, –58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122
	2	62	–122, –118, –114, –110, –106, –102, –98, –94, –90, –86, –82, –78, –74, –70, –66, –62, –58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6, –2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62, 66, 70, 74, 78, 82, 86, 90, 94, 98, 102, 106, 110, 114, 118, 122
	4	32	–122, –114, –106, –98, –90, –82, –74, –66, –58, –50, –42, –34, –26, –18, –10, –2, 2, 10, 18, 26, 34, 42, 50, 58, 66, 74, 82, 90, 98, 106, 114, 122
160 MHz	1	244	–250, –248, –246, –244, –242, –240, –238, –236, –234, –232, –230, –228, –226, –224, –222, –220, –218, –216, –214, –212, –210, –208, –206, –204, –202, –200, –198, –196, –194, –192, –190, –188, –186, –184, –182, –180, –178, –176, –174, –172, –170, –168, –166, –164, –162, –160, –158, –156, –154, –152, –150, –148, –146, –144, –142, –140, –138, –136, –134, –132, –130, –126, –124, –122, –120, –118, –116, –114, –112, –110, –108, –106, –104, –102, –100, –98, –96, –94, –92, –90, –88, –86, –84, –82, –80, –78, –76, –74, –72, –70, –68, –66, –64, –62, –60, –58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166, 168, 170, 172, 174, 176, 178, 180, 182, 184, 186, 188, 190, 192, 194, 196, 198, 200, 202, 204, 206, 208, 210, 212, 214, 216, 218, 220, 222, 224, 226, 228, 230, 232, 234, 236, 238, 240, 242, 244, 246, 248, 250 NOTE—Subcarriers 0, ± 2, ± 4, and ± 128 are skipped.

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Table 9-79—Number of subcarriers and subcarrier mapping *(continued)*

Channel Width	*Ng*	*Ns*'	Subcarrier indices for which the Delta SNR subfield is sent: *scidx*(0), *scidx*(1), … *scidx*(*Ns*'–1)
160 MHz	2	124	–250, –246, –242, –238, –234, –230, –226, –222, –218, –214, –210, –206, –202, –198, –194, –190, –186, –182, –178, –174, –170, –166, –162, –158, –154, –150, –146, –142, –138, –134, –130, –126, –122, –118, –114, –110, –106, –102, –98, –94, –90, –86, –82, –78, –74, –70, –66, –62, –58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62, 66, 70, 74, 78, 82, 86, 90, 94, 98, 102, 106, 110, 114, 118, 122, 126, 130, 134, 138, 142, 146, 150, 154, 158, 162, 166, 170, 174, 178, 182, 186, 190, 194, 198, 202, 206, 210, 214, 218, 222, 226, 230, 234, 238, 242, 246, 250 NOTE—Subcarriers ± 2 are skipped.
	4	64	–250, –242, –234, –226, –218, –210, –202, –194, –186, –178, –170, –162, –154, –146, –138, –130, –126, –118, –110, –102, –94, –86, –78, –70, –62, –54, –46, –38, –30, –22, –14, -6, 6, 14, 22, 30, 38, 46, 54, 62, 70, 78, 86, 94, 102, 110, 118, 126, 130, 138, 146, 154, 162, 170, 178, 186, 194, 202, 210, 218, 226, 234, 242, 250
80+80 MHz	1	244	–122(L), –120(L), –118(L), –116(L), –114(L), –112(L), –110(L), –108(L), –106(L), –104(L), –102(L), –100(L), –98(L), –96(L), –94(L), –92(L), –90(L), –88(L), –86(L), –84(L), –82(L), –80(L), –78(L), –76(L), –74(L), –72(L), –70(L), –68(L), –66(L), –64(L), –62(L), –60(L), –58(L), –56(L), –54(L), –52(L), –50(L), –48(L), –46(L), –44(L), –42(L), –40(L), –38(L), –36(L), –34(L), –32(L), –30(L), –28(L), –26(L), –24(L), –22(L), –20(L), –18(L), –16(L), –14(L), –12(L), –10(L), –8(L), –6(L), –4(L), –2(L), 2(L), 4(L), 6(L), 8(L), 10(L), 12(L), 14(L), 16(L), 18(L), 20(L), 22(L), 24(L), 26(L), 28(L), 30(L), 32(L), 34(L), 36(L), 38(L), 40(L), 42(L), 44(L), 46(L), 48(L), 50(L), 52(L), 54(L), 56(L), 58(L), 60(L), 62(L), 64(L), 66(L), 68(L), 70(L), 72(L), 74(L), 76(L), 78(L), 80(L), 82(L), 84(L), 86(L), 88(L), 90(L), 92(L), 94(L), 96(L), 98(L), 100(L), 102(L), 104(L), 106(L), 108(L), 110(L), 112(L), 114(L), 116(L), 118(L), 120(L), 122(L), –122(H), –120(H), –118(H), –116(H), –114(H), –112(H), –110(H), –108(H), –106(H), –104(H), –102(H), –100(H), –98(H), –96(H), –94(H), –92(H), –90(H), –88(H), –86(H), –84(H), –82(H), –80(H), –78(H), –76(H), –74(H), –72(H), –70(H), –68(H), –66(H), –64(H), –62(H), –60(H), –58(H), –56(H), –54(H), –52(H), –50(H), –48(H), –46(H), –44(H), –42(H), –40(H), –38(H), –36(H), –34(H), –32(H), –30(H), –28(H), –26(H), –24(H), –22(H), –20(H), –18(H), –16(H), –14(H), –12(H), –10(H), –8(H), –6(H), –4(H), –2(H), 2(H), 4(H), 6(H), 8(H), 10(H), 12(H), 14(H), 16(H), 18(H), 20(H), 22(H), 24(H), 26(H), 28(H), 30(H), 32(H), 34(H), 36(H), 38(H), 40(H), 42(H), 44(H), 46(H), 48(H), 50(H), 52(H), 54(H), 56(H), 58(H), 60(H), 62(H), 64(H), 66(H), 68(H), 70(H), 72(H), 74(H), 76(H), 78(H), 80(H), 82(H), 84(H), 86(H), 88(H), 90(H), 92(H), 94(H), 96(H), 98(H), 100(H), 102(H), 104(H), 106(H), 108(H), 110(H), 112(H), 114(H), 116(H), 118(H), 120(H), 122(H)
	2	124	–122(L), –118(L), –114(L), –110(L), –106(L), –102(L), –98(L), –94(L), –90(L), –86(L), –82(L), –78(L), –74(L), –70(L), –66(L), –62(L), –58(L), –54(L), –50(L), –46(L), –42(L), –38(L), –34(L), –30(L), –26(L), –22(L), –18(L), –14(L), –10(L), –6(L), –2(L), 2(L), 6(L), 10(L), 14(L), 18(L), 22(L), 26(L), 30(L), 34(L), 38(L), 42(L), 46(L), 50(L), 54(L), 58(L), 62(L), 66(L), 70(L), 74(L), 78(L), 82(L), 86(L), 90(L), 94(L), 98(L), 102(L), 106(L), 110(L), 114(L), 118(L), 122(L), –122(H), –118(H), –114(H), –110(H), –106(H), –102(H), –98(H), –94(H), –90(H), –86(H), –82(H), –78(H), –74(H), –70(H), –66(H), –62(H), –58(H), –54(H), –50(H), –46(H), –42(H), –38(H), –34(H), –30(H), –26(H), –22(H), –18(H), –14(H), –10(H), –6(H), –2(H), 2(H), 6(H), 10(H), 14(H), 18(H), 22(H), 26(H), 30(H), 34(H), 38(H), 42(H), 46(H), 50(H), 54(H), 58(H), 62(H), 66(H), 70(H), 74(H), 78(H), 82(H), 86(H), 90(H), 94(H), 98(H), 102(H), 106(H), 110(H), 114(H), 118(H), 122(H)

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Table 9-79—Number of subcarriers and subcarrier mapping *(continued)*

Channel Width	*Ng*	*Ns*'	Subcarrier indices for which the Delta SNR subfield is sent: *scidx*(0), *scidx*(1), … *scidx*(*Ns*'–1)
80+80 MHz	4	64	–122(L), –114(L), –106(L), –98(L), –90(L), –82(L), –74(L), –66(L), –58(L), –50(L), -42(L), –34(L), –26(L), –18(L), –10(L), –2(L), 2(L), 10(L), 18(L), 26(L), 34(L), 42(L), 50(L), 58(L), 66(L), 74(L), 82(L), 90(L), 98(L), 106(L), 114(L), 122(L), –122(H), –114(H), –106(H), –98(H), –90(H), –82(H), –74(H), –66(H), –58(H), –50(H), –42(H), –34(H), –26(H), –18(H), –10(H), –2(H), 2(H), 10(H), 18(H), 26(H), 34(H), 42(H), 50(H), 58(H), 66(H), 74(H), 82(H), 90(H), 98(H), 106(H), 114(H), 122(H)

NOTE 1—*scidx*() is defined in Table 9-78.

NOTE 2— *x*(L) denotes subcarrier index *x* in the frequency segment lower in frequency, and *x*(H) denotes subcarrier index *x* in the frequency segment higher in frequency.

9.4.1.52 TVHT MU Exclusive Beamforming Report field

See 9.4.1.51 with the following modifications:

— For each BCU in TVHT_MODE_1 and TVHT_MODE_2N, the subcarriers used in the Delta SNR subfield are defined in Table 9-79 for 40 MHz. See the subcarrier location description in Table 22-9.

— For TVHT_MODE_2C with 6 MHz and 8 MHz channelization, the subcarriers for which Delta SNR subfield is sent in the Lower BCU are based on subtracting 72 from the values shown in Table 9-79 and for the Upper BCU by adding 72.

— For TVHT_MODE_2C with 7 MHz channelization, the subcarriers for which Delta SNR subfield is sent in the Lower BCU are based on subtracting 84 from the values shown in Table 9-79 and for the Upper BCU by adding 84.

— For TVHT_MODE_4C with 6 MHz and 8 MHz channelization, the subcarriers for which Delta SNR subfield is sent in the lowest, second to lowest, second to highest, and highest BCUs are based on subtracting 216, subtracting 72, adding 72, and adding 216 from the values shown in Table 9-79, respectively.

— For TVHT_MODE_4C with 7 MHz channelization, the subcarriers for which Delta SNR subfield is sent in the lowest, second to lowest, second to highest, and highest BCUs are based on subtracting 252, subtracting 84, adding 84, and adding 252 from the values shown in Table 9-79, respectively.

— For TVHT_MODE_4N channelization, the subcarriers for which Delta SNR subfield is sent in each of the two noncontiguous frequency segments are as described for TVHT_MODE_2C.

9.4.1.53 Operating Mode field

The Operating Mode field is present in the Operating Mode Notification frame (see 9.6.22.4) and Operating Mode Notification element (see 9.4.2.165).

The Operating Mode field for a non-S1G STA is shown in Figure 9-135.

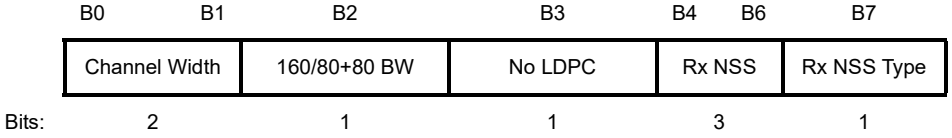

Figure 9-135—Operating Mode field format when it is carried in a non-S1G PPDU

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The Operating Mode field in an S1G PPDU is shown in Figure 9-136.

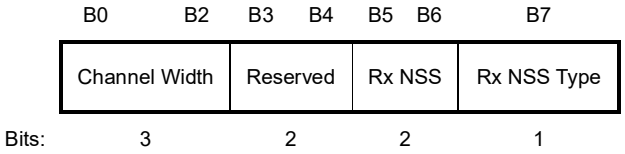

Figure 9-136—Operating Mode field format when it is carried in an S1G PPDU

The STA transmitting this field indicates its current operating channel width and the number of spatial streams it can receive using the settings defined in Table 9-80.

Table 9-80—Subfield values of the Operating Mode field

Subfield	Description
Channel Width	If the Rx NSS Type subfield is 0, indicates the supported channel width: In a VHT STA, see Table 9-81 In a TVHT STA: Set to 0 for TVHT_W Set to 1 for TVHT_2W and TVHT_W+W Set to 2 for TVHT_4W and TVHT_2W+2W The value 3 is reserved. In an S1G STA: Set to 0 for 1 MHz Set to 1 for 2 MHz Set to 2 for 4 MHz Set to 3 for 8 MHz Set to 4 for 16 MHz Reserved for values 5-7 Reserved if the Rx NSS Type subfield is 1.
160/80+80 BW	This subfield, combined with the Channel Width subfield, the Supported Channel Width Set subfield and the Supported VHT-MCS and NSS Set subfield indicates whether 80+80 MHz and 160 MHz operation is supported. In a VHT STA, see Table 9-81. In a TVHT STA, this field is reserved. In a STA with dot11VHTExtendedNSSBWCapable either equal to false or not present, this field is set to 0.
No LDPC	Set to 1 to indicate that the STA transmitting this field prefers not to receive LDPC-encoded PPDUs; set to 0 otherwise.

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Table 9-80—Subfield values of the Operating Mode field *(continued)*

Subfield	Description
Rx NSS	If the Rx NSS Type subfield is 0, this field, combined with other information described in 9.4.2.157.3, indicates the maximum number of spatial streams that the STA can receive. If the Rx NSS Type subfield is 1, this field indicates the maximum number of spatial streams that the STA can receive as a beamformee in an SU PPDU using a beamforming steering matrix derived from a VHT Compressed Beamforming report with Feedback Type subfield indicating MU in the corresponding VHT Compressed Beamforming frame sent by the STA. In a non-S1G STA: Set to 0 for $N_{SS} = 1$ Set to 1 for $N_{SS} = 2$ … Set to 7 for $N_{SS} = 8$ In an S1G STA: Set to 0 for $N_{SS} = 1$ Set to 1 for $N_{SS} = 2$ Set to 2 for $N_{SS} = 3$ Set to 3 for $N_{SS} = 4$ NOTE—In a STA with dot11VHTExtendedNSSBWCapable equal to true, NSS might be further modified per Table 9-81.
Rx NSS Type	Set to 0 to indicate that the Rx NSS subfield carries the maximum number of spatial streams that the STA can receive in any PPDU. Set to 1 to indicate that the Rx NSS subfield carries the maximum number of spatial streams that the STA can receive as a beamformee in an SU PPDU using a beamforming steering matrix derived from a VHT Compressed Beamforming report with the Feedback Type subfield indicating MU in the corresponding VHT Compressed Beamforming frame sent by the STA. NOTE—An AP always sets this field to 0.

Table 9-81—Setting of the Channel Width subfield and 160/80+80 BW subfield at a VHT STA transmitting the Operating Mode field

Transmitted Operating Mode field		VHT Capabilities of STA transmitting the Operating Mode field		NSS support of STA transmitting the Operating Mode field as a function of the VHT PPDU (×Max VHT NSS) (see requirements R1 and R2)					Location of 160 MHz center frequency if BSS bandwidth is 160 MHz	Location of secondary 80 MHz center frequency if BSS bandwidth is 80+80 MHz
Channel width	160/ 80+80 BW	Supported Channel Width Set	Extended NSS BW Support	20 MHz	40 MHz	80 MHz	160 MHz	80 +80 MHz		
0	0	0-2	0-3	1						
1	0	0-2	0-3	1	1					

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Table 9-81—Setting of the Channel Width subfield and 160/80+80 BW subfield at a VHT STA transmitting the Operating Mode field *(continued)*

Transmitted Operating Mode field		VHT Capabilities of STA transmitting the Operating Mode field		NSS support of STA transmitting the Operating Mode field as a function of the VHT PPDU (×Max VHT NSS) (see requirements R1 and R2)					Location of 160 MHz center frequency if BSS bandwidth is 160 MHz	Location of secondary 80 MHz center frequency if BSS bandwidth is 80+80 MHz
Channel width	160/ 80+80 BW	Supported Channel Width Set	Extended NSS BW Support	20 MHz	40 MHz	80 MHz	160 MHz	80 +80 MHz		
2	0	0-2	0-3	1	1	1				
2	1	0	1	1	1	1	1/2		CCFS2	
2	1	0	2	1	1	1	1/2	1/2	CCFS2	CCFS2
2	1	0	3	1	1	1	3/4	3/4	CCFS2	CCFS2
2	1	1	0	1	1	1	1		CCFS1	
2	1	1	1	1	1	1	1	1/2	CCFS1	CCFS2
2	1	1	2	1	1	1	1	3/4	CCFS1	CCFS2
2	1	1	3	2	2	2	2	1	CCFS1	CCFS1
2	1	2	0	1	1	1	1	1	CCFS1	CCFS1
2	1	2	3	2	2	2	1	1	CCFS1	CCFS1

R1: NSS support is rounded down to the nearest integer.
R2: The maximum NSS supported is 8.

NOTE 1—Max VHT NSS is defined per MCS in 9.4.2.157.3.

NOTE 2—1/2× or 3/4× Max VHT NSS support might end up being 0, indicating no support.

NOTE 3—Any other combination than the ones listed in this table is reserved.

NOTE 4—CCFS1 refers to the Channel Center Frequency Segment 1 field of the most recently transmitted VHT Operation element.

NOTE 5—CCFS2 refers to the Channel Center Frequency Segment 2 field of the most recently transmitted HT Operation element.

NOTE 6—CCFS1 is nonzero when the current BSS bandwidth is 160 MHz or 80+80 MHz and the NSS support is at least Max VHT NSS. CCFS2 is zero in this case.

NOTE 7—CCFS2 is nonzero when the current BSS bandwidth is 160 MHz or 80+80 MHz and the NSS support is less than Max VHT NSS. CCFS1 is zero in this case.

NOTE 8—At most one of CCFS1 and CCFS2 is nonzero.

NOTE 9—A supported multiple of Max VHT NSS applies to both transmit and receive.

NOTE 10—Some combinations of Supported Channel Width Set and Extended NSS BW support might not occur in practice.

NOTE 11—2× Max VHT NSS support might be used for 20 MHz or 40 MHz HT PPDU.

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9.4.1.54 Membership Status Array field

The Membership Status Array field is used in the Group ID Management frame (see 9.6.22.3). The length of the field is 8 octets. A Membership Status Array field (indexed by the group ID) consists of a 1-bit Membership Status subfield for each of the 64 group IDs, as shown in Figure 9-137.

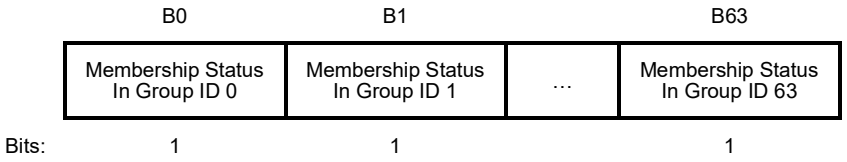

Figure 9-137—Membership Status Array field format

Within the Membership Status Array field, the 1-bit Membership Status subfield for each group ID is set as follows:

— Set to 0 if the STA is not a member of the group
— Set to 1 if STA is a member of the group

The Membership Status subfields for group ID 0 (transmissions to AP) and group ID 63 (downlink SU transmissions) are reserved.

9.4.1.55 User Position Array field

The User Position Array field is used in the Group ID Management frame (see 9.6.22.3). The length of the field is 16 octets. A User Position Array field (indexed by the Group ID) consists of a 2-bit User Position subfield for each of the 64 group IDs, as shown in Figure 9-138.

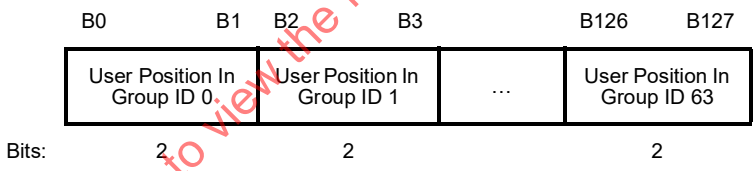

Figure 9-138—User Position Array field format

If the Membership Status subfield for a particular group ID is 1, then the corresponding User Position subfield in the User Position Array field contains the group ID's User Position.

If the Membership Status subfield for a group ID is 0 (meaning the STA is not a member of that group), then the corresponding User Position subfield in the User Position Array field is reserved.

The User Position subfields for group ID 0 (transmissions to AP) and group ID 63 (downlink SU transmissions) are reserved.

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9.4.1.56 Device Location Information Body field

A Device Location Information Body field includes the location configuration information (LCI), which contains latitude, longitude, and altitude information.

The format of the Device Location Information Body field is shown in Figure 9-139.

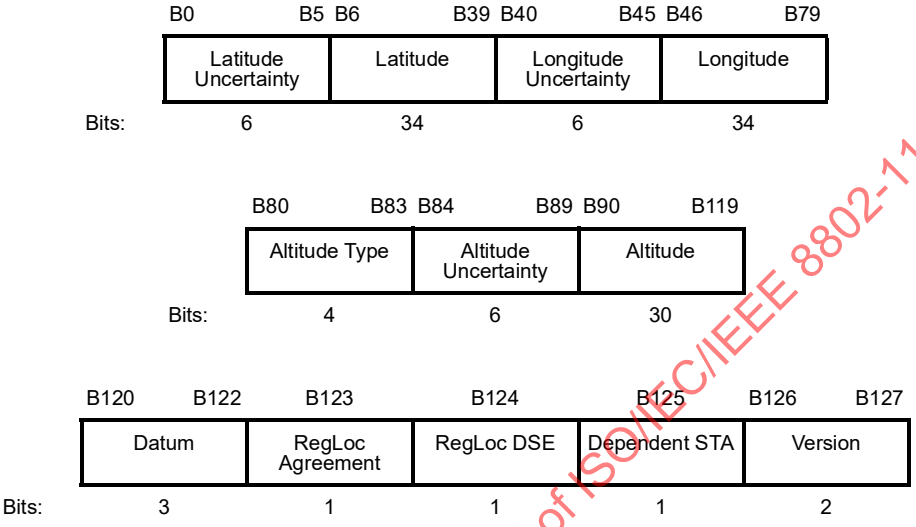

Figure 9-139—Device Location Information Body field format

The fields within the Device Location Information Body field are as defined in section 2.2 of IETF RFC 6225 except as defined in 9.4.2.51, and RegLoc Agreement and RegLoc DSE are set to 0.

9.4.1.57 WSM Type field and WSM Information field

The WSM Type field is set to a number that identifies the type of WSM information and the frequency band where the following WSM Information field is applicable. The values of WSM Types are shown in Table 9-82. The WSM Type field set to 1 indicates the WSM Information field of the WSM element contains available frequency information for operation in the TVWS. Other values are reserved.

Table 9-82—WSM Type definition

Name	WSM Type
Reserved	0
TV band WSM	1
Reserved	2–255

The WSM Information field indicates the available channel information as defined in 9.4.4.2.6.

The WSM Information field corresponding to a TV band WSM is shown in Table 9-329.

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9.4.1.58 Sync Control field

The Sync Control field is present in the Sync Control frame (see 9.6.24.4). The Sync Control field is shown in Figure 9-140.

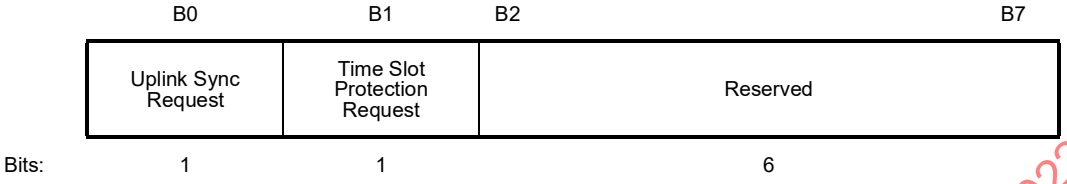

Figure 9-140—Sync Control field format

The non-AP STA transmitting this field indicates its mode of operation for the sync frame transmission. The subfields of the Sync Control field are defined in Table 9-83.

Table 9-83—Subfields of the Sync Control field

Subfield	Definition	Encoding
Uplink Sync Request	This subfield indicates request for sync frame transmission for uplink. (see 10.49)	Set to 0 if not requested. Set to 1 if requested.
Time Slot Protection Request	This subfield indicates request for a time slot protection during a time slot in a RAW (9.4.2.191) or for a duration defined in the Nominal Minimum TWT Wake Duration field for a TWT time (9.4.2.199), or for the duration of a TXOP after the expiration of wakeup timer.	Set to 0 if not requested. Set to 1 if requested.

9.4.1.59 Suspend Duration field

The format of the Suspend Duration field is shown in Figure 9-141.

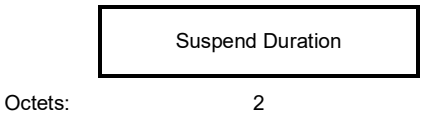

Figure 9-141—Suspend Duration field format

The Suspend Duration field contains an unsigned integer. See 10.61 for the use of this field.

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9.4.1.60 TWT Information field

The TWT Information field is present in the TWT Information frame (see 9.6.24.12). The TWT Information field format is shown in Figure 9-142.

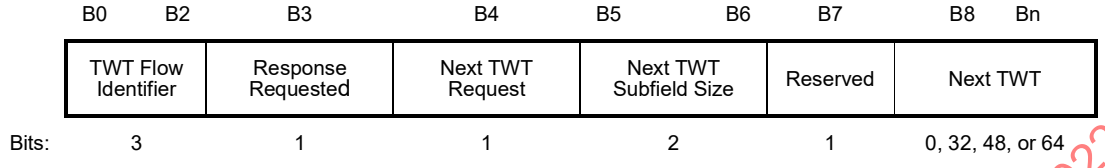

Figure 9-142—TWT Information field format

The TWT Information field size is variable and depends on the Next TWT Size field.

The TWT Flow Identifier subfield contains the TWT flow identifier for which TWT information is requested or being provided.

The Response Requested subfield indicates whether the transmitter of the frame containing the TWT Information field is requesting a TWT Information frame to be transmitted in response to this frame. The Response Requested subfield is set to 0 to request the recipient to not transmit a TWT Information frame in response to the frame. The Response Requested subfield is set to 1 to request the recipient to transmit a TWT Information frame in response to the frame.

The Next TWT Request subfield is set to 1 to indicate that the TWT Information frame is a request for the delivery of a TWT Information frame containing a nonzero length Next TWT field. Otherwise, it is set to 0.

The Next TWT Subfield Size subfield describes the size of the Next TWT subfield according to Table 9-84.

Table 9-84—Next TWT Subfield Size subfield encoding

Next TWT Subfield Size subfield value	Size of the Next TWT subfield in bits
0	0
1	32
2	48
3	64

The Next TWT subfield is of a variable size as determined by the Next TWT Subfield Size subfield value according to Table 9-84. The value contained in the Next TWT subfield is the least significant portion of the TSF at the next TWT for the TWT specified by the TWT Flow Identifier subfield.

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9.4.1.61 CMMG MIMO Control field

The CMMG MIMO Control field is used to manage the exchange of CMMG MIMO channel state or transmit beamforming feedback information. It is used in the CMMG Compressed Beamforming (see 9.6.29.2).

The CMMG MIMO Control field is defined in Figure 9-143.

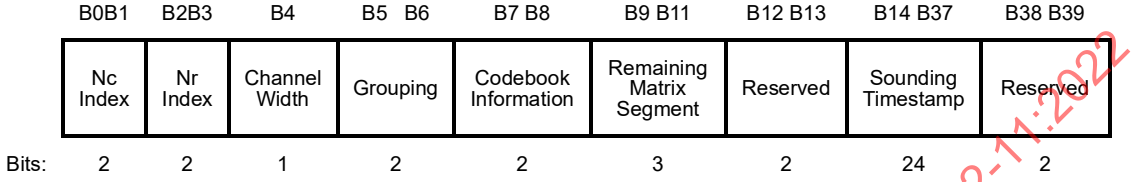

Figure 9-143—CMMG MIMO Control field format

The subfields of the CMMG MIMO Control field are defined in Table 9-85.

Table 9-85—Subfields of the CMMG MIMO Control field

Subfield	Description
Nc Index	Indicates the number of columns in the compressed beamforming feedback matrix minus 1.
Nr Index	Indicates the number of rows in the compressed beamforming feedback matrix minus 1.
Channel Width	Indicates the width of the channel in which a measurement was made: Set to 0 for 540 MHz Set to 1 for 1080 MHz
Grouping	Indicates the number of subcarriers grouped into one: Set to 0 for $N_g = 1$ (No grouping) Set to 1 for $N_g = 2$ Set to 2 for $N_g = 4$ Set to 3 for $N_g = 6$
Codebook Information	Indicates the size of codebook entries: Set to 0 for 2 bits for ψ, 4 bits for ϕ Set to 1 for 3 bits for ψ, 5 bits for ϕ The value 2 and 3 are reserved.
Remaining Matrix Segments	Contains the remaining segment number for the associated measurement report. Set to 0 for the last segment of a segmented report or the only segment of an unsegmented report.
Sounding Timestamp	Contains the lower 3 octets of the TSF timer sampled at the instant that the MAC received the PHY-CCA.indication(IDLE) primitive that corresponds to the end of the reception of the sounding PPDU that was used to generate feedback information contained in the frame.

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9.4.1.62 CMMG Compressed Beamforming Report field

The CMMG Compressed Beamforming Report field is used by the CMMG Compressed Beamforming frame (see 9.6.29.2) to carry explicit feedback information in the form of angles representing compressed beamforming feedback matrices V for use by a transmit CMMG beamformer to determine steering matrices Q, as described in 10.34.5 and 25.6.8.13.

The size of the CMMG Compressed Beamforming Report field depends on the values in the CMMG MIMO Control field.

The CMMG Compressed Beamforming Report field contains the channel matrix elements indexed, first, by matrix angles in the order shown in Table 9-86, second, by data subcarrier index from lowest frequency to highest frequency. The explanation of how these angles are generated from the beamforming feedback matrix V is given in 25.6.8.13.2.

Table 9-86—Order of angles in the CMMG Compressed Beamforming Report field

Size of V ($Nr \times Nc$)	Number of angles (Na)	The order of angles in the compressed beamforming feedback matrix
2 × 1	2	$\varphi_{1,1}, \psi_{2,1}$
2 × 2	2	$\varphi_{1,1}, \psi_{2,1}$
3 × 1	4	$\varphi_{1,1}, \varphi_{2,1}, \psi_{2,1}, \psi_{3,1}$
3 × 2	6	$\varphi_{1,1}, \varphi_{2,1}, \psi_{2,1}, \psi_{3,1}, \varphi_{2,2}, \psi_{3,2}$
3 × 3	6	$\varphi_{1,1}, \varphi_{2,1}, \psi_{2,1}, \psi_{3,1}, \varphi_{2,2}, \psi_{3,2}$
4 × 1	6	$\varphi_{1,1}, \varphi_{2,1}, \varphi_{3,1}, \psi_{2,1}, \psi_{3,1}, \psi_{4,1}$
4 × 2	10	$\varphi_{1,1}, \varphi_{2,1}, \varphi_{3,1}, \psi_{2,1}, \psi_{3,1}, \psi_{4,1}, \varphi_{2,2}, \varphi_{3,2}, \psi_{3,2}, \psi_{4,2}$
4 × 3	12	$\varphi_{1,1}, \varphi_{2,1}, \varphi_{3,1}, \psi_{2,1}, \psi_{3,1}, \psi_{4,1}, \varphi_{2,2}, \varphi_{3,2}, \psi_{3,2}, \psi_{4,2}, \varphi_{3,3}, \psi_{4,3}$
4 × 4	12	$\varphi_{1,1}, \varphi_{2,1}, \varphi_{3,1}, \psi_{2,1}, \psi_{3,1}, \psi_{4,1}, \varphi_{2,2}, \varphi_{3,2}, \psi_{3,2}, \psi_{4,2}, \varphi_{3,3}, \psi_{4,3}$

The angles are quantized as defined in Table 9-87. All angles are transmitted LSB to MSB.

Table 9-87—Quantization of angles

Quantized ψ	Quantized φ
$\psi = \frac{k\pi}{2^{b_\psi+1}} + \frac{\pi}{2^{b_\psi+2}}$ radians where $k = 0, 1, \ldots, 2^{b_\psi} - 1$ b_ψ is the number of bits used to quantize ψ defined by the Codebook Information field of the CMMG MIMO Control field	$\varphi = \frac{k\pi}{2^{b_\varphi+1}} + \frac{\pi}{2^{b_\varphi+2}}$ radians where $k = 0, 1, \ldots, 2^{b_\varphi} - 1$ b_φ is the number of bits used to quantize φ defined by the Codebook Information field of the CMMG MIMO Control field

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The Compressed Beamforming Report field has the structure defined in Table 9-88, where *Na* is the number of angles used for the CMMG compressed beamforming feedback matrix.

Table 9-88—Compressed Beamforming Report field

Field	Size (bits)	Meaning
Average SNR of Space-Time Stream 1	8	Signal-to-noise ratio at the beamformee for space-time stream 1 averaged over all data subcarriers
...	...	...
Average SNR of Space-Time Stream *Nc*	8	Signal-to-noise ratio at the beamformee for space-time stream *Nc* averaged over all data subcarriers.
Compressed Beamforming Feedback Matrix *V* for Subcarrier $k = scidx(0)$	$Na \times (b_{\varphi} + b_{\psi})/2$	Compressed beamforming feedback matrix
Compressed Beamforming Feedback Matrix *V* for Subcarrier $k = scidx(1)$	$Na \times (b_{\varphi} + b_{\psi})/2$	Compressed beamforming feedback matrix
Compressed Beamforming Feedback Matrix *V* for Subcarrier $k = scidx(2)$	$Na \times (b_{\varphi} + b_{\psi})/2$	Compressed beamforming feedback matrix
...	...	...
Compressed Beamforming Feedback Matrix *V* for Subcarrier $k = scidx(Ns - 1)$	$Na \times (b_{\varphi} + b_{\psi})/2$	Compressed beamforming feedback matrix
NOTE— *scidx()* is defined in Table 9-89.		

Ns is the number of subcarriers for which the CMMG compressed beamforming feedback matrix is sent back to the CMMG beamformer. *Ns* is a function of the Channel Width and Grouping subfields in the CMMG MIMO Control field. Table 9-89 lists *Ns*, the exact subcarrier indices and their order for which the compressed beamforming feedback matrix is sent back. No padding is present between angles in the CMMG compressed beamforming report information, even if they correspond to different subcarriers. If the length of the CMMG Compressed Beamforming Report field is not an integral multiple of 8 bits, up to 7 0s are appended to the end of the field to make its size an integral multiple of 8 bits.

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Table 9-89—Subcarrier indices for which a compressed beamforming feedback matrix is sent back

Channel width	N_g	Ns	Subcarrier indices for which compressed beamforming feedback matrix is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*–1)
540 MHz	1	168	–89, –88, –87, –86, –85, –84, –83, –82, –81, –80, –79, –78, –76, –75, –74, –73, –72, –71, –70, –69, –68, –67, –66, –65, –64, –63, –62, –61, –60, –59, –58, –57, –56, –54, –53, –52, –51, –50, –49, –48, –47, –46, –45, –44, –43, –42, –41, –40, –39, –38, –37, –36, –35, –34, –32, –31, –30, –29, –28, –27, –26, –25, –24, –23, –22, –21, –20, –19, –18, –17, –16, –15, –14, –13, –12, –10, –9, –8, –7, –6, –5, –4, –3, –2, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89 NOTE—Pilot subcarriers (± 77, ± 55, ± 33, ± 11) and DC subcarriers (0, ± 1) are skipped
	2	90	–89, –88, –86, –84, –82, –80, –78, –76, –74, –72, –70, –68, –66, –64, –62, –60, –58, –56 ,–54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 89
	4	46	–89, –86, –82, –78, –74, –70, –66, –62, –58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6, –2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62, 66, 70, 74, 78, 82, 86, 89
	6	32	–89, –86, –80, –74, –68, –62, –56, –50, –44, –38, –32, –26, –20, –14, –8, –2, 2, 8, 14, 20, 26, 32, 38, 44, 50, 56, 62, 68, 74, 80, 86, 89
1080 MHz	1	336	–177, –176, –175, –174, –173, –172, –171, –170, –169, –168, –167, –166, –164, –163, –162, –161, –160, –159, –158, –157, –156, –155, –154, –153, –152, –151, –150, –149, –148, –147, –146, –145, –144, –142, –141, –140, –139, –138, –137, –136, –135, –134, –133, –132, –131, –130, –126, –125, –124, –123, –122, –120, –119, –118, –117, –116, –115, –114, –113, –112, –111, –110, –109, –108, –107, –106, –105, –104, –103, –102, –101, –100, –98, –97, –96, –95, –94, –93, –92, –91, –90, –89, –88, –87, –86, –85, –84, –83, –82, –81, –80, –79, –78, –76, –75, –74, –73, –72, –71, –70, –69, –68, –67, –66, –65, –64, –63, –62, –61, –60, –59, –58, –57, –56, –54, –53, –52, –51, –50, –49, –48, –47, –46, –45, –44, –43, –42, –41, –40, –39, –38, –37, –36, –35, –34, –32, –31, –30, –29, –28, –27, –26, –25, –24, –23, –22, –21, –20, –19, –18, –17, –16, –15, –14, –13, –12, –10, –9, –8, –7, –6, –5, –4, –3, –2, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 122, 123, 124, 125, 126, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177 NOTE—Pilot subcarriers (± 165, ± 143, ± 121, ± 99, ± 77, ± 55, ± 33, ± 11) and DC subcarriers (0, ± 1) are skipped

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Table 9-89—Subcarrier indices for which a compressed beamforming feedback matrix is sent back *(continued)*

Channel width	N_g	Ns	Subcarrier indices for which compressed beamforming feedback matrix is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*–1)
1080 MHz	2	170	–177, –176, –174, –172, –170, –168, –166, –164, –162, –160, –158, –156, –154, –152, –150, –148, –146, –144, –142, –140, –138, –136, –134, –132, –130, –128, –126, –124, –122, –120, –118, –116, –114, –112, –110, –108, –106, –104, –102, –100, –98, –96, –94, –92, –90, –88, –86, –84, –82, –80, –78, –76, –74, –72, –70, –68, –66, –64, –62, –60, –58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132,134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166, 168, 170, 172, 174, 176, 177
	4	90	–177, –174, –170, –166, –162, –158, –154, –150, –146, –142, –138, –134, –130, –126, –122, –118, –114, –110, –106, –102, –98, –94, –90, –86, –82, –78, –74, –70, –66, –62, –58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6, –2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62, 66, 70, 74, 78, 82, 86, 90, 94, 98, 102, 106, 110, 114, 118, 122, 126, 130, 134, 138, 142, 146, 150, 154, 158, 162, 166, 170, 174, 177
	6	62	–177, –176, –170, –164, –158, –152, –146, –140, –134, –128, –122, –116, –110, –104, –98, –92, –86, –80,–74,–68, –62, –56, –50, –44, –38, –32, –26, –20, –14, –8, –2, 2, 8, 14, 20, 26, 32, 38, 44, 50, 56, 62, 68, 74, 80, 86, 92, 98, 104, 110, 116, 122, 128, 134, 140, 146, 152, 158, 164, 170, 176, 177

The SNR values are encoded as an 8-bit 2s complement value of 4×(SNR_average-22), where SNR_average is the sum of the values of SNR per subcarrier (in decibels) divided by the number of subcarriers represented.

The Average SNR of Space-Time Stream *i* subfield is an 8-bit 2s complement integer whose definition is shown in Table 9-90.

Table 9-90—Average SNR of Space-Time Stream *i* subfield

Average SNR of Space-Time Stream *i* subfield	$AvgSNR_i$ (dB)
–128	≤ –10
–127	–9.75
–126	–9.5
…	…
+126	53.5
+127	53.75

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9.4.1.63 CMMG Operating Mode field

The CMMG Operating Mode field is present in the CMMG Operating Mode Notification frame (see 9.6.29.3) and CMMG Operating Mode Notification element (see 9.4.2.231).

The CMMG Operating Mode field is shown in Figure 9-144.

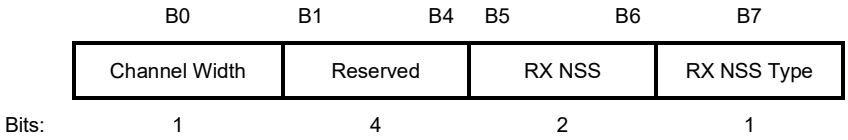

Figure 9-144—CMMG Operating Mode field format

The STA transmitting this field indicates its current operating channel width and the number of spatial streams it can receive using the settings defined in Table 9-91.

Table 9-91—Subfield values of the CMMG Operating Mode field

Subfield	Description
Channel Width	If the RX NSS Type subfield is 0, indicates the supported channel width: Set to 0 for 540 MHz Set to 1 for 1080 MHz Reserved if the Rx NSS Type subfield is 1.
RX NSS	If the RX NSS Type subfield is 0, indicates the maximum number of spatial streams that the STA can receive. If the RX NSS Type subfield is 1, indicates the maximum number of spatial streams that the STA can receive as a beamformee in an SU PPDU using a beamforming steering matrix derived from a CMMG Compressed Beamforming report with the Feedback Type subfield indicating SU in the corresponding CMMG Compressed Beamforming frame sent by the STA. Set to 0 for NSS = 1 Set to 1 for NSS = 2 … Set to 3 for NSS = 4
RX NSS Type	Set to 0 to indicate that the RX NSS subfield carries the maximum number of spatial streams that the STA can receive. Set to 1 to indicate that the RX NSS subfield carries the maximum number of spatial streams that the STA can receive in an SU PPDU using a beamforming steering matrix derived from a CMMG Compressed Beamforming report with the Feedback Type subfield indicating SU in the corresponding CMMG Compressed Beamforming frame sent by the STA. NOTE—An AP always sets this field to 0.

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9.4.2 Elements

9.4.2.1 General

Elements have a common general format shown in Figure 9-145.

	Element ID	Length	Element ID Extension	Information
Octets:	1	1	0 or 1	variable

Figure 9-145—Element format

An element is identified by the Element ID field and, if present, the Element ID Extension field.

The set of valid elements is defined in Table 9-92.

If an Element ID value has an entry in Table 9-92 in the Element column of Element ID Extension present, then the Element ID Extension field is present. Otherwise, the Element ID Extension field is not present.

The Length field indicates the number of octets in the element excluding the Element ID and Length fields.

The Information field carries information specific to the element.

Table 9-92—Element IDs

Element	Element ID	Element ID Extension	Extensible	Fragmentable
SSID (see 9.4.2.2)	0	N/A	No	No
Supported Rates and BSS Membership Selectors (see 9.4.2.3)	1	N/A	No	No
Reserved	2			
DSSS Parameter Set (see 9.4.2.4)	3	N/A	No	No
Reserved	4			
TIM (see 9.4.2.5)	5	N/A	No	No
IBSS Parameter Set (see 9.4.2.6)	6	N/A	No	No
Country (see 9.4.2.8)	7	N/A	No	No
Reserved	8			
Reserved	9			
Request (see 9.4.2.9)	10	N/A	No	No
BSS Load (see 9.4.2.27)	11	N/A	No	No
EDCA Parameter Set (see 9.4.2.28)	12	N/A	No	No
TSPEC (see 9.4.2.29)	13	N/A	In a non-DMG BSS: no In a DMG BSS: yes	No
TCLAS (see 9.4.2.30)	14	N/A	No	No

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Table 9-92—Element IDs *(continued)*

Element	Element ID	Element ID Extension	Extensible	Fragmentable
Schedule (see 9.4.2.33)	15	N/A	No	No
Challenge text (see 9.4.2.7)	16	N/A	No	No
Reserved	17–31			
Power Constraint (see 9.4.2.13)	32	N/A	No	No
Power Capability (see 9.4.2.14)	33	N/A	No	No
TPC Request (see 9.4.2.15)	34	N/A	No	No
TPC Report (see 9.4.2.16)	35	N/A	No	No
Supported Channels (see 9.4.2.17)	36	N/A	No	No
Channel Switch Announcement (see 9.4.2.18)	37	N/A	No	No
Measurement Request (see 9.4.2.20)	38	N/A	Subelements, for formats using 9.4.2.20.4 to 9.4.2.20.12.	No
Measurement Report (see 9.4.2.21)	39	N/A	Subelements, for formats using 9.4.2.21.4 to 9.4.2.21.11.	No
Quiet (see 9.4.2.22)	40	N/A	No	No
IBSS DFS (see 9.4.2.23)	41	N/A	No	No
ERP (see 9.4.2.11)	42	N/A	Yes	No
TS Delay (see 9.4.2.31)	43	N/A	No	No
TCLAS Processing (see 9.4.2.32)	44	N/A	No	No
HT Capabilities (see 9.4.2.55)	45	N/A	Yes	No
QoS Capability (see 9.4.2.34)	46	N/A	No	No
Reserved	47			
RSN (see 9.4.2.24)	48	N/A	Yes	No
Reserved	49			
Extended Supported Rates and BSS Membership Selectors (see 9.4.2.12)	50	N/A	No	No
AP Channel Report (see 9.4.2.35)	51	N/A	No	No
Neighbor Report (see 9.4.2.36)	52	N/A	Subelements	No
RCPI (see 9.4.2.37)	53	N/A	Yes	No
Mobility Domain (MDE) (see 9.4.2.46)	54	N/A	No	No
Fast BSS Transition (FTE) (see 9.4.2.47)	55	N/A	No	No
Timeout Interval (see 9.4.2.48)	56	N/A	No	No
RIC Data (RDE) (see 9.4.2.49)	57	N/A	No	No
DSE Registered Location (see 9.4.2.51)	58	N/A	No	No

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Table 9-92—Element IDs *(continued)*

Element	Element ID	Element ID Extension	Extensible	Fragmentable
Supported Operating Classes (see 9.4.2.53)	59	N/A	No	No
Extended Channel Switch Announcement (see 9.4.2.52)	60	N/A	No	No
HT Operation (see 9.4.2.56)	61	N/A	Yes	No
Secondary Channel Offset (see 9.4.2.19)	62	N/A	No	No
BSS Average Access Delay (see 9.4.2.38)	63	N/A	Yes	No
Antenna (see 9.4.2.39)	64	N/A	Yes	No
RSNI (see 9.4.2.40)	65	N/A	Yes	No
Measurement Pilot Transmission (see 9.4.2.41)	66	N/A	Subelements	No
BSS Available Admission Capacity (see 9.4.2.42)	67	N/A	Yes	No
BSS AC Access Delay (see 9.4.2.43)	68	N/A	Yes	No
Time Advertisement (see 9.4.2.60)	69	N/A	Yes	No
RM Enabled Capabilities (see 9.4.2.44)	70	N/A	Yes	No
Multiple BSSID (see 9.4.2.45)	71	N/A	Subelements	No
20/40 BSS Coexistence (see 9.4.2.59)	72	N/A	Yes	No
20/40 BSS Intolerant Channel Report (see 9.4.2.57)	73	N/A	No	No
Overlapping BSS Scan Parameters (see 9.4.2.58)	74	N/A	No	No
RIC Descriptor (see 9.4.2.50)	75	N/A	No	No
Management MIC (see 9.4.2.54)	76	N/A	No	No
Reserved	77			
Event Request (see 9.4.2.66)	78	N/A	Subelements	No
Event Report (see 9.4.2.67)	79	N/A	No	No
Diagnostic Request (see 9.4.2.68)	80	N/A	Subelements	No
Diagnostic Report (see 9.4.2.69)	81	N/A	Subelements	No
Location Parameters (see 9.4.2.70)	82	N/A	Subelements	No
Nontransmitted BSSID Capability (see 9.4.2.71)	83	N/A	No	No
SSID List (see 9.4.2.72)	84	N/A	No	No
Multiple BSSID-Index (see 9.4.2.73)	85	N/A	No	No
FMS Descriptor (see 9.4.2.74)	86	N/A	No	No
FMS Request (see 9.4.2.75)	87	N/A	Subelements	No
FMS Response (see 9.4.2.76)	88	N/A	Subelements	No
QoS Traffic Capability (see 9.4.2.77)	89	N/A	Yes	No

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Table 9-92—Element IDs *(continued)*

Element	Element ID	Element ID Extension	Extensible	Fragmentable
BSS Max Idle Period (see 9.4.2.78)	90	N/A	Yes	No
TFS Request (see 9.4.2.79)	91	N/A	Subelements	No
TFS Response (see 9.4.2.80)	92	N/A	Subelements	No
WNM Sleep Mode (see 9.4.2.81)	93	N/A	Yes	No
TIM Broadcast Request (see 9.4.2.82)	94	N/A	Yes	No
TIM Broadcast Response (see 9.4.2.83)	95	N/A	Yes	No
Collocated Interference Report (see 9.4.2.84)	96	N/A	Yes	No
Channel Usage (see 9.4.2.85)	97	N/A	Subelements	No
Time Zone (see 9.4.2.86)	98	N/A	Yes	No
DMS Request (see 9.4.2.87)	99	N/A	Subelements	No
DMS Response (see 9.4.2.88)	100	N/A	Subelements	No
Link Identifier (see 9.4.2.61)	101	N/A	Yes	No
Wakeup Schedule (see 9.4.2.62)	102	N/A	Yes	No
Reserved	103			
Channel Switch Timing (see 9.4.2.63)	104	N/A	Yes	No
PTI Control (see 9.4.2.64)	105	N/A	Yes	No
TPU Buffer Status (see 9.4.2.65)	106	N/A	Yes	No
Interworking (see 9.4.2.91)	107	N/A	No	No
Advertisement Protocol (see 9.4.2.92)	108	N/A	No	No
Expedited Bandwidth Request (see 9.4.2.93)	109	N/A	No	No
QoS Map (see 9.4.2.94)	110	N/A	Yes	No
Roaming Consortium (see 9.4.2.95)	111	N/A	Yes	No
Emergency Alert Identifier (see 9.4.2.96)	112	N/A	No	No
Mesh Configuration (see 9.4.2.97	113	N/A	Yes	No
Mesh ID (see 9.4.2.98	114	N/A	No	No
Mesh Link Metric Report (see 9.4.2.99)	115	N/A	No	No
Congestion Notification (see 9.4.2.100)	116	N/A	Yes	No
Mesh Peering Management (see 9.4.2.101)	117	N/A	Yes	No
Mesh Channel Switch Parameters (see 9.4.2.102)	118	N/A	Yes	No
Mesh Awake Window (see 9.4.2.103)	119	N/A	Yes	No
Beacon Timing (see 9.4.2.104)	120	N/A	No	No
MCCAOP Setup Request (see 9.4.2.105)	121	N/A	Yes	No
MCCAOP Setup Reply (see 9.4.2.106)	122	N/A	No	No

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Table 9-92—Element IDs *(continued)*

Element	Element ID	Element ID Extension	Extensible	Fragmentable
MCCAOP Advertisement (see 9.4.2.108)	123	N/A	Yes	No
MCCAOP Teardown (see 9.4.2.109)	124	N/A	Yes	No
GANN (see 9.4.2.110)	125	N/A	Yes	No
RANN (see 9.4.2.111)	126	N/A	Yes	No
Extended Capabilities (see 9.4.2.26)	127	N/A	Yes	No
Reserved	128–129			
PREQ (see 9.4.2.112)	130	N/A	Yes	No
PREP (see 9.4.2.113)	131	N/A	Yes	No
PERR (see 9.4.2.114)	132	N/A	Yes	No
Reserved	133–136			
PXU (see 9.4.2.115)	137	N/A	Yes	No
PXUC (see 9.4.2.116)	138	N/A	Yes	No
Authenticated Mesh Peering Exchange (see 9.4.2.117)	139	N/A	No	No
MIC (see 9.4.2.118)	140	N/A	No	No
Destination URI (see 9.4.2.89)	141	N/A	Yes	No
U-APSD Coexistence (see 9.4.2.90)	142	N/A	Subelements	No
DMG Wakeup Schedule (see 9.4.2.130)	143	N/A	Yes	No
Extended Schedule (see 9.4.2.131)	144	N/A	Yes	No
STA Availability (see 9.4.2.132)	145	N/A	Yes	No
DMG TSPEC (see 9.4.2.133)	146	N/A	Yes	No
Next DMG ATI (see 9.4.2.135)	147	N/A	Yes	No
DMG Capabilities (see 9.4.2.127)	148	N/A	Yes	No
Reserved	149–150			
DMG Operation (see 9.4.2.128	151	N/A	Yes	No
DMG BSS Parameter Change (see 9.4.2.126)	152	N/A	Yes	No
DMG Beam Refinement (see 9.4.2.129)	153	N/A	Yes	No
Channel Measurement Feedback (see 9.4.2.136)	154	N/A	Yes	No
Reserved	155–156			
Awake Window (see 9.4.2.137)	157	N/A	Yes	No
Multi-band (see 9.4.2.138)	158	N/A	Yes	No
ADDBA Extension (see 9.4.2.139)	159	N/A	Yes	No
NextPCP List (see 9.4.2.140)	160	N/A	Yes	No
PCP Handover (see 9.4.2.141)	161	N/A	Yes	No
DMG Link Margin (see 9.4.2.142)	162	N/A	Yes	No

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Table 9-92—Element IDs *(continued)*

Element	Element ID	Element ID Extension	Extensible	Fragmentable
Switching Stream (see 9.4.2.144)	163	N/A	Yes	No
Session Transition (see 9.4.2.145)	164	N/A	Yes	No
Reserved	165			
Cluster Report (see 9.4.2.146)	166	N/A	Yes	No
Relay Capabilities (see 9.4.2.147)	167	N/A	Yes	No
Relay Transfer Parameter Set (see 9.4.2.148)	168	N/A	Yes	No
BeamLink Maintenance (see 9.4.2.151)	169	N/A	Yes	No
Multiple MAC Sublayers (see 9.4.2.152)	170	N/A	Yes	No
U-PID (see 9.4.2.153)	171	N/A	Yes	No
DMG Link Adaptation Acknowledgment (see 9.4.2.143)	172	N/A	Yes	No
Reserved	173			
MCCAOP Advertisement Overview (see 9.4.2.107)	174	N/A	Yes	No
Quiet Period Request (see 9.4.2.149)	175	N/A	Yes	No
Reserved	176			
Quiet Period Response (see 9.4.2.150)	177	N/A	Yes	No
Reserved	178–180			
QMF Policy (see 9.4.2.119)	181	N/A	No	No
ECAPC Policy (see 9.4.2.154)	182	N/A	Yes	No
Cluster Time Offset (see 9.4.2.155)	183	N/A	Yes	No
Intra-Access Category Priority (see 9.4.2.120)	184	N/A	Yes	No
SCS Descriptor (see 9.4.2.121)	185	N/A	Subelements	No
QLoad Report (see 9.4.2.122)	186	N/A	Subelements	No
HCCA TXOP Update Count (see 9.4.2.123)	187	N/A	No	No
Higher Layer Stream ID (see 9.4.2.124)	188	N/A	Yes	No
GCR Group Address (see 9.4.2.125)	189	N/A	No	No
Antenna Sector ID Pattern (see 9.4.2.156)	190	N/A	Yes	No
VHT Capabilities (see 9.4.2.157)	191	N/A	Yes	No
VHT Operation (see 9.4.2.158)	192	N/A	Yes	No
Extended BSS Load (see 9.4.2.159)	193	N/A	Yes	No
Wide Bandwidth Channel Switch (see 9.4.2.160)	194	N/A	Yes	No
Transmit Power Envelope (see 9.4.2.161)	195	N/A	Yes	No
Channel Switch Wrapper (see 9.4.2.162)	196	N/A	Subelements	No

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Table 9-92—Element IDs *(continued)*

Element	Element ID	Element ID Extension	Extensible	Fragmentable
AID (see 9.4.2.163)	197	N/A	No	No
Quiet Channel (see 9.4.2.164)	198	N/A	Yes	No
Operating Mode Notification (see 9.4.2.165)	199	N/A	Yes	No
UPSIM (see 9.4.2.166)	200	N/A	Yes	No
Reduced Neighbor Report (see 9.4.2.170)	201	N/A	Yes	No
TVHT Operation (see 9.4.2.171)	202	N/A	Yes	No
Reserved	203			
Device Location (see 9.4.2.168)	204	N/A	Yes	No
White Space Map (see 9.4.2.169)	205	N/A	Yes	No
Fine Timing Measurement Parameters (see 9.4.2.167)	206	N/A	Yes	No
S1G Open-Loop Link Margin Index (see 9.4.2.190)	207	N/A	No	No
RPS (see 9.4.2.191)	208	N/A	No	No
Page Slice (see 9.4.2.192)	209	N/A	No	No
AID Request (see 9.4.2.193)	210	N/A	No	No
AID Response (see 9.4.2.194)	211	N/A	No	No
S1G Sector Operation (see 9.4.2.195)	212	N/A	Yes	No
S1G Beacon Compatibility (see 9.4.2.196)	213	N/A	No	No
Short Beacon Interval (see 9.4.2.197)	214	N/A	No	No
Change Sequence (see 9.4.2.198)	215	N/A	No	No
TWT (see 9.4.2.199)	216	N/A	Yes	No
S1G Capabilities (see 9.4.2.200)	217	N/A	Yes	No
Reserved	218–219			
Subchannel Selective Transmission (see 9.4.2.201)	220	N/A	No	No
Vendor Specific (see 9.4.2.25)	221	N/A	Vendor defined	Vendor defined
Authentication Control (see 9.4.2.202)	222	N/A	Yes	No
TSF Timer Accuracy (see 9.4.2.203)	223	N/A	No	No
S1G Relay (see 9.4.2.204)	224	N/A	Yes	No
Reachable Address (see 9.4.2.205)	225	N/A	Yes	No
S1G Relay Discovery (see 9.4.2.207)	226	N/A	No	No
Reserved	227			
AID Announcement (see 9.4.2.208)	228	N/A	No	No
PV1 Probe Response Option (see 9.4.2.209)	229	N/A	No	No

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Table 9-92—Element IDs *(continued)*

Element	Element ID	Element ID Extension	Extensible	Fragmentable
EL Operation (see 9.4.2.210)	230	N/A	No	No
Sectorized Group ID List (see 9.4.2.211)	231	N/A	Yes	No
S1G Operation (see 9.4.2.212)	232	N/A	No	No
Header Compression (see 9.4.2.213)	233	N/A	Yes	No
SST Operation (see 9.4.2.214)	234	N/A	No	No
MAD (see 9.4.2.215)	235	N/A	No	No
S1G Relay Activation (see 9.4.2.206)	236	N/A	Yes	No
CAG Number (see 9.4.2.176)	237	N/A	No	No
Reserved	238			
AP-CSN (see 9.4.2.181)	239	N/A	No	No
FILS Indication (see 9.4.2.182)	240	N/A	No	Yes
DILS (see 9.4.2.186)	241	N/A	Yes	No
Fragment (see 9.4.2.188)	242	N/A	No	No
Reserved	243			
RSN Extension (see 9.4.2.241)	244	N/A	Yes	No
Reserved	245–254			
Element ID Extension present	255			
Reserved	255	0		
Association Delay Info (see 9.4.2.175)	255	1	No	No
FILS Request Parameters (see 9.4.2.177)	255	2	No	No
FILS Key Confirmation (see 9.4.2.178)	255	3	No	Yes
FILS Session (see 9.4.2.179)	255	4	No	No
FILS HLP Container (see 9.4.2.183)	255	5	No	Yes
FILS IP Address Assignment (see 9.4.2.184)	255	6	No	No
Key Delivery (see 9.4.2.185)	255	7	No	Yes
FILS Wrapped Data (see 9.4.2.187)	255	8	No	Yes
FTM Synchronization Information (see 9.4.2.172)	255	9	Yes	No
Extended Request (see 9.4.2.10)	255	10	No	No
Estimated Service Parameters Inbound (see 9.4.2.173)	255	11	Yes	No
FILS Public Key (see 9.4.2.180)	255	12	No	Yes
FILS Nonce (see 9.4.2.189)	255	13	No	No
Future Channel Guidance (see 9.4.2.174)	255	14	No	No
Service Hint (see 9.4.2.237)	255	15	No	No
Service Hash (see 9.4.2.238)	255	16	No	No

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Table 9-92—Element IDs *(continued)*

Element	Element ID	Element ID Extension	Extensible	Fragmentable
CDMG Capabilities (see 9.4.2.219)	255	17	Yes	No
Dynamic Bandwidth Control (see 9.4.2.220)	255	18	Yes	No
CDMG Extended Schedule (see 9.4.2.221)	255	19	Yes	Yes
SSW Report (see 9.4.2.222)	255	20	Yes	Yes
Cluster Probe (see 9.4.2.223)	255	21	Yes	No
Extended Cluster Report (see 9.4.2.224)	255	22	Yes	No
Cluster Switch Announcement (see 9.4.2.225)	255	23	Yes	No
Enhanced Beam Tracking (see 9.4.2.226)	255	24	Yes	No
SPSH Report (see 9.4.2.227)	255	25	Yes	Yes
Clustering Interference Assessment (see 9.4.2.228)	255	26	Yes	No
CMMG Capabilities (see 9.4.2.229)	255	27	Yes	No
CMMG Operation (see 9.4.2.230)	255	28	Yes	No
CMMG Operating Mode Notification (see 9.4.2.231)	255	29	Yes	No
CMMG Link Margin (see 9.4.2.232)	255	30	Yes	No
CMMG Link Adaptation Acknowledgment (see 9.4.2.233)	255	31	Yes	No
Reserved	255	32		
Password identifier (see 9.4.2.216)	255	33	No	No
GLK-GCR Parameter Set (see 9.4.2.234)	255	34	Yes	No
Reserved	255	35–39		
GAS Extension (see 9.4.2.239)	255	40	Yes	Yes
Reserved	255	41–43		
Vendor Specific Request Element (see 9.4.2.218)	255	44	No	No
Reserved	255	45–51		
Max Channel Switch Time (see 9.4.2.217)	255	52	No	No
Estimated Service Parameters Outbound (see 9.4.2.235)	255	53	Yes	No
Operating Channel Information (OCI) Element (see 9.4.2.236)	255	54	Yes	No
Reserved	255	55		
Non-Inheritance (see 9.4.2.240)	255	56	Yes	No
Reserved	255	57–87		
MSCS Descriptor element (see 9.4.2.243)	255	88	Yes	No

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Table 9-92—Element IDs *(continued)*

Element	Element ID	Element ID Extension	Extensible	Fragmentable
TCLAS Mask (see 9.4.2.242)	255	89	Yes	No
Supplemental Class 2 Capabilities (see 9.4.2.244)	255	90	No	No
OCT Source (see 9.4.2.245)	255	91	Yes	No
Rejected Groups (see 9.4.2.246)	255	92	No	No
Anti-Clogging Token Container (see 9.4.2.247)	255	93	No	No
Reserved	255	94–255		
NOTE—See 10.28.6 on the parsing of elements.				

A Yes in the Extensible column of an element listed in Table 9-92 indicates that the length of the element might be extended in future revisions or amendments of this standard. See 10.28.8. When the Extensible column of an element is set to Subelements, then the element might be extended in future revisions or amendments of this standard by defining additional subelements. See 10.28.9. The element is not extensible otherwise (i.e., if marked as No). An element that is not defined as extensible will not be extended in future revisions or amendments of this standard.

A Yes in the Fragmentable column listed in Table 9-92 indicates that the element information might exceed the threshold that causes the element to be fragmented (see 10.28.11).

9.4.2.2 SSID element

The SSID element indicates the identity of an ESS or IBSS. See Figure 9-146.

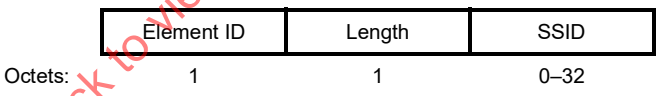

Figure 9-146—SSID element format

The Element ID and Length fields are defined in 9.4.2.1.

The length of the SSID field is between 0 and 32 octets. An SSID field of length 0 is used within Probe Request frames to indicate the wildcard SSID. The wildcard SSID is also used in Beacon and Probe Response frames transmitted by mesh STAs.

When the UTF-8 SSID subfield of the Extended Capabilities element is equal to 1 in the frame that includes the SSID element, or the Extended Capabilities of the source of the SSID information is known to include the UTF-8 SSID capability based on a previously received Extended Capabilities element, the SSID is a sequence of UTF-8 encoded code points. Otherwise, the character encoding of the octets in this SSID element is unspecified.

NOTE—If the SSID is a sequence of UTF-8 encoded code points, a terminating null might or might not be present.

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9.4.2.3 Supported Rates and BSS Membership Selectors element

The Supported Rates and BSS Membership Selectors element specifies any combination of up to eight BSS membership selectors and rates in the OperationalRateSet parameter, as described in the MLME-JOIN.request and MLME-START.request primitives.

Each octet of the Supported Rates field describes a single supported rate or BSS membership selector (see Figure 9-147).

	Element ID	Length	Supported Rates
Octets:	1	1	1–8

Figure 9-147—Supported Rates and BSS Membership Selectors element format

The Element ID and Length fields are defined in 9.4.2.1.

Within Beacon, Probe Response, Association Response, Reassociation Response, Mesh Peering Open, and Mesh Peering Confirm frames, each rate contained in the BSSBasicRateSet parameter is encoded as an octet with the MSB (bit 7) set to 1, and bits 6 to 0 are set to the data rate, if necessary rounded up to the next 500 kb/s, in units of 500 kb/s (e.g., a 2.25 Mb/s rate contained in the BSSBasicRateSet parameter is encoded as X'85'). Each rate in the OperationalRateSet parameter not contained in the BSSBasicRateSet parameter is encoded with the MSB set to 0, and bits 6 to 0 are set in the same way as for a rate contained in the BSSBasicRateSet parameter (e.g., a 2 Mb/s rate not contained in the BSSBasicRateSet parameter is encoded as X'04').

Within Beacon, Probe Response, Association Response, Reassociation Response, Mesh Peering Open, and Mesh Peering Confirm frames, each BSS membership selector contained in the BSSMembershipSelectorSet parameter is encoded as an octet with the MSB (bit 7) set to 1, and bits 6 to 0 are set to the encoded value for the selector as found in Table 9-93 (e.g., an HT PHY BSS membership selector contained in the BSSMembershipSelectorSet parameter is encoded as X'FF'). A BSS membership selector that has the MSB (bit 7) set to 1 in the Supported Rates and BSS Membership Selectors element is defined to be basic.

The MSB of each octet in the Supported Rates field in other management frame types is ignored by receiving STAs.

The valid values for BSS membership selectors and their associated features are shown in Table 9-93.

NOTE—Because the BSS membership selector and supported rates are carried in the same field, the BSS membership selector value cannot match the value corresponding to any valid supported rate. This allows any value to be determined as either a supported rate or a BSS membership selector.

Table 9-93—BSS membership selector value encoding

Value	Feature	Interpretation
127	HT PHY	Support for the mandatory features of Clause 19 is required in order to join the BSS that was the source of the Supported Rates and BSS Membership Selectors element or Extended Supported Rates and BSS Membership Selectors element containing this value.
126	VHT PHY	Support for the mandatory features of Clause 21 is required in order to join the BSS that was the source of the Supported Rates and BSS Membership Selectors element or Extended Supported Rates and BSS Membership Selectors element containing this value.

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Table 9-93—BSS membership selector value encoding *(continued)*

Value	Feature	Interpretation
125	GLK	Indicates that support for the mandatory features of 11.50 is required in order to join the BSS that was the source of the Supported Rates and BSS Membership Selectors element or Extended Supported Rates and BSS Membership Selectors element containing this value.
124	EPD	Indicates that support for EPD is required in order to join the BSS that was the source of the Supported Rates and BSS Membership Selectors element or Extended Supported Rates and BSS Membership Selectors element containing this value.
123	SAE Hash to Element Only	Indicates that support for the direct hashing to element technique in SAE is required in order to join the BSS.

See 11.1.4.6.

9.4.2.4 DSSS Parameter Set element

The DSSS Parameter Set element contains information to allow channel number identification for STAs. See Figure 9-148.

	Element ID	Length	Current Channel
Octets:	1	1	1

Figure 9-148—DSSS Parameter Set element format

The Element ID and Length fields are defined in 9.4.2.1.

The Current Channel field is set to dot11CurrentChannel (see 15.4.4.3, 16.3.6.3, 17.3.8.4.2 and 19.3.15 for values).

9.4.2.5 TIM element

9.4.2.5.1 General

The TIM element is used to signal the timing and availability of data for associated STAs. The format of this element is shown in Figure 9-149.

	Element ID	Length	DTIM Count	DTIM Period	Bitmap Control	Partial Virtual Bitmap
Octets:	1	1	1	1	0 or 1	0 –251

Figure 9-149—TIM element format

The Element ID and Length fields are defined in 9.4.2.1.

The Length field for this element is constrained as described below.

The DTIM Count field indicates how many Beacon frames (including the current frame) appear before the next DTIM. A DTIM count of 0 indicates that the current TIM is a DTIM. The DTIM Count field is a single octet. When a TIM element is included in a TIM frame, the DTIM Count field is reserved.

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The DTIM Period field indicates the number of beacon intervals or short beacon intervals between successive DTIMs. If all TIMs are DTIMs, the DTIM Period field has the value 1. The DTIM Period value 0 is reserved. The DTIM Period field is a single octet. If dot11ShortBeaconInterval is equal to true, the DTIM Period field is set to dot11ShortBeaconDTIMPeriod. If dot11ShortBeaconInterval is equal to false, the DTIM Period field is set to dot11DTIMPeriod (see 11.1.3.10.2).

The Bitmap Control field is a single octet. Bit 0 of the field contains the traffic indication virtual bitmap bit associated with AID 0. This bit is set to 1 in TIM elements with the DTIM Count field set to 0 when one or more group addressed MSDUs/MMPDUs are buffered at the AP or the mesh STA and they are not to be delivered using group AID as described in 10.55. When the TIM is carried in a non-S1G PPDU, the remaining 7 bits of the field form the Bitmap Offset as shown in Figure 9-150. When the TIM is carried in an S1G PPDU, bit 1 to bit 5 of the field form the Page Slice Number subfield, and bit 6 and bit 7 of the field form the Page Index subfield as shown in Figure 9-151.

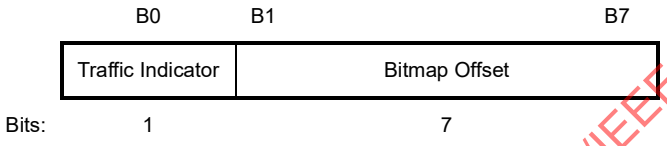

Figure 9-150—Bitmap Control field format when TIM is carried in a non-S1G PPDU

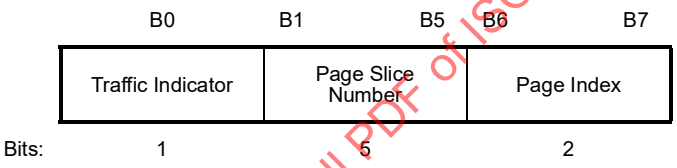

Figure 9-151—Bitmap Control field format when TIM is carried in an S1G PPDU

The Page Slice Number subfield indicates which page slice is encoded in the Partial Virtual Bitmap field (see 10.51) when the subfield is in the range of 0 to 30. If the Page Slice Number subfield is 31, then the entire page indicated by the Page Index subfield value is encoded in the Partial Virtual Bitmap field of the TIM elements with the same page index.

The Page Index subfield indicates the index of the page encoded in the Partial Virtual Bitmap field.

When the TIM is carried in a non-S1G PPDU, the traffic indication virtual bitmap, maintained by the AP or the mesh STA that generates a TIM, consists of 2008 bits, and it is organized into 251 octets such that bit number N ($0 \le N \le 2007$) in the bitmap corresponds to bit number (N mod 8) in octet number $\lfloor N / 8 \rfloor$ where the low order bit of each octet is bit number 0, and the high order bit is bit number 7. When the TIM is carried in an S1G PPDU, the traffic-indication virtual bitmap has the hierarchical structure shown in Figure 9-152. Each bit in the traffic indication virtual bitmap corresponds to traffic buffered for a specific neighbor peer mesh STA within the MBSS that the mesh STA is prepared to deliver[24] or for a STA within the BSS that the AP is prepared to deliver at the time the Beacon frame is transmitted. Bit number N indicates the status of buffered, individually addressed MSDUs/MMPDUs for the STA whose AID is N, or group addressed MSDUs/MMPDUs for the STAs whose group AID is N. It is set as follows:

— If the STA is not using APSD, and any individually addressed MSDUs/MMPDUs for that STA are buffered and the AP or the mesh STA is prepared to deliver them, then bit number N in the traffic indication virtual bitmap is 1.

[24] How the AP or mesh STA determines the traffic it is prepared to deliver is outside the scope of this standard.

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— If the STA is using APSD, and any individually addressed MSDUs/MMPDUs for that STA are buffered in at least one nondelivery-enabled AC (if there exists at least one nondelivery-enabled AC), then bit number *N* in the traffic indication virtual bitmap is 1.
— If the STA is using APSD, all ACs are delivery-enabled, and any individually addressed MSDUs/MMPDUs for that STA are buffered in any AC, then bit number *N* in the traffic indication virtual bitmap is 1.
— Otherwise, bit number *N* in the traffic indication virtual bitmap is 0.

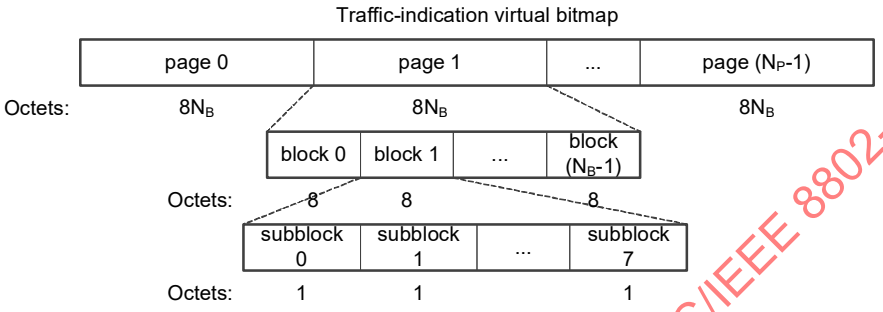

Figure 9-152—Hierarchical structure of traffic-indication virtual bitmap carried in an S1G PPDU

When dot11MultiBSSIDImplemented is false and the TIM is carried in a non-S1G PPDU, the Partial Virtual Bitmap field consists of octets numbered *N*1 to *N*2 of the traffic indication virtual bitmap, where *N*1 is the largest even number such that bits numbered 1 to (*N*1 × 8) − 1 in the traffic indication virtual bitmap are all 0 and *N*2 is the smallest number such that bits numbered (*N*2 + 1) × 8 to 2007 in the traffic indication virtual bitmap are all 0. In this case, the Bitmap Offset subfield value contains the number *N*1/2, and the Length field is set to (*N*2 – *N*1) + 4.

NOTE 1—The bit numbered 0 in the traffic indication virtual bitmap need not be included in the Partial Virtual Bitmap field even if that bit is set.

When the TIM is carried in a non-S1G PPDU, in the event that all bits other than bit 0 in the traffic indication virtual bitmap are 0, the Partial Virtual Bitmap field is encoded as a single octet equal to 0, the Bitmap Offset subfield is 0, and the Length field is 4. When the TIM is carried in an S1G PPDU, if all bits in virtual bitmap are 0, the Partial Virtual Bitmap field is not present in the TIM element and the Length field of the TIM element is set to 3. If all bits in the virtual bitmap are 0 and all the bits of the Bitmap Control field are 0, both the Partial Virtual Bitmap field and the Bitmap Control field are not present in the TIM element and the Length field of the TIM element is set to 2. The Bitmap Control field is present if the Partial Virtual Bitmap field is present.

When dot11MultiBSSIDImplemented is true, the Partial Virtual Bitmap field of the TIM element is constructed as follows, where the maximum possible number of BSSIDs is an integer power of 2, $n = \log2$ (maximum possible number of BSSIDs).

— The bits 1 to $(2^n - 1)$ of the bitmap are used to indicate that one or more group addressed frames are buffered for each AP corresponding to a nontransmitted BSSID and are called NonTxBSS identifiers (NonTxBSS IDs). The NonTxBSS ID equals the value carried in the BSSID Index field of the Multiple BSSID-Index element carried in its nontransmitted BSSID profile (see 9.4.2.45). The AIDs from 1 to $(2^n - 1)$ are not allocated to a STA (in each page for an S1G STA). A bit position corresponding to an inactive nontransmitted BSSID is reserved and set to 0 (in each page for an S1G STA). The remaining AIDs are shared by the BSSs corresponding to the transmitted BSSID and all nontransmitted BSSIDs.

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— When the DTIM Count field carried in a Multiple BSSID-Index element is 0 for a BSS that has a nontransmitted BSSID, and one or more group addressed frames are buffered at the AP for this BSS, the corresponding NonTxBSS ID bit is set to 1.

— Each bit starting from bit 2^n in the traffic indication virtual bitmap corresponds to individually addressed traffic buffered for a specific STA within any BSS corresponding to a transmitted or nontransmitted BSSID at the time the Beacon frame is transmitted. The correspondence is based on the AID of the STA.

— Based upon its knowledge of the capability of associated stations to support the multiple BSSID capability, as indicated by the corresponding field in the Extended Capabilities element and the content of the traffic indication virtual bitmap, an AP encodes the Partial Virtual Bitmap and the Bitmap Control field of the TIM element using one of the three following methods. Specifically, a non-S1G AP uses Method B when it determines that the bit for each associated non-AP STA in the traffic indication virtual bitmap that is reconstructed by each non-AP STA from the received TIM element encoded using Method B is set correctly. Otherwise, a non-S1G AP uses Method A and an S1G AP uses Method C.

Method A, Method B and Method C are described as follows:

a) Method A: The Partial Virtual Bitmap field consists of octets numbered 0 to $N2$ of the traffic indication virtual bitmap, where $N2$ is the smallest number such that bits numbered $(N2 + 1) \times 8$ to 2007 in the traffic indication virtual bitmap are all 0. If such a value $N2$ does not exist, that is, when not all bits in the last octet of the traffic indication virtual bitmap are equal to 0, $N2 = 250$. When using this method, the Bitmap Offset subfield value always contains the number 0, and the Length field is $N2 + 4$.

b) Method B: The Partial Virtual Bitmap field consists of a concatenation of octets numbered 0 to $N0 - 1$ and octets numbered $N1$ to $N2$ of the traffic indication virtual bitmap, where $N0$ is the largest positive integer such that $N0 \times 8 - 2^n < 8$. If $N0$ is an odd number, then $N1$ is the largest odd number such that $N0 < N1$and each of the bits $N0 \times 8$ to $(N1 \times 8 - 1)$ is equal to 0. When $N0$ is an even number, $N1$ is the largest even number such that $N0 < N1$ and each of the bits $N0 \times 8$ to $(N1 \times 8 - 1)$ is equal to 0. If such a value $N1 > N0$ does not exist, $N1 = N0$. Additionally, $N2$ is the smallest integer value for which the values for bit $(N2+1) \times 8$ to 2007 in the traffic indication virtual bitmap are all 0. If such a value $N2$ does not exist, that is, when not all bits in the last octet of the traffic indication virtual bitmap are equal to 0, $N2 = 250$. When using this method, the Bitmap Offset subfield contains $(N1 - N0)/2$, and the Length field is $N0 + N2 - N1 + 4$.

c) Method C: The Partial Virtual Bitmap field of the TIM that is carried in an S1G PPDU consists of a concatenation of Encoded Block subfields that contain NonTxBSS IDs and Encoded Block subfields that contain AIDs. When using this method, the Page Slice Number subfield is equal to 31, and the Page Index subfield is equal to the page index of the TIM to which the AIDs belong.

NOTE 2—When $N1 = N0$, Method B reduces to Method A.

For both Method A and Method B, when there are no frames buffered for any BSS corresponding to a transmitted or nontransmitted BSSID supported, the Partial Virtual Bitmap field is encoded as a single octet equal to 0, the Bitmap Offset subfield is 0, and the Length field is 4. For Method C when the Partial Virtual Bitmap field is not present in the TIM element then the Length field is 3 and when both the Partial Virtual Bitmap field and the Bitmap Control field are not present in the TIM element then the Length field is 2. For both Method A and Method B, when there are no buffered individually addressed frames for any BSS corresponding to a transmitted or nontransmitted BSSID, but there are buffered group addressed frames for one or more of the BSSs, the Partial Virtual Bitmap field consists of the octets number 0 to $N0 - 1$ where $N0$ is the largest positive integer such that $(N0 \times 8 - 2^n < 8)$. For Method C, the Partial Virtual Bitmap field consists of Encoded Block subfields that contain the NonTxBSS IDs of the BSSs for which there are buffered group addressed frames. In this case for Method A and Method B, the Bitmap Offset subfield value contains the number 0, and the Length field is $N0+3$, while for Method C, the Length field is equal to 3 plus the size of the encoded blocks that carry the NonTxBSS IDs, which are present in the TIM element.

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When the TIM with a nonzero Partial Virtual Bitmap field is carried in an S1G PPDU, the Partial Virtual Bitmap field is constructed with one or more Encoded Block subfields as shown in Figure 9-153. The Encoded Block subfield consists of the Block Control subfield, the Block Offset subfield, and the Encoded Block Information subfield as shown in Figure 9-154. When dot11MultiBSSIDImplemented is true, the Partial Virtual Bitmap field contains zero or more Encoded Block subfields that contain NonTxBSS IDs.

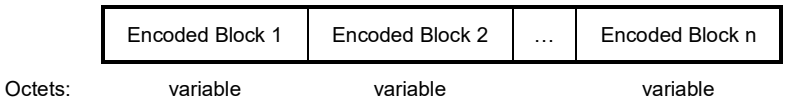

Figure 9-153—Partial Virtual Bitmap field format

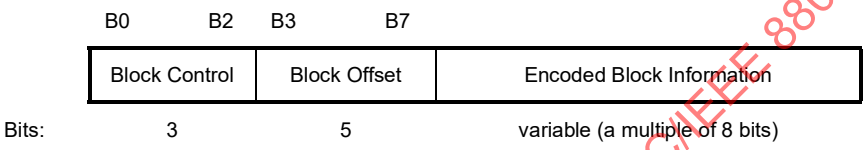

Figure 9-154—Encoded Block subfield format

The Block Control subfield indicates the encoding mode used in the Encoded Block subfield as shown in Table 9-94. The format of the Block Control subfield is as shown in Figure 9-155. The Block Control subfield consists of the Encoding Mode subfield and the Inverse Bitmap subfield.

Table 9-94—Block Control field encoding

Bit 2	Bit 1	Bit 0	Encoding mode
0	0	0	Block Bitmap
0	0	1	Single AID
0	1	0	OLB
0	1	1	ADE
1	0	0	Inverse Bitmap + Block Bitmap
1	0	1	Inverse Bitmap + Single AID
1	1	0	Inverse Bitmap + OLB
1	1	1	Inverse Bitmap + ADE

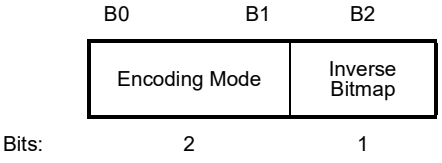

Figure 9-155—Block Control subfield format

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The Inverse Bitmap subfield is set to 1, if the Encoded Block Information field is encoded based on the inverted version of the block, which inverts each bit value of the block. The Inverse Bitmap subfield is set to 0, otherwise.

The Encoding Mode subfield indicates one of the four encoding modes: the Block Bitmap mode, the Single AID mode, the offset length bitmap (OLB) mode, and the AID with differential encoding (ADE) mode. The four encoding modes are explained in the following subclauses.

The Block Offset field indicates the index of the block that is encoded in the Encoded Block subfield.

The Encoded Block Information subfield is defined depending on the Encoding Mode subfield and explained within the subclause for each of the encoding modes.

9.4.2.5.2 Block Bitmap mode

The Encoded Block Information field consists of the Block Bitmap subfield and n Subblock subfields, where n is the number of bits equal to 1 in the Block Bitmap subfield. The format of the Encoded Block Information subfield is shown in Figure 9-156.

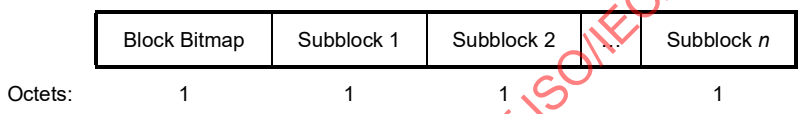

Figure 9-156—Encoded Block Information (Block Bitmap mode)

The bit in position *m* of the Block Bitmap subfield, if equal to 1, indicates that the subblock in position *m* of the Block is present in the Encoded Block Information subfield. The bit in position *m* of the Block Bitmap subfield, if equal to 0, indicates that the subblock in position *m* of the block is not present in the Encoded Block Information subfield. When *n* bits in the Block Bitmap subfield are equal to 1, *n* Subblock subfields follow the Block Bitmap field in ascending order of the subblock positions in the block.

Each Subblock subfield contains a subblock of the block, which has at least one bit position equal to 1. The bit in position *q* of the Subblock subfield, which contains the Subblock in position *m* of the block, indicates traffic buffered for the STA whose AID is *N*, where *N* is constructed by concatenating *q* (*N*[0:2]), *m* (*N*[3:5]), the Block Offset field (*N*[6:10]), and the Page Index field (*N*[11:12]) in sequence from LSB to MSB.

9.4.2.5.3 Single AID mode

The Encoded Block Information subfield consists of the Single AID subfield as shown in Figure 9-157. The Single AID subfield contains the 6 LSBs of the single AID in the block. The rest of the bits of the Encoded Block Information subfield are reserved. The value in the Single AID subfield indicates traffic buffered for the STA whose AID is *N*, where *N* is constructed by concatenating the Single AID subfield(*N*[0:5]), the Block Offset field (*N*[6:10]), and the Page Index field (*N*[11:12]) in sequence from LSB to MSB.

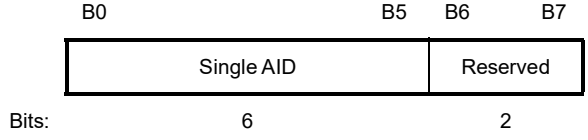

Figure 9-157—Encoded Block Information (Single AID mode)

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9.4.2.5.4 OLB mode

The Encoded Block Information field consists of the Length subfield and *n* Subblock subfields. The format of the Encoded Block Information field is shown in Figure 9-158.

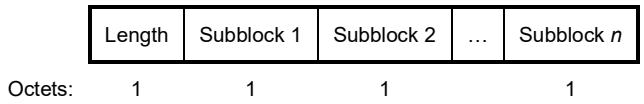

Figure 9-158—Encoded Block Information (OLB mode)

The Length subfield is 1 octet. A Length subfield equal to *n* indicates that the Encoded Block Information field contains *n* contiguous subblocks in ascending order from multiple blocks starting from the first subblock of the block in position Block Offset.

Each Subblock subfield contains a subblock of the Partial Virtual Map. A subblock *m* of the Encoded Block Information field is located in block *k* where *k* is obtained as Block Offset + $\lfloor m / 8 \rfloor$. The bit in position *q* of the subblock *m*, which is located in block *k*, when set to 1, indicates that there is traffic buffered for the STA whose AID is *N*, where *N* is constructed by concatenating *q* (*N*[0:2]), the subblock offset *m* mod 8 (*N*[3: 5]), the block *k* (*N*[6:10]), and the Page Index field (*N*[11:12]), in sequence from LSB to MSB.

9.4.2.5.5 ADE mode

The Encoded Block Information field consists of the Encoding Word Length (EWL) subfield, Length subfield, *n* AID Differential Values (ΔAID) subfields and padding subfield, where *n* is the number of paged AIDs encoded in the ADE block. The format of the Encoded Block Information field is shown in Figure 9-159.

Figure 9-159—Encoded Block Information (ADE Block)

The length of each ΔAID subfields (*WL*) represents the encoded word length (the number of bits of each encoded words) of each AID. All *WL* have the same length. *WL* is indicated by EWL subfield.

The EWL subfield is 3 bits with B0 being LSB. The values of EWL subfield ranging from 0 to 7 represent *WL* being 1 to 8, respectively.

The Length subfield is 5 bits with B3 being LSB and it specifies the total length of the current ADE block in octets, excluding EWL and Length subfields.

The padding subfield contains 0–7 padding bits. The padding bits are set to 0.

To encode a list of paged AIDs, denoted as AID1, AID2 … AIDn, an AP can derive the *offset* value in the Block Offset field (9.4.2.5) for the current ADE Block by $\lfloor (\mathrm{AID}_1 \bmod 2048) / 64 \rfloor$.

The encoding procedure is as follows:

If all AIDs in the ADE blocks are paged, AP sets the Inverse Bitmap subfield to 1 and ADE block consists only EWL and Length fields, where both EWL and Length Field are set to 0s.

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If all but one AIDs in the ADE blocks are paged, AP sets the Inverse Bitmap subfield to 1 and ADE block consists only one ΔAID subfield. The AP sets the EWL to 7 and the Length subfield to one. ΔAID subfield is set to (AID – (*Page Index* × 2048 + *Block Offset* × 64)).

If only one AID is paged in the ADE blocks, AP sets the Inverse Bitmap subfield to 0 and uses the Single AID mode.

For all other cases, AP sorts all AID*i*, i = 1, 2…n in an ascending order (AID1 < AID2 < … < AIDn) and then calculates the AID differential values according to the following formulas:

$$\Delta AID1 = AID1 - (Page\ Index \times 2048 + Block\ Offset \times 64)$$

$$\Delta AID_i = AID_i - AID_{i-1},\ i = 2 \ldots n$$

Determine *WL* as the minimum bits that can represent the largest ΔAID*i* (or mathematically $\lfloor \log_2(MAX)(\Delta AID_i) \rfloor + 1$ where $MAX(\Delta AID_i)$ denotes the largest ΔAID_i), i=1,2,…,n. The EWL subfield is set to *WL*-1. For n AID differential values, a total of $WL \times n$ bits are required. The number of bits is less than or equal to 248 since maximum payload in an ADE block is 31 × 8=248 (31 is the maximum value in the 5-bit Length subfield). If the total number of bits $WL \times n$ is not a multiple of an octet, $[WL \times n/8] \times 8 - WL \times n$ zero bits are padded to make the ADE block end at octet boundary.

When decoding, if the Inverse Bitmap subfield is 1, and the EWL and Length subfield are 0s, then all AIDs in the ADE blocks are paged.

If the Inverse Bitmap subfield is 1, the EWL is 7 and the Length subfield is 1, then all AIDs except one in the ADE blocks are paged. The unpaged AID is ΔAID1 + *Block Offset* × 64 + *Page Index* × 2048.

For other cases, a STA can extract *Page Index* (9.4.2.5) and *Block Offset* (9.4.2.5), EWL and Length values from the respective fields. It derives *WL* by adding 1 to the value from EWL field. The paged AIDs are then derived with following formulas:

$$AID1 = \Delta AID1 + (Page\ Index \times 2048 + Block\ Offset \times 64)$$

$$AID_i = \Delta AID_i + AID_i - 1,\ i = 2, \ldots, n$$

The decoder stops the decoding of the current ADE block when either one of following conditions is satisfied:

— The number of bits left for decoding is less than WL.
— ΔAIDi is zero and $i > 1$.

AIDs from the same or different blocks can be encoded into one ADE block. A STA can derive the number of AIDs, including both paged and unpaged AIDs, encoded in one ADE block with following method:

If an ADE block is not the last encoded block in the TIM element, the decoder can derive the number of AIDs encoded by this ADE block based on the *Block offset* values in the current and the immediate next encoded blocks. For example, the offset values in the current ADE block and the next encoded block are *Offset*1 and *Offset*2. Then the AIDs encoded by this ADE block is [*Page Index* × 2048 + *Offset*1 × 64, *Page Index* × 2048 + *Offset*2×64), *Page Index*×2048 + *Offset*1 × 64 is included and *Page Index* × 2048 + *Offset*2 × 64 is excluded.

If an ADE block is the last one in the TIM element, the number of AIDs encoded by the last ADE block can be determined based on the offset value and page length or page slice length if its TIM page is sliced.

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9.4.2.6 IBSS Parameter Set element

The IBSS Parameter Set element contains the set of parameters necessary to support an IBSS. See Figure 9-160.

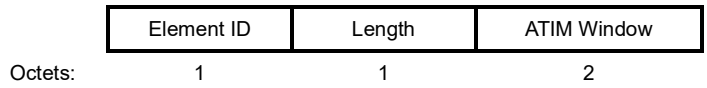

Figure 9-160—IBSS Parameter Set element format

The Element ID and Length fields are defined in 9.4.2.1.

The ATIM Window field contains the ATIM window length in TU.

9.4.2.7 Challenge Text element

The Challenge Text element contains the challenge text within Authentication exchanges. See Figure 9-161.

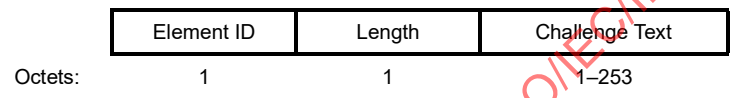

Figure 9-161—Challenge Text element format

The Element ID and Length fields are defined in 9.4.2.1.

The content of the Challenge Text field is dependent upon the authentication algorithm and the transaction sequence number as specified in 12.3.3.2.

9.4.2.8 Country element

The Country element contains the information required to allow a STA to identify the regulatory domain in which the STA is located and to configure its PHY for operation in that regulatory domain. The format of this element is as shown in Figure 9-162.

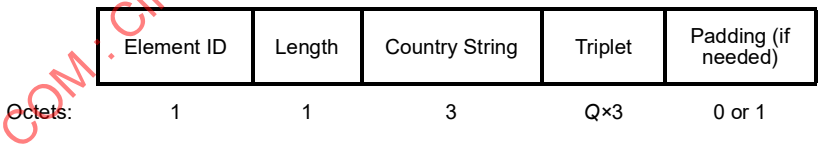

Figure 9-162—Country element format

The Element ID and Length fields are defined in 9.4.2.1. The length of the element is variable, as the element contains the variable length Triplet field.

The AP and mesh STA set the Country String field to the value contained in dot11CountryString before transmission in a Beacon or Probe Response frame. Upon reception of this element, a STA sets the dot11CountryString to the value contained in this field. The three octets of the Country String have additional structure as defined by dot11CountryString (see Annex C).

If dot11OperatingClassesRequired is false, then the Triplet field is a single Subband Triplet Sequence field, as shown in Figure 9-163, that is composed of *Q* Subband Triplet fields, where *Q* is one or more. The format of the Subband Triplet field is shown in Figure 9-164.

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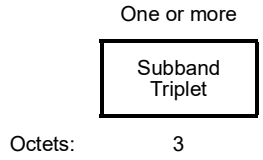

Figure 9-163—Subband Triplet Sequence format

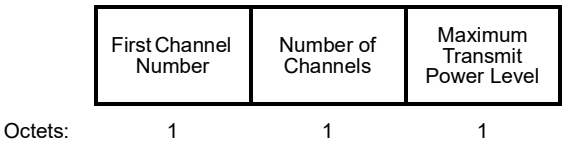

Figure 9-164—Subband Triplet field format

If dot11OperatingClassesRequired is true, then the Triplet field is composed of zero or more Subband Triplet fields followed by one or more Operating/Subband Sequences, as shown in Figure 9-165. Each Operating/Subband Sequence is composed of one Operating Triplet field followed by one Subband Triplet Sequence field, as shown in Figure 9-166. Each Subband Triplet Sequence field is composed of zero or more Subband Triplet fields. If dot11OperatingClassesRequired is true, the number of triplets in the Triplet field is $Q = N + \sum_{m=1}^{M} (1 + P(m))$, where N is the total number of Subband Triplet fields and M is the total number of Operating/Subband Sequences contained in Country element and $P(m)$ is the number of Subband Triplet fields making up Operating/Subband Sequence field m.

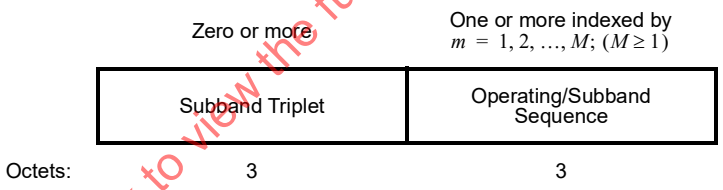

Figure 9-165—Triplet field format if dot11OperatingClassRequired is true

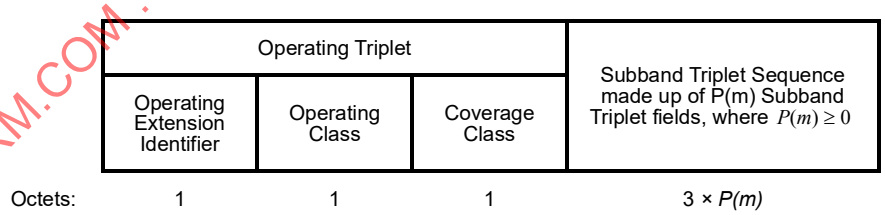

Figure 9-166—Format of *m*-th Operating/Subband Sequence field

The number Q of Subband fields or Operating triplet fields in the element is determined by the Length field.

An operating class for an 80+80 MHz channel width is expressed by two consecutive Operating/Subband Sequences, where the first Operating/Subband Sequence field contains an Operating Triplet field indicating an 80 MHz channel spacing with an 80+ behavior limit and the second Operating/Subband Sequence field contains an Operating Triplet field indicating an 80 MHz channel spacing without an 80+ behavior limit.

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Operating/Subband Sequence fields that contain an Operating Class field for which the Channel spacing (MHz) column in the appropriate table in Annex E equals 80 or 160 contain zero Subband Triplet fields.

NOTE 1—Any Operating Triplet field indicating 80 MHz, 160 MHz, and 80+80 MHz can be omitted from the Country element (see 10.22.3).

NOTE 2—The Transmit Power Envelope element is always used for TPC for 80 MHz, 160 MHz, or 80+80 MHz operating classes instead of Subband Triplet fields (see 11.38.1).

The first octet in each Subband Triplet field or Operating Triplet field contains an unsigned integer and identifies the type of field. If the integer has a value less than or equal to 200, then the field is a Subband Triplet field. If the integer has a value of 201 or greater, then the field is an Operating Triplet field.

The minimum length of the element is 8 octets.

The First Channel Number field indicates the lowest channel number in the Subband Triplet field. No channel is indicated by more than one pair of First Channel Number and Number of Channels fields within a Subband Triplet Sequence field. [For example, the (First Channel Number, Number of Channels) pairs (2,4) and (5,2) in 2.4 GHz each indicate channel 5, therefore are not used within the same Subband Triplet Sequence field.] The First Channel Numbers are monotonically increasing within a Subband Triplet Sequence field. The First Channel Number and the Number of Channels pairs in a Country element are used to describe channels only in the band on which the frame containing the element is transmitted.

Outside the 2.4 GHz band, the channel numbers that are included in a group of channels are separated by the BSS bandwidth. For Subband Triplet fields that are not within an Operating/Subband Sequence field, the BSS bandwidth is 20 MHz. For Subband Triplet fields that are within an Operating/Subband Sequence field, the BSS bandwidth is as indicated by the operating class in the same Operating/Subband Sequence field. In the 2.4 GHz band, the channel numbers that are included in a group of channels are separated by 5 MHz (for both 20 and 40 MHz BSS bandwidth), except that channel 14 is treated as if it were 5 MHz above channel 13.

NOTE 3—For example, the channels 1 to 11 in the 2.4 GHz band can be represented using one Subband Triplet subfield with First Channel Number = 1 and Number of Channels = 11. The channels 36, 40, 44, and 48 with 20 MHz BSS bandwidth in the 5 GHz band can be represented using one Subband Triplet subfield with First Channel Number = 36 and Number of Channels = 4. The six channels 183, 184, 185, 187, 188, and 189 (but not 186) with 10 MHz BSS bandwidth can be represented using three Subband Triplet subfields: one with First Channel Number = 183 and Number of Channels = 4, one with First Channel Number = 184 and Number of Channels = 1 and one with First Channel Number = 188 and Number of Channels = 1.

The Maximum Transmit Power Level field is a 2s complement signed integer. The Maximum Transmit Power Level field indicates the maximum power, in dBm, allowed to be transmitted. As the method of measurement for maximum transmit power level differs by regulatory domain, the value in this field is interpreted according to the regulations applicable for the domain identified by the Country String.

An operating class is an index into a set of values for radio equipment sets of rules.

A coverage class is an index into a set of values for aAirPropagationTime. The Coverage Class field is reserved in a DMG BSS.

The Coverage Class field of the Operating Triplet field specifies the aAirPropagationTime characteristic used in BSS operation, as shown in Table 9-95. The characteristic aAirPropagationTime describes variations in actual propagation time that are accounted for in a BSS and, together with maximum transmit power level, allow control of BSS diameter.

The Padding field is used to add, if needed, a single octet (with the value 0) to the Country element so that its length is evenly divisible by 2.

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Table 9-95—Coverage Class field parameters

Coverage class value	aAirPropagationTime (μs)
0–31	$n \times 3$, where n is the value of the coverage class
32–255	Reserved

9.4.2.9 Request element

This element is placed in a Probe Request frame or Information Request frame to request that the responding STA include the requested information in the Probe Response frame or Information Response frame, respectively. The format of the element is as shown in Figure 9-167.

	Element ID	Length	Requested Element IDs
Octets:	1	1	variable

Figure 9-167—Request element format

The Element ID and Length fields are defined in 9.4.2.1.

The Requested Element IDs are the list of elements that are requested to be included in the Probe Response or Information Response frame. The Requested Element IDs are listed in order of increasing element ID. The Requested Element IDs within a Request element transmitted in an Information Request frame do not include an element ID that corresponds to an element that will be included in the Information Response frame even in the absence of the Request element, as shown in Table 9-461. A given element ID is included at most once among the Requested Element IDs.

NOTE—Some implementations might unnecessarily include in a Probe Request frame a Request element that contains the element ID of an element that will be included in the Probe Response frame even in the absence of the element ID in the Request element; see the notes in Table 9-39. Some implementations might include in a Probe Request frame a Request element that contains the element ID of an element that will not be included in the Probe Response frame even in the presence of the element ID in the Request element.

The Request element does not support elements that contain an Element ID Extension field.

See 11.1.4.3.9 for additional requirements.

9.4.2.10 Extended Request element

This element is placed in a Probe Request frame or Information Request frame to request that the responding STA include the requested information in the Probe Response frame or Information Response frame, respectively. The format of the element is as shown in Figure 9-168.

	Element ID	Length	Element ID Extension	Requested Element ID	Requested Element ID Extensions
Octets:	1	1	1	1	variable

Figure 9-168—Extended Request element format

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The Element ID, Element ID Extension, and Length fields are defined in 9.4.2.1.

The Requested Element ID field contains one of the Element IDs used to indicate an extended element.

The Requested Element ID Extensions field contains a list of 1-octet element ID extension values that, combined with the value of the Requested Element ID field, identify elements that are requested to be included in the Probe Response or Information Response frame. The values in this field are listed in increasing order. The requested elements within an Extended Request element transmitted in a Probe Request frame do not identify an element that will be included in the Probe Response frame even in the absence of the Request element, or will be excluded from the Probe Response frame even in the presence of the Extended Request element as described by the notes in Table 9-39. The requested elements within an Extended Request element transmitted in an Information Request frame do not identify an element that will be included in the Information Response frame even in the absence of the Extended Request element, as shown in Table 9-461. A given element ID extension value is included at most once in the Requested Element ID Extensions field.

See 11.1.4.3.9 for additional requirements.

9.4.2.11 ERP element

The ERP element contains information on the presence of Clause 15 or Clause 16 STAs in the BSS that are not capable of Clause 18 (ERP-OFDM) data rates. It also contains the requirement of the ERP element sender (AP, IBSS STA, or mesh STA) as to the use of protection mechanisms to optimize BSS performance and as to the use of long or short Barker preambles. See Figure 9-169 for a definition of the frame element.

The ERP element has the form shown in Figure 9-169.

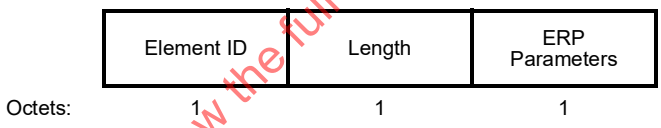

Figure 9-169—ERP element format

The Element ID and Length fields are defined in 9.4.2.1.

The ERP Parameters field is defined in Figure 9-170.

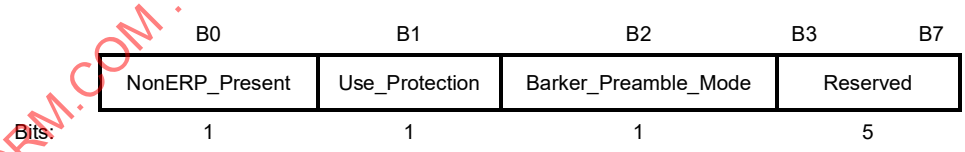

Figure 9-170—ERP Parameters field format

Recommended behavior for setting the Use_Protection bit is contained in 10.27.

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9.4.2.12 Extended Supported Rates and BSS Membership Selectors element

The Extended Supported Rates and BSS Membership Selectors element specifies the rates in the OperationalRateSet parameter, as described in the MLME-JOIN.request and MLME-START.request primitives, and zero or more BSS membership selectors, where these are not carried in the Supported Rates and BSS Membership Selectors element. See Figure 9-171.

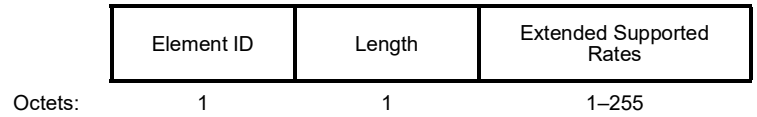

Figure 9-171—Extended Supported Rates and BSS Membership Selectors element format

The Element ID and Length fields are defined in 9.4.2.1.

The format and interpretation of each octet of the Extended Supported Rates field is the same as that of an octet in the Supported Rates field in a Supported Rates and BSS Membership Selectors element (see 9.4.2.3).

9.4.2.13 Power Constraint element

The Power Constraint element contains the information necessary to allow a STA to determine the local maximum transmit power in the current channel. The format of the Power Constraint element is shown in Figure 9-172.

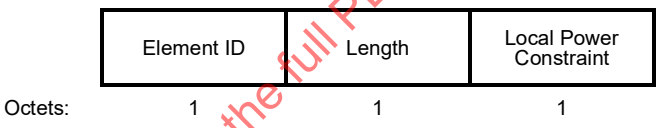

Figure 9-172—Power Constraint element format

The Element ID and Length fields are defined in 9.4.2.1.

The Local Power Constraint field is coded as an unsigned integer in units of decibels. The local maximum transmit power for a channel is thus defined as the maximum transmit power level specified for the channel in the Country element minus the local power constraint specified for the channel (from the MIB) in the Power Constraint element.

The Power Constraint element is included in Beacon frames, as described in 9.3.3.2, and Probe Response frames, as described in 9.3.3.10. The use of Power Constraint elements is described in 11.7.5.

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9.4.2.14 Power Capability element

The Power Capability element specifies the minimum and maximum transmit powers with which a STA is capable of transmitting in the current channel. The format of the Power Capability element is shown in Figure 9-173.

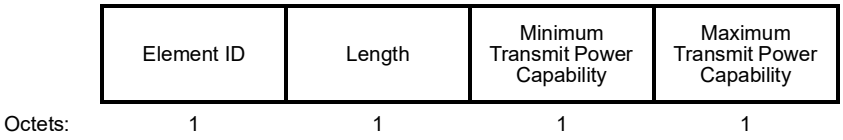

Figure 9-173—Power Capability element format

The Element ID and Length fields are defined in 9.4.2.1.

The Minimum Transmit Power Capability field is set to the nominal minimum transmit power with which the STA is capable of transmitting in the current channel, with a tolerance ± 5 dB. The field is coded as a 2s complement signed integer in units of decibels relative to 1 mW. Further interpretation of this field is defined in 11.7.4.

The Maximum Transmit Power Capability field is set to the nominal maximum transmit power with which the STA is capable of transmitting in the current channel, with a tolerance ± 5 dB. The field is coded as a 2s complement signed integer in units of decibels relative to 1 mW. Further interpretation of this field is defined in 11.7.4.

The Power Capability element is included in Association Request frames, as described in 9.3.3.5; Reassociation Request frames, as described in 9.3.3.7; and Mesh Peering Open frame, as described in 9.6.15.2.2. The use of Power Capability elements is described in 11.7.2.

9.4.2.15 TPC Request element

The TPC Request element contains a request for a STA to report transmit power and link margin information using a TPC Report element. The format of the TPC Request element is shown in Figure 9-174.

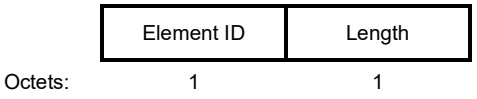

Figure 9-174—TPC Request element format

The Element ID and Length fields are defined in 9.4.2.1.

The TPC Request element is included in TPC Request frames, as described in 9.6.2.4. The use of TPC Request elements and frames is described in 11.7.7.

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9.4.2.16 TPC Report element

The TPC Report element contains transmit power and link margin information sent in response to a TPC Request element or a Link Measurement Request frame. A TPC Report element is included in a Beacon frame or Probe Response frame without a corresponding request. The format of the TPC Report element is shown in Figure 9-175.

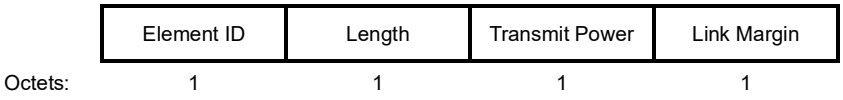

Figure 9-175—TPC Report element format

The Element ID and Length fields are defined in 9.4.2.1.

The Transmit Power field is set to the transmit power used to transmit the frame containing the TPC Report element. The field is coded as a 2s complement signed integer in units of decibels relative to 1 mW. The tolerance for the transmit power value reported in the TPC Response element is ± 5 dB. This tolerance is defined as the difference, in decibels, between the reported power value and the actual EIRP of the STA (when transmitting 1500 octet frames or maximum MPDU sized-frames, whichever is smaller).

The Link Margin field contains the link margin for the receive time and for the receive rate of the frame containing the TPC Request element or the Link Measurement Request frame. The field is coded as a 2s complement signed integer in units of decibels. The Link Margin field is reserved when a TPC Report element is included in a Beacon frame or Probe Response frame. The method used to measure the link margin is beyond the scope of this standard.

The TPC Report element is included in TPC Report frames, as described in 9.6.2.5; Link Measurement Report frames, as described in 9.6.6.5; Beacon frames, as described in 9.3.3.2; and Probe Response frames, as described in 9.3.3.10. The use of TPC Report elements and frames is described in 11.7.7.

9.4.2.17 Supported Channels element

The Supported Channels element contains a list of channel subbands (from those channels defined in 17.3.8.4.3) in which a STA is capable of operating. The format of the Supported Channels element is shown in Figure 9-176.

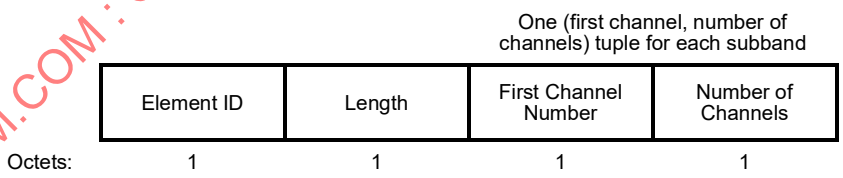

Figure 9-176—Supported Channels element format

The Element ID and Length fields are defined in 9.4.2.1.

The First Channel Number field is set to the first channel (as defined in 17.3.8.4.3) in a subband of supported channels.

The Number of Channels field is set to the number of channels in a subband of supported channels.

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The Supported Channels element is included in Association Request frames, as described in 9.3.3.5; Reassociation Request frames, as described in 9.3.3.7; and Mesh Peering Open frame, as described in 9.6.15.2.2. The use of the Supported Channels element is described in 11.8.2 and 11.8.8.

9.4.2.18 Channel Switch Announcement element

The Channel Switch Announcement element is used by a non-DMG AP, non-DMG IBSS STA, or mesh STA to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 9-177.

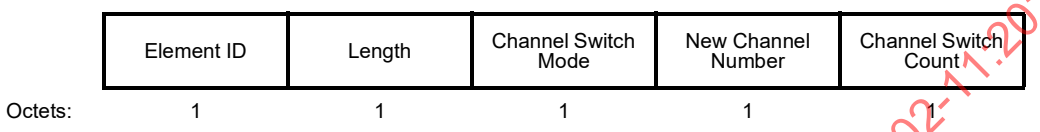

Figure 9-177—Channel Switch Announcement element format

The Element ID and Length fields are defined in 9.4.2.1.

The Channel Switch Mode field indicates any restrictions on transmission until a channel switch. A non-DMG AP or non-DMG IBSS STA sets the Channel Switch Mode field to either 0 or 1 on transmission. In an MBSS, the Channel Switch Mode field is reserved. See 11.8.9.

The New Channel Number field is set to the number of the channel to which the STA is moving (as defined in 17.3.8.4.3).

For nonmesh STAs, the Channel Switch Count field is set to the number of TBTTs until the STA sending the Channel Switch Announcement element switches to the new channel. The value 1 indicates that the switch occurs at the next TBTT (the ensuing Beacon frame is created assuming the new channel), and the value 0 indicates that the switch occurs at any time after the frame containing the element is transmitted.

For mesh STAs, the Channel Switch Count field is encoded as an octet with bits 6 to 0 set to the time, in units of 2 TU when the MSB (bit 7) is 0, or in units of 100 TU when the MSB (bit 7) is 1, until the mesh STA sending the Channel Switch Announcement element switches to the new channel. An octet with bits 6 to 0 indicates that the switch occurs at any time after the frame containing the element is transmitted. For example, a 200 TU channel switch time is encoded as X'82' and a 10 TU channel switch time is encoded as X'05'.

The Channel Switch Announcement element is included in Channel Switch Announcement frames, as described in 9.6.2.6, and can be included in Beacon frames, as described in 9.3.3.2, and Probe Response frames, as described in 9.3.3.10. The use of Channel Switch Announcement elements and frames is described in 11.8.8.

9.4.2.19 Secondary Channel Offset element

The Secondary Channel Offset element is used by an AP, IBSS STA or mesh STA when changing to a new 40 MHz or wider channel. The format of the Secondary Channel Offset element is shown in Figure 9-178.

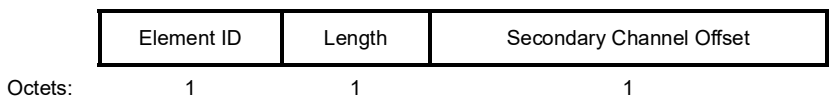

Figure 9-178—Secondary Channel Offset element format

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The Secondary Channel Offset element is included in Channel Switch Announcement frames, as described in 9.6.2.6.

The Element ID and Length fields are defined in 9.4.2.1.

The Secondary Channel Offset field of the Secondary Channel Offset element represents the position of the secondary channel relative to the primary channel. The values of the Secondary Channel Offset field are defined in Table 9-96.

Table 9-96—Values of the Secondary Channel Offset field

Value	Name	Description
0	SCN - no secondary channel	Indicates that no secondary channel is present.
1	SCA - secondary channel above	Indicates that the secondary channel is above the primary channel.
2		Reserved.
3	SCB - secondary channel below	Indicates that the secondary channel is below the primary channel.
4–255		Reserved.

9.4.2.20 Measurement Request element

9.4.2.20.1 General

The Measurement Request element contains a request that the receiving STA undertake the specified measurement action. The Measurement Request element is included in Spectrum Measurement Request frames, as described in 9.6.2.2, or Radio Measurement Request frames, as described in 9.6.6.2. Measurement types 0, 1, and 2 are defined for spectrum management and are included only in Spectrum Measurement Request frames. The use of Measurement Request elements for spectrum management is described in 11.8.7. All other measurement types are included only in Radio Measurement Request frames. The use of Measurement Request elements for radio measurement is described in 11.10.

The format of the Measurement Request element is shown in Figure 9-179.

	Element ID	Length	Measurement Token	Measurement Request Mode	Measurement Type	Measurement Request
Octets:	1	1	1	1	1	variable

Figure 9-179—Measurement Request element format

The Element ID and Length fields are defined in 9.4.2.1.

The Measurement Token is set to a nonzero number that is unique among the Measurement Request elements in a particular Spectrum or Radio Measurement Request frame.

The Measurement Request Mode field (shown in Figure 9-180) is a bit field with the following bits defined:

— The Parallel bit (bit 0) is used to request that more than one measurement is to be started in parallel. Parallel is set to 1 to request that the measurement is to start at the same time as the measurement described by the next Measurement Request element in the same Radio Measurement Request

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frame. Parallel is set to 0 if the measurements are to be performed in sequence. The Parallel bit is reserved when Enable is 1, in the last or only Measurement Request element in the frame, or when the Measurement Type field is 0, 1, or 2 (spectrum management measurements). See 11.10.6.

— The Enable bit (bit 1) is used to differentiate between a request to make a measurement and a request to control the measurement requests and triggered or autonomous reports generated by the destination STA. The Enable bit is further described in Table 9-97.

— Request bit (bit 2) is described in Table 9-97.

— Report bit (bit 3) is described in Table 9-97.

— The Duration Mandatory bit (bit 4) indicates whether the measurement duration contained within the measurement request is interpreted as mandatory by the STA receiving the request. A 0 indicates that the duration requested is a maximum duration, and the requesting STA accepts measurement results taken over any shorter duration. A 1 indicates that the duration requested is a mandatory duration. The Duration Mandatory bit is reserved when the Enable bit is 1, or when the Measurement Type field is 0, 1, 2, 8, or 255. See 11.10.4.

— All other bits are reserved.

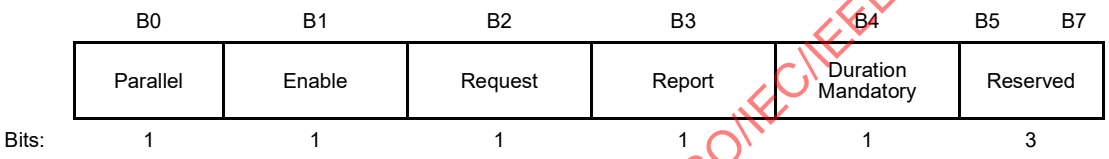

Figure 9-180—Measurement Request Mode field format

The use of the Enable, Request, and Report bits is summarized in Table 9-97. See 11.8.7 and 11.10.6 for the description of how a STA handles requests to enable or disable measurement requests and autonomous reports. See 11.10.8 for a description of the use of the Enable and Report bits in triggered reporting.

Table 9-97—Summary of use of Enable, Request, and Report bits

Bits			Meaning of bits
Enable	Request	Report	
0	Reserved	Reserved	The transmitting STA is requesting that the destination STA make a measurement of type indicated in the Measurement Type field. When Enable bit is 0, Request and Report bits are reserved.
1	0	0	The transmitting STA is requesting that the destination STA not send any measurement requests or reports of the type indicated in the Measurement Type field.
1	1	0	The transmitting STA is indicating to the destination STA that it can accept measurement requests and is requesting the destination STA not send autonomous or triggered measurement reports of the type indicated in the Measurement Type field. NOTE—This setting corresponds to the default STA behavior.
1	0	1	The transmitting STA is requesting that the destination STA not send measurement requests and indicating it accepts autonomous or triggered measurement reports of the type indicated in the Measurement Type field.
1	1	1	The transmitting STA is indicating to the destination STA that it can accept measurement requests and can accept autonomous or triggered measurement reports of the type indicated in the Measurement Type field.

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The Measurement Type field is set to a number that identifies a type of measurement request or measurement report. The measurement types that have been allocated for measurement requests are shown in Table 9-98 and measurement reports are shown in Table 9-125 (in 9.4.2.21).

Table 9-98—Measurement type definitions for measurement requests

Name	Measurement type
Basic	0
Clear Channel Assessment (CCA)	1
Receive Power Indication (RPI) Histogram	2
Channel Load	3
Noise Histogram	4
Beacon	5
Frame	6
STA Statistics	7
LCI	8
Transmit Stream/Category Measurement	9
Multicast Diagnostics	10
Location Civic	11
Location Identifier	12
Directional Channel Quality	13
Directional Measurement	14
Directional Statistics	15
Fine Timing Measurement Range	16
Reserved	17–254
Measurement Pause	255

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When the Enable bit is 0, the Measurement Request field contains the specification of a single measurement request corresponding to the measurement type, as described in 9.4.2.20.2 to 9.4.2.20.12. When the Enable bit is 1, the Measurement Request field is present only when requesting a triggered measurement.

9.4.2.20.2 Basic request

The Measurement Request field corresponding to a Basic request is shown in Figure 9-181. See 11.8.7.

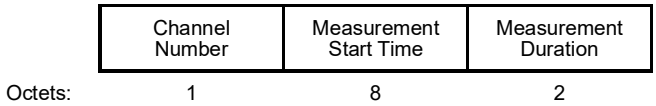

Figure 9-181—Measurement Request field format for a Basic request

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The Channel Number field is set to the channel number for which the measurement request applies where the channel number is a value from the Channel set column in Table E-4, in a row having the same value in the Channel spacing (MHz) column as the width of the primary channel.

The Measurement Start Time field is set to the TSF timer at the time (± 32 μs) at which the requested Basic request measurement starts. A 0 indicates it starts immediately.

The Measurement Duration field is set to the duration of the requested measurement, expressed in TUs.

9.4.2.20.3 CCA request (Clear channel access request)

The Measurement Request field corresponding to a CCA request is shown in Figure 9-182.

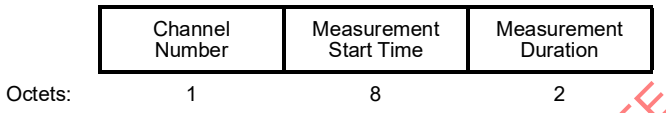

Figure 9-182—Measurement Request field format for a CCA request

The Channel Number field is set to the channel number for which the measurement request where the channel number is a value from the Channel set column in Table E-4, in a row having the same value in the Channel spacing (MHz) column as the width of the primary channel.

The Measurement Start Time field is set to the TSF at the time (± 32 μs) at which the requested CCA request measurement starts. A 0 indicates it starts immediately.

The Measurement Duration field is set to the duration of the requested measurement, expressed in TUs.

9.4.2.20.4 RPI histogram request (Received power indicator histogram request)

The Measurement Request field corresponding to an RPI Histogram request is shown in Figure 9-183.

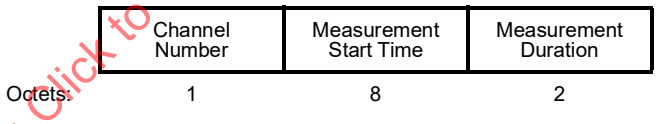

Figure 9-183—Measurement Request field format for an RPI Histogram request

The Channel Number field is set to the channel number for which the measurement request where the channel number is a value from the Channel set column in Table E-4, in a row having the same value in the Channel spacing (MHz) column as the width of the primary channel.

The Measurement Start Time field is set to the TSF at the time (± 32 μs) at which the requested RPI Histogram request measurement starts. A 0 indicates it starts immediately.

The Measurement Duration field is set to the duration of the requested measurement, expressed in TUs.

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9.4.2.20.5 Channel Load request

The Measurement Request field corresponding to a Channel Load request is shown in Figure 9-184.

	Operating Class	Channel Number	Randomization Interval	Measurement Duration	Optional Subelements
Octets:	1	1	2	2	variable

Figure 9-184—Measurement Request field format for Channel Load request

If the Wide Bandwidth Channel Switch subelement is not included, the Operating Class field indicates the operating class that identifies the channel set for which the measurement request applies. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing for which the measurement request applies. Valid operating classes are listed in Annex E, excluding operating classes that encompass a primary channel but do not identify the location of the primary channel. The Channel Number field indicates the channel number for which the measurement request applies. Channel number is defined within an operating class as shown in Annex E.

NOTE—Examples of operating classes that encompass a primary channel but do not identify the location of the primary channel are operating classes with 80 or 160 in the Channel spacing (MHz) column in the applicable table in Annex E.

If the Wide Bandwidth Channel Switch subelement is included, the fields in the Wide Bandwidth Channel Switch subelement indicate the channel for which the measurement request applies, and the Operating Class field and Channel Number field together specify the primary channel and primary 40 MHz channel within the channel identified by the Wide Bandwidth Channel Switch subelement.

The Randomization Interval field specifies the upper bound of the random delay to be used prior to making the measurement, in units of TUs. See 11.10.3.

The Measurement Duration field is set to the preferred or mandatory duration of the requested measurement, in units of TUs. See 11.10.4.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-99.

Table 9-99—Optional subelement IDs for Channel Load request

Subelement ID	Name	Extensible
0	Reserved	
1	Channel Load Reporting	Yes
2–162	Reserved	
163	Wide Bandwidth Channel Switch	Yes
164–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

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The Channel Load Reporting subelement indicates the condition for issuing a Channel Load report. The Channel Load Reporting subelement Data field format is shown in Figure 9-185 and contains a 1-octet Reporting Condition subfield and a 1-octet Channel Load Reference Value subfield. The Reporting Condition subfield is described in Table 9-100. The Channel Load Reference value is a Channel Load value as defined in 11.10.9.3 and is the reference value for the indicated reporting condition.

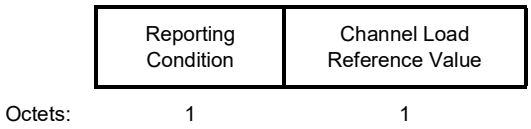

Figure 9-185—Channel Load Reporting subelement Data field format

Table 9-100—Reporting Condition subfield for Channel Load report

Condition for report to be issued	Reporting Condition
Report to be issued after each measurement (default, used when the Channel Load Reporting subelement is not included in the Channel Load request).	0
Report to be issued when the measured Channel Load is greater than or equal to the reference value.	1
Report to be issued when the measured Channel Load is less than or equal to the reference value.	2
Reserved	3–255

The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.160), with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.20.6 Noise Histogram request

The Measurement Request field corresponding to a Noise Histogram request is shown in Figure 9-186.

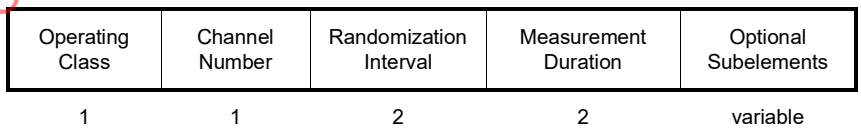

Figure 9-186—Measurement Request field format for Noise Histogram request

If the Wide Bandwidth Channel Switch subelement is not included, the Operating Class field indicates the operating class that identifies the channel set for which the measurement request applies. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing for which the measurement request applies. Valid operating classes are listed in Annex E, excluding operating classes that encompass a primary channel but do not identify the location of the primary channel. The Channel Number field indicates the channel number for which the measurement request applies. Channel number is defined within an operating class as shown in Annex E.

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If the Wide Bandwidth Channel Switch subelement is included, the fields in the Wide Bandwidth Channel Switch subelement indicate the channel for which the measurement request applies, and the Operating Class and Channel Number together specify the primary channel and primary 40 MHz channel within the channel identified by the Wide Bandwidth Channel Switch subelement.

The Randomization Interval field specifies the upper bound of the random delay to be used prior to making the measurement, in units of TUs. See 11.10.3.

The Measurement Duration field is set to the preferred or mandatory duration of the requested measurement, in units of TUs. See 11.10.4.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-101.

Table 9-101—Optional subelement IDs for Noise Histogram request

Subelement ID	Name	Extensible
0	Reserved	
1	Noise Histogram Reporting	Yes
2–162	Reserved	
163	Wide Bandwidth Channel Switch	Yes
164–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Noise Histogram Reporting subelement indicates the condition for issuing a Noise Histogram report. The Noise Histogram Reporting subelement Data field format is shown in Figure 9-187 and contains a 1-octet Reporting Condition subfield and a 1-octet ANPI Reference Value subfield. The Reporting Condition subfield is described in Table 9-102. The ANPI Reference Value is an ANPI value as defined in 11.10.9.4 and is the reference value for the indicated reporting condition.

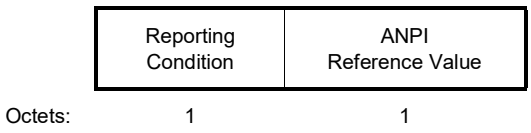

Figure 9-187—Noise Histogram Reporting subelement Data field format

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Table 9-102—Reporting Condition subfield for Noise Histogram report

Condition for report to be issued	Reporting Condition
Report to be issued after each measurement (default, used when Noise Histogram Reporting subelement is not included in a Noise Histogram request).	0
Noise Histogram report to be issued when measured ANPI is greater than or equal to the reference value.	1
Noise Histogram report to be issued when measured ANPI is less than or equal to the reference value.	2
Reserved	3–255

The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.160), with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.20.7 Beacon request

The Measurement Request field corresponding to a Beacon request is shown in Figure 9-188.

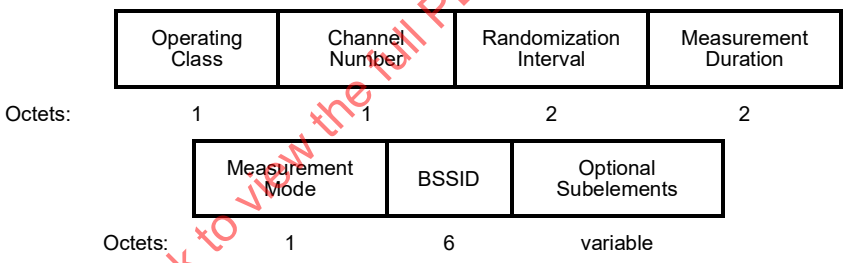

Figure 9-188—Measurement Request field format for Beacon request

If the Wide Bandwidth Channel Switch subelement is not included, the Operating Class field indicates the operating class that identifies the channel set for which the measurement request applies. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing for which the measurement request applies. Valid operating classes are listed in Annex E.

For operating classes that encompass a primary channel but do not identify the location of the primary channel, the Channel Number field value is either 0 or 255; otherwise, the Channel Number field value is 0, 255, or the channel number for which the measurement request applies and is defined within an operating class as shown in Annex E.

For operating classes that identify the location of the primary channel, a Channel Number field set to 0 indicates a request to make iterative measurements for all supported channels in the operating class where the measurement is permitted on the channel and the channel is valid for the current regulatory domain.

For operating classes that encompass a primary channel but do not identify the location of the primary channel, a Channel Number field set to 0 indicates a request to make iterative measurements for all primary

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channel positions within all requested and supported channels where the measurement is permitted on the channel and the channel is valid for the current regulatory domain.

For operating classes that identify the location of the primary channel, a Channel Number field set to 255 indicates a request to make iterative measurements for all supported channels in the current operating class listed in the latest AP Channel Report received from the serving AP.

A request frame is a request to make iterative measurements for all primary channel positions in all channels listed in the frame's AP Channel Report subelement when all of the following pertain:

— The operating class indicated by the Operating Class field in that frame encompasses a primary channel.
— The frame does not identify the location of that primary channel.
— The frame's Channel Number field is 255.
— The channel is supported.
— The measurement is permitted on the channel.
— The channel is permitted in the current regulatory domain.

If the Wide Bandwidth Channel Switch subelement is included, the fields in the Wide Bandwidth Channel Switch subelement indicate the channel for which the measurement request applies, and the Operating Class and Channel Number fields together specify the primary channel and primary 40 MHz channel within the channel identified by the Wide Bandwidth Channel Switch subelement.

The Randomization Interval field specifies the upper bound of the random delay to be used prior to making the measurement, in units of TUs. See 11.10.3.

The Measurement Duration field is set to the preferred or mandatory duration of the requested measurement, in units of TUs. See 11.10.4.

The Measurement Mode field indicates the mode to be used for the measurement. The valid measurement modes are listed in Table 9-103. The procedures for each mode are described in 11.10.9.1.

Table 9-103—Measurement Mode definitions for Beacon request

Mode	Value
Passive	0
Active	1
Beacon Table	2
Reserved	3–255

The BSSID field indicates the BSSID of the BSS(s) for which a beacon report is requested. When requesting beacon reports for all BSSs on the channel, the BSSID field contains the wildcard BSSID; otherwise the BSSID field contains a specific BSSID for a single BSS.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

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The Subelement ID field values for the defined subelements are shown in Table 9-104.

Table 9-104—Optional subelement IDs for Beacon request

Subelement ID	Name	Extensible
0	SSID	No
1	Beacon Reporting	Yes
2	Reporting Detail	Yes
3–9	Reserved	
10	Request	No
11	Extended Request	No
12–50	Reserved	
51	AP Channel Report	No
52–162	Reserved	
163	Wide Bandwidth Channel Switch	Yes
164	Last Beacon Report Indication Request	No
165–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The SSID subelement indicates the ESS(s) or IBSS(s) for which a beacon report is requested. When SSID is not included in a Beacon request, the default "wildcard SSID" is used; otherwise the SSID is included in the Beacon request and contains a specific SSID for a single ESS or IBSS. The wildcard SSID is used to represent all possible SSIDs. The SSID element is described in 9.4.2.2.

The Beacon Reporting subelement indicates the condition for issuing a Beacon report. The Beacon Reporting subelement is optionally present in a Beacon request for repeated measurements; otherwise it is not present. The Beacon Reporting subelement Data field format is shown in Figure 9-189 and contains a 1-octet Reporting Condition subfield and a 1-octet Threshold/Offset Reference subfield. The Reporting Condition subfield is described in Table 9-105. The Threshold/Offset Reference subfield contains either the threshold value or the offset value to be used for conditional reporting. For Reporting Condition subfield 1 and 2, the threshold value is a logarithmic function of the received signal power, as defined 9.4.2.37. For Reporting Condition subfield 3 and 4, the threshold value is a logarithmic function of the signal-to-noise ratio, as described in 9.4.2.40. For Reporting Condition subfield 5 to 10, the offset value is an 8-bit 2s complement integer in units of 0.5 dBm. The indicated reporting condition applies individually to each measured Beacon, Measurement Pilot, or Probe Response frame. Reporting conditions are further described in 11.10.9.1.

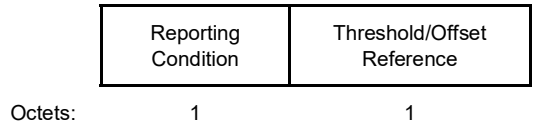

Figure 9-189—Beacon Reporting subelement Data field format

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Table 9-105—Reporting Condition subfield for Beacon report

Condition for report to be issued in Repeated Measurement	Reporting Condition
Report to be issued after each measurement (default, used when the Beacon Reporting subelement is not included in a Beacon request).	0
The measured RCPI level is greater than the threshold value contained in the Threshold/Offset Reference.	1
The measured RCPI level is less than the threshold value contained in the Threshold/ Offset Reference.	2
The measured RSNI level is greater than the threshold value contained in the Threshold/Offset Reference.	3
The measured RSNI level is less than the threshold value contained in the Threshold/ Offset Reference.	4
The measured RCPI level is greater than a threshold defined by an offset from the serving AP's reference RCPI, where the offset value is contained in the Threshold/ Offset Reference.	5
The measured RCPI level is less than a threshold defined by an offset from the serving AP's reference RCPI, where the offset value is contained in the Threshold/ Offset Reference.	6
The measured RSNI level is greater than a threshold defined by an offset from the serving AP's reference RSNI, where the offset value is contained in the Threshold/ Offset Reference.	7
The measured RSNI level is less than a threshold defined by an offset from the serving AP's reference RSNI, where the offset value is contained in the Threshold/ Offset Reference.	8
The measured RCPI level is in a range bound by the serving AP's reference RCPI and an offset from the serving AP's reference RCPI, where the offset value is contained in the Threshold/Offset Reference.	9
The measured RSNI level is in a range bound by the serving AP's reference RSNI and an offset from the serving AP's reference RSNI, where the offset value is contained in the Threshold/Offset Reference.	10
Reserved	11–255

The Reporting Detail subelement contains a 1-octet Reporting Detail data field that defines the level of detail per AP to be reported to the requesting STA. The Reporting Detail values are defined in Table 9-106. The indicated reporting detail applies individually to each measured Beacon, Measurement Pilot, or Probe Response frame. If the Reporting Detail equals 1, a Request element is optionally present in the list of optional subelements. If included, the Request element lists the Element IDs of the elements requested to be reported in the Reported Frame Body of the Beacon report.

The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.160) with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

The Last Beacon Report Indication Request subelement has the format defined in Figure 9-789, with a Length field set to 1. When included in a Beacon request with the Data field set to 1, it indicates that the requesting STA asks the responding STA to include an indication in the Beacon report to indicate the last frame of the sequence of frames generated as a response to a Beacon request.

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Table 9-106—Reporting Detail values

Level of detail requested	Reporting Detail
No fixed-length fields or elements	0
All fixed-length fields and any requested elements in the Request element if present	1
All fixed-length fields and elements (default, used when Reporting Detail subelement is not included in a Beacon request)	2
Reserved	3–255

The Request, Extended Request, AP Channel Report, and Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.9, 9.4.2.10, 9.4.2.35, and 9.4.2.25, respectively). Zero or more AP Channel Report subelements and zero or more Vendor Specific subelements are included in the list of optional subelements. An AP Channel Report subelement containing an operating class with an 80+ behavior limit (as defined in Annex E) is interpreted in conjunction with following AP Channel Report elements as defined in 11.10.9.1.

If one or more AP Channel Report elements are included, they indicate that iterative measurements are requested first on the channel(s) indicated by the Operating Class and Channel Number fields included in the Beacon request, and second on the channel(s) indicated by the Operating Class and Channel List fields of each AP Channel Report element included in the Beacon request. The procedures for iterative measurements on multiple channels are described in 11.10.9.1.

9.4.2.20.8 Frame request

The Measurement Request field corresponding to a Frame request is shown Figure 9-190.

	Operating Class	Channel Number	Randomization Interval	Measurement Duration	Frame Request Type	MAC Address	Optional subelements
Octets:	1	1	2	2	1	6	variable

Figure 9-190—Measurement Request field format for Frame request

If the Wide Bandwidth Channel Switch subelement is not included, the Operating Class field indicates the operating class that identifies the channel set for which the measurement request applies. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing for which the measurement request applies. Valid operating classes are listed in Annex E, excluding operating classes that encompass a primary channel but do not identify the location of the primary channel. The Channel Number field indicates the channel number for which the measurement request applies. Channel number is defined within an operating class as shown in Annex E.

If the Wide Bandwidth Channel Switch subelement is included, the fields in the Wide Bandwidth Channel Switch subelement indicate the channel for which the measurement request applies, and the Operating Class and Channel Number fields together specify the primary channel and primary 40 MHz channel within the channel identified by the Wide Bandwidth Channel Switch subelement.

The Randomization Interval field specifies the upper bound of the random delay to be used prior to making the measurement, in units of TUs. See 11.10.3.

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The Measurement Duration field is set to the preferred or mandatory duration of the requested measurement, in units of TUs. See 11.10.4.

The Frame Request Type indicates the subelements requested in the Frame report. A 1 signifies that a Frame Count Report is requested. The values 0 and 2 to 255 are reserved.

The MAC Address field indicates the TA field to match against Data and Management frames in order to count toward the Frame report generated in response to this Frame request.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-107.

Table 9-107—Optional subelement IDs for Frame request

Subelement ID	Name	Extensible
0–162	Reserved	
163	Wide Bandwidth Channel Switch	Yes
164–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.160), with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.20.9 STA Statistics request

The Measurement Request field corresponding to a STA Statistics request is shown in Figure 9-191.

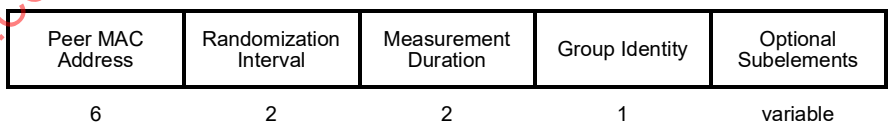

Figure 9-191—Measurement Request field format for STA Statistics request

The Peer MAC Address field is the RA or TA MAC address for the frame statistics of this measurement.

The Randomization Interval field specifies the upper bound of the random delay to be used prior to making the measurement, in units of TUs. See 11.10.3.

The Measurement Duration field is set to the duration of the requested measurement in TUs except when triggered reporting is used. When triggered reporting is used, the measurement duration is 0.

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The Group Identity field indicates the requested statistics group according to Table 9-108.

Table 9-108—Group Identity for a STA Statistics request

Statistics Group Name	Group Identity
STA Counters from dot11CountersTable	0
STA Counters from dot11MacStatistics group	1
QoS STA Counters for UP0 from dot11QosCountersTable	2
QoS STA Counters for UP1 from dot11QosCountersTable	3
QoS STA Counters for UP2 from dot11QosCountersTable	4
QoS STA Counters for UP3 from dot11QosCountersTable	5
QoS STA Counters for UP4 from dot11QosCountersTable	6
QoS STA Counters for UP5 from dot11QosCountersTable	7
QoS STA Counters for UP6 from dot11QosCountersTable	8
QoS STA Counters for UP7 from dot11QosCountersTable	9
BSS Average Access Delays as described in 9.4.2.38 and 9.4.2.43	10
STA Counters from dot11CountersGroup3 (A-MSDU)	11
STA Counters from dot11CountersGroup3 (A-MPDU)	12
STA Counters from dot11CountersGroup3 (BlockAckReq, Channel Width, PSMP)	13
STA Counters from dot11CountersGroup3 (RD, dual CTS)	14
STA Counters from dot11CountersGroup3 (beamforming and STBC)	15
RSNA Counters	16
Reserved	17–255

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-109.

Table 9-109—Optional subelement IDs for STA Statistics request

Subelement ID	Name	Extensible
0	Reserved	
1	Triggered Reporting	No
2–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Triggered Reporting subelement is used to specify trigger conditions and thresholds for triggered STA Statistics measurements. It is present when setting up triggered reporting from STA Counters, QoS STA Counters, or RSNA Counters; see 11.10.9.5.

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The format of the Triggered Reporting subelement for STA Counters is shown in Figure 9-192. The fields marked as optional are only present if the appropriate bit in the STA Counter Trigger Condition field is 1.

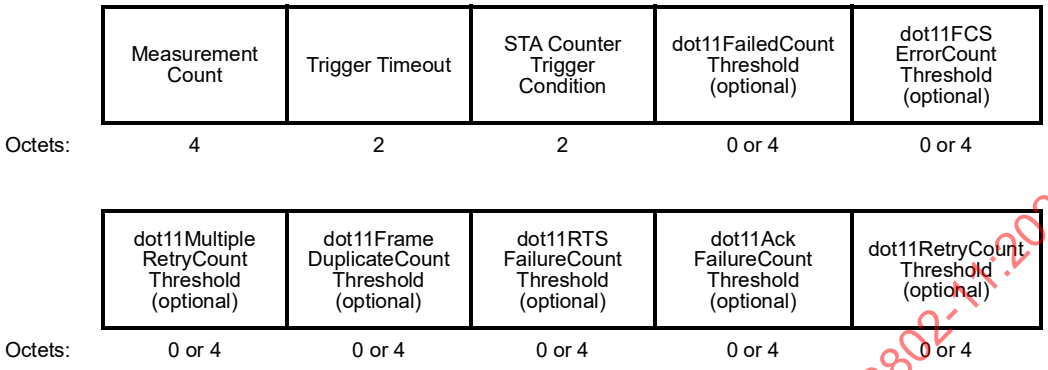

Figure 9-192—Triggered Reporting subelement format for STA Counters

The value in the Measurement Count field specifies the number of MSDUs or MPDUs transmitted and/or received by the STA that are to be used to determine if one or more of the trigger conditions have been met.

The Trigger Timeout field contains a value in units of 100 TUs during which a measuring STA does not generate further triggered STA Statistics reports after a trigger condition has been met.

The STA Counter Trigger Condition field specifies trigger values used when requesting triggered STA Statistics reporting. The format of the STA Counter Trigger Condition field is shown in Figure 9-193.

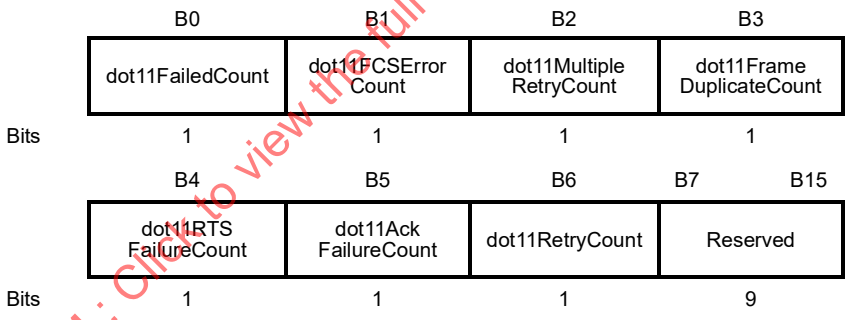

Figure 9-193—STA Counter Trigger Condition field format

For each bit in the STA Counter Trigger Condition field that is 1, a corresponding threshold value exists (defined in Figure 9-192) in the Triggered Reporting subelement for STA Counters. With this, the STA Statistics request indicates that a STA Statistics report be generated when the corresponding STA counter defined in 9-237 and 9-238 (in 9.4.2.21.9) exceeds the value of the specified threshold, within the total number of MSDUs or MPDUs indicated in the Measurement Count field. See 11.10.9.5. One or more trigger conditions are set with specified thresholds. In the triggered STA Statistics request, the Group Identity field is either 0 or 1. When the Group Identity field of the triggered STA Statistics request is 0, B2–B6 in the STA Counter Trigger Condition field are set to 0. When the group identity of the triggered STA Statistics request is 1, B0 and B1 in the STA Counter Trigger Condition field are set to 0.

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The format of the Triggered Reporting subelement for QoS STA Counters is shown in Figure 9-194. The fields marked as optional are only present if the appropriate bit in the QoS STA Counter Trigger Condition subfield is 1.

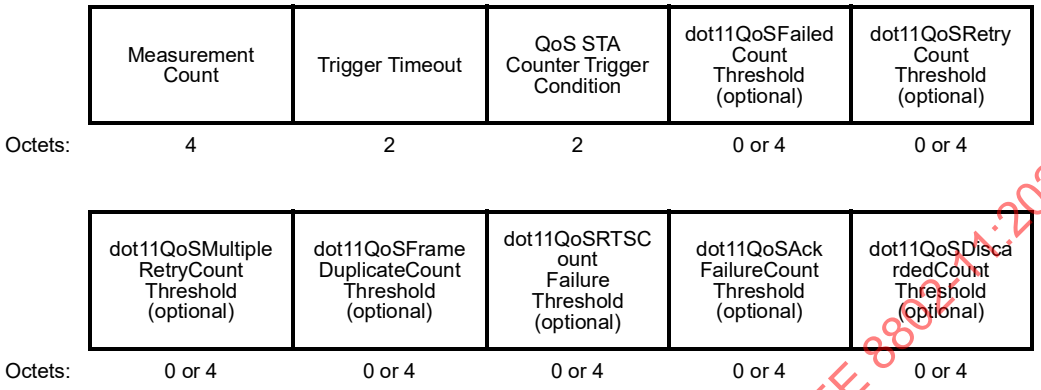

Figure 9-194—Triggered Reporting subelement format for QoS STA Counters

The UP of the QoS STA Counters for triggered QoS Statistics measurement is determined by the group identity of the Measurement Request field for a STA Statistics request as defined in 9-108.

The value in the Measurement Count field specifies the number of MSDUs or MPDUs transmitted and/or received by the STAs that are to be used to determine if one or more of the trigger conditions have been met.

The Trigger Timeout field contains a value in units of 100 TUs during which a measuring STA does not generate further triggered STA Statistics reports after a trigger condition has been met.

The QoS STA Counter Trigger Condition field specifies reporting triggers when requesting triggered STA Statistics reporting. The format of the QoS STA Counter Trigger Condition field is shown in Figure 9-195.

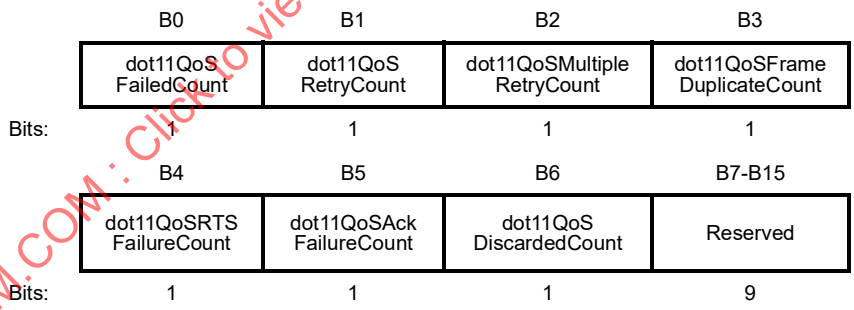

Figure 9-195—QoS STA Counter Trigger Condition field format

For each bit in the QoS STA Counter Trigger Condition field that is 1, a corresponding threshold value exists (defined in Figure 9-194) in the Triggered Reporting subelement for QoS STA Counters. With this, the STA Statistics request indicates that a STA Statistics report be generated when the corresponding QoS STA counter defined in Figure 9-239 (in 9.4.2.21.9) exceeds the value of the specified threshold, within the total number of MSDUs or MPDUs indicated in the Measurement Count field. See 11.10.9.5. One or more trigger conditions are set with specified thresholds.

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The format of the Triggered Reporting subelement for RSNA Counters is shown in Figure 9-196. The fields marked as optional are only present if the appropriate bit in the RSNA Trigger Condition subfield is 1.

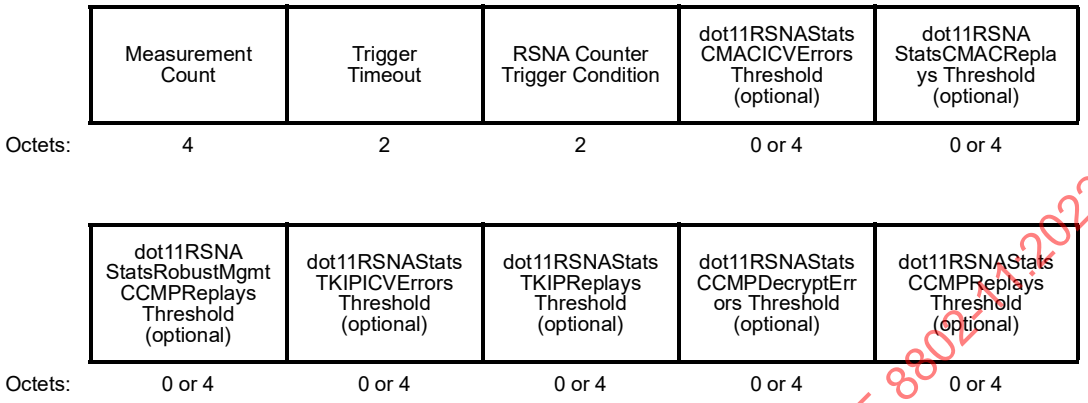

Figure 9-196—Triggered Reporting subelement format for RSNA Counters

The value in the Measurement Count field specifies the number of MPDUs transmitted and/or received by the STA that are to be used to determine if one or more of the trigger conditions have been met.

The Trigger Timeout field contains a value in units of 100 TUs during which a measuring STA does not generate further triggered STA Statistics reports after a trigger condition has been met.

The RSNA Counter Trigger Condition field specifies reporting triggers when requesting triggered STA Statistics reporting. The format of the RSNA Trigger Condition field is shown in Figure 9-197.

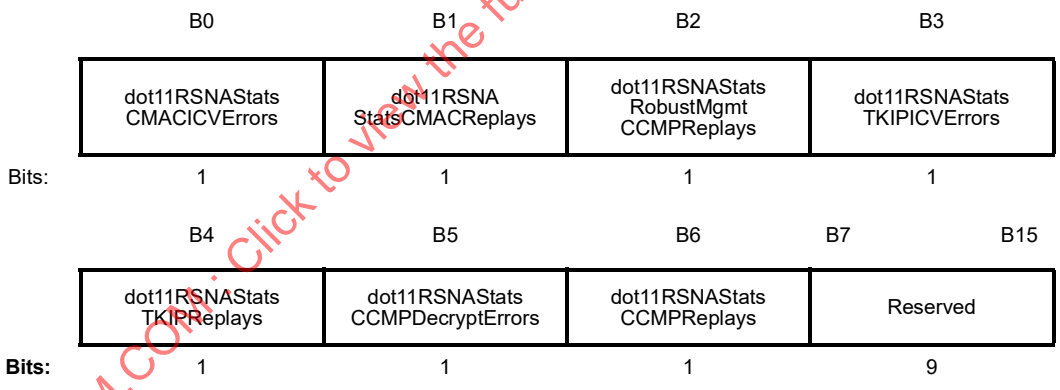

Figure 9-197—RSNA Trigger Condition field format

For each bit in the RSNA Trigger Condition field that is 1, a corresponding threshold value exists (defined in Figure 9-196) in the Triggered Reporting subelement for RSNA Counters. With this, the STA Statistics request indicates that a STA Statistics report be generated when the corresponding RSNA counter defined in Figure 9-241 (in 9.4.2.21.9) exceeds the value of the specified threshold, within the total number of MPDUs indicated in the Measurement Count field. See 11.10.9.5. One or more trigger conditions are set with specified thresholds.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

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9.4.2.20.10 LCI request (Location configuration information request)

The Measurement Request field corresponding to an LCI request is shown in Figure 9-198.

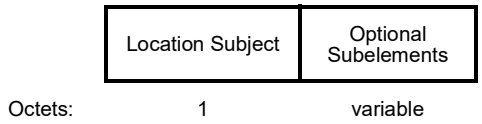

Figure 9-198—Measurement Request field format for LCI request

The Location Subject field of an LCI request is 1 octet. See Table 9-110.

Table 9-110—Location Subject field definition

Value	Location Subject
0	Location Subject Local
1	Location Subject Remote
2	Location Subject Third Party
3–255	Reserved

The term Local refers to the location of the requesting STA, and Remote refers to the location of the reporting STA.

NOTE 1—A measurement request with its Location Subject value Location Subject Local is used by a requesting STA to obtain its own location, asking "Where am I?". The Measurement Request with its Location Subject value Location Subject Remote is used by a requesting STA to obtain the location of the reporting STA, asking "Where are you?"

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-111.

Table 9-111—Optional subelement IDs for LCI request

Subelement ID	Name	Extensible
0	Reserved	
1	Azimuth Request	Yes
2	Originator Requesting STA MAC Address	No
3	Target MAC Address	No
4	Maximum Age	Yes
5–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

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The Azimuth Request subelement is present when requesting azimuth information. The Azimuth Request subelement is as shown in Figure 9-199.

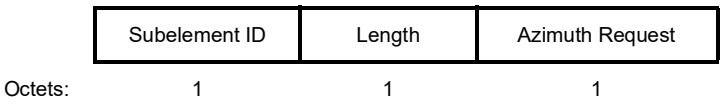

Figure 9-199—Azimuth Request subelement format

The Subelement ID field is defined in Table 9-111.

The Length field is defined in 9.4.3.

The Azimuth Request field of an Azimuth Request subelement is shown in Figure 9-200.

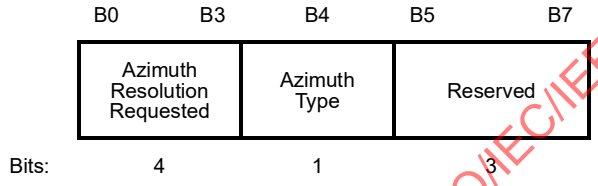

Figure 9-200—Azimuth Request field format

Azimuth Resolution Requested is the number of valid most significant bits requested for the fixed-point value of Azimuth, reported in integer degrees. Values above 9 are reserved.

Azimuth Type (bit 4) is set to 1 to request a report of the Azimuth of radio reception and is set to 0 to request a report of the Azimuth of front surface of the reporting STA.

NOTE 2—A geographic feature is an abstraction of a real-world phenomenon; it is a geographic feature if it is associated with a location relative to the Earth. The designation of a horizontal plane is relative to the Earth. The designation of the "front surface" of a station is arbitrary, but refers to an orientable surface (possessing a centerline) of the station. It is common to use a direction cosine matrix to convert from one coordinate system to another, i.e., body-centered coordinates to earth-centered coordinates.

The Originator Requesting STA MAC Address subelement contains the MAC address of the STA requesting the Location Information and it is present whenever the Location Subject field is set to 2. The format of the Originator Requesting STA MAC Address subelement is shown in Figure 9-201.

Figure 9-201—Originator Requesting STA MAC Address subelement format

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The Target MAC Address subelement contains the MAC address of the STA whose Location Information is requested and it is present whenever the Location Subject field is set to 2. The format of the Target MAC Address subelement is shown in Figure 9-202.

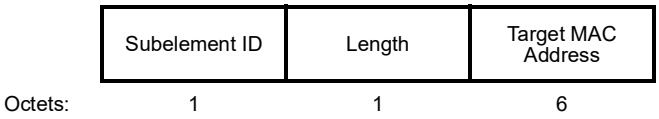

Figure 9-202—Target MAC Address subelement format

The Maximum Age subelement indicates the maximum age of the requested LCI. The format of the Maximum Age subelement is defined in Figure 9-203. The absence of a Maximum Age subelement indicates that an LCI determined at or after the LCI request is received is requested.

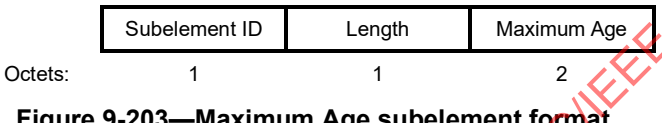

Figure 9-203—Maximum Age subelement format

The Length field is defined in 9.4.3.

The Maximum Age field of a Maximum Age subelement indicates the maximum elapsed time between when an LCI is determined and when an LCI request is received, within which the LCI satisfies the LCI request. The Maximum Age field is encoded as an unsigned integer with units of 0.1 s. The value of 0 is reserved. The value of 65 535 indicates that any LCI age is acceptable.

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.20.11 Transmit Stream/Category Measurement request

The Transmit Stream/Category Measurement applies to TIDs for traffic streams associated with TSPECs and also to TIDs for traffic categories for QoS traffic without TSPECs. The Measurement Request field corresponding to a Transmit Stream/Category Measurement request is shown in Figure 9-204.

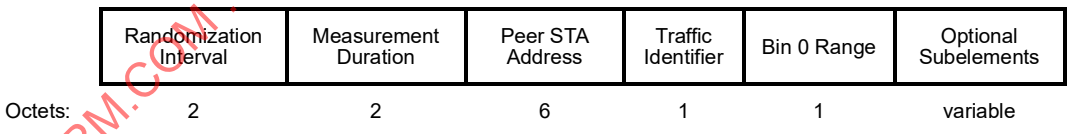

Figure 9-204—Measurement Request field format for Transmit Stream/Category Measurement Request

The Randomization Interval field is set to the maximum random delay in the measurement start time, in units of TUs. The use of the Randomization Interval field is described in 11.10.3. When requesting a triggered Transmit Stream/Category Measurement, the randomization interval is not used and the Randomization Interval field is reserved. See 11.10.9.8.

The Measurement Duration is set to the duration of the requested measurement, in units of TUs except when setting up a triggered QoS measurement, when it is not used and is set to 0.

The Peer STA Address contains a MAC address indicating the RA in the MSDUs to be measured.

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The Traffic Identifier field contains the TID subfield as shown in Figure 9-205.

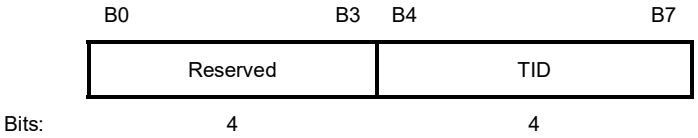

Figure 9-205—Traffic Identifier field format

The TID subfield indicates the TC or TS for which traffic is to be measured.

Bin 0 Range indicates the delay range of the first bin (Bin 0) of the Transmit Delay Histogram, in units of TUs. The Bin 0 Range value is used to calculate the delay ranges of the other 5 bins making up the histogram. The delay range for each bin increases in a binary exponential fashion as described in 9.4.2.21.11.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-112.

Table 9-112—Optional subelement IDs for Transmit Stream/Category Measurement Request

Subelement ID	Name	Extensible
0	Reserved	
1	Triggered Reporting	Yes
2–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Triggered Reporting subelement is used to specify measurement trigger thresholds. It is present only if requesting triggered transmit stream/category measurement reporting. The Triggered Reporting subelement format is shown in Figure 9-206.

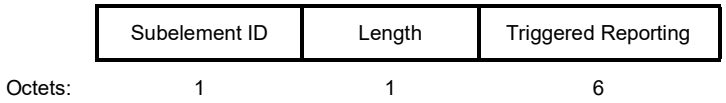

Figure 9-206—Triggered Reporting subelement format

The Subelement ID field is defined in Table 9-112.

The Length field is defined in 9.4.3.

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The Triggered Reporting field is as shown in Figure 9-207.

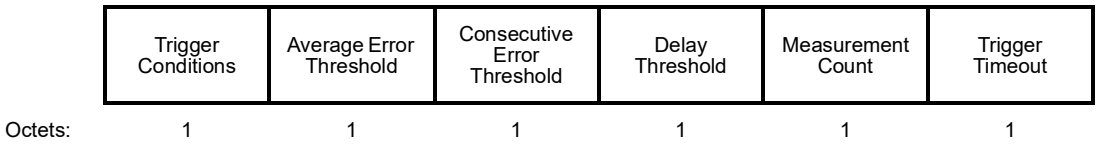

Figure 9-207—Triggered Reporting field format

Trigger Conditions is a bit-field that specifies reporting triggers when requesting a triggered transmit stream/category measurement. The format of the Trigger Conditions bit-field is shown in Figure 9-208.

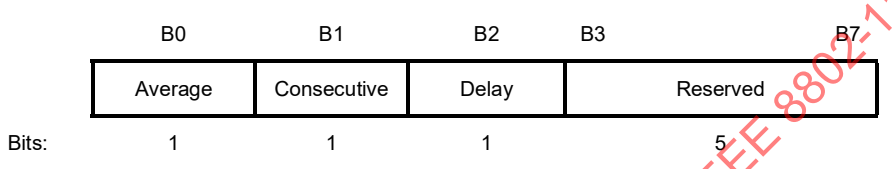

Figure 9-208—Trigger Conditions bit-field format

— The Average bit is set to 1 to request that a Transmit Stream/Category Measurement report be generated when the number of MSDUs for the TC or TS given by the TID that are discarded out of the number of preceding MSDUs specified in Measurement Count is greater than or equal to the value given in Average Error Threshold. MSDUs discarded due to the number of transmit attempts exceeding dot11ShortRetryLimit, or due to the MSDU lifetime having been reached, are counted.

— The Consecutive bit is set to 1 to request that a Transmit Stream/Category Measurement report be generated when the number of MSDUs for the TC or TS given by the TID that are discarded in succession is greater than or equal to the value given in Consecutive Error Threshold. MSDUs discarded due to the number of transmit attempts exceeding dot11ShortRetryLimit, or due to the MSDU lifetime having been reached, are counted.

— The Delay bit is set to 1 to request that a Transmit Stream/Category Measurement report be generated when the number of consecutive MSDUs for the TC or TS given by the TID that experience a transmit delay greater than or equal to the value specified in the Delay Threshold subfield is greater than or equal to the value given in Delayed MSDU Count. Delay is measured from the time the MSDU is passed to the MAC until the point at which the entire MSDU has been successfully transmitted, including receipt of the final Ack frame from the peer STA if the QoSAck service class is being used.

The Average Error Threshold field contains a value representing the number of discarded MSDUs to be used as the threshold value for the Average trigger condition. The field is reserved if the Average Error Threshold subfield of the Trigger Conditions bit-field is 0.

The Consecutive Error Threshold field contains a value representing the number of discarded MSDUs to be used as the threshold value for the consecutive trigger condition. The field is reserved if the Consecutive Error Threshold subfield of the Trigger Conditions bit-field is 0.

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The Delay Threshold field contains two subfields as shown in Figure 9-209. The Delay Threshold field is reserved if the Delay Threshold subfield of the Trigger Conditions bit-field is 0.

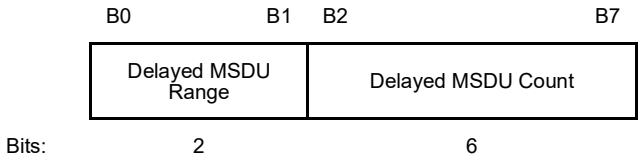

Figure 9-209—Delay Threshold subfield format

The Delayed MSDU Range field contains a value representing the MSDU transmit delay at or above which an MSDU is counted toward the Delayed MSDU Count threshold. The Delayed MSDU Range field is encoded as a value representing the lower bound of a bin in the Transmit Delay Histogram as shown in Table 9-113. The Transmit Delay Histogram is defined in 9.4.2.21.11.

Table 9-113—Delayed MSDU Range Definitions

Delayed MSDU Range	Condition
0	Transmit Delay = Lower Bound of Bin 2
1	Transmit Delay = Lower Bound of Bin 3
2	Transmit Delay = Lower Bound of Bin 4
3	Transmit Delay = Lower Bound of Bin 5

The Delayed MSDU Count field contains a value representing the number of MSDUs to be used as the threshold value for the delay trigger condition.

The Measurement Count field contains a number of MSDUs. This value is used to calculate an average discard count for the average trigger condition. It is also used in place of measurement duration in determining the scope of the reported results when a report is triggered; see 11.10.9.8.

The Trigger Timeout field contains a value, in units of 100 TU, during which a measuring STA does not generate further triggered transmit stream/category measurement reports after a trigger condition has been met. See 11.10.9.8.

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.20.12 Measurement Pause request

The Measurement Request field corresponding to a Measurement Pause request is shown in Figure 9-210. The Measurement Pause request cannot be processed in parallel with any other measurement request. See 11.10.9.7.

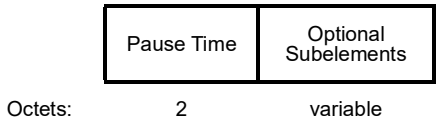

Figure 9-210—Measurement Request field format for Measurement Pause request

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The Pause Time field contains a number between 1 and 65 535 representing the time period for which measurements are suspended or paused. The time unit for the Pause Time is 10 TUs. The Pause Time value 0 is reserved. Measurement Pause requests are used to provide time delays between the execution times of Measurement Request elements in a Radio Measurement Request frame.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-114.

Table 9-114—Optional subelement IDs for Measurement Pause request

Subelement ID	Name	Extensible
0–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.20.13 Multicast Diagnostics request

The Measurement Request field corresponding to a Multicast Diagnostics request is shown in Figure 9-211. The response to a Multicast Diagnostics request is a Multicast Diagnostics report.

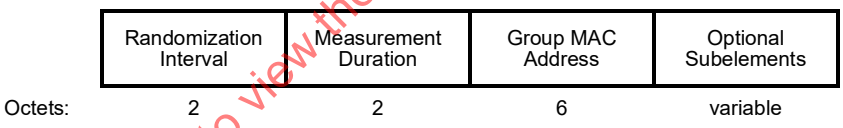

Figure 9-211—Measurement Request field format for a Multicast Diagnostics request

The Randomization Interval field is the upper limit of random delay before the measurement begins, expressed in TUs. The use of the Randomization Interval field is described in 11.11.3. When requesting a triggered multicast diagnostic report, the Randomization Interval field is reserved.

The Measurement Duration field is the duration of the requested measurement, expressed in TUs. When requesting a triggered multicast diagnostic report, the Measurement Duration field is reserved.

A Group MAC Address field with bit 0 set to 1 contains the MAC address of the group addressed frames to which the measurement request relates. A Group MAC Address field with bit 0 set to 0 indicates that all group addressed frames, apart from the broadcast address, are requested.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

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The Subelement ID field values for the defined subelements are shown in Table 9-115.

Table 9-115—Optional subelement IDs for STA Multicast Diagnostics request

Subelement ID	Name	Extensible
0	Reserved	
1	Multicast Triggered Reporting	No
2–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Multicast Triggered Reporting subelement is used to specify trigger conditions and thresholds. It is present only when requesting triggered multicast diagnostic reporting. The format of Multicast Triggered Reporting subelement is shown in Figure 9-212.

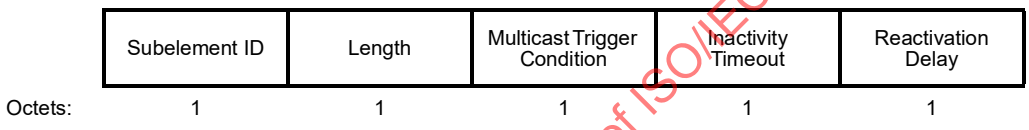

Figure 9-212—Multicast Triggered Reporting subelement format

The Multicast Trigger Condition field specifies reporting triggers for triggered management diagnostic reporting. The format of the Multicast Trigger Condition field is shown in Figure 9-213.

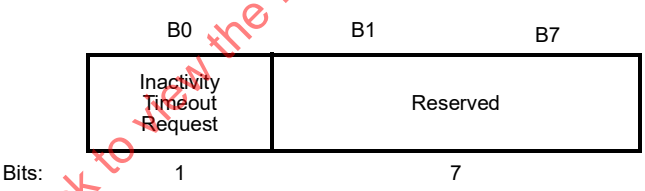

Figure 9-213—Multicast Trigger Condition field format

The Inactivity Timeout Request field is 1 to request that a multicast triggered report be generated when no group addressed frames with the monitored group address are received in a time equal to the value given in the Inactivity Timeout field. The Inactivity Timeout Request field is 0 when a multicast reception timeout is not requested.

The Inactivity Timeout field contains a time value in units of 100 TUs to be used as the threshold value for the inactivity timeout trigger condition.

The Reactivation Delay field contains a value in units of 100 TUs during which a measuring STA does not generate further multicast triggered reports after a trigger condition has been met.

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.25).

The use of Multicast Diagnostics request is defined in 11.10.19.

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9.4.2.20.14 Location Civic request

The Measurement Request field corresponding to a Location Civic request is shown in Figure 9-214. The response to a Location Civic request is a Location Civic report.

	Location Subject	Civic Location Type	Location Service Interval Units	Location Service Interval	Optional Subelements
Octets:	1	1	1	2	variable

Figure 9-214—Location Civic Request field format

The Location Subject field is 1 octet and is defined in Table 9-110.

The Civic Location Type field contains the format of location information in the Location Civic report, as indicated in Table 9-116.

Table 9-116—Civic Location Type field values

Civic Location Type field value	Name	Description
0	IETF RFC 4776	Starting at the country code field (i.e., excluding the GEOCONF_CIVIC/ OPTION_GEOCONF_CIVIC, N/option-len and what fields); includes all subsequent RFCs that define additional civic address Types
1	Vendor Specific	
2–255	Reserved	

When the Civic Location Type value is Vendor Specific, a Vendor Specific subelement is included in the list of optional subelements that identifies the Organization Identifier corresponding to the Civic Location Type field.

The Location Service Interval Units field contains the units for the Location Service Interval field, as indicated in Table 9-117.

Table 9-117—Location Service Interval Units

Location Service Interval Units value	Description
0	Seconds
1	Minutes
2	Hours
3–255	Reserved

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The Location Service Interval field is the time interval, expressed in the units indicated in the Location Service Interval Units field, at which the STA requests to receive Location Civic reports. A Location Service Interval of 0 indicates that only a single Location Civic report is requested.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-118.

Table 9-118—Optional subelement IDs for Location Civic request

Subelement ID	Name	Extensible
0	Reserved	
1	Originator Requesting STA MAC Address	No
2	Target MAC Address	No
3–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Originator Requesting STA MAC Address subelement contains the MAC address of the STA requesting for the Location Information and it is present whenever the Location Subject field is set to 2. The format of the Originator Requesting STA MAC Address subelement is shown in Figure 9-201.

The Target MAC Address subelement contains the MAC address of the STA whose Location Information is requested and it is present whenever the Location Subject field is set to 2. The format of the Target MAC Address subelement is shown in Figure 9-202.

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.25).

9.4.2.20.15 Location Identifier request

The Measurement Request field corresponding to a Location Identifier request is shown in Figure 9-215. The response to a Location Identifier request is a Location Identifier report.

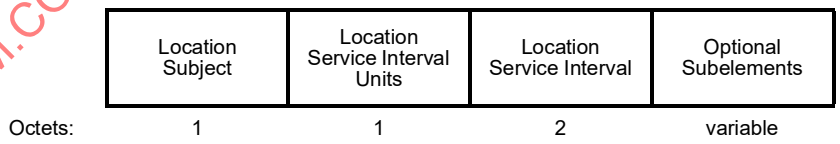

Figure 9-215—Location Identifier request field format

The Location Subject field is 1 octet and is defined in Table 9-110.

The Location Service Interval Units field is defined in Table 9-117.

The Location Service Interval field is the time interval, expressed in the units indicated in the Location Service Interval Units field, at which the STA requests to receive Location Identifier reports. A Location Service Interval of 0 indicates that only a single Location Identifier report is requested.

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The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-119.

Table 9-119—Optional subelement IDs for Location Identifier request

Subelement ID	Name	Extensible
0	Reserved	
1	Originator Requesting STA MAC Address	No
2	Target MAC Address	No
3–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Originator Requesting STA MAC Address subelement contains the MAC address of the STA requesting the Location Information and it is present whenever the Location Subject field is set to 2. The format of the Originator Requesting STA MAC Address subelement is shown in Figure 9-201.

The Target MAC Address subelement contains the MAC address of the STA whose Location Information is requested and it is present whenever the Location Subject field is set to 2. The format of the Target MAC Address subelement is shown in Figure 9-202.

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.25).

9.4.2.20.16 Directional Channel Quality request

The Measurement Request field corresponding to a Directional Channel Quality request is shown in Figure 9-216. This Measurement Request is transmitted from a Requesting STA to a Requested STA to perform measurements toward a Target STA.

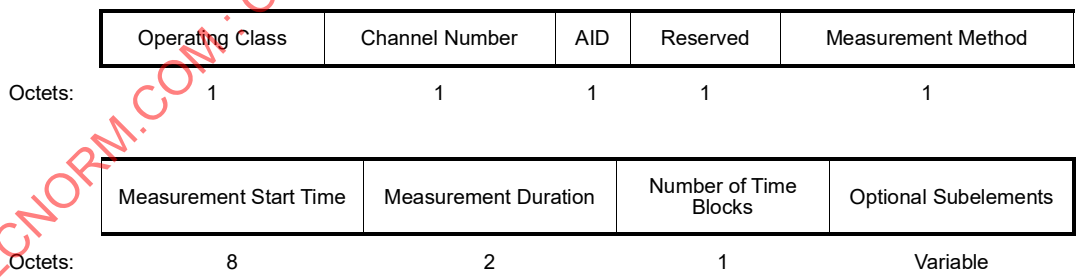

Figure 9-216—Measurement Request field format for Directional Channel Quality request

The Operating Class field indicates the channel set for which the measurement request applies. Operating Class and Channel Number together specify the channel frequency and spacing for which the measurement request applies. Valid values of Operating Class are shown in Annex E.

The Channel Number field indicates the channel number for which the measurement request applies. Channel Number is defined within an Operating Class as shown in Annex E.

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The AID field contains the AID assigned to the Target STA by the AP or PCP.

The Measurement Method field indicates the method that is to be used by the Requested STA to carry out this measurement request and report back in the measurement report. If this field is set to 0, it indicates ANIPI. If this field is set to 1, it indicates RSNI. Other values are reserved.

The Measurement Start Time field is set to the TSF timer at the time at which the requested measurement starts. A 0 indicates that the measurement starts immediately.

The Measurement Duration field is set to the preferred or mandatory duration of the requested measurement, in units of TUs. See 11.10.4.

The Number of Time Blocks field indicates the number of time blocks within the Measurement Duration. The ratio (Measurement Duration/Number of Time Blocks) provides the duration of an individual measurement unit.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-120.

Table 9-120—Optional subelement IDs for Directional Channel Quality request

Subelement ID	Name	Extensible
0	Reserved	
1	Directional Channel Quality Reporting	Yes
2–220	Reserved	No
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Directional Channel Quality Reporting subelement indicates the condition for issuing a Directional Channel Quality report. The Directional Channel Quality Reporting subelement Data field format is shown in Figure 9-217 and contains a 1-octet Reporting Condition subfield and a 1-octet Directional Channel Quality Reference Value subfield. The Reporting Condition subfield is described in Table 9-121. The Directional Channel Quality Reference value is a Directional Channel Quality value and is the reference value for the indicated reporting condition.

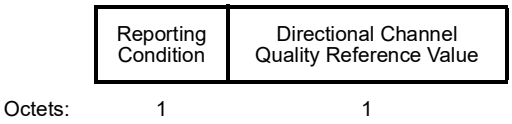

Figure 9-217—Directional Channel Quality Reporting subelement Data field format

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Table 9-121—Reporting Condition subfield for Directional Channel Quality report

Condition for report to be issued	Reporting condition
Report to be issued after each measurement (default, used when Directional Channel Quality Reporting subelement is not included in Directional Channel Quality Request).	0
Report to be issued when measured ANIPI or RSNI is greater than or equal to the reference value.	1
Report to be issued when measured ANIPI or RSNI is less than or equal to the reference value.	2
Reserved	3–255

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.20.17 Directional Measurement request

The Measurement Request field corresponding to a Directional Measurement request is shown in Figure 9-218. This Measurement Request is transmitted from a Requesting STA to a Requested STA to perform directional channel measurements in all sectored receiving directions.

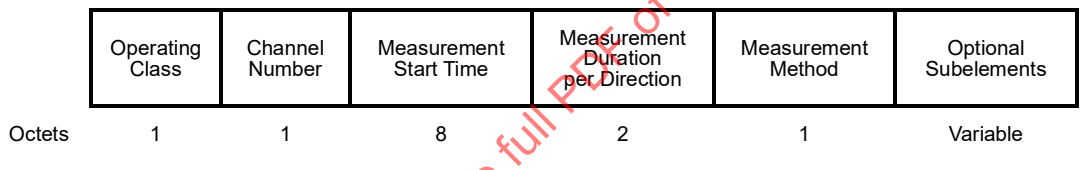

Figure 9-218—Measurement Request field format for Directional Measurement request

The Operating Class field indicates the channel set for which the measurement request applies. Operating Class and Channel Number together specify the channel frequency and spacing for which the measurement request applies. Valid values of Operating Class are shown in Annex E.

The Channel Number field indicates the channel number for which the measurement request applies. Channel Number is defined within an Operating Class as shown in Annex E.

The Measurement Start Time field is set to the TSF timer at the time at which the requested measurement starts. A 0 indicates that the measurement starts immediately.

The Measurement Duration per Direction field is set to the preferred or mandatory duration of the requested measurement in each receiving direction, in units of TUs.

The Measurement Method field indicates the method that is to be used by the Requested STA to carry out this measurement request and report back in the measurement report. If this field is set to 0, it indicates ANIPI. If this field is set to 1, it indicates RCPI. If the field is set to 2, it indicates Channel Load. Other values are reserved.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-122.

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Table 9-122—Optional subelement IDs for Directional Measurement request

Subelement ID	Name	Extensible
0–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.20.18 Directional Statistics request

The Measurement Request field corresponding to a Directional Statistics request is shown in Figure 9-219. This Measurement Request is transmitted from a Requesting STA to a Requested STA to perform directional channel measurements in all sectored receiving directions.

	Operating Class	Channel Number	Measurement Start Time	Measurement Duration per Direction	Measurement Method	Directional Statistics Bitmap	Optional Subelements
Octets	1	1	8	2	1	1	Variable

Figure 9-219—Measurement Request field format for Directional Statistics request

The Operating Class field indicates the channel set for which the measurement request applies. Operating Class and Channel Number together specify the channel frequency and spacing for which the measurement request applies. Valid values of Operating Class are shown in Annex E.

The Channel Number field indicates the channel number for which the measurement request applies. Channel Number is defined within an Operating Class as shown in Annex E.

The Measurement Start Time field is set to the TSF timer at the time at which the requested measurement starts. A 0 indicates that the measurement starts immediately.

The Measurement Duration per Direction field is set to the preferred or mandatory duration of the requested measurement in each receiving direction, in units of TUs.

The Measurement Method field indicates the method that is to be used by the Requested STA to carry out this measurement request and report back in the measurement report. If this field is set to 0, it indicates ANIPI. If this field is set to 1, it indicates RCPI. If the field is set to 2, it indicates Channel Load. Other values are reserved.

The Directional Statistics Bitmap field format is shown in Figure 9-220. The Maximum field set to 1 indicates that the maximum measurement result among all directions is expected in the measurement report. The Minimum field set to 1 indicates that the minimum measurement result among all directions is expected in the measurement report. The Average field set to 1 indicates that the average measurement result among all directions is expected in the measurement report. The Variance field set to 1 indicates that the variance of measurement results among all directions is expected in the measurement report. Other bits are reserved.

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	B0	B1	B2	B3	B4 B7
	Maximum	Minimum	Average	Variance	Reserved
Bits:	1	1	1	1	4

Figure 9-220—Directional Statistics Bitmap field format

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-123.

Table 9-123—Optional subelement IDs for Directional Statistics request

Subelement ID	Name	Extensible
0–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.20.19 Fine Timing Measurement Range request

The Measurement Request field corresponding to a Fine Timing Measurement Range request is shown in Figure 9-221.

	Randomization Interval	Minimum AP Count	FTM Range Subelements
Octets:	2	1	variable

Figure 9-221—Measurement Request field format for a Fine Timing Measurement Range request

The Randomization Interval field specifies the upper bound of the random delay to be used prior to making the measurement, in units of TUs. See 11.10.3.

The Minimum AP Count field specifies the minimum number of FTM ranges between the requested STA and the APs listed in the Neighbor Report subelements that are requested. The value 0 and values above 15 are reserved.

The FTM Range Subelements field contains one or more subelements. The subelement format and ordering of subelements are defined in 9.4.3. The FTM Range subelements are listed in Table 9-124.

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The Subelement IDs for subelements in the Fine Timing Measurement Range request are defined in Table 9-124. The number of Neighbor Report subelements included in the FTM Range Subelements field is at least the value of the Minimum AP Count field. Each Neighbor Report subelement has the same format as the Neighbor Report element and contains the Wide Bandwidth Channel subelement. See Table 9-124 and 9.4.2.36. The Neighbor Report subelements specify a set of nearby APs; the requested STA is requested to perform the FTM procedure with a subset of these APs (see 11.10.9.11).

Table 9-124—FTM Range subelement IDs for Fine Timing Measurement Range request

Subelement ID	Name	Extensible
0–3	Reserved	
4	Maximum Age	Yes
5–51	Reserved	
52	Neighbor Report	Subelements
53–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

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The Maximum Age subelement indicates the maximum age of the requested FTM ranges. The format of the Maximum Age subelement is defined in Figure 9-203. The absence of a Maximum Age subelement indicates that FTM ranges determined at or after the Fine Timing Measurement Range request is received are requested.

The Subelement ID field is defined in Table 9-124.

The Length field is defined in 9.4.3.

The Maximum Age field of the Maximum Age subelement indicates the maximum elapsed time between when FTM ranges are determined and when a Fine Timing Measurement Range request is received, within which the FTM ranges satisfy the Fine Timing Measurement Range request. The Maximum Age field is encoded as an unsigned integer with units of 0.1 s. The value 0 is reserved. The value 65 535 indicates that FTM ranges determined at any time are acceptable.

The Vendor Specific subelement has the same format as the corresponding element (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.21 Measurement Report element

9.4.2.21.1 General

The Measurement Report element contains a measurement report. The format of the Measurement Report element is shown in Figure 9-222. The Measurement Report element is included in Measurement Report frames, as described in 9.6.2.3, or Radio Measurement Report frames, as described in 9.6.6.3. Measurement Types 0, 1, and 2 are used for spectrum management and are included only in Measurement Report frames. All other Measurement Types are included only in Radio Measurement Report frames. The use of

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Measurement Report elements and frames for spectrum management is described in 11.8.7. The use of Measurement Report elements and frames for radio measurement is described in 11.10.

	Element ID	Length	Measurement Token	Measurement Report Mode	Measurement Type	Measurement Report
Octets:	1	1	1	1	1	variable

Figure 9-222—Measurement Report element format

The Element ID and Length fields are defined in 9.4.2.1.

The Measurement Token field is set to the value of the Measurement Token field in the corresponding Measurement Request element. If the Measurement Report element is being sent autonomously, then the Measurement Token is set to 0. If the Measurement Report element is being sent in a Location Track Notification frame, then the Measurement Token field is set to the same value as the Location Configuration Request frame Dialog Token field that configured the STA to send the Location Track Notification frames.

The Measurement Report Mode field (shown in Figure 9-223) is used to indicate the reason for a failed or rejected measurement request. The Measurement Report Mode is a bit field with the following bits defined:

— Late bit (bit 0) indicates whether this STA is unable to carry out a measurement request because it received the request after the requested measurement time. The Late bit is set to 1 to indicate the request was too late. The Late bit is set to 0 to indicate the request was received in time for the measurement to be executed. The Late bit only applies to spectrum management measurement and is set to 0 in all measurement report elements for radio measurement types (see Table 9-125).

— Incapable bit (bit 1) indicates whether this STA is incapable of generating a report of the type specified in the Measurement Type field that was previously requested by the destination STA of this Measurement Report element. The Incapable bit is set to 1 to indicate the STA is incapable. The Incapable bit is set to 0 to indicate the STA is capable or the report is autonomous.

— Refused bit (bit 2) indicates whether this STA is refusing to generate a report of the type specified in the Measurement Type field that was previously requested by the destination STA of this Measurement Report element. The Refused bit is set to 1 to indicate the STA is refusing. The Refused bit is set to 0 to indicate the STA is not refusing or the report is autonomous.

— All other bits are reserved.

	B0	B1	B2	B3	B7
	Late	Incapable	Refused	Reserved	
Bits:	1	1	1	5	

Figure 9-223—Measurement Report Mode field format

No more than one bit is set to 1 within a Measurement Report Mode field. All bits within the Measurement Mode field are set to 0 if the results of a successful measurement request or an autonomous measurement are being reported.

The Measurement Type field is set to a number that identifies the measurement report. The Measurement Types that have been allocated are shown in Table 9-125.

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Table 9-125—Measurement Type field definitions for measurement reports

Name	Measurement Type
Basic	0
CCA	1
RPI Histogram	2
Channel Load	3
Noise Histogram	4
Beacon	5
Frame	6
STA Statistics	7
LCI	8
Transmit Stream/Category Measurement	9
Multicast Diagnostics	10
Location Civic	11
Location Identifier	12
Directional Channel Quality	13
Directional Measurement	14
Directional Statistics	15
Fine Timing Measurement Range	16
Reserved	17–255

The Measurement Report field is not present when the Late bit is equal to 1, the Incapable bit is equal to 1, or the Refused bit is equal to 1. Otherwise, it contains a single measurement report, as described in 9.4.2.21.2 to 9.4.2.21.11.

References in this standard to a '<name> report', where <name> corresponds to one of the Measurement Types in Table 9-125 is equivalent to (according to context) a) 'a Measurement Report frame or Radio Measurement Report frame carrying a Measurement Report element with the Measurement Type field equal to <name>' or b) 'a Measurement Report element with the Measurement Type field equal to <name>'.

ANIPI is set to the average noise plus interference power value measured during the indicated Measurement Duration, using the same units and accuracy as defined for ANPI in 11.10.9.4.

RCPI is a logarithmic indication of the received channel power of the corresponding Link Measurement Request frame, as defined in 9.4.2.37.

RSNI is the ratio of the received signal power to the noise plus interference power, as defined in 9.4.2.40.

Channel Load is measured and reported as defined in 11.10.9.3.

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9.4.2.21.2 Basic report

The format of the Measurement Report field corresponding to a Basic report is shown in Figure 9-224.

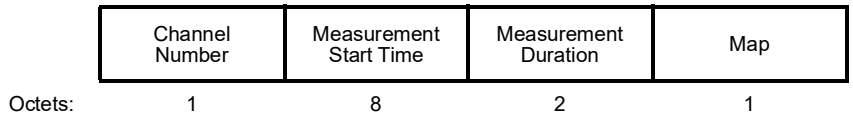

Figure 9-224—Measurement Report field format for a Basic report

The Channel Number field is set to the channel number to which the Basic report applies where the Channel Number is a value from the Channel set column in Table E-4, in a row having the same value in the Channel spacing (MHz) column as the width of the primary channel.

The Measurement Start Time field is set to the TSF at the time (± 32 μs) at which the Basic report measurement started.

The Measurement Duration field is set to the duration over which the Basic report was measured, expressed in TUs.

The Map field is coded as a bit field, as shown in Figure 9-225, and contains the following bits:

— BSS bit, which is set to 1 when at least one valid MPDU was received in the channel during the measurement period from another BSS. Otherwise, the BSS bit is set to 0.

— OFDM Preamble bit, which is set to 1 when at least one sequence of short training symbols, as defined in 17.3.3, was detected in the channel during the measurement period without a subsequent valid SIGNAL field (see 17.3.4). This indicates the presence of an OFDM preamble, such as high-performance RLAN/2 (HIPERLAN/2). Otherwise, the OFDM Preamble bit is set to 0.

— Unidentified Signal bit, which is set to 1 when, in the channel during the measurement period, there is significant power detected that is not characterized as radar, an OFDM preamble, or a valid MPDU. Otherwise, the Unidentified Signal bit is set to 0. The definition of significant power is implementation dependent.

— Radar bit, which is set to 1 when radar was detected operating in the channel during the measurement period. The radar detection algorithm that satisfies regulatory requirements is outside the scope of this standard. Otherwise, the Radar bit is set to 0.

— Unmeasured bit, which is set to 1 when this channel has not been measured. Otherwise, the Unmeasured bit is set to 0. When the Unmeasured field is equal to 1, all of the other bit fields are set to 0.

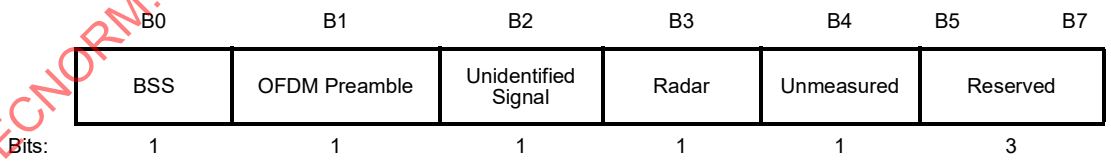

Figure 9-225—Map field format

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9.4.2.21.3 CCA report

The format of the Measurement Report field corresponding to a CCA report is shown in Figure 9-226.

	Channel Number	Measurement Start Time	Measurement Duration	CCA Busy Fraction
Octets:	1	8	2	1

Figure 9-226—Measurement Report field format for a CCA report

The Channel Number field contains the channel number to which the CCA report applies where the Channel Number is a value from the Channel set column in Table E-4, in a row having the same value in the Channel spacing (MHz) column as the width of the primary channel.

The Measurement Start Time field is set to the TSF at the time (± 32 μs) at which the CCA report measurement started.

The Measurement Duration field is set to the duration over which the CCA report was measured, expressed in TUs.

The CCA Busy Fraction field contains the fractional duration over which CCA indicated the channel was busy during the measurement duration. The resolution of the CCA busy measurement is in microseconds. The CCA Busy Fraction value is defined as

$$\left\lceil \frac{255 \times t_{busy}}{1024 \times t_{MD}} \right\rceil$$

where

t_{busy} is the duration CCA indicated channel was busy (μs)
t_{MD} is the measurement duration (TUs)

9.4.2.21.4 RPI histogram report

The format of the Measurement Report field corresponding to an RPI histogram report is shown in Figure 9-227.

	Channel Number	Measurement Start Time	Measurement Duration
Octets:	1	8	2

	RPI 0 density	RPI 1 density	RPI 2 density	RPI 3 density	RPI 4 density	RPI 5 density	RPI 6 density	RPI 7 density
Octets:	1	1	1	1	1	1	1	1

Figure 9-227—Measurement Report field format for an RPI histogram report

The Channel Number field is set to the channel number to which the RPI histogram report applies where the Channel Number is a value from the Channel set column in Table E-4, in a row having the same value in the Channel spacing (MHz) column as the width of the primary channel.

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The Measurement Start Time field is set to the TSF at the time (± 32 μs) at which the RPI histogram report measurement started.

The Measurement Duration field is set to the duration over which the RPI histogram report was measured, expressed in TUs.

The RPI histogram report contains the RPI densities observed in the channel for the eight RPI levels defined in Table 9-126. See 11.10.12.

Table 9-126—RPI definitions for an RPI histogram report

RPI	Power observed at the antenna connector (dBm)
0	Power ≤ –87
1	–87 < Power ≤ –82
2	–82 < Power ≤ –77
3	–77 < Power ≤ –72
4	–72 < Power ≤ –67
5	–67 < Power ≤ –62
6	–62 < Power ≤ –57
7	–57 < Power

The RPI histogram report provides an additional mechanism for a STA to gather information on the state of a channel from other STAs. The STA might use this information to assist in the choice of new channel, to help avoid false radar detections, and to assess the general level of interference present on a channel.

9.4.2.21.5 Channel Load report

The format of the Measurement Report field corresponding to a Channel Load report is shown in Figure 9-228.

	Operating Class	Channel Number	Actual Measurement Start Time	Measurement Duration	Channel Load	Optional Subelements
Octets:	1	1	8	2	1	variable

Figure 9-228—Measurement Report field format for Channel Load report

If the Wide Bandwidth Channel Switch subelement is not included, the Operating Class field indicates the operating class that identifies the channel set for which the measurement report applies. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing for which the measurement report applies. Valid operating classes are listed in Annex E, excluding operating classes that encompass a primary channel but do not identify the location of the primary channel. The Channel Number field indicates the channel number for which the measurement report applies. Channel number is defined within an operating class as shown in Annex E.

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NOTE—Examples of operating classes that encompass a primary channel but do not identify the location of the primary channel are operating classes with a value of 80 or 160 in the Channel Spacing (MHz) column of the applicable table in Annex E.

If the Wide Bandwidth Channel Switch subelement is included, the fields in the Wide Bandwidth Channel Switch subelement indicate the channel for which the measurement report applies, and the Operating Class and Channel Number fields together specify the primary channel and primary 40 MHz channel within the channel identified by the Wide Bandwidth Channel Switch subelement.

The Actual Measurement Start Time field is set to the value of the measuring STA's TSF timer at the time the measurement started.

The Measurement Duration field is set to the duration over which the Channel Load report was measured, in units of TUs.

The Channel Load field contains the proportion of measurement duration for which the measuring STA determined the channel to be busy. Procedure for Channel Load measurement and definition of channel load values are found in 11.10.9.3.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-127.

Table 9-127—Optional subelement IDs for Channel Load report

Subelement ID	Name	Extensible
0–162	Reserved	
163	Wide Bandwidth Channel Switch	Yes
164–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.160), with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

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9.4.2.21.6 Noise Histogram report

The format of the Measurement Report field of a Noise Histogram report is shown in Figure 9-229.

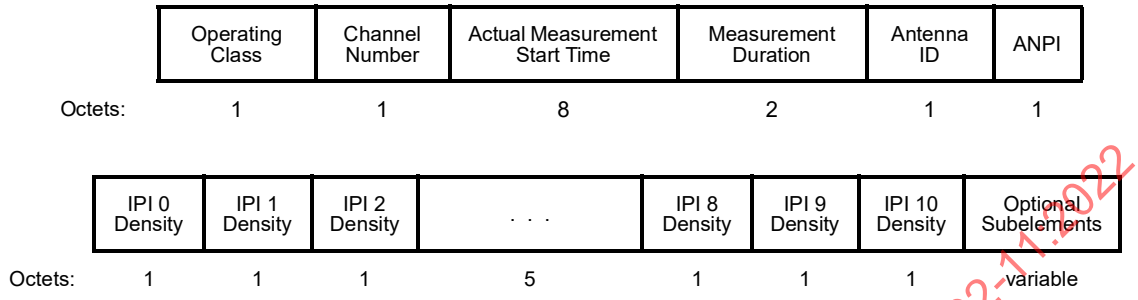

Figure 9-229—Measurement Report field format for Noise Histogram report

If the Wide Bandwidth Channel Switch subelement is not included, the Operating Class field indicates the operating class that identifies the channel set for which the measurement report applies. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing for which the measurement report applies. Valid operating classes are listed in Annex E, excluding operating classes that encompass a primary channel but do not identify the location of the primary channel. The Channel Number field indicates the channel number for which the measurement report applies. Channel number is defined within an operating class as shown in Annex E.

If the Wide Bandwidth Channel Switch subelement is included, the fields in the Wide Bandwidth Channel Switch subelement indicate the channel for which the measurement report applies, and the Operating Class and Channel Number together specify the primary channel and primary 40 MHz channel within the channel identified by the Wide Bandwidth Channel Switch subelement.

The Actual Measurement Start Time field is set to the value of the measuring STA's TSF timer at the time the measurement started.

The Measurement Duration field is set to the duration over which the Noise Histogram report was measured, in units of TUs.

The Antenna ID field is set to the identifying number for the antenna(s) or DMG antenna(s) used for this measurement. The antenna ID or DMG antenna ID is defined in 9.4.2.39.

The ANPI field is set to the average noise plus interference power value measured during the indicated measurement duration while the indicated channel is idle as described in 11.10.9.4.

The Noise Histogram report contains the IPI densities, as defined in 11.10.9.4, observed in the channel for the eleven IPI levels defined in Table 9-128.

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Table 9-128—IPI Definitions for a Noise Histogram report

IPI Level	IPI Measured Power (dBm)
0	IPI ≤ –92
1	–92 < IPI ≤ –89
2	–89 < IPI ≤ –86
3	–86 < IPI ≤ –83
4	–83 < IPI ≤ –80
5	–80 < IPI ≤ –75
6	–75 < IPI ≤ –70
7	–70 < IPI ≤ –65
8	–65 < IPI ≤ –60
9	–60 < IPI ≤ –55
10	–55 < IPI

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-129.

Table 9-129—Optional subelement IDs for Noise Histogram report

Subelement ID	Name	Extensible
0–162	Reserved	
163	Wide Bandwidth Channel Switch	Yes
164–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.160) with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

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9.4.2.21.7 Beacon report

The format of the Measurement Report field corresponding to a Beacon report is shown in Figure 9-230.

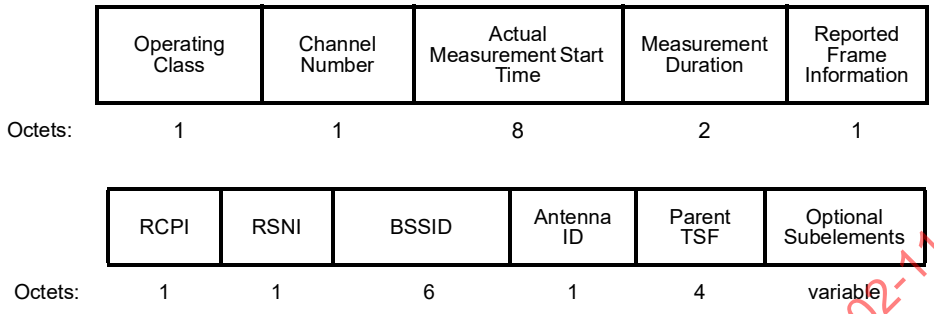

Figure 9-230—Measurement Report field format for Beacon report

The Operating Class field indicates the operating class that identifies the channel set of the received Beacon or Probe Response frame. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing of the received Beacon or Probe Response frame. Valid operating classes are listed in Annex E.

The Channel Number field indicates the channel number of the received Beacon or Probe Response frame. Channel number is defined within an operating class as shown in Annex E.

If the PPDU carrying the received frame comprises noncontiguous frequency segments, the Operating Class and Channel Number fields identify the center frequency of frequency segment 0, and a Wide Bandwidth Channel Switch subelement is included to identify the center frequency of frequency segment 1 (the other fields in the subelement indicate 80+80 bandwidth and the same center frequency of frequency segment 0 as the Operating Class and Channel Number fields); otherwise the Wide Bandwidth Channel Switch subelement is not included.

The Actual Measurement Start Time field is set to the value of the measuring STA's TSF timer at the time the measurement started.

The Measurement Duration field is set to the duration over which the Beacon report was measured, in units of TUs.

The Reported Frame Information field contains two subfields as shown in Figure 9-231.

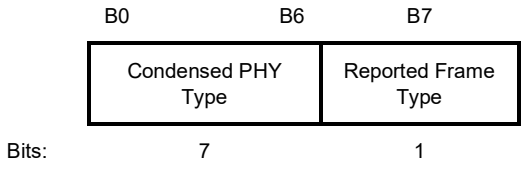

Figure 9-231—Reported Frame Information field format

The Condensed PHY Type subfield indicates the physical medium type on which the Beacon, Measurement Pilot, or Probe Response frame being reported was received. It has an integer value between 0 and 127 coded according to dot11PHYType.

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The Reported Frame Type subfield indicates the type of frame reported. A 0 indicates a Beacon or Probe Response frame; a 1 indicates a Measurement Pilot frame.

The RCPI field indicates the received channel power of the Beacon, Measurement Pilot, or Probe Response frame, which is a logarithmic function of the received signal power, as defined 9.4.2.37.

The RSNI field indicates the received signal-to-noise indication for the Beacon, Measurement Pilot, or Probe Response frame, as described in 9.4.2.40.

The BSSID field contains the BSSID from the Beacon, Measurement Pilot, or Probe Response frame being reported.

The Antenna ID field contains the identifying number for the antenna(s) or DMG antenna used for this measurement. The antenna ID or DMG antenna ID is defined in 9.4.2.39.

The Parent TSF field contains the value of the 4 least significant octets of the measuring STA's TSF timer at the start of reception of the first octet of the Timestamp field of the reported Beacon, Measurement Pilot, or Probe Response frame at the time the Beacon, Measurement Pilot, or Probe Response frame being reported was received.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-130.

Table 9-130—Optional subelement IDs for Beacon report

Subelement ID	Name	Extensible
0	Reserved	
1	Reported Frame Body	No
2	Reported Frame Body Fragment ID	No
3–162	Reserved	
163	Wide Bandwidth Channel Switch	Yes
164	Last Beacon Report Indication	No
165-220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Reported Frame Body subelement contains the requested fields and elements of the frame body of the reported Beacon, Measurement Pilot, or Probe Response frame. If the Reporting Detail subelement of the corresponding Beacon request equals 0, the Reported Frame Body subelement is not included in the Beacon report. If the Reporting Detail subelement equals 1, all fields and any elements identified in a Request element or Extended Request element in the corresponding Beacon request are included in the Reported Frame Body subelement, in the order that they appeared in the reported frame.

If the Reporting Detail field equals 2, all fields and elements are included in the order they appeared in the reported frame.

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Some elements in the Reported Frame Body subelement, or the Reported Frame Body subelement itself, might be large. In this case, some of the elements included in the Reported Frame Body subelement might be truncated, and the subelement itself might be truncated or fragmented over multiple Beacon Reports when its size exceeds the maximum element size, as described below:

— Reported TIM elements might be truncated such that only the first 4 octets of the element are reported and the element Length field is modified to indicate the truncated length of 4.

— Reported IBSS DFS elements might be truncated so that only the lowest and highest channel number map are reported and the element Length field is modified to indicate the truncated length of 13.

— Reported RSNEs might be truncated so that only the first 4 octets of the element are reported and the element Length field is modified to indicate the truncated length of 4.

— If the length of the Reported Frame Body subelement would cause the Measurement Report element to exceed the maximum element size, when Reported Frame Body subelement fragmentation is not supported, then the Reported Frame Body subelement is truncated so that the last element in the Reported Frame Body subelement is a complete element.

— If the length of the Reported Frame Body subelement would cause the Measurement Report element to exceed the maximum element size, when Reported Frame Body subelement fragmentation is supported, then the Reported Frame Body subelement is fragmented over multiple Beacon Reports. When the Reported Frame Body subelement is fragmented, then the Reported Frame Body Fragment ID subelement is present in each Beacon Report frame that contains a fragment of this Reported Frame Body subelement. When the Reported Frame Body Fragment ID subelement is present, the reporting STA does not truncate any of the elements included into the Reported Frame Body subelement.

The format of the Data field of the Reported Frame Body Fragment ID subelement is shown in Figure 9-232.

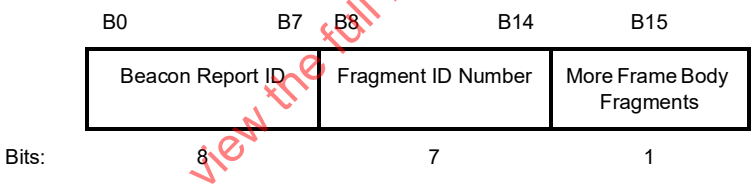

Figure 9-232—Data field format

The Beacon Report ID field identifies the Beacon Report instance sent as a response to a Beacon Request. The responding STA sets the Fragment ID Number field to 0 for the initial fragment and increments it by 1 for each subsequent fragment in a multi-fragment Reported Frame Body subelement of a Beacon Report identified by the Beacon Report ID.

The More Frame Body Fragments field is set to 0 whenever the final fragment of a Reported Frame Body subelement is being transmitted, otherwise it is set to 1.

The Reported Frame Body subelement is fragmented so that the last element in every Reported Frame Body subelement fragment is a complete element.

The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.160) with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

The Last Beacon Report Indication subelement has the format defined in Figure 9-789, with a Length field set to 1. When the Data field is set to 1, it indicates that this Beacon report is the last frame sent as a response to a Beacon request. A 0 indicates that there are more frames expected.

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The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.21.8 Frame report

The format of the Measurement Report field corresponding to a Frame report is shown in Figure 9-233.

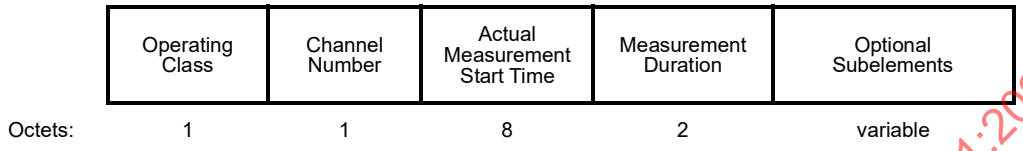

Figure 9-233—Measurement Report field format for Frame report

If the Wide Bandwidth Channel Switch subelement is not included, the Operating Class field indicates the operating class that identifies the channel set for which the measurement report applies. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing for which the measurement report applies. Valid operating classes are listed in Annex E, excluding operating classes that encompass a primary channel but do not identify the location of the primary channel. The Channel Number field indicates the channel number for which the measurement report applies. Channel number is defined within an operating class as shown in Annex E.

If the Wide Bandwidth Channel Switch subelement is included, the fields in the Wide Bandwidth Channel Switch subelement indicate the channel for which the measurement report applies, and the Operating Class and Channel Number fields together specify the primary channel and primary 40 MHz channel within the channel identified by the Wide Bandwidth Channel Switch subelement.

The Actual Measurement Start Time field is set to the value of the measuring STA's TSF timer at the time the measurement started.

The Measurement Duration field is set to the duration over which the Frame report was measured, in units of TUs.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-131.

Table 9-131—Optional subelement IDs for Frame report

Subelement ID	Name	Extensible
0	Reserved	
1	Frame Count Report	No
2–162	Reserved	
163	Wide Bandwidth Channel Switch	Yes
164–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

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The Frame Count Report subelement is used to report information about frames sent by a transmitter. The Frame Count Report subelement is as shown in Figure 9-234.

	Subelement ID	Length	Frame Report Entries
Octets:	1	1	$n \times 19$

Figure 9-234—Frame Count Report subelement format

The Subelement ID field is defined in Table 9-131.

The Length field is defined in 9.4.3.

The Frame Report Entries field contains zero or more (n) Frame Report Entry fields. The format of a Frame Report Entry field is shown in Figure 9-235.

	Transmitter Address	BSSID	PHY Type	Average RCPI	Last RSNI	Last RCPI	Antenna ID	Frame Count
Octets:	6	6	1	1	1	1	1	2

Figure 9-235—Frame Report Entry field format

The Transmitter Address field contains the transmitter address (TA) from the frames being reported.

The BSSID field contains the BSSID from the frames being reported.

The PHY Type field indicates the physical medium type for the frame(s) being reported. Valid entries are coded according to dot11PHYType.

The Average RCPI field indicates the average value for the received channel power of frames received and counted in this Frame Report Entry field, as described in 11.10.9.2. Average RCPI is a logarithmic function of the received signal power, as defined 9.4.2.37.

The Last RSNI field indicates the received signal-to-noise indication of the most recently measured frame counted in this Frame Report Entry field, as described in 9.4.2.40.

The Last RCPI field indicates the received channel power of the most recently measured frame counted in this Frame Report Entry field. Last RCPI is a logarithmic function of the received signal power, as defined in 9.4.2.37.

The Antenna ID field contains the identifying number for the antenna(s) or DMG antenna used to receive the most recently measured frame counted in this Frame Report Entry field. The antenna ID or DMG antenna ID is defined in 9.4.2.39.

The Frame Count field is a count of the Data and Management frames received with the indicated transmitter address and BSSID during the measurement duration. The value 65 535 indicates a count of 65 535 or more.

The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.160), with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

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The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.21.9 STA Statistics report

The format of the Measurement Report field of a STA Statistics report is shown in Figure 9-236.

	Measurement Duration	Group Identity	Statistics Group Data	Optional Subelements
Octets:	2	1	variable	variable

Figure 9-236—Measurement Report field format for STA Statistics report

The STA Statistics report reports the change in, or current values of, the requested statistics group data measured within the measurement duration.

The Measurement Duration field is set to the duration over which the change in statistics group data was measured and reported, in units of TUs. A Measurement Duration field set to 0 indicates a report of the current values of the statistics group data.

The Group Identity field indicates the requested statistics group describing the Statistics Group Data field according to Table 9-132.

The Statistics Group Data field contains the requested statistics from the MIB in Annex C related to the interface on which the request was received according to Table 9-132. Units used for reporting a statistic or change in statistic are the units used to define the statistic in Annex C. When the Measurement Duration field is nonzero, the reported data values for statistics that are not counters are the current values of the statistics data at the end of the measurement duration. When the Measurement Duration field is zero the current values of the requested statistics group data are reported, rather than the change.

Table 9-132—Group Identity for a STA Statistics report

Group Identity Requested	Statistics Group Data field length (octets)	Statistics Returned
0	28	dot11Counters Group for the Interface on which the STA Statistics request was received (with the exception of WEPUndecryptableCount and those counters listed in Group Identity 1): dot11TransmittedFragmentCount (Counter32), dot11GroupTransmittedFrameCount (Counter32), dot11FailedCount (Counter32), dot11ReceivedFragmentCount (Counter32), dot11GroupReceivedFrameCount (Counter32), dot11FCSErrorCount (Counter32), dot11TransmittedFrameCount (Counter32)

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Table 9-132—Group Identity for a STA Statistics report *(continued)*

Group Identity Requested	Statistics Group Data field length (octets)	Statistics Returned
1	24	dot11MACStatistics Group for the Interface on which the STA Statistics request was received: dot11RetryCount (Counter32), dot11MultipleRetryCount (Counter32), dot11FrameDuplicateCount (Counter32), dot11RTSSuccessCount (Counter32), dot11RTSFailureCount (Counter32), dot11AckFailureCount (Counter32)
2	52	dot11QosCounters Group for UP0 for the Interface on which the STA Statistics request was received: dot11QosTransmittedFragmentCount (Counter32), dot11QosFailedCount (Counter32), dot11QosRetryCount (Counter32), dot11QosMultipleRetryCount (Counter32), dot11QosFrameDuplicateCount (Counter32), dot11QosRTSSuccessCount (Counter32), dot11QosRTSFailureCount (Counter32), dot11QosAckFailureCount (Counter32), dot11QosReceivedFragmentCount (Counter32), dot11QosTransmittedFrameCount (Counter32), dot11QosDiscardedFrameCount (Counter32), dot11QosMPDUsReceivedCount (Counter32), dot11QosRetriesReceivedCount (Counter32)
3	52	dot11QosCounters Group for UP1 for the Interface on which the STA Statistics request was received: dot11QosTransmittedFragmentCount (Counter32), dot11QosFailedCount (Counter32), dot11QosRetryCount (Counter32), dot11QosMultipleRetryCount (Counter32), dot11QosFrameDuplicateCount (Counter32), dot11QosRTSSuccessCount (Counter32), dot11QosRTSFailureCount (Counter32), dot11QosAckFailureCount (Counter32), dot11QosReceivedFragmentCount (Counter32), dot11QosTransmittedFrameCount (Counter32), dot11QosDiscardedFrameCount (Counter32), dot11QosMPDUsReceivedCount (Counter32), dot11QosRetriesReceivedCount (Counter32)

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Table 9-132—Group Identity for a STA Statistics report *(continued)*

Group Identity Requested	Statistics Group Data field length (octets)	Statistics Returned
4	52	dot11QosCounters Group for UP2 for the Interface on which the STA Statistics request was received: dot11QosTransmittedFragmentCount (Counter32), dot11QosFailedCount (Counter32), dot11QosRetryCount (Counter32), dot11QosMultipleRetryCount (Counter32), dot11QosFrameDuplicateCount (Counter32), dot11QosRTSSuccessCount (Counter32), dot11QosRTSFailureCount (Counter32), dot11QosAckFailureCount (Counter32), dot11QosReceivedFragmentCount (Counter32), dot11QosTransmittedFrameCount (Counter32), dot11QosDiscardedFrameCount (Counter32), dot11QosMPDUsReceivedCount (Counter32), dot11QosRetriesReceivedCount (Counter32)
5	52	dot11QosCounters Group for UP3 for the Interface on which the STA Statistics request was received: dot11QosTransmittedFragmentCount (Counter32), dot11QosFailedCount (Counter32), dot11QosRetryCount (Counter32), dot11QosMultipleRetryCount (Counter32), dot11QosFrameDuplicateCount (Counter32), dot11QosRTSSuccessCount (Counter32), dot11QosRTSFailureCount (Counter32), dot11QosAckFailureCount (Counter32), dot11QosReceivedFragmentCount (Counter32), dot11QosTransmittedFrameCount (Counter32), dot11QosDiscardedFrameCount (Counter32), dot11QosMPDUsReceivedCount (Counter32), dot11QosRetriesReceivedCount (Counter32)
6	52	dot11QosCounters Group for UP4 for the Interface on which the STA Statistics request was received: dot11QosTransmittedFragmentCount (Counter32), dot11QosFailedCount (Counter32), dot11QosRetryCount (Counter32), dot11QosMultipleRetryCount (Counter32), dot11QosFrameDuplicateCount (Counter32), dot11QosRTSSuccessCount (Counter32), dot11QosRTSFailureCount (Counter32), dot11QosAckFailureCount (Counter32), dot11QosReceivedFragmentCount (Counter32), dot11QosTransmittedFrameCount (Counter32), dot11QosDiscardedFrameCount (Counter32), dot11QosMPDUsReceivedCount (Counter32), dot11QosRetriesReceivedCount (Counter32)

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Table 9-132—Group Identity for a STA Statistics report *(continued)*

Group Identity Requested	Statistics Group Data field length (octets)	Statistics Returned
7	52	dot11QosCounters Group for UP5 for the Interface on which the STA Statistics request was received: dot11QosTransmittedFragmentCount (Counter32), dot11QosFailedCount (Counter32), dot11QosRetryCount (Counter32), dot11QosMultipleRetryCount (Counter32), dot11QosFrameDuplicateCount (Counter32), dot11QosRTSSuccessCount (Counter32), dot11QosRTSFailureCount (Counter32), dot11QosAckFailureCount (Counter32), dot11QosReceivedFragmentCount (Counter32), dot11QosTransmittedFrameCount (Counter32), dot11QosDiscardedFrameCount (Counter32), dot11QosMPDUsReceivedCount (Counter32), dot11QosRetriesReceivedCount (Counter32)
8	52	dot11QosCounters Group for UP6 for the Interface on which the STA Statistics request was received: dot11QosTransmittedFragmentCount (Counter32), dot11QosFailedCount (Counter32), dot11QosRetryCount (Counter32), dot11QosMultipleRetryCount (Counter32), dot11QosFrameDuplicateCount (Counter32), dot11QosRTSSuccessCount (Counter32), dot11QosRTSFailureCount (Counter32), dot11QosAckFailureCount (Counter32), dot11QosReceivedFragmentCount (Counter32), dot11QosTransmittedFrameCount (Counter32), dot11QosDiscardedFrameCount (Counter32), dot11QosMPDUsReceivedCount (Counter32), dot11QosRetriesReceivedCount (Counter32)
9	52	dot11QosCounters Group for UP7 for the Interface on which the STA Statistics request was received: dot11QosTransmittedFragmentCount (Counter32), dot11QosFailedCount (Counter32), dot11QosRetryCount (Counter32), dot11QosMultipleRetryCount (Counter32), dot11QosFrameDuplicateCount (Counter32), dot11QosRTSSuccessCount (Counter32), dot11QosRTSFailureCount (Counter32), dot11QosAckFailureCount (Counter32), dot11QosReceivedFragmentCount (Counter32), dot11QosTransmittedFrameCount (Counter32), dot11QosDiscardedFrameCount (Counter32), dot11QosMPDUsReceivedCount (Counter32), dot11QosRetriesReceivedCount (Counter32)

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Table 9-132—Group Identity for a STA Statistics report *(continued)*

Group Identity Requested	Statistics Group Data field length (octets)	Statistics Returned
10	8	dot11BSSAverageAccessDelay Group (only available at an AP): dot11STAStatisticsAPAverageAccessDelay (INTEGER), dot11STAStatisticsAverageAccessDelayBestEffort (INTEGER), dot11STAStatisticsAverageAccessDelayBackGround (INTEGER), dot11STAStatisticsAverageAccessDelayVideo (INTEGER), dot11STAStatisticsAverageAccessDelayVoice (INTEGER), dot11STAStatisticsStationCount (INTEGER), dot11STAStatisticsChannelUtilization (INTEGER)
11	40	STA Counters from dot11CountersGroup3 (A-MSDU): dot11TransmittedAMSDUCount (Counter32), dot11FailedAMSDUCount (Counter32), dot11RetryAMSDUCount (Counter32), dot11MultipleRetryAMSDUCount (Counter32), dot11TransmittedOctetsInAMSDUCount (Counter64), dot11AMSDUAckFailureCount (Counter32), dot11ReceivedAMSDUCount (Counter32), dot11ReceivedOctetsInAMSDUCount (Counter64)
12	36	STA Counters from dot11CountersGroup3 (A-MPDU): dot11TransmittedAMPDUCount (Counter32), dot11TransmittedMPDUsInAMPDUCount (Counter32), dot11TransmittedOctetsInAMPDUCount (Counter64), dot11AMPDUReceivedCount (Counter32), dot11MPDUInReceivedAMPDUCount (Counter32), dot11ReceivedOctetsInAMPDUCount (Counter64), dot11AMPDUDelimiterCRCErrorCount (Counter32)
13	36	STA Counters from dot11CountersGroup3 (BlockAckReq, Channel Width, PSMP): dot11ImplicitBARFailureCount (Counter32), dot11ExplicitBARFailureCount (Counter32), dot11ChannelWidthSwitchCount (Counter32), dot11TwentyMHzFrameTransmittedCount (Counter32), dot11FortyMHzFrameTransmittedCount (Counter32), dot11TwentyMHzFrameReceivedCount (Counter32), dot11FortyMHzFrameReceivedCount (Counter32), dot11PSMPUTTGrantDuration (Counter32), dot11PSMPUTTUsedDuration (Counter32)
14	36	STA Counters from dot11CountersGroup3 (RD, dual CTS): dot11GrantedRDGUsedCount (Counter32), dot11GrantedRDGUnusedCount (Counter32), dot11TransmittedFramesInGrantedRDGCount (Counter32), dot11TransmittedOctetsInGrantedRDGCount (Counter64), dot11DualCTSSuccessCount (Counter32), dot11DualCTSFailureCount (Counter32), dot11RTSLSIGSuccessCount (Counter32), dot11RTSLSIGFailureCount (Counter32)
15	20	STA Counters from dot11CountersGroup3 (beamforming and STBC): dot11BeamformingFrameCount (Counter32), dot11STBCCTSSuccessCount (Counter32), dot11STBCCTSFailureCount (Counter32), dot11nonSTBCCTSSuccessCount (Counter32), dot11nonSTBCCTSFailureCount (Counter32)

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Table 9-132—Group Identity for a STA Statistics report *(continued)*

Group Identity Requested	Statistics Group Data field length (octets)	Statistics Returned
16	28	dot11RSNAStats Group for the Interface on which the STA Statistics request was received: dot11RSNAStatsBIPMICErrors (Counter32) dot11RSNAStatsCMACReplays (Counter32) dot11RSNAStatsRobustMgmtCCMPReplays(Counter32) dot11RSNAStatsTKIPICVErrors (Counter32) dot11RSNAStatsTKIPReplays (Counter32) dot11RSNAStatsCCMPDecryptErrors (Counter32) dot11RSNAStatsCCMPReplays (Counter32)
17–255		Reserved

The format of the Measurement Report field for dot11Counters Group is shown in Figure 9-237.

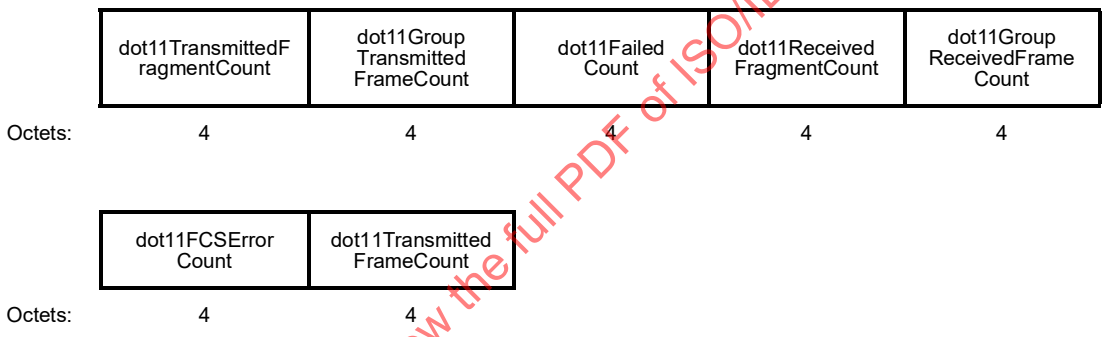

Figure 9-237—Measurement Report field format for dot11Counters Group

The format of the Measurement Report field for dot11MACStatistics is shown in Figure 9-238.

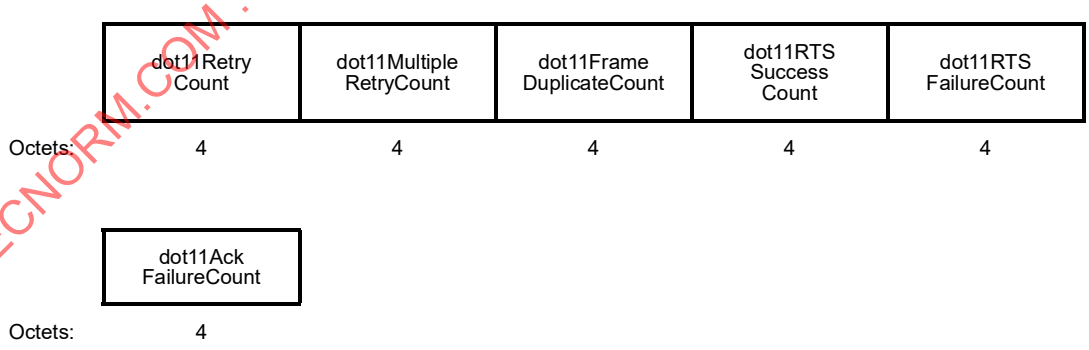

Figure 9-238—Measurement Report field format for dot11MACStatistics Group

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The format of the Measurement Report field for dot11QosCounters Group for UPx is shown in Figure 9-239, where x is 0 – 7 and where the listed variables are obtained from the column of the QoS Counters Table indexed by x + 1. For example, the variables for dot11QosCounters Group for UP2 are from the third column of the dot11QosCountersTable, obtained from the dot11QosCountersEntry in which dot11QosCountersIndex is equal to 3.

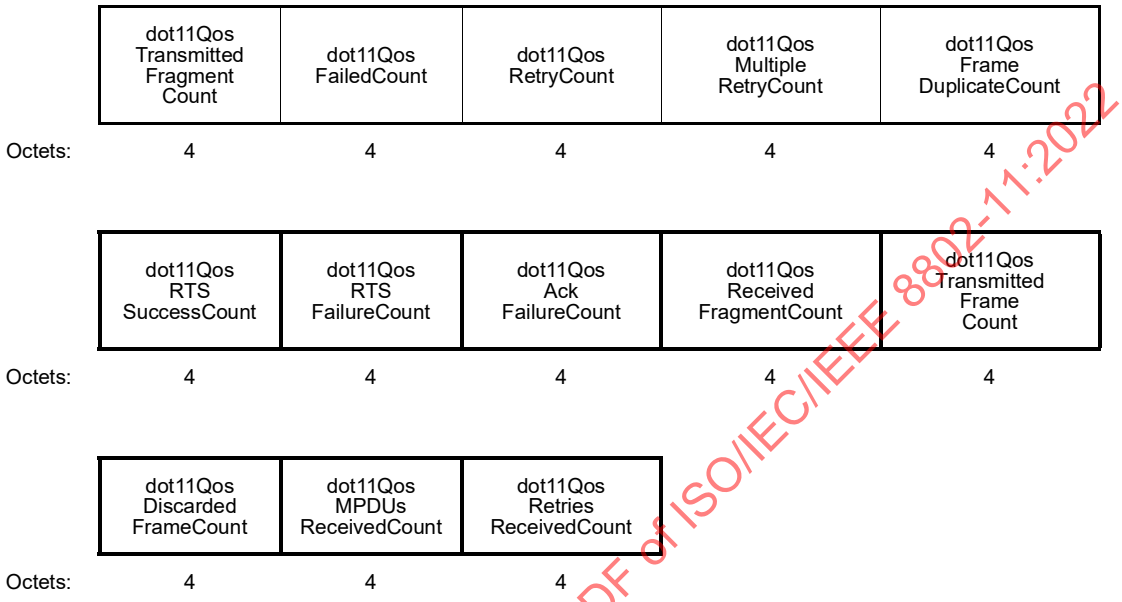

Figure 9-239—Measurement Report field format for dot11QosCounters Group for UPx

The format of the Measurement Report field for dot11BSSAverageAccessDelay Group is shown in Figure 9-240. Non-QoS APs set dot11STAStatisticsAverageAccessDelayBestEffort, dot11STAStatisticsAverageAccessDelayBackGround, dot11STAStatisticsAverageAccessDelayVideo, and dot11STAStatisticsAverageAccessDelayVoice to 255 (not available).

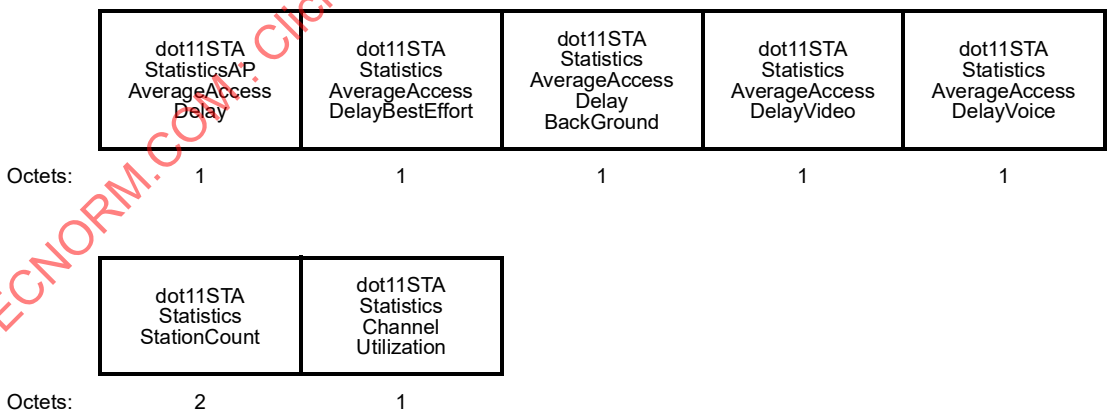

Figure 9-240—Measurement Report field format for dot11BSSAverageAccessDelay Group

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The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-133.

Table 9-133—Optional subelement IDs for STA Statistics report

Subelement ID	Name	Extensible
0	Reserved	
1	Reporting Reason	No
2–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The format of the Measurement Report field for RSNA Counters Group is shown in Figure 9-241.

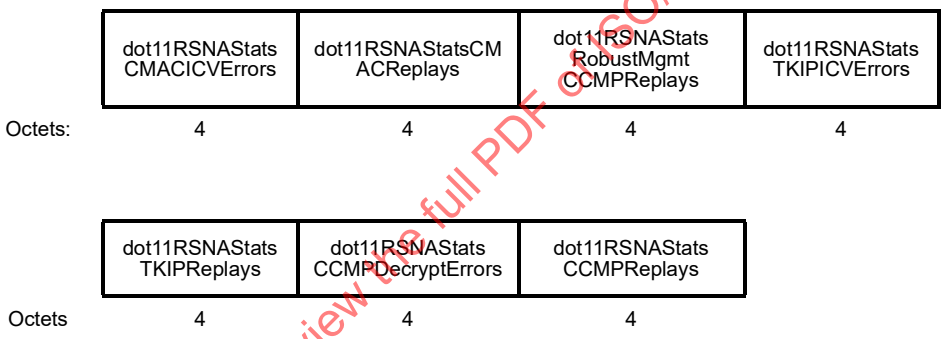

Figure 9-241—Measurement Report field format for RSNA Counters Group

The Reporting Reason subelement indicates the reason why the measuring STA sent the STA Statistics report. It is present if Statistics Group Name is from STA Counters, QoS STA Counters, or RSNA Counters (see 11.10.9.5).

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The Data field of the Reporting Reason subelement for STA Statistics Group Identities 0 or 1 (STA Counters) is shown in Figure 9-242.

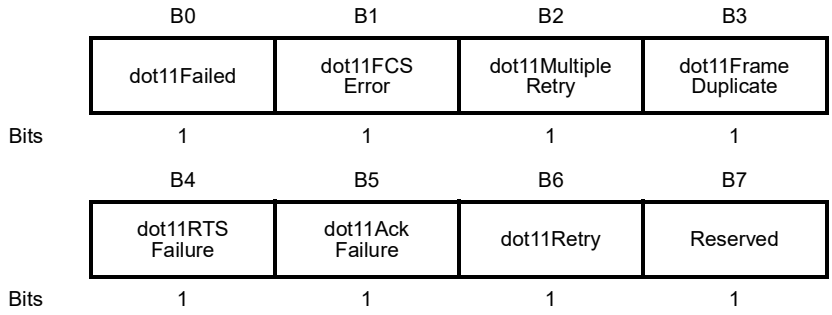

Figure 9-242—Data field format of the Reporting Reason subelement for STA Counters

The Data field of the Reporting Reason subelement for STA Statistics Group Identity 2 to 9 (QoS STA Counters) is shown in Figure 9-243.

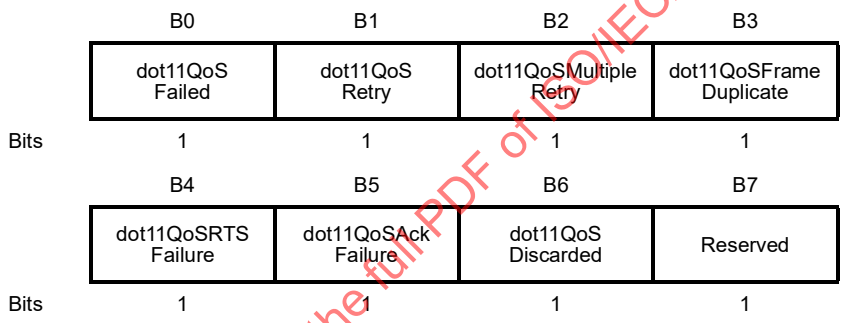

Figure 9-243—Data field format of the Reporting Reason subelement for QoS STA Counters

The Data field of the Reporting Reason subelement for STA Statistics Group Identity 16 (RSNA Counters) is shown in Figure 9-244.

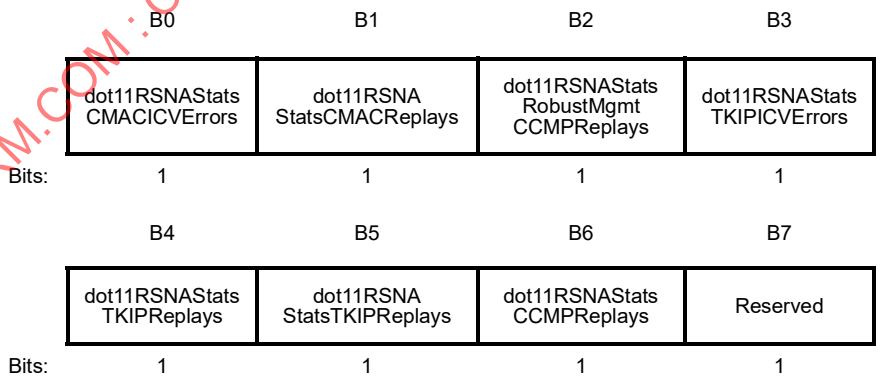

Figure 9-244—Data field format of the Reporting Reason subelement for RSNA Counters

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In a nontriggered STA Statistics report, all subfields of the Data field of the Reporting Reason subelement are set to 0.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.21.10 LCI report (Location configuration information report)

An LCI report for a known LCI includes latitude, longitude, altitude, and related information. An unknown LCI is indicated by the Length field of the LCI subelement being set to 0 and there being no following subelements. The LCI report field format is shown in Figure 9-245.

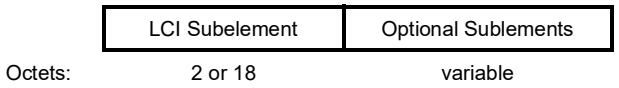

Figure 9-245—Format of Location Configuration Information Report

The subelements in the LCI report are defined in Table 9-134.

Table 9-134—Subelement IDs for LCI Report

Subelement ID	Name	Extensible
0	LCI	No
1	Azimuth Report	Yes
2	Originator Requesting STA MAC Address	No
3	Target MAC Address	No
4	Z	Subelements
5	Relative Location Error	Yes
6	Usage Rules/Policy	Yes
7	Co-Located BSSID List	Yes
8–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The LCI Subelement field contains an LCI subelement. The LCI subelement is formatted as shown in Figure 9-246.

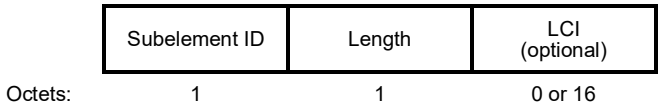

Figure 9-246—LCI subelement format

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The Subelement ID field is equal to the value for LCI in Table 9-134.

The Length field is defined in 9.4.3.

The LCI field is formatted as shown in Figure 9-247.

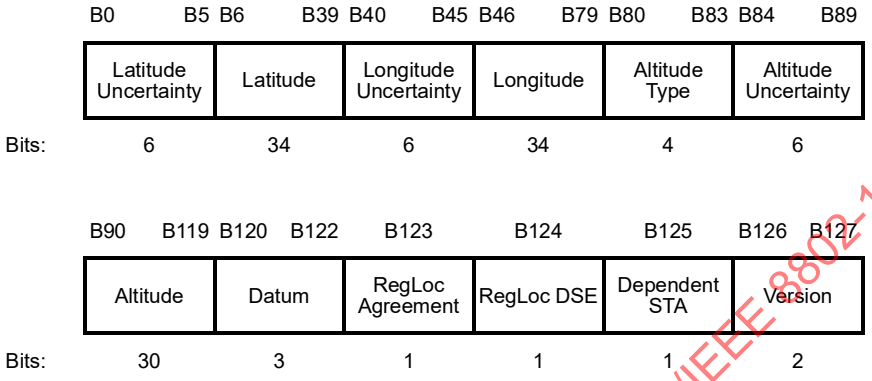

Figure 9-247—LCI field format

The definitions of fields within the LCI field are as specified in Section 2.2 of IETF RFC 6225 (July 2011) or as defined herein. This structure and information fields are based on the LCI format described in IETF RFC 6225.

NOTE 1—This example shows how to encode the coordinates of the Sydney Opera House using the encoding defined in IETF RFC 6225. The building is a polygon with the following (latitude, longitude) coordinates:

(–33.856 625°, +151.215 906°)
(–33.856 299°, +151.215 343°)
(–33.856 326°, +151.214 731°)
(–33.857 533°, +151.214 495°)
(–33.857 720°, +151.214 613°)
(–33.857 369°, +151.215 375°)

Latitude ranges from –33.857 720° to –33.856 299°; longitude ranges from +151.214 495° to +151.215 906°.

For this example, the point that is encoded is chosen by finding the middle of each range, that is (–33.857 009 5°, +151.215 200 5°), which is encoded as (11101111000100100100111011000001101,

01001011100110111000101111011000011) (2s complement, 9 bits before binary point, 25 after, MSB first).

These values can be derived as 2^{34} – Round (33.857 009 5 × 2^{25}) and Round (151.215 200 5 × 2^{25}), respectively.

The latitude uncertainty (LatUnc) is given by inserting the difference between the center value and the outer value into the formula from Section 2.3.2 of IETF RFC 6225. This gives:

LatUnc = $8 - \lceil \log2(-33.8570095 - (-33.857720)) \rceil$. The result is 18, which is encoded as 010010.

Similarly, longitude uncertainty (LongUnc) is given by the formula:

LongUnc = $8 - \lceil \log2(151.2152005 - 151.214495) \rceil$. The result is also 18, which is encoded as 010010.

The top of the building is 67.4 meters above sea level, and a starting altitude of 0 meters above sea level is assumed. At the GPS coordinates of the Sydney Opera House, the sea level is approximately 22.5 m below the WGS84 ellipsoid. Therefore, the lowest altitude of the building is –22.5 m, while the highest altitude is (67.4 – 22.5) = 44.9 m from the WGS84 ellipsoid. The middle of the range is (44.9 – 22.5)/2 = 11.2 m, which is encoded as 00000000000000000101100110011 (22 bits before binary point, 8 after, MSB first).

Altitude uncertainty is given by the height of the building. Since the building is 67.4 m above sea level and basement is assumed to be at sea level, the uncertainty to be encoded is half of 67.4 m.

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Altitude uncertainty (AltUnc) uses the formula from Section 2.4.5 from IETF RFC 6225:

AltUnc = $21 - \lceil \log2(33.7 - 0) \rceil$, the result is 15, which is encoded as 001111 (MSB first).

The Altitude Type field is set to 1, indicating that the altitude is specified in meters.

The Datum field is set to 1, indicating WGS84 coordinates.

The RegLoc Agreement field is set to 0 for this example.

The RegLoc DSE field is set to 0 for this example.

The Dependent STA field is set to 0 for this example.

The Version field is set to 1, as that is the only value currently defined in IETF RFC 6225.

The LCI configuration information report for this example is encoded as (where underscores are used as field or octet delimiters):

010010_1110111100010010010011011000001101_010010_0100101110011011100010111011000011_0001_001111_000000000000000000010110011001 1_001_0_0_0_01 (binary, MSB first per field)

010010_1011000001101100100100100011110111_010010_1100001101110100011101000111010010_1000_111100_1100110011010000000000000000000_100_0_0_0_10 (binary, LSB first per field)

01001010_11000001_10110010_01001000_11110111_01001011_00001101_11010001_11011001_11010010_10001111_00110011_00110100_00000000_00000000_10000010 (binary, rearranged into octets, with LSB first per octet)

01010010_10000011_01001101_00010010_11101111_11010010_10110000_10001011_10011011_01001011_11110001_11001100_00101100_00000000_00000000_01000001 (binary, MSB first, per octet)

52 83 4d 12 ef d2 b0 8b 9b 4b f1 cc 2c 00 00 41 (order over the PHY SAP, see 8.3.5 and 9.2.2)

The RegLoc Agreement field is set to 1 to report that the STA is operating within a national policy area or an international agreement area near a national border (see 11.11.3); otherwise, it is 0.

The RegLoc DSE field is set to 1 to report that the enabling STA is enabling the operation of STAs with DSE; otherwise, it is 0.

The Dependent STA field is set to 1 to report that the STA is operating with the enablement of the enabling STA whose LCI is being reported; otherwise, it is 0.

The Version field is defined in IETF RFC 6225, and the use is described in IETF RFC 6225.

The Optional Subelements field contains zero or more subelements with subelement ID greater than or equal to 1 as listed in Table 9-134. The subelement format and ordering of subelements are defined in 9.4.3.

The Azimuth Report subelement is used to report an azimuth. The Azimuth Report subelement is as shown in Figure 9-248.

	Subelement ID	Length	Azimuth Report
Octets:	1	1	2

Figure 9-248—Azimuth Report subelement format

The Subelement ID field is defined in Table 9-134.

The Length field is defined in 9.4.3.

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The Azimuth Report field of an Azimuth Report subelement contains three subfields as shown in Figure 9-249.

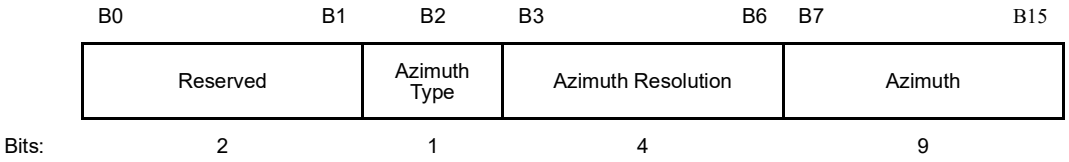

Figure 9-249—Azimuth Report subfield format

The Azimuth Type field is set to 1 to report the Azimuth of the bearing of the requester with respect to the responder and is set to 0 to report the Azimuth of front surface of the reporting STA.

The Azimuth Resolution field is 4 bits, indicating the number of valid most significant bits in the Azimuth.

The Azimuth field is an unsigned integer value in degrees from true north, of the type defined by the Azimuth Type field.

The Originator Requesting STA MAC Address subelement contains the MAC address of the STA that requested the Location Information and it is present whenever the Location Subject field in the corresponding LCI request was set to 2. The format of the Originator Requesting STA MAC Address subelement is shown in Figure 9-201.

The Target MAC Address subelement contains the MAC address of the STA whose Location Information was requested and it is present whenever the Location Subject field in the corresponding LCI request was set to 2. The format of the Target MAC Address subelement is shown in Figure 9-202.

The Z subelement is used to report the floor and location of the STA with respect to the floor level. The format of the Z subelement is shown in Figure 9-250.

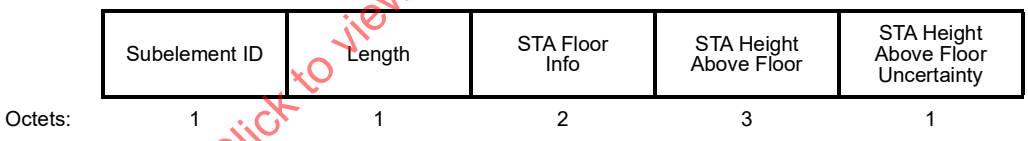

Figure 9-250—Z subelement format

The Subelement ID field is equal to the value for Z in Table 9-134.

The Length field is defined in 9.4.3.

The format of the STA Floor Info field is defined in Figure 9-250.

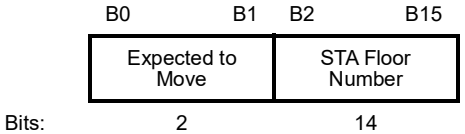

Figure 9-251—STA Floor Info field format

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The Expected to Move field indicates whether the STA is expected to change its location. The value 1 indicates that the STA is expected to change its location. The value 0 indicates that the STA is not expected to change its location. The value 2 indicates that the STA's movement patterns are unknown. The value 3 is reserved.

NOTE 2—Examples of STAs that are expected to move include a) battery-powered STAs, b) STAs installed within trains/vehicles, c) STAs installed for temporary events.

The STA Floor Number field indicates the floor number of the STA. A higher value indicates a higher floor, and the integer approximates the floor number labels used at the venue (e.g., in stairwells and elevators, if present). The field is encoded as a 2s complement integer with units of 1/16th of a floor. The value –8192 indicates an unknown floor number. The value 8191 indicates the STA's floor is 8191/16 floors or more. The value –8191 indicates the STA's floor is –8191/16 floors or less.

NOTE 3—For example, a building with floors labeled as Basement 1, Ground, Mezzanine, 1, and 2 might have the floors identified by STA Floor Number values equal –16, 0, 8, 16 and 32 respectively.

The STA Height Above Floor field indicates the height of the STA above the floor. The field is coded as a 2s complement integer with units of 1/4096 m. The value –8 388 608 indicates an unknown STA height above floor. The value –8 388 607 indicates the height of the STA above the floor is –8 388 607/4096 m or less. The value 8 388 607 indicates the height of the STA above the floor is 8 388 607/4096 m or more.

A STA Height Above Floor Uncertainty field set to 0 indicates an unknown STA height above floor uncertainty. Values 25 or higher are reserved. A STA Height Above Floor Uncertainty field set from 1 to 24 indicates that the actual STA height above floor, a, is bounded according to:

$$h - 2^{11-u} \le a \le h + 2^{11-u}$$

where

h is the value in units of 1/4096 m of the STA Height Above Floor field
u is the value of the STA Height Above Floor Uncertainty field

If the STA Height Above Floor field indicates an unknown STA height above floor, the STA Height Above Floor Uncertainty field is set to 0.

The Relative Location Error subelement is used to report the location error of STAs with respect to a reference STA (rather than with respect to an absolute geographic location). The format of the Relative Location Error subelement is defined in Figure 9-252.

	Subelement ID	Length	Reference STA	Relative Location Error
Octets:	1	1	6	1

Figure 9-252—Relative Location Error subelement format

The Subelement ID field is equal to the value for Relative Location Error in Table 9-134.

The Length field is defined in 9.4.3.

The Reference STA field contains the MAC address of the reference STA.

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The format of the Relative Location Error field is defined in Figure 9-253.

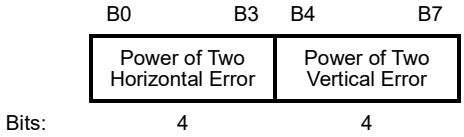

Figure 9-253—Relative Location Error field format

The Power Of Two Horizontal Error field contains an upper bound on the error between the horizontal location of the Reference STA and the Latitude and Longitude fields in the LCI subelement. The Power Of Two Horizontal Error field indicates a relative horizontal error of 2^{p-8} m, where p is the value of the Power of Two Horizontal Error field in the range 0 to 13. The value 14 indicates a relative horizontal error of greater than 32 m. The value 15 indicates an unknown relative horizontal error.

The Power Of Two Vertical Error field contains an upper bound on the error between the vertical location of the Reference STA and the Altitude field in the LCI subelement. The Power Of Two Vertical Error field indicates a relative vertical error of 2^{p-8} m, where p is the value of the Power Of Two Vertical Error field in the range 0 to 13. The value 14 indicates a relative vertical error of greater than 32 m. The value 15 indicates an unknown relative vertical error.

The Usage Rules/Policy subelement is used to report the usage rules of the reporting STA and whether additional STA or neighboring STA location information is available if the additional information can be transferred more securely. The format of the Usage Rules/Policy subelement is defined in Figure 9-254.

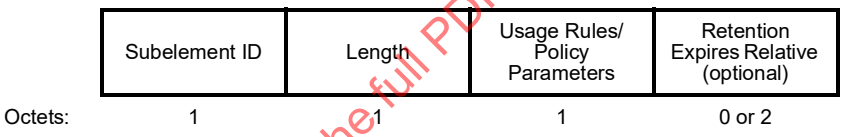

Figure 9-254—Usage Rules/Policy subelement format

The Subelement ID field is equal to the value for Usage Rules/Policy in Table 9-134.

The Length field is defined in 9.4.3.

The Usage Rules/Policy Parameters field is defined in Figure 9-255.

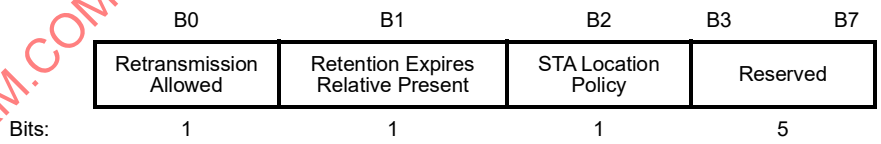

Figure 9-255—Usage Rules/Policy Parameters field format

The Retransmission Allowed field definition is the same as the definition for the retransmission-allowed element in IETF RFC 4119, except that the “no” and “yes” text encoding specified in IETF RFC 4119 is replaced by 0 and 1, respectively.

The Retention Expires Relative Present field indicates whether Retention Expires Relative field is present. The value 1 indicates that the Retention Expires Relative field is present; otherwise the Retention Expires Relative field is not present. If the Retention Expires Relative field is not present, it indicates that the retention duration of the LCI report field is unbounded.

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The STA Location Policy field indicates whether additional STA or neighboring STA location information is available if the additional information can be transferred more securely. The security of the transfer is (from lowest to highest): unassociated, associated without RSNA established, associated with RSNA established but without management frame protection negotiated, and associated with both RSNA established and management frame protection negotiated. The additional information might be one or more of (1) the STA's location with reduced uncertainty and (2) the location of additional neighbor APs, if the STA Location Policy field is carried within a Neighbor Report Response frame. A STA Location Policy field set to 1 indicates additional STA or neighboring STA location information is available. A STA Location Policy field set to 0 indicates no additional STA or neighboring STA location information is available.

The definition of the Retention Expires Relative field is the same as the definition for the retention-expires element in IETF RFC 4119, except that the absolute time text encoding specified in IETF RFC 4119 is replaced by a relative binary encoding: the Retention Expires Relative field is encoded as a number of hours in the future relative to the time of transmission of the Usage Rules/Policy subelement.

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

The Co-Located BSSID List subelement is used to report the list of BSSIDs of the BSSs sharing the same antenna connector with the reporting STA if the subelement is contained within a Fine Time Measurement frame, otherwise the BSSs that are co-located within the same physical device as the reporting STA.

The format of the Co-Located BSSID List subelement is shown in Figure 9-256.

	Subelement ID	Length	MaxBSSID Indicator	BSSID List (optional)
Octets:	1	1	1	$n \times 6$

Figure 9-256—Co-Located BSSID List subelement format

The Subelement ID field is equal to the value for Co-Located BSSID list in Table 9-134.

The Length field is defined in 9.4.3.

The MaxBSSID Indicator field is defined in 9.4.2.45. When set to a nonzero value, it indicates the maximum possible number of BSSs, including the reference BSS, which share the same antenna connector and have the same 48 bits (BSSID[0:(47-n)]) of the BSSIDs. When the BSSIDs of the co-located BSSs are configured at the reporting STA but not represented by the MaxBSSID Indicator field, the BSSID List field is present in the Co-located BSSID List subelement to provide an explicit list of such BSSID values.

When the MaxBSSID Indicator field is equal to 0, the BSSID List field contains one or more (n) BSSID values of the BSSs sharing the same antenna connector with the reporting STA.

NOTE 4—For example, if there are 4 BSSs sharing the same antenna connector and their BSSIDs end with 16, 24, 30, and 31, and the range of MAC addresses ending with 16-31 are not assigned to other BSSs using a different antenna connector, then this list of 4 BSSIDs can be indicated with a MaxBSSID Indicator field set to 5. Otherwise, the MaxBSSID Indicator field is set to 0 and the BSSIDs are listed separately.

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9.4.2.21.11 Transmit Stream/Category Measurement report

The Transmit Stream/Category Measurement report applies to TIDs for Traffic Streams associated with TSPECs and also to TIDs for Traffic Categories for QoS traffic without TSPECs. The format of the Measurement Report field corresponding to a Transmit Stream/Category Measurement report is shown in Figure 9-257.

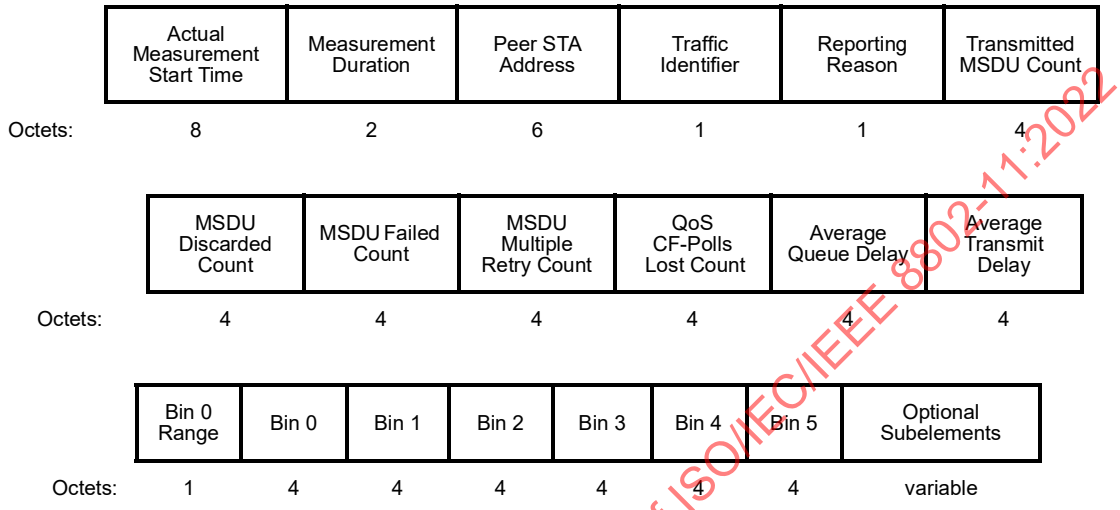

Figure 9-257—Measurement Report field format for Transmit Stream/Category Measurement report

The Actual Measurement Start Time field is set to the TSF at the time at which the measurement started, or for a triggered Transmit Stream/Category Measurement report, the TSF value at the reporting QoS STA when the trigger condition was met.

The Measurement Duration field is set to the duration over which the Transmit Stream/Category Measurement report was measured, in units of TUs. In a triggered Transmit Stream/Category Measurement report, metrics are reported over a number of transmitted MSDUs rather than a duration; hence Measurement Duration is set to 0; see 11.10.9.8.

The Peer STA Address field contains a MAC address indicating the RA for the measured frames.

The Traffic Identifier field contains the TID subfield as shown in Figure 9-204. The TID subfield indicates the TC or TS for which traffic was measured.

The Reporting Reason field is a bit field indicating the reason that the measuring QoS STA sent the transmit stream/category measurement report. The Reporting Reason field is shown in Figure 9-258.

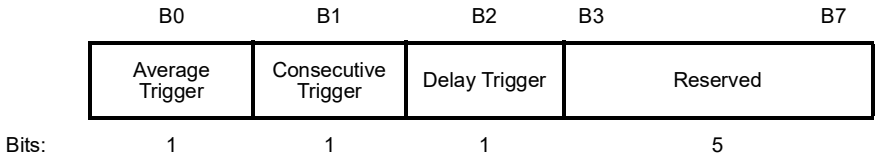

Figure 9-258—Reporting Reason field format

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— The Average Trigger bit set to 1 indicates that the Transmit Stream/Category Measurement report was generated as a triggered report due to the Average Error trigger.
— The Consecutive Trigger bit set to 1 indicates that the Transmit Stream/Category Measurement report was generated as a triggered report due to the Consecutive Error trigger.
— The Delay Trigger bit set to 1 indicates that the Transmit Stream/Category Measurement report was generated as a triggered report due to the delay exceeding the Delay Threshold.

When a Transmit Stream/Category Measurement report is sent as a direct response to a Transmit Stream/Category Measurement request and not as a triggered Transmit Stream/Category Measurement report, all bit fields in the Reporting Reason field are set to 0. This is termed a requested Transmit Stream/Category Measurement report. Within a triggered Transmit Stream/Category Measurement report, more than one bit field in the Reporting Reason field might be set to 1 if more than one trigger condition was met.

The Transmitted MSDU Count, MSDU Failed Count, MSDU Discarded Count, MSDU Multiple Retry Count, QoS CF-Polls Lost Count, Average Queue Delay, Average Transmit Delay, and delay histogram fields relate to transmissions to the QoS STA given in the Peer STA Address field. Metrics are reported over the Measurement Duration, or for triggered transmit stream/category measurements, over the Measurement Count. Any counter that increments to a value of $2^{32}-1$ terminates the measurement.

The Transmitted MSDU Count field contains the number of MSDUs for the TC or the TS specified by the TID that were successfully transmitted.

The MSDU Discarded Count field contains the number of MSDUs for the TC or the TS specified by the TID that were discarded due either to the number of transmit attempts exceeding dot11ShortRetryLimit, or due to the MSDU lifetime having been reached.

The MSDU Failed Count field contains the number of MSDUs for the TC or the TS specified by the TID that were discarded due to the number of transmit attempts exceeding dot11ShortRetryLimit.

The MSDU Multiple Retry Count field contains the number of MSDUs for the TC or the TS specified by the TID that were successfully transmitted after more than one retransmission attempt.

The QoS CF-Polls Lost Count field contains the number of QoS (+)CF-Poll frames that were transmitted where there was no response from the QoS STA. QoS CF-Polls Lost Count are returned only if the reporting QoS STA is contained within an AP and the TID is for a TS. This field is set to 0 when QoS CF-Polls Lost Count is not returned.

The Average Queue Delay field is the average queuing delay of the frames (MSDUs) that are passed to the MAC for the indicated peer STA address and the indicated traffic identifier. Queue Delay is expressed in TUs and is measured from the time the MSDU is passed to the MAC until the point at which the first or only corresponding MPDU begins transmission.

The Average Transmit Delay field is the average delay of the frames (MSDUs) that are successfully transmitted for the indicated Peer STA Address and TID. Average Transmit Delay is measured from the time the MSDU is passed to the MAC until the point at which the entire MSDU has been successfully transmitted, including receipt of the final Ack frame from the peer STA if the QoSAck service class is being used. Average Transmit delay is expressed in units of TUs.

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The Bin 0 Range field value indicates the delay range of the first bin (Bin 0) of the Transmit Delay Histogram, in units of TUs. It is also used to calculate the delay ranges of the other five bins making up the histogram. The delay range for each bin increases in a binary exponential fashion as follows:

Bin 0 range: $0 \le \text{Delay} < B_0$ = Bin 0 Range field value

Bin i range: $2^{i-1} \times B_0 \le \text{Delay} < 2^i \times B_0$, for $1 \le i \le 4$

Bin 5 range: $16 \times B_0 \le \text{Delay}$

For example, if the Bin 0 Range field value is 10 TUs, the bin delay ranges are as defined in Table 9-135.

Table 9-135—Delay definitions for a Transmit Stream/Category Measurement report for a Bin 0 Range field value of 10 TU

Bin	Measured MSDU Transmit Delay (TUs)
0	Delay < 10
1	10 ≤ Delay < 20
2	20 ≤ Delay < 40
3	40 ≤ Delay < 80
4	80 ≤ Delay < 160
5	160 ≤ Delay

To compute the value reported in Bin i (i.e., B_i for i = 0, 1...5 of the Transmit Delay Histogram), the STA initializes all bin values to 0. For each MSDU successfully transmitted, the measured MSDU Transmit Delay determines the bin to be incremented. If the measured delay has a duration t within Bin i, then Bin i is increased by one. MSDU Transmit Delay is measured from the time the MSDU is passed to the MAC until the point at which the entire MSDU has been successfully transmitted, including receipt of the final Ack frame from the peer STA if the QoSAck service class is being used. The sum of the values in all six bins is equal to the value reported in the Transmitted MSDU Count.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-136.

Table 9-136—Optional subelement IDs for Transmit Stream/Category Measurement report

Subelement ID	Name	Extensible
0–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

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The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.21.12 Multicast Diagnostics report

The format of the Measurement Report field of a Multicast Diagnostics report is shown in Figure 9-259.

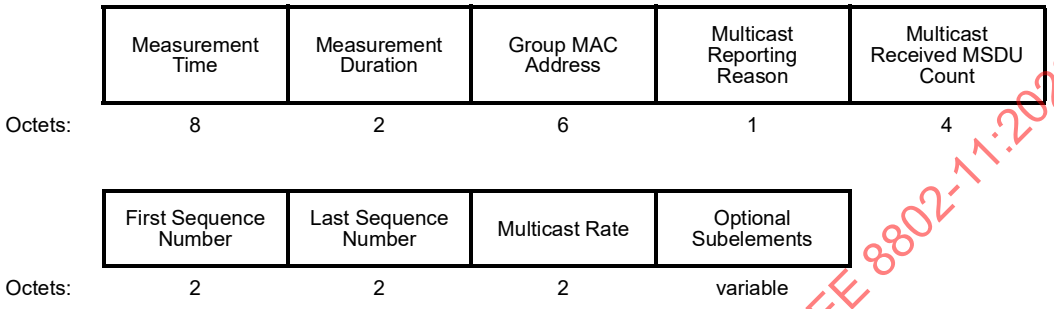

Figure 9-259—Measurement Report field format for a Multicast Diagnostics report

The Measurement Time field is the value of the STA TSF timer at the time the measurement started. In a triggered Multicast Diagnostics report, this is the TSF value at the reporting STA when the trigger condition was met. When the reason for sending the report is Performance Measurement and the Multicast Received MSDU Count is nonzero, the Measurement Time field is the value of the STA TSF timer at the time of the first group addressed MSDU received during the measurement interval.

The Measurement Duration field specifies the period over which the Multicast Diagnostic report was generated, in units of TUs.

The Group MAC Address field contains the value from the Group MAC Address field from the Multicast Diagnostics request to which the report relates.

The Multicast Reporting Reason field indicates the reason why the measuring STA sent the Multicast Diagnostics report. The Multicast Reporting Reason field is shown in Figure 9-260.

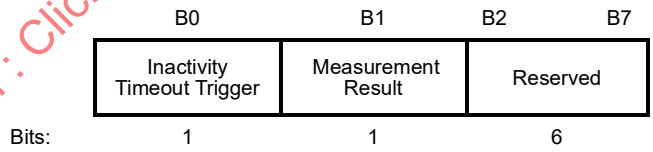

Figure 9-260—Multicast Reporting Reason field format

The subfields of the Multicast Reporting Reason field are defined as follows:

— The Inactivity Timeout Trigger field set to 1 indicates that Multicast Diagnostics report was generated as a triggered report due to the timeout of the multicast diagnostic timer.

— The Measurement Result field set to 1 indicates that the Multicast Diagnostic report contains the result of completing a Multicast Diagnostic request that did not contain a Multicast Triggered Reporting subelement.

All of the bits in the Multicast Reporting Reason field are independent.

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The Multicast Received MSDU Count field contains the total number of group addressed MSDUs with the indicated multicast MAC address that were received during the measurement duration. For a triggered multicast diagnostics measurement, the Multicast Received MSDU Count field contains the total number of group addressed MSDUs with the indicated multicast MAC address that were received between the acceptance of the multicast diagnostics measurement request and the occurrence of the trigger condition.

When bit 0 of the Multicast MAC address field in the Multicast Diagnostics request is 1, the twelve LSBs of the First Sequence Number field contain the sequence number of the first frame received with destination address equal to the value in the Multicast MAC address field during the measurement period. When bit 0 of the Multicast MAC address field in the Multicast Diagnostics request is 0, the twelve LSBs of the First Sequence Number field contain the sequence number of the first group addressed frame, that does not have the broadcast address as its destination, received during the measurement period. The four most significant bits of the First Sequence Number field are set to 0.

When bit 0 of the Multicast MAC address field in the Multicast Diagnostics request is 1, the twelve LSBs of the Last Sequence Number field contain the sequence number of the last frame received with destination address equal to the value in the Multicast MAC address field during the measurement period. When bit 0 of the Multicast MAC address field in the Multicast Diagnostics request is 0, the twelve LSBs of the Last Sequence Number field contain the sequence number of the last group addressed frame, that does not have the broadcast address as its destination, received during the measurement period. The four most significant bits of the Last Sequence Number field are set to 0.

The First Sequence Number field and the Last Sequence Number field are set to 0 if the Multicast Received MSDU Count is 0.

The Multicast Rate field specifies the highest data rate, in 0.5 Mb/s units, at which the STA has received a group addressed frame during the measurement period. The Multicast Rate field is encoded with the MSB set to 1 to indicate that the data rate is in the basic rate set, and set to 0 to indicate that the data rate is not in the basic rate set. The remaining 15 bit value is multiplied by 0.5 Mb/s to indicate the data rate. The Multicast Rate field is 0 by the STA to indicate that it has not received a group addressed frame during the measurement period.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-137.

Table 9-137—Optional subelement IDs for Multicast Diagnostics report

Subelement ID	Name	Extensible
0–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.25).

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The summary of fields used in the STA Multicast Diagnostics report is shown in Table 9-138.

Table 9-138—Summary of fields used in the STA Multicast Diagnostics report

Field	Measurement Result	Triggered Report
Measurement Time	Yes	Yes
Measurement Duration	Yes	Yes
Group MAC Address	Yes	Yes
Multicast Reporting Reason	Yes	Yes
Multicast Received MSDU Count	Yes	Yes
First Sequence Number	Yes	Yes
Last Sequence Number	Yes	Yes
Multicast Rate	Yes	Yes
Optional Subelements	Optional	Optional

The use of Multicast Diagnostics report is defined in 11.10.19.

9.4.2.21.13 Location Civic report

The Location Civic report includes the location information defined in civic format for the location subject provided in the Location Civic request, as shown in Figure 9-261.

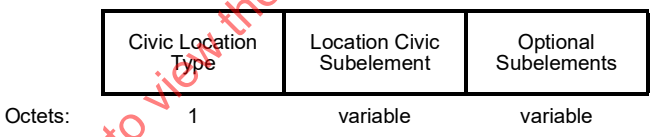

Figure 9-261—Location Civic report field format

The Civic Location Type field contains the format of location information in the Civic Location field, as indicated in Table 9-116.

The subelement IDs of the Location Civic report are defined in Table 9-139.

Table 9-139—Subelement IDs for Location Civic report

Subelement ID	Name	Extensible
0	Location Civic	No
1	Originator Requesting STA MAC Address	No
2	Target MAC Address	No
3	Location Reference	No
4	Location Shape	No
5	Map Image	No

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Table 9-139—Subelement IDs for Location Civic report *(continued)*

Subelement ID	Name	Extensible
6	Reserved	
7	Co-Located BSSID List	Yes
8–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Location Civic Subelement field contains a Location Civic subelement. The Location Civic subelement of the Location Civic report (see Figure 9-261) is formatted according to Figure 9-262.

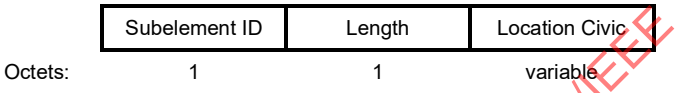

Figure 9-262—Location Civic subelement format

The Subelement ID is equal to Location Civic as defined in Table 9-139.

The Location Civic field contains the location information in the format as indicated in the Civic Location Type field. When the Civic Location Type field is IETF RFC 4776:

- The Location Civic field is formatted according to IETF RFC 4776 starting at the country code field (i.e., excluding the GEOCONF_CIVIC/ OPTION_GEOCONF_CIVIC, N/option-len and what fields)
- An unknown civic location is indicated by a subelement Length of 0 and a zero-length Location Civic field
- The Civic Location field follows the little-endian octet ordering

When the Civic Location Type field is IETF RFC 4776, the list of optional subelements optionally includes the Location Reference, Location Shape, Map Image, and Vendor Specific subelements as defined in Table 9-139.

When the Civic Location Type field value is Vendor Specific, a Vendor Specific subelement is included in the list of optional subelements that identifies the Organization Identifier corresponding to the Civic Location Type field.

The Optional Subelements field contains zero or more subelements with subelement ID greater than or equal to 1 as listed in Table 9-139. The subelement format and ordering of subelements are defined in 9.4.3.

The Originator Requesting STA MAC Address subelement contains the MAC address of the STA that requested the Location Information and it is present whenever the Location Subject field in the corresponding Location Civic request was set to 2. The format of the Originator Requesting STA MAC Address subelement is shown in Figure 9-201.

The Target MAC Address subelement contains the MAC address of the STA whose Location Information was requested and it is present whenever the Location Subject field in the corresponding Location Civic request was set to 2. The format of the Target MAC Address subelement is shown in Figure 9-202.

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The format of the Location Reference subelement is shown in Figure 9-263.

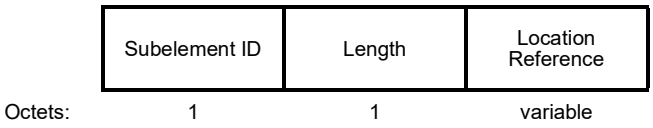

Figure 9-263—Location Reference subelement format

The Location Reference field is an ASCII string that defines a position on a floor from which the relative location contained in the Location Shape subelement is offset. A Location Reference subelement set to 0 indicates that the position of the Location Shape is top north west corner (i.e., 0,0) of the floor plan on which the Location Shape is defined.

The format of the Location Shape subelement is shown in Figure 9-264.

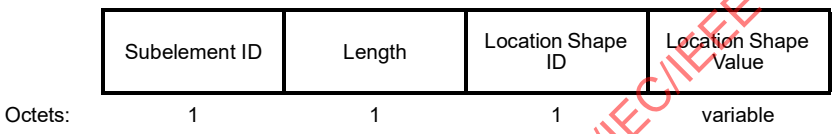

Figure 9-264—Location Shape subelement format

The Location Shape subelement defines the position in meters, including uncertainty, of the entity being located. A Shape is specified with respect to either a 2-Dimensional or 3-Dimensional Coordinate Reference System where each point in the shape defines the direction from the Location Reference value's starting point. A positive X-axis value corresponds to an easterly direction relative to the Location Reference value's starting point; a negative X-axis value corresponds to a westerly direction relative to the Location Reference value's starting point; a positive Y-axis value corresponds to a northerly direction relative to the Location Reference value's starting point; a negative Y-axis value corresponds to a southerly direction relative to the Location Reference value's starting point and the Z-axis value corresponds to the altitude above the horizontal plane at the Location Reference value's starting point.

The Location Shape ID field contains a 1-octet identifier that defines the shape contained in the subelement and is one of the values defined in Table 9-140.

Table 9-140—Location Shape IDs

Location Shape ID	Name
0	Reserved
1	2-Dimension Point
2	3-Dimension Point
3	Circle
4	Sphere
5	Polygon
6	Prism
7	Ellipse
8	Ellipsoid
9	Arcband
10–255	Reserved

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The Location Shape Value field contains the location shape value for each corresponding Location Shape ID. The formats of Location Shape Values are described in the following text.

All shape field value units that are 4-octet single precision floating point values are in meters and are represented by binary32 floating point values as defined in IEEE Std 754-2008, with the least significant bit of the fraction occurring in bit 0 of the field.

The format of the 2-Dimension Point Location Shape Value field is defined in Figure 9-265.

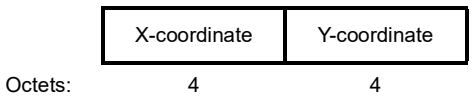

Figure 9-265—2-Dimension Point Location Shape Value format

The X-coordinate field contains a 4-octet single precision floating point value.

The Y-coordinate field contains a 4-octet single precision floating point value.

The format of the 3-Dimension Point Location Shape Value field is defined in Figure 9-266.

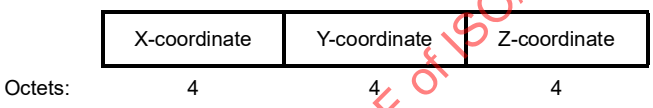

Figure 9-266—3-Dimension Point Location Shape Value format

The X-coordinate field contains a 4-octet single precision floating point value.

The Y-coordinate field contains a 4-octet single precision floating point value.

The Z-coordinate field contains a 4-octet single precision floating point value.

The format of the Circle Location Shape Value field is defined in Figure 9-267.

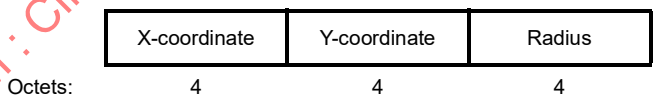

Figure 9-267—Circle Location Shape Value format

The X-coordinate field contains a 4-octet single precision floating point value.

The Y-coordinate field contains a 4-octet single precision floating point value.

The Radius field contains a 4-octet single precision floating point value.

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The format of the Sphere Location Shape Value field is defined in Figure 9-268.

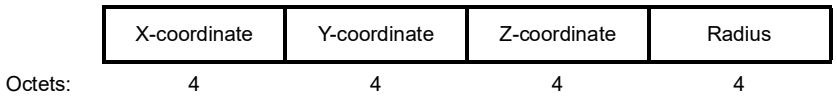

Figure 9-268—Sphere Location Shape Value format

The X-coordinate field contains a 4-octet single precision floating point value.

The Y-coordinate field contains a 4-octet single precision floating point value.

The Z-coordinate field contains a 4-octet single precision floating point value.

The Radius field contains a 4-octet single precision floating point value.

The format of the Polygon Location Shape Value field is defined in Figure 9-269.

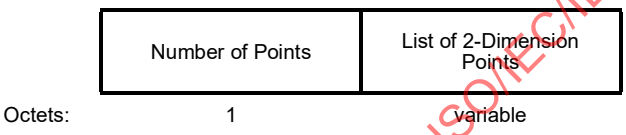

Figure 9-269—Polygon Location Shape Value format

The Number of Points field is an unsigned integer that specifies the number of points defined in the polygon. The value 0 is reserved.

The List of 2-Dimension Points field is a sequence of 2D Point field values that define the closed polygon.

The format of the Prism Location Shape Value field is defined in Figure 9-270.

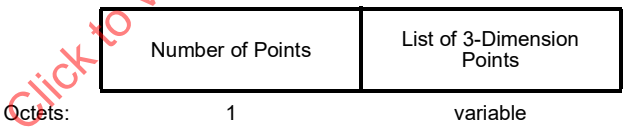

Figure 9-270—Prism Location Shape Value format

The Number of Points field is an unsigned integer that specifies the number of points defined in the prism. The value 0 is reserved.

The List of 3-Dimension Points field is a sequence of 3-Dimension Point field values that define the closed prism.

The format of the Ellipse Location Shape Value field is defined in Figure 9-271.

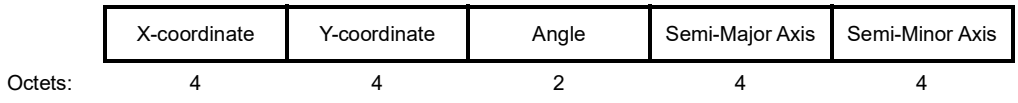

Figure 9-271—Ellipse Location Shape Value format

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The X-coordinate field contains a 4-octet single precision floating point value.

The Y-coordinate field contains a 4-octet single precision floating point value.

The Angle field contains an unsigned integer between 0 and 359°.

The Semi-Major Axis field contains a 4-octet single precision floating point value.

The Semi-Minor Axis field contains a 4-octet single precision floating point value.

The format of the Ellipsoid Location Shape Value field is defined in Figure 9-272.

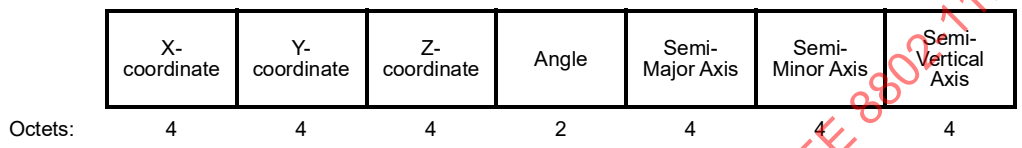

Figure 9-272—Ellipsoid Location Shape Value format

The X-coordinate field contains a 4-octet single precision floating point value.

The Y-coordinate field contains a 4-octet single precision floating point value.

The Z-coordinate field contains a 4-octet single precision floating point value.

The Angle field contains an unsigned integer between 0 and 359°.

The Semi-Major Axis field contains a 4-octet single precision floating point value.

The Semi-Minor Axis field contains a 4-octet single precision floating point value.

The Semi-Vertical Axis field contains a 4-octet single precision floating point value.

The format of the Arcband Location Shape Value field is defined in Figure 9-273.

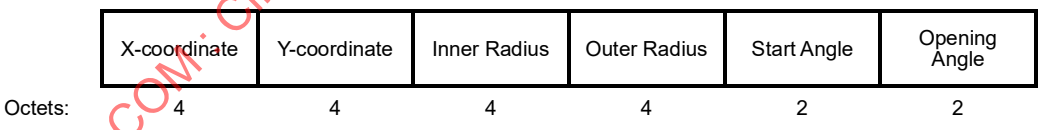

Figure 9-273—Arcband Location Shape Value format

The X-coordinate field contains a 4-octet single precision floating point value.

The Y-coordinate field contains a 4-octet single precision floating point value.

The Inner Radius field contains a 4-octet single precision floating point value.

The Outer Radius field contains a 4-octet single precision floating point value.

The Start Angle field contains an unsigned integer between 0 and 359.

The Opening Angle field contains an unsigned integer between 0 and 359.

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The Map Image subelement contains a map reference that is used in combination with the Location Reference and Location Shape subelements. The format of the Map Image subelement is shown in Figure 9-274.

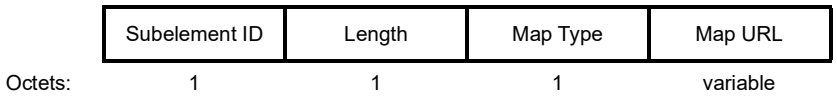

Figure 9-274—Map Image subelement format

The Map Type field is an unsigned integer that defines the type of map referred to by the Map URL field, as defined in Table 9-141.

Table 9-141—Map types

Map Type Value	Name
0	URL Defined
1	png
2	gif
3	jpeg
4	svg
5	dxf
6	dwg
7	dwf
8	cad
9	tiff
10	gml
11	kml
12	bmp
13	pgm
14	ppm
15	xbm
16	xpm
17	ico
18–255	Reserved

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The Map Type field value “URL Defined” indicates the Map URL field value has a file extension, and that the type of map referred to by the Map URL field is to be determined from this.

The Map URL field is a variable length field formatted in accordance with IETF RFC 3986 and provides the location of a floor map.

The Co-Located BSSID List subelement is used to report the list of BSSIDs of the BSSs sharing the same antenna connector with the reporting STA if the subelement is contained within a Fine Time Measurement

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frame, otherwise the BSSs that are co-located within the same physical device as the reporting STA. The Co-Located BSSID List subelement is described in 9.4.2.21.10.

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.25).

9.4.2.21.14 Location Identifier report

The Location Identifier report includes an indirect reference to the location information for the location subject provided in the Location Identifier request, as shown in Figure 9-275.

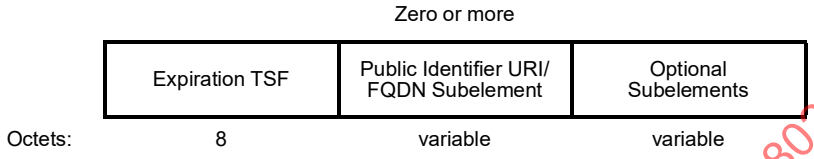

Figure 9-275—Location Identifier report field format

The Expiration TSF field is the value of the TSF when the Public Identifier URI/FQDN subelement(s) that indicate a location object are no longer valid. The Expiration TSF field set to 0 indicates the Public Identifier URI/FQDN subelement(s) that indicate a location object do not expire.

The Public Identifier URI/FQDN Subelement field contains zero or more Public Identifier URI/FQDN subelements.

The subelement IDs for the Location Identifier report are shown in Table 9-142.

Table 9-142—Subelement IDs for Location Identifier report

Subelement ID	Name	Extensible
0	Public Identifier URI/FQDN	No
1	Originator Requesting STA MAC Address	No
2	Target MAC Address	No
3–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Public Identifier URI/FQDN subelement of the Location Identifier report (see Figure 9-275) is formatted according to Figure 9-276.

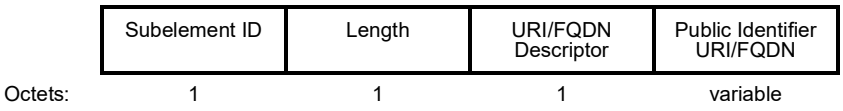

Figure 9-276—Public Identifier URI/FQDN subelement format

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The Subelement ID is equal to Public Identifier URI/FQDN as defined in Table 9-142.

The URI/FQDN Descriptor field describes the Public Identifier URI/FQDN field. The URI/FQDN Descriptor field is defined in Table 9-143.

Table 9-143—URI/FQDN Descriptor field values

Value	Usage
0	Reserved
1	The uniform resource locator (URI) of the Hypertext Transfer Protocol (HTTP) enabled location delivery (HELD) location object [IETF RFC 5985]
2	Fully qualified domain name of D-SLP SUPL server (excludes port number) [OMA-TS-ULP-V2_0_1] (or higher version)
3–255	Reserved

The Public Identifier URI/FQDN field contains a URI as a UTF-8 string, formatted in accordance with IETF RFC 3986, that points to a location object or an FQDN that identifies a location server.

A Public Identifier URI/FQDN field that points to a location object can be used to return the location value for the requesting STA. The format of the location value returned when the URI is dereferenced is dependent on the provider of the URI as indicated by the URI/FQDN Descriptor field. The Public Identifier URI field confirms the validity of the location estimate to an external agent when a STA forwards a location estimate to that agent. The protocol used to query the infrastructure for a location report based on the Public Identifier URI field is beyond the scope of this standard.

A Public Identifier URI/FQDN field that points to a location server can be used to discover the location server and establish communications with it. The protocol used with the location server is indicated by the URI/FQDN Descriptor field.

The Optional Subelements field contains zero or more subelements with subelement ID greater than or equal to 1 as listed in Table 9-142. The subelement format and ordering of subelements are defined in 9.4.3.

The Originator Requesting STA MAC Address subelement contains the MAC address of the STA that requested the Location Information and it is present whenever the Location Subject field in the corresponding Location Identifier request was set to 2. The format of the Originator Requesting STA MAC Address subelement is shown in Figure 9-201.

The Target MAC Address subelement contains the MAC address of the STA whose Location Information was requested and it is present whenever the Location Subject field in the corresponding Location Identifier request was set to 2. The format of the Target MAC Address subelement is shown in Figure 9-202.

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.25).

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9.4.2.21.15 Directional Channel Quality report

The format of the Measurement Report field of a Directional Channel Quality report is shown in Figure 9-277.

	Operating Class	Channel Number	AID	Reserved	Measurement Method	Measurement Start Time
Octets:	1	1	1	1	1	8

	Measurement Duration	Number of Time Blocks	Measurement for Time Block List	Optional Subelements
Octets:	2	1	$n \times 1$	Variable

Figure 9-277—Measurement report field format for Directional Channel Quality report

The Operating Class field indicates the channel set for which the measurement report applies. The Operating Class and Channel Number fields together specify the channel frequency and spacing for which the measurement report applies. Valid values of the Operating Class field are shown in Annex E.

The Channel Number field indicates the channel number for which the measurement report applies. The channel number is defined within an Operating Class as shown in Annex E.

The AID field contains the AID assigned to the Target STA by the AP or PCP.

The Measurement Method field indicates the method used by the STA to carry out this measurement request and the format of the Measurement for Time Block field(s). If this field is set to 0, it indicates that the Measurement for Time Block fields are expressed in ANIPI. If this field is set to 1, it indicates that the Measurement for Time Block fields are expressed in RSNI. Other values are reserved.

Measurement Start Time field is set to the value of the measuring STA's TSF timer at the time the measurement started.

The Measurement Duration field is set to the duration of the measurement, in units of TUs.

The Number of Time Blocks field indicates the number of time blocks, *n*, within the measurement duration. The ratio (Measurement Duration/Number of Time Blocks) provides the duration of an individual measurement unit.

The Measurement for Time Block List field contains one or more (*n*) Measurement for Time Block fields.

Each Measurement for Time Block field is set to the ANIPI or RSNI value measured during each (Measurement Duration/Number of Time Blocks) measurement units. The measurement units are set in the report in increasing order of start times.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-144.

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Table 9-144—Optional subelement IDs for Directional Channel Quality report

Subelement ID	Name	Extensible
0–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.21.16 Directional Measurement report

The format of the Measurement Report field of a Directional Measurement report is shown in Figure 9-278.

	Operating Class	Channel Number	Measurement Start Time	Measurement Duration per Direction	Measurement Method	Measurement Results	Optional Subelements
Octets	1	1	8	2	1	Variable	Variable

Figure 9-278—Measurement Report field format for Directional Measurement report

The Operating Class field indicates the channel set for which the measurement report applies. The Operating Class and Channel Number fields together specify the channel frequency and spacing for which the measurement report applies. Valid values of the Operating Class field are shown in Annex E.

The Channel Number field indicates the channel number for which the measurement report applies. The channel number is defined within an Operating Class as shown in Annex E.

The Measurement Start Time field is set to the value of the measuring STA's TSF timer at the time the measurement started.

The Measurement Duration per Direction field is set to the duration of the measurement in each receiving direction, in units of TUs.

The Measurement Method field indicates the method used by the STA to carry out the measurement request and the format of values in the Measurement for Direction fields. If this field is set to 0, it indicates that the values in the Measurement for Direction fields are expressed in ANIPI. If this field is set to 1, it indicates that the values in the Measurement for Direction fields are expressed in RCPI. If this field is set to 2, it indicates that the values in the Measurement for Direction fields are expressed in Channel Load. Other values are reserved.

The format of the Measurement Results field is shown in Figure 9-279.

	Number of Directions	Measurement for Direction List
Octets:	1	variable

Figure 9-279—Measurement Results field format

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The Number of Directions field is set to the number of measurement directions, *n*.

The Measurement for Direction List field contains one or more (*n*) Measurement for Direction fields.

Each Measurement for Direction field is set to the format of values specified in the Measurement Method field.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-145.

Table 9-145—Optional subelement IDs for Directional Measurement report

Subelement ID	Name	Extensible
0–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.21.17 Directional Statistics report

The format of the Measurement Report field of a Directional Statistics report is shown in Figure 9-280.

	Operating Class	Channel Number	Measurement Start Time	Measurement Duration per Direction	Measurement Method	Directional Statistics Bitmap	Measurement Results	Optional Subelements
Octets	1	1	8	2	1	1	Variable	Variable

Figure 9-280—Measurement Report field format for Directional Statistics report

The Operating Class field indicates the channel set for which the measurement report applies. The Operating Class and Channel Number fields together specify the channel frequency and spacing for which the measurement report applies. Valid values of the Operating Class field are shown in Annex E.

The Channel Number field indicates the channel number for which the measurement report applies. The channel number is defined within an Operating Class as shown in Annex E.

The Measurement Start Time field is set to the value of the measuring STA's TSF timer at the time the measurement started.

The Measurement Duration per Direction field is set to the duration of the measurement in each receiving direction, in units of TUs.

The Measurement Method field indicates the method used by the STA to carry out the measurement request and the format of values in the Measurement Results field. If this field is set to 0, it indicates that the values in the Measurement Results field are expressed in ANIPI. If this field is set to 1, it indicates that the values in

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the Measurement Results field are expressed in RCPI. If this field is set to 2, it indicates that the values in the Measurement Results field are expressed in Channel Load. Other values are reserved.

The Directional Statistics Bitmap field format is described in 9.4.2.20.18. When the Maximum field is set, it indicates that the maximum measurement result among all directions is included in the Measurement Results field. When the Minimum field is set, it indicates that the minimum measurement result among all directions is included in the Measurement Results field. If the Average field is set, it indicates that the average measurement result among all directions is included in the Measurement Results field. If the Variance field is set, it indicates that the variance of measurement results among all directions is included in the Measurement Results field. Other bits are reserved.

The Measurement Results field is set based on the values in the Measurement Method field and the Directional Statistics Bitmap field. If two or more subfields in the Directional Statistics Bitmap are set to 1, the corresponding measurement results are included in the Measurement Results field in the same sequence as they appear in the Directional Statistics Bitmap field.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-146.

Table 9-146—Optional subelement IDs for Directional Statistics report

Subelement ID	Name	Extensible
0–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.21.18 Fine Timing Measurement Range report

The format of the Measurement Report field corresponding to a Fine Timing Measurement Range report is shown in Figure 9-281.

	Range Entry Count	Range Entry	Error Entry Count	Error Entry	Optional Subelements
Octets:	1	*M* x 15	1	*N* x 11	variable

Figure 9-281—Measurement Report field format for a Fine Timing Measurement Range report

The Range Entry Count field indicates the number of Range Entry fields (i.e., *M* in Figure 9-281).

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The Range Entry field indicates parameters relating to a successful range measurement with a single AP and is formatted according to Figure 9-282.

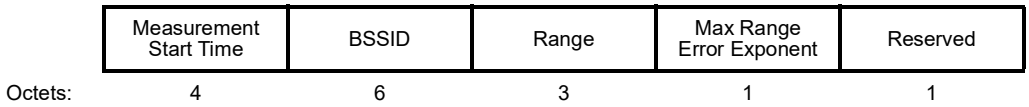

Figure 9-282—Range Entry field format

The Measurement Start Time field contains the least significant 4 octets of the TSF (synchronized with the associated AP) at the time (± 32 μs) at which the first Fine Timing Measurement frame within the first burst (FTM_2 in Figure 11-35. FTM_1 in Figure 11-36 and FTM_1 in Figure 11-37) was transmitted where the timestamps of both the frame and response frame were successfully measured.

The BSSID field contains the BSSID of the BSS of the AP whose range is being reported.

The Range field indicates the estimated range between the requested STA and the AP using the FTM procedure, in units of 1/4096 m. A value of $2^{24}–1$ indicates a range of $(2^{24} – 1)/4096$ m or higher. See 11.10.9.11.

The Max Range Error Exponent field contains an upper bound for the error in the value specified in the Range field. A Max Range Error Exponent field set to 0 indicates an unknown error. A nonzero value indicates a maximum range error of $2^{(Max\ Range\ Error\ Exponent\ –\ 13)}$ m. The Max Range Error Exponent field has a maximum value of 25. Values in the range 26–255 are reserved. A Max Range Error Exponent field set to 25 indicates a maximum range error of 4096 m or higher. For example, a Max Range Error Exponent field set to 14 indicates that the Range field has a maximum error of ± 2 m.

The Error Entry Count field indicates the number of Error Entry fields (i.e., *N* in Figure 9-281).

The Error Entry field indicates parameters relating to a failed range measurement with a single AP and is formatted according to Figure 9-283.

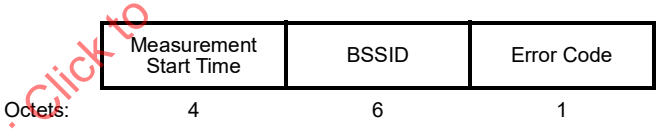

Figure 9-283—Error Entry field format

The Measurement Start Time field contains the least significant 4 octets of the TSF (synchronized with the associated AP) at the time (± 32 μs) at which the FTM failure was first detected.

The BSSID field contains the BSSID of the BSS of the AP whose range was attempted to be measured.

The Error Code field is defined in Table 9-147.

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Table 9-147—Error Code field values

Error code	Meaning
0–1	Reserved
2	AP reported “Request incapable”
3	AP reported “Request failed. Do not send new request for a specified period”
4–7	Reserved
8	Unable to successfully transmit to AP
9–255	Reserved

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-148.

Table 9-148—Optional subelement IDs for Fine Timing Measurement Range report

Subelement ID	Name	Extensible
0–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.22 Quiet element

The Quiet element defines an interval during which no transmission occurs in the current channel. This interval might be used to assist in making channel measurements without interference from other STAs in the BSS. The format of the Quiet element is shown in Figure 9-284.

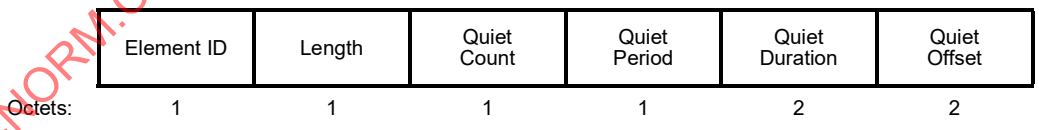

Figure 9-284—Quiet element format

The Element ID and Length fields are defined in 9.4.2.1.

The Quiet Count field is set to the number of TBTTs until the beacon interval during which the next quiet interval starts. The value of 0 is reserved.

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The Quiet Period field is set to the number of beacon intervals between the start of regularly scheduled quiet intervals defined by this Quiet element. A Quiet Period field set to 0 indicates that no periodic quiet interval is defined.

The Quiet Duration field is set to the duration of the quiet interval, expressed in TUs.

The Quiet Offset field is set to the offset of the start of the quiet interval from the TBTT specified by the Quiet Count field, expressed in TUs. The value of the Quiet Offset field is less than one beacon interval.

The Quiet element is optionally present in Beacon frames, as described in 9.3.3.2, and Probe Response frames, as described in 9.3.3.10. The use of Quiet elements is described in 11.8.3.

9.4.2.23 IBSS DFS element

The IBSS DFS element contains information for DFS operation in an IBSS. The format of the IBSS DFS element is shown in Figure 9-285.

Figure 9-285—IBSS DFS element format

The Element ID and Length fields are defined in 9.4.2.1.

The DFS Owner field is set to the individual IEEE MAC address of the STA that is the currently known DFS Owner in the IBSS.

The DFS Recovery Interval field indicates the time interval that is used for DFS owner recovery, expressed as an integer number of beacon intervals. The DFS Recovery Interval value is static throughout the lifetime of the IBSS and is determined by the STA that starts the IBSS.

The Channel Map field shown in Figure 9-286 contains a Channel Number field and a Map field (see 9.4.2.21.2) for each channel supported by the STA transmitting the IBSS DFS element. Note that *n* in Figure 9-285 is the number of channels supported by the STA.

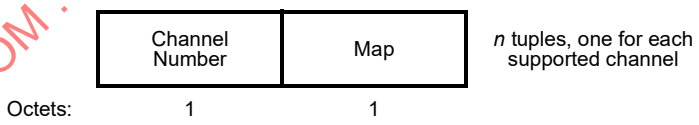

Figure 9-286—Channel Map field format

The IBSS DFS element is optionally present in Beacon frames, as described in 9.3.3.2, and Probe Response frames, as described in 9.3.3.10. The use of IBSS DFS elements is described in 11.8.8.3.

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9.4.2.24 RSNE

9.4.2.24.1 General

The RSNE field contains the information required to establish an RSNA. The format of the RSNE field is defined in Figure 9-287.

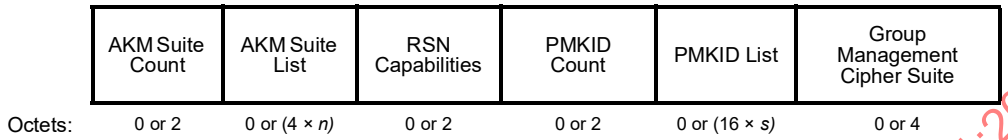
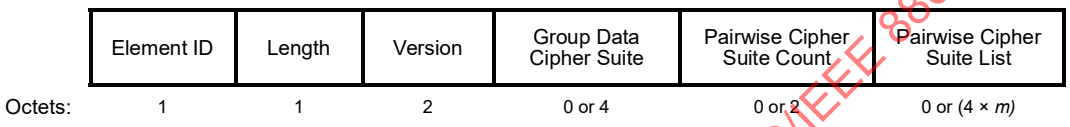


Figure 9-287—RSNE format



The Element ID and Length fields are defined in 9.4.2.1.

The size of the RSNE field is limited by the size of an element, which is 255 octets. Therefore, the number of pairwise cipher suites, AKM suites, and PMKIDs is limited.

In Figure 9-287, *m* denotes the pairwise cipher suite count, *n* the AKM suite count, and *s* the PMKID count.

All fields use the bit convention from 9.2.2. The RSNE field contains up to and including the Version field. All fields after the Version field are optional. If any nonzero-length field is absent, then none of the subsequent fields are included.

The Version field indicates the version number of the RSN protocol. Version 1 is defined in this standard. Other values are reserved.

NOTE—The following represent sample elements:

IEEE 802.1X authentication, CCMP-128 pairwise and group data cipher suites (WEP-40, WEP-104, and TKIP not allowed):

30, // element id, 48 expressed as hexadecimal value
14, // length in octets, 20 expressed as hexadecimal value
01 00, // Version 1
00 0F AC 04, // CCMP-128 as group data cipher suite
01 00, // pairwise cipher suite count
00 0F AC 04, // CCMP-128 as pairwise cipher suite
01 00, // authentication count
00 0F AC 01 // IEEE 802.1X authentication
00 00 // No capabilities

IEEE 802.1X authentication, CCMP-128 pairwise and group data cipher suites (WEP-40, WEP-104 and TKIP not allowed), preauthentication supported:

30, // element id, 48 expressed as hexadecimal value
14, // length in octets, 20 expressed as hexadecimal value
01 00, // Version 1
00 0F AC 04, // CCMP-128 as group data cipher suite
01 00, // pairwise cipher suite count
00 0F AC 04, // CCMP-128 as pairwise cipher suite
01 00, // authentication count
00 0F AC 01 // IEEE 802.1X authentication
01 00 // Preauthentication capabilities

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IEEE 802.1X authentication, Use GTK for pairwise cipher suite, WEP-40 group data cipher suites, optional RSN Capabilities field omitted:

30, // element id, 48 expressed as hexadecimal value
12, // length in octets, 18 expressed as hexadecimal value
01 00, // Version 1
00 0F AC 01, // WEP-40 as group data cipher suite
01 00, // pairwise cipher suite count
00 0F AC 00, // Use group cipher suite as pairwise cipher suite
01 00, // authentication count
00 0F AC 01 // IEEE 802.1X authentication

IEEE 802.1X authentication, Use CCMP-128 for pairwise cipher suite, CCMP-128 group data cipher suites, preauthentication and a PMKID:

30, // element id, 48 expressed as hexadecimal value
26 // length in octets, 38 expressed as hexadecimal value
01 00, // Version 1
00 0F AC 04, // CCMP-128 as group data cipher suite
01 00, // pairwise cipher suite count
00 0F AC 04, // CCMP-128 as pairwise cipher suite
01 00, // authentication count
00 0F AC 01 // IEEE 802.1X authentication
01 00 // Preauthentication capabilities
01 00 // PMKID Count
01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F 10 // PMKID

IEEE 802.1X authentication, CCMP-128 pairwise and group data cipher suites (WEP-40, WEP-104, and TKIP are not allowed), and management frame protection with BIP-CMAC-128 as the group management suite selector.

30, // element id, 48 expressed as hexadecimal value
1A, // length in octets, 26 expressed as hexadecimal value
01 00, // Version 1
00 0F AC 04, // CCMP-128 as group data cipher suite
01 00, // pairwise cipher suite count
00 0F AC 04, // CCMP-128 as pairwise cipher suite
01 00, // authentication count
00 0F AC 01 // IEEE 802.1X authentication
80 00 // management frame protection is enabled but not required
00 00 // No PMKIDs
00 0F AC 06, // BIP-CMAC-128 as the broadcast/multicast management cipher suite

9.4.2.24.2 Cipher suites

The Group Data Cipher Suite field contains the cipher suite selector used in the BSS to protect group addressed Data frames.

The Pairwise Cipher Suite Count field indicates the number of pairwise cipher suite selectors that are contained in the Pairwise Cipher Suite List field. The value 0 is reserved.

The Pairwise Cipher Suite List field contains a series of cipher suite selectors that indicate the pairwise cipher suites used in the BSS to protect individually addressed Data frames.

The Group Management Cipher Suite field contains the cipher suite selector used by the BSS to protect group addressed robust Management frames.

When management frame protection is negotiated, the negotiated pairwise cipher suite is used to protect individually addressed robust Management frames, and the group management cipher suite is used to protect group addressed robust Management frames. Use of BIP-CMAC-128, BIP-GMAC-128, BIP-GMAC-256, and BIP-CMAC-256 is not valid as a data cipher suite.

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A suite selector has the format shown in Figure 9-288.

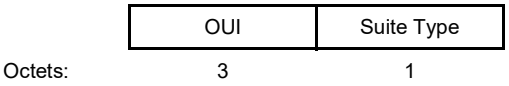

Figure 9-288—Suite selector format

The OUI field contains an OUI or CID. The order of the OUI field is described in 9.2.2.

Table 9-149 provides the cipher suite selectors defined by this standard.

Table 9-149—Cipher suite selectors

OUI	Suite type	Meaning
00-0F-AC	0	Use group cipher suite
00-0F-AC	1	WEP-40
00-0F-AC	2	TKIP
00-0F-AC	3	Reserved
00-0F-AC	4	CCMP-128
00-0F-AC	5	WEP-104
00-0F-AC	6	BIP-CMAC-128
00-0F-AC	7	Group addressed traffic not allowed
00-0F-AC	8	GCMP-128
00-0F-AC	9	GCMP-256
00-0F-AC	10	CCMP-256
00-0F-AC	11	BIP-GMAC-128
00-0F-AC	12	BIP-GMAC-256
00-0F-AC	13	BIP-CMAC-256
00-0F-AC	14–255	Reserved
Other OUI or CID	Any	Vendor-specific

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In non-DMG RSNA, the cipher suite selector 00-0F-AC:4 (CCMP-128) is the default group cipher suite for Data frames when the Group Data Cipher Suite field is not included in the RSNE field.

In non-DMG RSNA, the cipher suite selector 00-0F-AC:4 (CCMP-128) is the default pairwise cipher suite when the Pairwise Cipher Suite List field is not included in the RSNE field.

In DMG RSNA, the cipher suite selector 00-0F-AC:8 (GCMP-128) is the default group cipher suite for Data frames when the Group Data Cipher Suite field is not included in the RSNE field.

In DMG RSNA, the cipher suite selector 00-0F-AC:8 (GCMP-128) is the default pairwise cipher suite when the Pairwise Cipher Suite List field is not included in the RSNE field.

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In an RSNA with management frame protection enabled, the cipher suite selector 00-0F-AC:6 (BIP-CMAC-128) is the default group cipher suite for Management frames when the Group Management Cipher Suite field is not included in the RSNE field.

The cipher suite selectors 00-0F-AC:1 (WEP-40) and 00-0F-AC:5 (WEP-104) are only valid as a group cipher suite in a transition security network (TSN) to allow pre-RSNA STAs to join an IBSS or to associate with an infrastructure BSS.

Use of any group cipher suite other than TKIP, WEP-104, or WEP-40 with TKIP as the pairwise cipher suite is not supported.

The cipher suite selector 00-0F-AC:0 (Use group cipher suite) is valid only as the pairwise cipher suite. An AP specifies the selector 00-0F-AC:0 (Use group cipher suite) for a pairwise cipher suite if it does not support any pairwise cipher suites. If an AP specifies 00-0F-AC:0 (Use group cipher suite) as the pairwise cipher selection, this is the only pairwise cipher selection the AP advertises.

If any cipher suite other than TKIP, WEP-104, or WEP-40 is enabled, then the AP supports pairwise keys, and thus the suite selector 00-0F-AC:0 (Use group cipher suite) is not a valid option.

Table 9-150 indicates the circumstances under which each cipher suite is used.

Table 9-150—Cipher suite usage

Cipher suite selector	GTK	PTK	IGTK or BIGTK
Use group cipher suite	No	Yes	No
WEP-40	Yes	No	No
WEP-104	Yes	No	No
TKIP	Yes	Yes	No
CCMP-128	Yes	Yes	No
BIP-CMAC-128	No	No	Yes
GCMP-128	Yes	Yes	No
GCMP-256	Yes	Yes	No
CCMP-256	Yes	Yes	No
BIP-GMAC-128	No	No	Yes
BIP-GMAC-256	No	No	Yes
BIP-CMAC-256	No	No	Yes

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9.4.2.24.3 AKM suites

The AKM Suite Count field indicates the number of AKM suite selectors that are contained in the AKM Suite List field. The value 0 is reserved.

The AKM Suite List field contains a series of AKM suite selectors. In an IBSS only a single AKM suite selector is specified because IBSS STAs use the same AKM suite and because there is no mechanism to negotiate the AKMP in an IBSS (see 12.6.5).

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Each AKM suite selector specifies an AKMP. Table 9-151 gives the AKM suite selectors defined by this standard. An AKM suite selector has the format shown in Figure 9-288.

Table 9-151—AKM suite selectors

OUI	Suite type	Meaning			Authentication algorithm numbers (see 9.4.1.1)
		Authentication type	Key management type	Key derivation type	
00-0F-AC	0	Reserved	Reserved	Reserved	Reserved
00-0F-AC	1	Authentication negotiated over IEEE Std 802.1X	RSNA key management as defined in 12.7	Defined in 12.7.1.2	0 (open)
00-0F-AC	2	PSK	RSNA key management as defined in 12.7	Defined in 12.7.1.2	0 (open)
00-0F-AC	3	FT authentication negotiated over IEEE Std 802.1X	FT key management as defined in 12.7.1.6	Defined in 12.7.1.6.2 using SHA-256	2 (FT) for FT protocol reassociation as defined in 13.5 0 (open) for FT Initial Mobility Domain Association over IEEE Std 802.1X or PMKSA caching
00-0F-AC	4	FT authentication using PSK	FT key management as defined in 12.7.1.6	Defined in 12.7.1.6.2 using SHA-256	2 (FT) for FT protocol reassociation as defined in 13.5 0 (open) for FT Initial Mobility Domain Association using PSK
00-0F-AC	5	Authentication negotiated over IEEE Std 802.1X	RSNA key management as defined in 12.7	Defined in 12.7.1.6.2 using SHA-256	0 (open)
00-0F-AC	6	PSK	RSNA Key Management as defined in 12.7	Defined in 12.7.1.6.2 using SHA-256	0 (open)
00-0F-AC	7	TDLS	TPK handshake	Defined in 12.7.1.6.2 using SHA-256	N/A
00-0F-AC	8	SAE authentication	RSNA key management as defined in 12.7, or authenticated mesh peering exchange as defined in 14.5	Defined in 12.7.1.6.2 using the hash algorithm specified in 12.4.2	3 (SAE) for SAE Authentication 0 (open) for PMKSA caching

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Table 9-151—AKM suite selectors *(continued)*

OUI	Suite type	Meaning			Authentication algorithm numbers (see 9.4.1.1)
		Authentication type	Key management type	Key derivation type	
00-0F-AC	9	FT authentication over SAE	FT key management defined in 12.7.1.6	Defined in 12.7.1.6.2 using the hash algorithm specified in 12.4.2	3 (SAE) for FT Initial Mobility Domain Association 2 (FT) for FT protocol reassociation as defined in 13.5 0 (open) for FT Initial Mobility Domain Association over PMKSA caching
00-0F-AC	10	APPeerKey Authentication with SHA-256	RSNA key management as defined in 12.7	Defined in 12.7.1.6.2 using SHA-256	N/A
00-0F-AC	11	Authentication negotiated over IEEE Std 802.1X using a Suite B compliant EAP method supporting SHA-256	RSNA key management as defined in 12.7	Defined in 12.7.1.6.2 using SHA-256	0 (open)
00-0F-AC	12	Authentication negotiated over IEEE Std 802.1X using a CNSA Suite compliant EAP method	RSNA key management as defined in 12.7	Defined in 12.7.1.6.2 using SHA-384	0 (open)
00-0F-AC	13	FT authentication negotiated over IEEE Std 802.1X	FT key management as defined in 12.7.1.6	Defined in 12.7.1.6.2 using SHA-384	2 (FT) for FT protocol reassociation as defined in 13.5 0 (open) for FT Initial Mobility Domain Association over IEEE Std 802.1X or PMKSA caching
00-0F-AC	14	Key management over FILS using SHA-256 and AES-SIV-256, or authentication negotiated over IEEE Std 802.1X	FILS key management defined in 12.11.2.5	Defined in 12.11.2.5 using SHA-256	4, 5 or 6 (FILS) for FILS Authentication 0 (open) for IEEE Std 802.1X
00-0F-AC	15	Key management over FILS using SHA-384 and AES-SIV-512, or authentication negotiated over IEEE Std 802.1X	FILS key management defined in 12.11.2.5	Defined in 12.11.2.5 using SHA-384	4, 5 or 6 (FILS) for FILS Authentication 0 (open) for IEEE Std 802.1X

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Table 9-151—AKM suite selectors *(continued)*

OUI	Suite type	Meaning			Authentication algorithm numbers (see 9.4.1.1)
		Authentication type	Key management type	Key derivation type	
00-0F-AC	16	FT authentication over FILS with SHA-256 and AES-SIV-256 or authentication negotiated over IEEE Std 802.1X	FT key management as defined in 12.7.1.6	Defined in 12.7.1.6.2 using SHA-256	4, 5 or 6 (FILS) for FT Initial Mobility Domain Association over FILS 2 (FT) for FT protocol reassociation as defined in 13.5 0 (open) for FT Initial Mobility Domain Association over IEEE Std 802.1X or PMKSA caching
00-0F-AC	17	FT authentication over FILS with SHA-384 and AES-SIV-512, or authentication negotiated over IEEE Std 802.1X	FT key management as defined in 12.7.1.6	Defined in 12.7.1.6.2 using SHA-384	4, 5 or 6 (FILS) for FT Initial Mobility Domain Association over FILS 2 (FT) for FT protocol reassociation as defined in 13.5 0 (open) for FT Initial Mobility Domain Association over IEEE Std 802.1X or PMKSA caching
00-0F-AC	18	Reserved	Reserved	Reserved	Reserved
00-0F-AC	19	FT authentication using PSK	FT key management as defined in 12.7.1.6	Defined in 12.7.1.6.2 using SHA-384	2 (FT) for FT protocol reassociation as defined in 13.5 0 (open) for FT Initial Mobility Domain Association using PSK
00-0F-AC	20	PSK	RSNA key management as defined in 12.7	Defined in 12.7.1.6.2 using SHA-384	0 (open)
00-0F-AC	21–255	Reserved	Reserved	Reserved	Reserved
Other OUI or CID	Any	Vendor-specific	Vendor-specific	Vendor-specific	Vendor-specific

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The AKM suite selector value 00-0F-AC:1 (i.e., Authentication negotiated over IEEE Std 802.1X with RSNA key management as defined in 12.7 is the default AKM suite when the AKM Suite List field is not included in the RSNE.

NOTE 1—The selector value 00-0F-AC:1 specifies only that IEEE Std 802.1X-2010 is used as the authentication transport. IEEE Std 802.1X-2010 selects the authentication mechanism.

The AKM suite selector value 00-0F-AC:8 (i.e., SAE authentication with SHA-256 is used when either a password or PSK is used with RSNA key management.

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NOTE 2—Selector values 00-0F-AC:1 and 00-0F-AC:8 can simultaneously be enabled by an Authenticator.

The AKM suite selector value 00-0F-AC:2 (PSK) is used when an alternate form of PSK is used with RSNA key management.

NOTE 3—Selector values 00-0F-AC:1 and 00-0F-AC:2 can simultaneously be enabled by an Authenticator.

The AKM suite selector value 00-0F-AC:11 is used only with cipher suite selector values 00-0F-AC:8 (GCMP-128) and 00-0F-AC:11 (BIP-GMAC-128). The AKM suite selector value 00-0F-AC:12 is used only with cipher suite selector values 00-0F-AC:9 (GCMP-256), 00-0F-AC:10 (CCMP-256), 00-0F-AC:13 (BIP-CMAC-256), and 00-0F-AC:12 (BIP-GMAC-256). The AKM suite selector value 00-0F-AC:13 is used only with cipher suite selector values 00-0F-AC:9 (GCMP-256), 00-0F-AC:10 (CCMP-256), 00-0F-AC:13 (BIP-CMAC-256), and 00-0F-AC:12 (BIP-GMAC-256).

NOTE 4—The AKM suite selector value 00-0F-AC:11 is deprecated.

NOTE 5—The usage of selector values with authentication algorithms is defined in the Authentication algorithm numbers column of Table 9-151; see 9.4.1.1.

A PMKSA established using a given AKM selector value may be cached and used in a subsequent (re)association as defined in 12.6.10.3.

9.4.2.24.4 RSN capabilities

The RSN Capabilities field indicates requested or advertised capabilities. If the RSN Capabilities field is not present, the default value of 0 is used for all of the capability subfields.

The length of the RSN Capabilities field is 2 octets. The format of the RSN Capabilities field is as shown in Figure 9-289 and described after the figure.

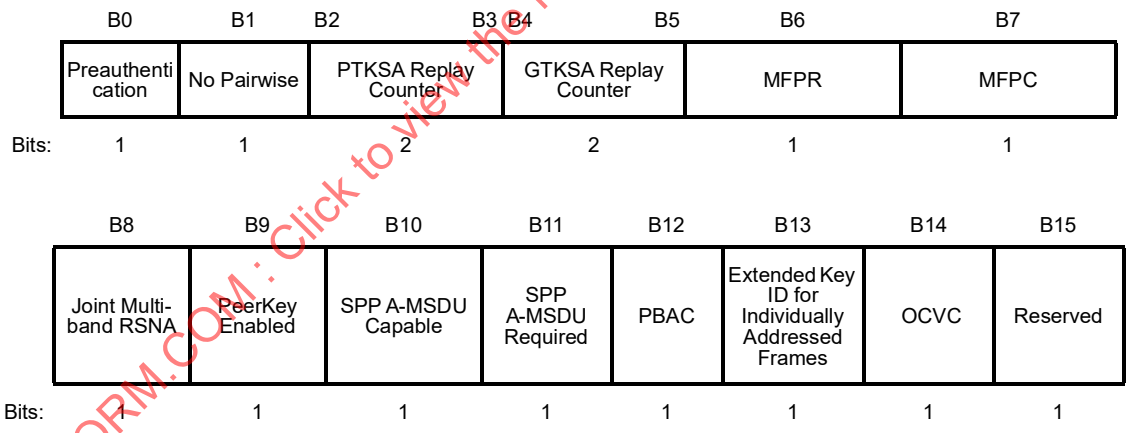

Figure 9-289—RSN Capabilities field format

— Bit 0: Preauthentication. An AP sets the Preauthentication subfield of the RSN Capabilities field to 1 to signal it supports preauthentication (see 12.6.10.2) and sets the subfield to 0 when it does not support preauthentication. A non-AP STA sets the Preauthentication subfield to 0.

— Bit 1: No Pairwise. If a STA supports WEP default key 0 simultaneously with a pairwise key (see 12.7.1), then the STA sets the No Pairwise subfield of the RSN Capabilities field to 0.

If a STA does not support WEP default key 0 simultaneously with a pairwise key (see 12.7.1), then the STA sets the No Pairwise subfield of the RSN Capabilities field to 1.

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The No Pairwise subfield describes a capability of a non-AP STA. IBSS STAs and APs set the No Pairwise subfield to 0.

The No Pairwise subfield is set to 1 only in a TSN and when the pairwise cipher suite selected by the STA is TKIP.

— Bits 2–3: PTKSA Replay Counter. A STA sets the PTKSA Replay Counter subfield of the RSN Capabilities field to the value contained in dot11RSNAConfigNumberOfPTKSAReplayCounters. The least significant bit (LSB) of dot11RSNAConfigNumberOfPTKSAReplayCounters is put in bit 2. See 12.5.2.6 and 12.5.3.4.4. The meaning of the value in the PTKSA/GTKSA Replay Counter subfield is defined in Table 9-152.

Table 9-152—PTKSA/GTKSA replay counters usage

Replay counter value	Meaning
0	1 replay counter per PTKSA/GTKSA
1	2 replay counters per PTKSA/GTKSA
2	4 replay counters per PTKSA/GTKSA
3	16 replay counters per PTKSA/GTKSA

— Bits 4–5: GTKSA Replay Counter. A STA sets the GTKSA Replay Counter subfield of the RSN Capabilities field to the value contained in dot11RSNAConfigNumberOfGTKSAReplayCounters. The LSB of dot11RSNAConfigNumberOfGTKSAReplayCounters is put in bit 4. See 12.5.2.6 and 12.5.3.4.4. The meaning of the value in the GTKSA Replay Counter subfield is defined in Table 9-152.

— Bit 6: MFPR. A STA sets this bit to 1 to advertise that protection of robust Management frames is mandatory. A STA sets this bit to 1 when dot11RSNAProtectedManagementFramesActivated is true and dot11RSNAUnprotectedManagementFramesAllowed is false; otherwise it sets this bit to 0. If a STA sets this bit to 1, then that STA only allows RSNAs with STAs that provide Management Frame Protection.

— Bit 7: MFPC . A STA sets this bit to 1 when dot11RSNAProtectedManagementFramesActivated is true to advertise that protection of robust Management frames is enabled.

— Bit 8: Joint Multi-band RSNA. A STA sets the Joint Multi-band RSNA subfield to 1 to indicate that it supports the Joint Multi-band RSNA (12.6.22). Otherwise, this subfield is set to 0.

— Bits 9: PeerKey Enabled. An AP sets the PeerKey Enabled subfield of the RSN Capabilities field to 1 to signal it supports PeerKey handshake (see 12.7.8). Otherwise, this subfield is set to 0.

— Bit 10: SPP A-MSDU Capable. A STA sets the SPP A-MSDU Capable subfield of the RSN Capabilities field to 1 to signal that it supports signaling and payload protected A-MSDUs (SPP A-MSDUs) (see 10.11). Otherwise, this subfield is set to 0.

— Bit 11: SPP A-MSDU Required. A STA sets the SPP A-MSDU Required subfield of the RSN Capabilities field to 1 when it allows only SPP A-MSDUs (i.e., does not send or receive payload protected A-MSDUs (PP A-MSDUs) (see 10.11). Otherwise, this subfield is set to 0.

— Bit 12: PBAC (protected block ack agreement capable). A STA sets the PBAC subfield of RSN Capabilities field to 1 to indicate it is PBAC. Otherwise, this subfield is set to 0.

— Bit 13: Extended Key ID for Individually Addressed Frames. This subfield is set to 1 to indicate that the STA supports Key ID values in the range 0 to 1 for a PTKSA when the cipher suite is CCMP or GCMP. Bit 13 set to 0 indicates that the STA only supports Key ID 0 for a PTKSA.

— Bit 14: OCVC. This subfield is set to 1 to indicate that the STA supports operating channel validation by including Operating Channel Information (OCI) in RSNA exchanges and validates the information when received from another STA that indicated this capability.

— Bits 15: Reserved. The remaining subfields of the RSN Capabilities field are reserved.

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9.4.2.24.5 PMKID

The PMKID Count field indicates the number of PMKIDs that are contained in the PMKID List field. The PMKID List field contains a series (possibly empty) of PMKIDs.

When one or more PMKIDs are included in a (Re)Association Request frame or FILS Authentication frame to an AP, they identify PMKSAs that the STA believes to be valid for the destination AP. When a PMKID is included in a FILS Authentication frame to a STA, it identifies a PMKID that the AP has selected.

A PMKID in the PMKID List field can refer to

a) The PMKID of a cached PMKSA that has been obtained through preauthentication with the target AP
b) The PMKID of a cached PMKSA from an EAP, FILS, or SAE authentication
c) The PMKID of a PMKSA derived from a PSK for the target AP
d) The PMKR0Name of a PMK-R0 security association derived as part of an FT initial mobility domain association
e) The PMKR1Name of a PMK-R1 security association derived as part of an FT initial mobility domain association or as part of a fast BSS transition.

See 12.7.1.3 and 12.7.1.6.3 for the construction of the PMKID, 13.8 for the population of PMKID List for fast BSS transitions, 12.6.10.3 for the population of PMKID List when using PMKSA caching, 13.4 for the population of PMKID List for FT initial mobility domain association, 12.11.2 for the population of PMKID List with FILS authentication, and 12.7.1.6 for the construction of PMKR0Name and PMKR1Name.

NOTE—A STA need not insert a PMKID in the PMKID List field if the STA will not be using that PMKSA.

9.4.2.25 Vendor Specific element

The Vendor Specific element is used to carry information not defined in this standard within a single defined format, so that reserved element IDs are not usurped for nonstandard purposes and so that interoperability is more easily achieved in the presence of nonstandard information. The element is in the format shown in Figure 9-290.

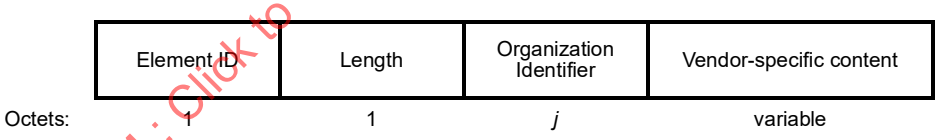

Figure 9-290—Vendor Specific element format

The Element ID and Length fields are defined in 9.4.2.1.

The Organization Identifier field identifies (see 9.4.1.31) the entity that has defined the content of the particular Vendor Specific element. See 9.4.1.31 for the definition of *j*.

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9.4.2.26 Extended Capabilities element

The Extended Capabilities element carries information about the capabilities of a STA that augment the capabilities specified in the Capability Information field. The format of this element is shown in Figure 9-291.

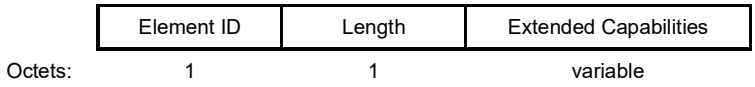

Figure 9-291—Extended Capabilities element format

The Element ID and Length fields are defined in 9.4.2.1.

The Extended Capabilities field is a bit field indicating the extended capabilities being advertised by the STA transmitting the element. The length of the Extended Capabilities field is variable. If fewer bits are received in an Extended Capabilities field than shown in Table 9-153, the rest of the Extended Capabilities field bits are assumed to be zero. The Extended Capabilities field is shown in Table 9-153.

Table 9-153—Extended Capabilities field

Bit	Information	Notes
0	20/40 BSS Coexistence Management Support	The 20/40 BSS Coexistence Management Support field indicates support for the 20/40 BSS Coexistence Management frame and its use. The 20/40 BSS Coexistence Management Support field is set to 1 to indicate support for the communication of STA information through the transmission and reception of the 20/40 BSS Coexistence Management frame. The 20/40 BSS Coexistence Management Support field is set to 0 to indicate a lack of support for the communication of STA information through the transmission and reception of the 20/40 BSS Coexistence Management frame.
1	GLK	The STA sets the GLK field to 1 when dot11GLKImplemented is true and sets it to 0 otherwise.
2	Extended Channel Switching	The Extended Channel Switching field is 1 to indicate support for the communication of channel switching information through the transmission and reception of the Extended Channel Switch Announcement element and Management frame, as described in 9.6.7.7. The Extended Channel Switching field is 0 to indicate a lack of support for extended channel switching.
3	GLK-GCR	The STA sets the GLK-GCR field to 1 when dot11GLKGCRImplemented is true and sets it to 0 otherwise.
4	PSMP Capability	This field indicates support for PSMP operation. See 10.30. Set to 0 if the STA does not support PSMP operation Set to 1 if the STA supports PSMP operation.
5	Reserved	
6	S-PSMP Support	Indicates support for scheduled PSMP. When the PSMP Capability field is equal to 0, the S-PSMP Support field is set to 0. When the PSMP Capability field is equal to 1, the S-PSMP Support field is defined as follows: Set to 0 if STA does not support S-PSMP Set to 1 if STA supports S-PSMP

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Table 9-153—Extended Capabilities field *(continued)*

Bit	Information	Notes
7	Event	The STA sets the Event field to 1 when dot11EventsActivated is true, and sets it to 0 otherwise. See 11.21.2.
8	Diagnostics	The STA sets the Diagnostics field to 1 when dot11DiagnosticsActivated is true, and sets it to 0 otherwise. See 11.21.3.
9	Multicast Diagnostics	The STA sets the Multicast Diagnostics field to 1 when dot11MulticastDiagnosticsActivated is true, and sets it to 0 otherwise. See 11.21.3.
10	Location Tracking	The STA sets the Location Tracking field to 1 when dot11LocationTrackingActivated is true, and sets it to 0 otherwise. See 11.21.4.
11	FMS	The STA sets the FMS field to 1 when dot11FMSActivated is true, and sets it to 0 otherwise. See 11.2.3.14 and 11.21.8.
12	Proxy ARP Service	The AP sets the Proxy ARP Service field to 1 when dot11ProxyARPActivated is true, and sets it to 0 otherwise. See 11.21.14. A non-AP STA sets the Proxy ARP Service field to 0.
13	Collocated Interference Reporting	The STA sets the Collocated Interference Reporting field to 1 when dot11CoLocIntfReportingActivated is true, and sets it to 0 otherwise. See 11.21.9.
14	Civic Location	The STA sets the Civic Location field to 1 when dot11RMCivicConfigured is true, and sets it to 0 otherwise. See 11.10.9.9.
15	Geospatial Location	The STA sets the Geospatial Location field to 1 when dot11RMLCIConfigured is true, and sets it to 0 otherwise. See 11.10.9.6.
16	TFS	The STA sets the TFS field to 1 when dot11TFSActivated is true, and sets it to 0 otherwise. See 11.21.12.
17	WNM Sleep Mode	The STA sets the WNM Sleep Mode field to 1 when dot11WNMSleepModeActivated is true, and sets it to 0 otherwise. See 11.2.3.16.
18	TIM Broadcast	The STA sets the TIM Broadcast field to 1 when dot11TIMBroadcastActivated is true, and sets it to 0 otherwise. See 11.2.3.15.
19	BSS Transition	The STA sets the BSS Transition field to 1 when dot11BSSTransitionActivated is true, and sets it to 0 otherwise. See 11.21.7.
20	QoS Traffic Capability	The STA sets the QoS Traffic Capability field to 1 when dot11QoSTrafficCapabilityActivated is true, and sets it to 0 otherwise. See 11.21.10.
21	AC Station Count	The STA sets the AC Station Count field to 1 when dot11ACStationCountActivated is true, and sets it to 0 otherwise. See 11.21.11.
22	Multiple BSSID	The STA sets the Multiple BSSID field to 1 when dot11MultiBSSIDImplemented is true, and sets it to 0 otherwise. See 11.10.14 and 11.1.3.8.
23	Timing Measurement	The STA sets the Timing Measurement field to 1 when dot11TimingMsmtActivated is true, and sets it to 0 otherwise. See 11.21.5.
24	Channel Usage	The STA sets the Channel Usage field to 1 when dot11ChannelUsageActivated is true and sets it to 0 otherwise. See 11.21.15.

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Table 9-153—Extended Capabilities field *(continued)*

Bit	Information	Notes
25	SSID List	The STA sets the SSID List field to 1 when dot11SSIDListActivated is true, and sets it to 0 otherwise. See 11.1.4.
26	DMS	The STA sets the DMS field to 1 when dot11DMSActivated is true and sets it to 0 otherwise. See 11.21.16.
27	UTC TSF Offset	The STA sets the UTC TSF Offset field to 1 when dot11UTCTSFOffsetActivated is true and sets it to 0 otherwise. See 11.19.3.
28	TPU Buffer STA Support	The TPU Buffer STA Support subfield indicates support for the TPU buffer STA function, as defined in 11.2.3.13. When dot11TDLSPeerUAPSDBufferSTAActivated is true, and to indicate support for TPU on this link, the TPU Buffer STA Support subfield is set to 1. Otherwise, the TPU Buffer STA Support subfield is set to 0 to indicate that this capability is not supported on this link.
29	TDLS Peer PSM Support	The TDLS Peer PSM Support subfield indicates support for TDLS peer PSM, as defined in 11.2.3.12. When dot11TDLSPeerPSMActivated is true, and to indicate support for TDLS peer PSM on this link, the TDLS Peer PSM Support subfield is set to 1. Otherwise, the TDLS Peer PSM Support subfield is set to 0 to indicate that this capability is not supported on this link.
30	TDLS channel switching	When dot11TDLSChannelSwitchingActivated is true, and to indicate that the STA supports TDLS with TDLS channel switching on this link as described in 11.20, the TDLS Channel Switching subfield is set to 1. Otherwise, the TDLS Channel Switching subfield is set to 0 to indicate that this capability is not supported on this link.
31	Interworking	When dot11InterworkingServiceActivated is true, the Interworking field is set to 1 to indicate the STA supports interworking service as described in 11.22. When dot11InterworkingServiceActivated is false, the Interworking field is set to 0 to indicate the STA does not support this capability.
32	QoS Map	When dot11QosMapActivated is true, the QoS Map field is set to 1 to indicate the STA supports QoS Map service as described in 11.22.9. When dot11QosMapActivated is false, the QoS Map field is set to 0 to indicate the STA does not support this capability.
33	EBR	When dot11EBRActivated is true, the EBR field is set to 1 to indicate the STA supports EBR operation as described in 11.4. When dot11EBRActivated is false, the EBR field is set to 0 to indicate the STA does not support this capability.
34	SSPN Interface	When dot11SSPNInterfaceActivated is true, the SSPN Interface field is set to 1 to indicate the AP supports SSPN Interface service as described in 11.22.5. When dot11SSPNInterfaceActivated is false, the SSPN Interface is set to 0 to indicate the AP does not support this capability. Non-AP STAs set this field to 0.
35	Reserved	
36	MSGCF Capability	When dot11MSGCFActivated is true, the MSGCF Capability field is set to 1 to indicate the non-AP STA supports the MSGCF in 6.4. When dot11MSGCFActivated is false, the MSGCF Capability is set to 0 to indicate the non-AP STA does not support this capability. APs set this field to 0.
37	TDLS Support	The TDLS Support subfield indicates support for TDLS, as defined in 11.20. When dot11TunneledDirectLinkSetupImplemented is true, this field is set to 1 to indicate support for TDLS. The field is set to 0 otherwise, to indicate that TDLS is not supported.

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Table 9-153—Extended Capabilities field *(continued)*

Bit	Information	Notes
38	TDLS Prohibited	The TDLS Prohibited subfield indicates whether the use of TDLS is prohibited. The field is set to 1 to indicate that TDLS is prohibited and to 0 to indicate that TDLS is allowed.
39	TDLS Channel Switching Prohibited	The TDLS Channel Switching Prohibited subfield indicates whether the use of TDLS Channel Switching is prohibited. The field is set to 1 to indicate that TDLS Channel Switching is prohibited and to 0 to indicate that TDLS Channel Switching is allowed.
40	Reject Unadmitted Frame	When dot11RejectUnadmittedTraffic is true, the Reject Unadmitted Frame bit is set to 1 to indicate that the STA does not transmit frames belonging to an unadmitted TS. When dot11RejectUnadmittedTraffic is false, the Reject Unadmitted Frame bit is set to 0 to indicate that the STA might transmit frames belonging to an unadmitted TS. When dot11RejectUnadmittedTraffic is not present, the Reject Unadmitted frame bit is set to 0.
41-43	Service Interval Granularity	Duration of the shortest service interval (SI). Used for scheduled PSMP only. This field is defined when the S-PSMP Support field is set to 1; otherwise, it is reserved. See 11.4.6. Set to 0 for 5 ms Set to 1 for 10 ms Set to 2 for 15 ms Set to 3 for 20 ms Set to 4 for 25 ms Set to 5 for 30 ms Set to 6 for 35 ms Set to 7 for 40 ms
44	Identifier Location	The STA sets the Identifier Location field to 1 when dot11RMIdentifierMeasurementActivated is true, and sets it to 0 otherwise. See 11.10.9.10.
45	U-APSD Coexistence	The STA sets the U-APSD Coexistence field to 1 when dot11UAPSDCoexistenceActivated is true and sets it to 0 otherwise. See 11.2.3.5.2.
46	WNM Notification	The STA sets the WNM Notification field to 1 when dot11WNMNotificationActivated is true and sets it to 0 otherwise. See 11.21.17.
47	QAB Capability	Set to 1 if AP supports QAB Set to 0 otherwise
48	UTF-8 SSID	The SSID in this BSS is a sequence of UTF-8 encoded code points
49	QMFActivated	The STA sets the QMFActivated field to 1 when dot11QMFActivated is true and sets it to 0 otherwise. See 11.24.
50	QMFReconfigurationActivated	The STA sets the QMFReconfigurationActivated field to 1 when dot11QMFActivated is true and sets it to 0 otherwise. See 11.24.

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Table 9-153—Extended Capabilities field *(continued)*

Bit	Information	Notes
51	Robust AV Streaming	The STA sets the Robust AV Streaming field to 1 when dot11RobustAVStreamingImplemented is true and sets it to 0 otherwise. See 11.25.
52	Advanced GCR	The STA sets the Advanced GCR field to 1 when dot11AdvancedGCRActivated is true and sets it to 0 otherwise. See 11.21.16.3.
53	Mesh GCR	The STA sets the mesh GCR field to 1 when dot11MeshGCRActivated is true and sets it to 0 otherwise. See 11.21.16.3.
54	SCS	The STA sets the SCS field to 1 when dot11SCSActivated is true and sets it to 0 otherwise. See 11.25.2.
55	QLoad Report	The STA sets the QLoad Report field to 1 when dot11QLoadReportActivated is true and sets it to 0 otherwise. See 11.26.2.
56	Alternate EDCA	The STA sets the Alternate EDCA field to 1 when dot11AlternateEDCAActivated is true and sets it to 0 otherwise. See 10.2.3.2.
57	Unprotected TXOP Negotiation	The STA sets the Unprotected TXOP Negotiation field to 1 when dot11PublicTXOPNegotiationActivated is true and sets it to 0 otherwise. See 11.26.3.
58	Protected TXOP Negotiation	The STA sets the Protected TXOP Negotiation field to 1 when dot11ProtectedTXOPNegotiationActivated is true and sets it to 0 otherwise. See 11.26.3.
59	Reserved	
60	Protected QLoad Report	The STA sets the Protected QLoad Report field to 1 when dot11ProtectedQLoadReportActivated is true and sets it to 0 otherwise. See 11.26.2.
61	TDLS Wider Bandwidth	The TDLS Wider Bandwidth subfield indicates whether the STA supports a wider bandwidth than the BSS bandwidth for a TDLS direct link with a primary channel equal to the base channel. The field is set to 1 to indicate that the STA supports a wider bandwidth and to 0 to indicate that the STA does not support a wider bandwidth. A 160 MHz bandwidth is defined to be identical to an 80+80 MHz bandwidth (i.e., one is not wider than the other).
62	Operating Mode Notification	If dot11OperatingModeNotificationImplemented is true, the Operating Mode Notification field is set to 1 to indicate support for reception of the Operating Mode Notification element and the Operating Mode Notification frame. If dot11OperatingModeNotificationImplemented is false or not present, the Operating Mode Notification field is set to 0 to indicate lack of support for reception of the Operating Mode Notification element and the Operating Mode Notification frame.
63–64	Max Number Of MSDUs In A-MSDU	Indicates the maximum number of MSDUs in an A-MSDU that the STA is able to receive from a VHT STA: Set to 0 to indicate that no limit applies. Set to 1 for 32. Set to 2 for 16. Set to 3 for 8 Reserved if A-MSDU is not supported or if the STA is not an HT STA.
65	Channel Schedule Management	The STA sets the Channel Schedule Management field to 1 when dot11ChannelScheduleManagementActivated is true and sets it to 0 otherwise. See 11.42.5.

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Table 9-153—Extended Capabilities field *(continued)*

Bit	Information	Notes
66	Geodatabase Inband Enabling Signal	The STA sets the Geodatabase Inband Enabling Signal field to 1 when dot11GDDActivated is true and the STA permits GDD dependent STAs to operate. See 11.42.2.
67	Network Channel Control	The STA sets the Network Channel Control field to 1 when dot11NetworkChannelControlActivated is true and sets it to 0 otherwise. See 11.42.7.
68	White Space Map	The STA sets the White Space Map field to 1 when dot11WhiteSpaceMapActivated is true and sets it to 0 otherwise. See 11.42.8.
69	Channel Availability Query	The STA sets the Channel Availability Query field to 1 when dot11GDDActivated is true and sets it to 0 otherwise. See 11.42.4.
70	Fine Timing Measurement Responder	The STA sets the Fine Timing Measurement Responder field to 1 when dot11FineTimingMsmtRespActivated is true and sets it to 0 otherwise. See 11.21.6.
71	Fine Timing Measurement Initiator	The STA sets the Fine Timing Measurement Initiator field to 1 when dot11FineTimingMsmtInitActivated is true and sets it to 0 otherwise. See 11.21.6.
72	FILS Capability	The FILS Capability field is set to 1 if dot11FILSActivated is true. Otherwise, the FILS Capability field is 0.
73	Extended Spectrum Management Capable	The STA sets the Extended Spectrum Management Capable field to 1 when dot11ExtendedSpectrumManagementImplemented is true and dot11VHTOptionImplemented is false, and sets it to 0 otherwise.
74	Future Channel Guidance	The STA sets the Future Channel Guidance field to 1 when dot11FutureChannelGuidanceActivated is true and sets it to 0 otherwise. See 11.8.10.
75	PAD	Indicates support for PAD (see 11.23).
76–79	Reserved	
80	Complete List of NonTxBSSID Profiles	This field is reserved for a non-AP STA or when the AP has dot11MultiBSSIDImplemented set to false. When set to 1, indicates that the frame carrying this element includes a complete list of nontransmitted BSSID profiles. When set to 0, there is no indication about the completeness of the list of nontransmitted BSSID profiles in the frame. Also see 11.1.3.8.
81	SAE Password Identifiers In Use	The AP sets the SAE Password Identifiers In Use field to 1 when any password in the dot11RSNAConfigPasswordValueTable has a password identifier and sets it to 0 otherwise. See 12.4.3.
82	SAE Password Identifiers Used Exclusively	The AP sets the SAE Password Identifiers Used Exclusively field to 1 when every password in the dot11RSNAConfigPasswordValueTable has a password identifier and sets it to 0 otherwise. See 12.4.3.
83	Reserved	
84	Beacon Protection Enabled	The AP sets the Beacon Protection Enabled field to 1 when dot11BeaconProtectionEnabled is true. Otherwise, it is set to 0. This field is reserved for a non-AP STA. See 11.52.

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Table 9-153—Extended Capabilities field *(continued)*

Bit	Information	Notes
85	Mirrored SCS	The STA sets the Mirrored SCS field to 1 when dot11MSCSActivated is true and sets it to 0 otherwise.
86	Reserved	
87	Local MAC Address Policy	When dot11LocalMACAddressPolicyActivated is true, the Local MAC Address Policy subfield is set to 1. When dot11LocalMACAddressPolicyActivated is false, the Local MAC Address Policy subfield is set to 0.
88–*n*	Reserved	

If a STA does not support any of capabilities defined in the Extended Capabilities element, then the STA is not required to transmit the Extended Capabilities element.

NOTE—The fields of the Extended Capabilities element are not dynamic. They are determined by the parameters of the MLME-START.request or MLME-JOIN.request primitive that caused the STA to start or join its current BSS, and they remain unchanged until the next MLME-START.request or MLME-JOIN.request primitive.

9.4.2.27 BSS Load element

The BSS Load element contains information on the current STA population and traffic levels in the BSS. The element information format is defined in Figure 9-292. This element might be used by the STA for vendor-specific AP selection algorithm when roaming.

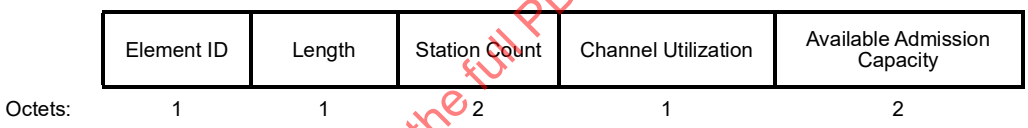

Figure 9-292—BSS Load element format

The Element ID and Length fields are defined in 9.4.2.1.

The STA Count field is interpreted as an unsigned integer that indicates the total number of STAs currently associated with this BSS.

The Channel Utilization field is defined as the percentage of time, linearly scaled with 255 representing 100%, that the AP sensed the medium was busy, as indicated by either the physical or virtual carrier sense (CS) mechanism. When more than one channel is in use for the BSS, the Channel Utilization field value is calculated only for the primary channel. This percentage is computed using the following formula:

$$\text{Channel Utilization} = \left\lfloor \frac{\text{channel busy time}}{\text{dot11ChannelUtilizationBeaconIntervals} \times \text{dot11BeaconPeriod} \times 1024} \times 255 \right\rfloor$$

where

channel busy time is defined to be the number of microseconds during which the CS mechanism, as defined in 10.3.2.1, has indicated a channel busy indication,

dot11ChannelUtilizationBeaconIntervals represents the number of consecutive beacon intervals during which the channel busy time is measured.

The Available Admission Capacity field contains an unsigned integer that specifies the remaining amount of medium time available via explicit admission control, in units of 32 μs/s. The field is helpful for roaming

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STAs to select an AP that is likely to accept future admission control requests, but it does not represent an assurance that the HC admits these requests.

9.4.2.28 EDCA Parameter Set element

The EDCA Parameter Set element provides information needed by STAs for proper operation of the QoS facility. The format of the EDCA Parameter Set element is defined in Figure 9-293.

	Element ID	Length	QoS Info	Update EDCA Info	AC_BE Parameter Record	AC_BK Parameter Record	AC_VI Parameter Record	AC_VO Parameter Record
Octets:	1	1	1	1	4	4	4	4

Figure 9-293—EDCA Parameter Set element format

The Element ID and Length fields are defined in 9.4.2.1.

For an infrastructure BSS, the EDCA Parameter Set element is used by the AP to establish policy (by changing default MIB attribute values), to change policies when accepting new STAs or new traffic, or to adapt to changes in offered load. The most recent EDCA parameter set element received by a STA is used to update the appropriate MIB values.

The format of the QoS Info field is defined in 9.4.1.17. The QoS Info field contains the EDCA Parameter Set Update Count subfield, which is initially set to 0 and is incremented each time any of the announced EDCA parameters change. This subfield is used by non-AP STAs to determine whether the EDCA parameter set has changed and requires updating the appropriate MIB attributes.

The Update EDCA Info field is reserved for non-S1G STAs. For S1G STAs, it is shown in Figure 9-294.

	B0	B1 B2	B3 B4	B5 B6	B7
	Override	PS-Poll ACI	RAW ACI	STA Type	Reserved
Bits:	1	2	2	2	1

Figure 9-294—Update EDCA Info field format

The Override field is used by S1G APs to indicate to S1G STAs that this element overrides previously stored EDCA parameters as described in 10.2.3.2.

The PS-Poll ACI field is used by S1G APs to inform the S1G STAs of the access category for sending a PS-Poll frame. The mapping between the PS-Poll ACI field and AC is identical to the one defined in Table 9-154.

The RAW ACI field is used by S1G APs to inform the S1G STAs of the access category for accessing the WM in the RAW as described in 10.23.5.5. The mapping between the RAW ACI field and AC is identical to the one defined in Table 9-154.

The STA Type field indicates the type of STA for which the information in the element is provided. The S1G AP sets the STA Type field to

— 0 to indicate that the information provided by this element is valid for STAs (i.e., both sensor STAs and non-sensor STAs)

— 1 to indicate that the information is valid for sensor STAs

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— 2 to indicate that the information provided by this element is valid for non-sensor STAs
— 3 to indicate a reserved value

NOTE—An S1G STA that transmits a (NDP) PS-Poll frame within a RAW uses the access category indicated by PS-Poll ACI subfield rather than the access category indicated by the RAW ACI subfield.

The formats of AC_BE, AC_BK, AC_VI, and AC_VO Parameter Record fields are identical and are shown in Figure 9-295.

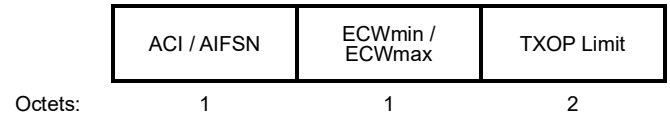

Figure 9-295—AC_BE, AC_BK, AC_VI, and AC_VO Parameter Record field format

The format of the ACI/AIFSN field is shown in Figure 9-296.

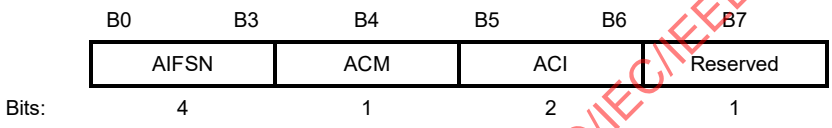

Figure 9-296—ACI/AIFSN field format

The value of the AC index (ACI) references the AC to which all parameters in this record correspond. The mapping between ACI and AC is defined in Table 9-154. The ACM (admission control mandatory) subfield indicates that admission control is required for the AC. If the ACM subfield is equal to 0, then there is no admission control for the corresponding AC. If the ACM subfield is set to 1, admission control has to be used prior to transmission using the access parameters specified for this AC. The AIFSN subfield indicates the number of slots after a SIFS a STA defers before either invoking a backoff or starting a transmission. The minimum value of the AIFSN subfield is 2.

Table 9-154—ACI-to-AC coding

ACI	AC	Description
0	AC_BE	Best effort
1	AC_BK	Background
2	AC_VI	Video
3	AC_VO	Voice

The ECWmin/ECWmax field is shown in Figure 9-297.

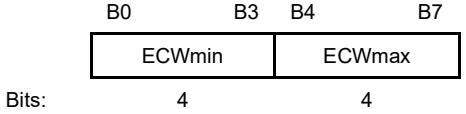

Figure 9-297—ECWmin/ECWmax field format

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The ECWmin and ECWmax subfields encode the values of CWmin and CWmax, respectively, in an exponent form. The ECWmin and ECWmax values are defined so that

$$CWmin = 2^{ECWmin} - 1$$

$$CWmax = 2^{ECWmax} - 1$$

Hence the minimum encoded value of CWmin and CWmax is 0, and the maximum value is 32 767.

The TXOP Limit field is specified as an unsigned integer, in units of 32 μs. A TXOP Limit field set to 0 has a special meaning (see 10.23.2.9).

Table 9-155 defines the default EDCA parameter values used by a non-AP STA if dot11OCBActivated is false.[25]

Table 9-155—Default EDCA Parameter Set element parameter values if dot11OCBActivated is false or the STA is a non-sensor STA

AC	CWmin	CWmax	AIFSN	TXOP limit				
				For PHYs defined in Clause 15 and Clause 16	For PHYs defined in Clause 17, Clause 18, Clause 19, and Clause 21	For PHY defined in Clause 22	Clause 23	Other PHYs
AC_BK	aCWmin	aCWmax	7	3.264 ms	2.528 ms	0	15.008 ms	0
AC_BE	aCWmin	aCWmax	3	3.264 ms	2.528 ms	0	15.008 ms	0
AC_VI	(aCWmin+1)/ 2 – 1	aCWmin	2	6.016 ms	4.096 ms	22.56 ms (BCU: 6 or 7 MHz), 16.92 ms (BCU: 8 MHz)	15.008 ms	0
AC_VO	(aCWmin+1)/ 4 – 1	(aCWmin+1)/ 2 – 1	2	3.264 ms	2.080 ms	11.28 ms (BCU: 6 or 7 MHz), 8.46 ms (BCU: 8 MHz)	15.008 ms	0

[25] The default values for TXOP limit are expressed in milliseconds and are multiples of 32 μs.

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If dot11OCBActivated is true, the default EDCA parameter set for STAs transmitting QoS frames is given in Table 9-156.

Table 9-156—Default EDCA parameter set for STA operation if dot11OCBActivated is true

AC	CWmin	CWmax	AIFSN	TXOP limit
AC_BK	aCWmin	aCWmax	9	0
AC_BE	aCWmin	aCWmax	6	0
AC_VI	aCWmin	aCWmax	4	0
AC_VO	(aCWmin+1)/4–1	(aCWmin+1)/2–1	2	0

The default EDCA parameter set used by sensor STAs is given in Table 9-157.

Table 9-157—Default EDCA Parameter Set element parameter values if the STA is a sensor STA

AC	CWmin	CWmax	AIFSN	TXOP limit
AC_BK	aCWmin	aCWmax	7	0
AC_BE	(aCWmin+1)/4 – 1	aCWmin	2	0
AC_VI	(aCWmin+1)/2 – 1	aCWmin	5	0
AC_VO	(aCWmin+1)/2 – 1	aCWmin	4	0

9.4.2.29 TSPEC element

The TSPEC element contains the set of parameters that define the characteristics and QoS expectations of a traffic flow, in the context of a particular STA, for use by the HC or PCP and STA(s) or a mesh STA and its peer mesh STAs in support of QoS traffic transfer using the procedures defined in 11.4 and 11.21.16.3. The element information format comprises the items as defined in this subclause, and the structure is defined in Figure 9-298.

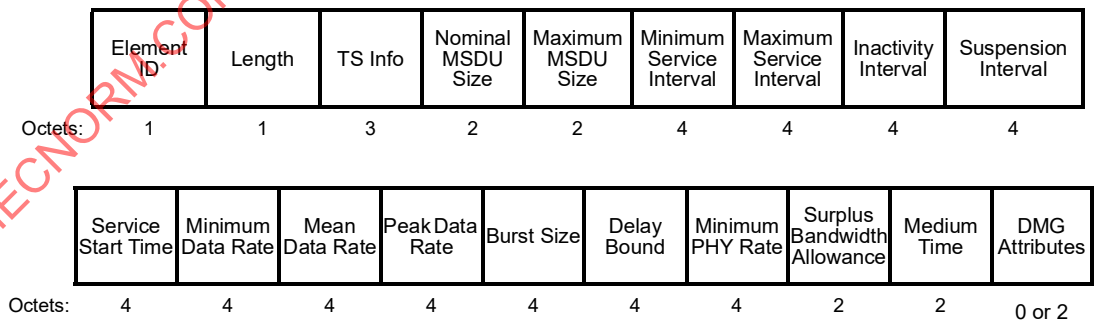

Figure 9-298—TSPEC element format

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The TSPEC element allows a set of parameters more extensive than might be needed, or might be available, for any particular instance of parameterized QoS traffic. Unless indicated otherwise, fields that follow the TS Info field are set to 0 for any unspecified parameter values. STAs set any parameters to unspecified if they have no information for setting that parameter.

The structure of the TS Info field is defined in Figure 9-299.

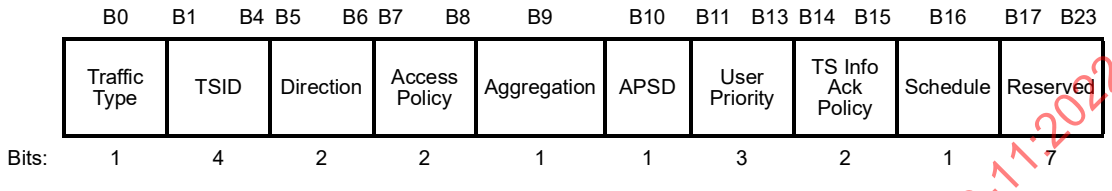

Figure 9-299—TS Info field format

The subfields of the TS Info field are defined as follows:

— The Traffic Type subfield is set to 1 for a periodic traffic pattern (e.g., isochronous TS of MSDUs or A-MSDUs, with constant or variable sizes, that are originated at fixed rate) or set to 0 for an aperiodic, or unspecified, traffic pattern (e.g., asynchronous TS of low-duty cycles).

— The TSID subfield contains a value that is a TSID. Note that the MSB (bit 4 in TS Info field) of the TSID subfield is always set to 1 when the TSPEC element is included within an ADDTS Response frame.

— The Direction subfield specifies the direction of data carried by the TS as defined in Table 9-158.

Table 9-158—Direction subfield encoding

Bit 5	Bit 6	Usage
0	0	Uplink, defined as follows: — Non-DMG BSS: MSDUs or A-MSDUs are sent from the non-AP STA to HC — DMG BSS: MSDUs or A-MSDUs are sent by the originator of the ADDTS Request frame
1	0	Downlink, defined as follows: — Non-DMG BSS: MSDUs or A-MSDUs are sent from the HC to the non-AP STA — DMG BSS: MSDUs or A-MSDUs are sent by the recipient of the ADDTS Request frame
0	1	Direct link (MSDUs or A-MSDUs are sent from the non-AP STA to another non-AP STA)
1	1	Bidirectional link (equivalent to a downlink request plus an uplink request, each direction having the same parameters). The fields in the TSPEC element specify resources for a single direction. Double the specified resources are required to support both streams.

— The Access Policy subfield specifies the access method to be used for the TS, and is defined in Table 9-159.

— The Aggregation subfield is valid only when the access method is HCCA or SPCA or when the access method is EDCA and the Schedule subfield is equal to 1. It is set to 1 by a non-AP STA to indicate that an aggregate schedule is required. It is set to 1 by the AP if an aggregate schedule is being provided to the STA. It is set to 0 otherwise. In all other cases, the Aggregation subfield is reserved.

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Table 9-159—Access Policy subfield

Bit 7	Bit 8	Usage
0	0	Reserved
1	0	Contention based channel access (EDCA)
0	1	Controlled channel access (HCCA for non-DMG STAs and SPCA for DMG STAs)
1	1	Controlled and contention based channel access (HCCA, EDCA mixed mode (HEMM) for non-DMG STAs; SPCA, EDCA mixed mode (SEMM) for DMG STAs)

— The APSD subfield is set to 1 to indicate that automatic PS delivery is to be used for the traffic associated with the TSPEC and set to 0 otherwise.

— The UP subfield indicates the actual value of the UP to be used for the transport of MSDUs or A-MSDUs belonging to this TS when relative prioritization is required. When the TCLAS element is present in the request, the UP subfield in TS Info field of the TSPEC element is reserved.

— The TS Info Ack Policy subfield indicates whether MAC acknowledgments are required for MPDUs or A-MSDUs belonging to this TSID and the form of those acknowledgments. The encoding of the TS Info Ack Policy subfield is shown in Table 9-160.

Table 9-160—TS Info Ack Policy subfield encoding

Bit 14	Bit 15	Usage
0	0	Normal Acknowledgment The addressed recipient returns an Ack or QoS +CF-Ack frame after a SIFS, according to the procedures defined in 10.3.2.11 and 10.23.3.5.
1	0	No Ack: The recipient(s) do not acknowledge the transmission.
0	1	Reserved
1	1	Block Ack: A separate block ack mechanism described in 10.25 is used.

— The Schedule subfield specifies the requested type of schedule. The setting of the subfield when the access policy is EDCA is shown in Table 9-161. When the Access Policy subfield is equal to any value other than EDCA, the Schedule subfield is reserved. When the Schedule and APSD subfields are equal to 1, the AP sets the Aggregation subfield to 1, indicating that an aggregate schedule is being provided to the STA.

Table 9-161—Setting of Schedule subfield

APSD	Schedule	Usage
0	0	No Schedule
1	0	Unscheduled APSD
0	1	Scheduled PSMP or GCR-SP
1	1	Scheduled APSD

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The Nominal MSDU Size field contains an unsigned integer that specifies the nominal size, in octets, of MSDUs or (where A-MSDU aggregation is employed) A-MSDUs belonging to the TS under this TSPEC element and is defined in Figure 9-300. If the Fixed subfield is equal to 1, then the size of the MSDU or A-MSDU is fixed and is indicated by the Size subfield. If the Fixed subfield is equal to 0, then the size of the MSDU or A-MSDU might not be fixed and the Size subfield indicates the nominal MSDU size. If both the Fixed and Size subfields are equal to 0, then the nominal MSDU or A-MSDU size is unspecified.

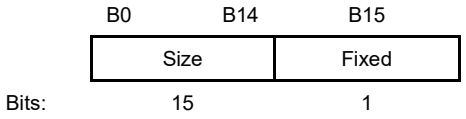

Figure 9-300—Nominal MSDU Size field format

The Maximum MSDU Size field contains an unsigned integer that specifies the maximum size, in octets, of MSDUs or A-MSDUs belonging to the TS under this TSPEC element.

The Minimum Service Interval field contains an unsigned integer that specifies the minimum interval, in microseconds, between the start of two successive SPs. If the TSPEC element is included within a GCR Request subelement that has the GCR delivery method equal to GCR-SP, a Minimum Service Interval field set to 0 indicates that SPs up to the maximum service interval are requested, including the continuous SP used by the GCR-A delivery method.

The Maximum Service Interval field contains an unsigned integer that, when the TSPEC element is for the admitting of HCCA streams, specifies the maximum interval, in microseconds, between the start of two successive SPs. If the TSPEC element is intended for EDCA Admission Control, the Maximum Service Interval field is used to indicate a latency limit, which limits the amount of aggregation (A-MSDU or A-MPDU) used, so that excessive latency does not occur (see K.4.3.1). The Maximum Service Interval field is greater than or equal to the Minimum Service Interval field. If the TSPEC element is included within a GCR Request subelement that has the GCR delivery method equal to GCR-SP, a Maximum Service Interval field set to 0 indicates that the continuous SP used by the GCR-A delivery method is requested.

K.4.3.2 provides guidance on the use of the Maximum Service Interval field to determine the limit of aggregation of nominal MSDUs.

The Inactivity Interval field contains an unsigned integer that specifies the minimum amount of time, in microseconds, that can elapse without arrival or transfer of an MPDU belonging to the TS before this TS is deleted by the MAC entity at the HC.

The Suspension Interval field contains an unsigned integer that specifies the minimum amount of time, in microseconds, that can elapse without arrival or transfer of an MSDU belonging to the TS before the generation of successive QoS(+)CF-Poll is stopped for this TS. A value of 4 294 967 295 ($= 2^{32} - 1$) disables the suspension interval, indicating that polling for the TS is not to be interrupted based on inactivity. The suspension interval is always less than or equal to the inactivity interval.

The Service Start Time field contains an unsigned integer that specifies the time, expressed in microseconds, when the first scheduled SP starts. The service start time indicates to the AP the time when a STA first expects to be ready to send frames and a power saving STA needs to be awake to receive frames. This might help the AP to schedule service so that the MSDUs encounter small delays in the MAC and help the power saving STAs to reduce power consumption. The field represents the four lower order octets of the TSF timer at the start of the SP. If APSD and Schedule subfields are 0, this field is also set to 0 (unspecified).

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The Minimum Data Rate field indicates the lowest data rate specified at the MAC SAP, for transport of MSDUs or A-MSDUs belonging to this TS within the bounds of this TSPEC element. The field is encoded as a piecewise linear function described as follows:

$$R_{min} = \begin{cases} F_{min}, & F_{min} \le 2^{31} \\ 1024 \times (F_{min} - 2^{31}) + 2^{31}, & F_{min} > 2^{31} \end{cases}$$

where

R_{min} is the minimum data rate (in units of bits per second)
F_{min} is the value of the Minimum Data Rate field

The Mean Data Rate[26] field indicates the average data rate specified at the MAC SAP, for transport of MSDUs or A-MSDUs belonging to this TS within the bounds of this TSPEC element. The field is encoded as a piecewise linear function described as follows:

$$R_{mean} = \begin{cases} F_{mean}, & F_{mean} \le 2^{31} \\ 1024 \times (F_{mean} - 2^{31}) + 2^{31}, & F_{mean} > 2^{31} \end{cases}$$

where

R_{mean} is the mean data rate (in units of bits per second)
F_{mean} is the value of the Mean Data Rate field

The Peak Data Rate field indicates the maximum allowable data rate specified at the MAC SAP for transport of MSDUs or A-MSDUs belonging to this TS within the bounds of this TSPEC element. The field is encoded as a piecewise linear function described as follows:

$$R_{peak} = \begin{cases} F_{peak}, & F_{peak} \le 2^{31} \\ 1024 \times (F_{peak} - 2^{31}) + 2^{31}, & F_{peak} > 2^{31} \end{cases}$$

where

R_{peak} is the peak data rate (in units of bits per second)
F_{peak} is the value of the Peak Data Rate field

If p is the peak rate in bits per second, then the maximum amount of data, belonging to this TS, arriving in any time interval $[t1,t2]$, where $t1 < t2$ and $t2 - t1 > 1$ TU, does not exceed $p \times (t2 - t1)$ bits.

The Minimum, Mean and Peak Data Rates do not include the MAC and PHY overheads incurred in transporting the MSDUs or A-MSDUs, with the exception of the MAC overheads specific to A-MSDUs (A-MSDU subframe header and padding). K.4.4 provides guidance on how to determine the standard deviation of the TS and how to calculate the total traffic when there are multiple TSs.

[26] The mean data rate, the peak data rate, and the burst size are the parameters of the token bucket model, which provides standard terminology for describing the behavior of a traffic source. The token bucket model is described in IETF RFC 2212 [B27], IETF RFC 2215 [B28], and IETF RFC 3290 [B36].

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The Burst Size field contains an unsigned integer that specifies the maximum burst, in octets, of the MSDUs or A-MSDUs belonging to this TS that arrive at the MAC SAP at the peak data rate. A Burst Size field set to 0 indicates that there are no bursts.

The Delay Bound field contains an unsigned integer that specifies the maximum amount of time, in microseconds, allowed to transport an MSDU or A-MSDU belonging to the TS in this TSPEC element, measured between the time marking the arrival of the MSDU, or the first MSDU of the MSDUs constituting an A-MSDU, at the local MAC sublayer from the local MAC SAP and the time of completion of the successful transmission or retransmission of the MSDU or A-MSDU to the destination. The completion of the MSDU or A-MSDU transmission includes the relevant acknowledgment frame transmission time, if present.

The Minimum PHY Rate field indicates the minimum PHY rate for transport of MSDUs or A-MSDUs belonging to this TS within the bounds of this TSPEC element.[27] See 11.4.2 for constraints on the selection of this field. The field is encoded as a piecewise linear function described as follows:

$$R_{minphy} = \begin{cases} F_{minphy}, & F_{minphy} \le 2^{31} \\ 1024 \times (F_{minphy} - 2^{31}) + 2^{31}, & F_{minphy} > 2^{31} \end{cases}$$

where

R_{minphy} is the minimum PHY rate (in units of bits per second)
F_{minphy} is the value of the Minimum PHY Rate field

The Surplus Bandwidth Allowance field specifies the excess allocation of time (and bandwidth) over and above the stated application rates required to transport an MSDU or A-MSDU belonging to the TS in this TSPEC. This field is represented as an unsigned binary number and, when specified, is greater than 0. The 13 least significant bits (LSBs) indicate the decimal part while the three MSBs indicate the integer part of the number. This field takes into account the retransmissions, as the rate information does not include retransmissions. It represents the ratio of over-the-air bandwidth (i.e., time that the scheduler allocates for the transmission of MSDUs or A-MSDUs at the required rates) to bandwidth of the transported MSDUs or A-MSDUs required for successful transmission (i.e., time that would be necessary at the minimum PHY rate if there were no errors on the channel) to meet throughput and delay bounds under this TSPEC, when specified. As such, it should be greater than unity. A Surplus Bandwidth Allowance field set to 1 indicates that no additional allocation of time is requested. K.4.2 provides guidance on how to calculate the value for Surplus Bandwidth Allowance element.

The Medium Time field is an unsigned integer and contains the amount of time admitted to access the medium, in units of 32 μs/s. This field is reserved in the ADDTS Request frame and is set by the HC in the ADDTS Response frame. The derivation of this field is described in K.2.2. This field is not used for controlled channel access.

The UP, Minimum Data Rate, Mean Data Rate, Peak Data Rate, Burst Size, Minimum PHY Rate, and Delay Bound fields in a TSPEC element express the QoS expectations requested by a STA, if this TSPEC element was issued by that STA, or provided by the HC, if this TSPEC element was issued by the HC, when these fields are specified with nonzero values. Unspecified parameters in these fields as indicated by a value of 0 indicate that the STA does not have specific requirements for these parameters if the TSPEC element was issued by that STA or that the HC does not provide any specific values for these parameters if the TSPEC

[27] This rate information is intended to confirm that the TSPEC parameter values resulting from an admission control negotiation are sufficient to provide the required throughput for the TS. In a typical implementation, a TS is admitted only if the defined traffic volume can be accommodated at the specified rate within an amount of WM occupancy time that the admissions control entity is willing to allocate to this TS.

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element was issued by the HC. Annex K provides guidance on the use of the TSPEC element and the settings of values of the various fields.

The DMG Attributes field is defined in Figure 9-301. The DMG Attributes field is present in a TSPEC element when the BSS to which the TSPEC element applies is a DMG BSS; otherwise absent.

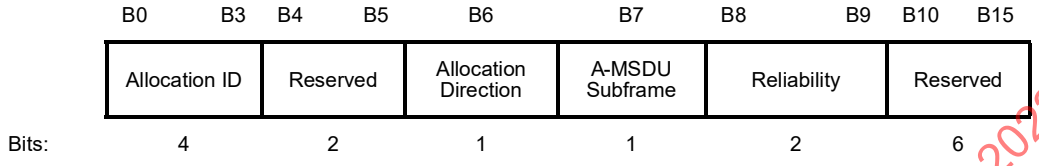

Figure 9-301—DMG Attributes field format

— Traffic streams can share an allocation through TSPEC aggregation (see Annex V). The Allocation ID subfield is used as follows:
  — When setting up a TS, the DMG STA that transmits an ADDTS Request frame containing a TSPEC or PTP TSPEC element sets the Allocation ID subfield to a nonzero value to identify the allocation it requires to carry the TS. Alternatively, the same DMG STA sets the Allocation ID subfield to 0 to indicate any CBAP allocation with the broadcast AID as Source AID.
  — When setting up a TS, the DMG STA that transmits the ADDTS Response frame containing the TSPEC or PTP TSPEC element sets the Allocation ID subfield to a nonzero value that identifies the allocation carrying the TS. Alternatively, the same DMG STA sets the Allocation ID subfield to 0 to indicate any CBAP allocation with the broadcast AID as Source AID and Destination AID.
  — When deleting a TS, the DMG STA that transmits the DELTS frame containing a TSPEC or PTP TSPEC element sets the Allocation ID subfield to a nonzero value to identify the allocation that is carrying the TS to be deleted. Alternatively, the same DMG STA sets the Allocation ID subfield to 0 to indicate no allocation exists to carry the TS to be deleted.
— The Allocation Direction subfield is equal to 1 when the originator of the ADDTS request is also the source of the allocation identified by the Allocation ID subfield and is equal to 0 otherwise. The Allocation Direction subfield is equal to 0 when the Allocation ID subfield is equal to 0.
— The A-MSDU Subframe subfield contains a value that indicates the A-MSDU subframe structure to be used for this TS. The A-MSDU Subframe subfield is set to 0 to indicate the Basic A-MSDU subframe structure and set to 1 to indicate the Short A-MSDU subframe structure.
— The Reliability subfield contains an expected reliability index. The reliability index refers to the PHY PER (PSDU error rate as in 20.3.3.8). The relation between the reliability index and the PER is shown in Table 9-162.

Table 9-162—Reliability subfield values

Reliability index	PER
0	Not specified
1	10^{-2}
2	10^{-3}
3	10^{-4}

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The Reliability subfield in an ADDTS Request frame that has the Direction subfield set to downlink or in an ADDTS Response frame that has the Direction field set to uplink indicates the expectation of the PER of the destination DMG STA for this TS. The Reliability subfield in an ADDTS Request frame that has the Direction subfield set to uplink or in an ADDTS Response frame that has the Direction field set to downlink is reserved. The reliability information is provided by the SME using the MLME-ADDTS.request primitive and MLME-ADDTS.response primitives. Together with the link margin (10.42.9) and other implementation-specific information, this value can be used by the source DMG STA of this TS to estimate the MCS to be used for this particular TS.

9.4.2.30 TCLAS element

The TCLAS element contains a set of parameters necessary to identify various kinds of PDU or incoming MSDU (from a higher layer in all STAs or from the DS in an AP) that belong to a particular TS. The TCLAS element is also used when the traffic does not belong to a TS, for example, by the FMS, DMS, and TFS services. If required, the TCLAS element is provided in ADDTS Request and ADDTS Response frames only for the downlink or bidirectional links. The TCLAS element is always included when a PTP TSPEC is transmitted to a peer STA via an AP or PCP. The structure of this element is shown in Figure 9-302.

	Element ID	Length	User Priority	Frame Classifier
Octets:	1	1	1	variable

Figure 9-302—TCLAS element format

The Element ID and Length fields are defined in 9.4.2.1.

When the UP field contains a value that is less than or equal to 7, the value specifies the UP of the associated MSDUs. When the UP field contains a value that is greater than or equal to 8 and less than or equal to 11, the value specifies the access category of the associated MPDUs. The UP field value 255 is reserved and indicates that the UP of the MSDU and the access category of the MPDU are not compared as part of the traffic filter. The encoding of the contents of the User Priority field of an TCLAS element is specified in Table 9-163.

Table 9-163—User Priority field of TCLAS element

User Priority	Meaning
0–7	The User Priority value of an MSDU.
8	The AC value of an MPDU is AC-VO.
9	The AC value of an MPDU is AC-VI.
10	The AC value of an MPDU is AC-BE.
11	The AC value of an MPDU is AC-BK.
12–254	Reserved.
255	The User Priority field is not used for comparison.

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The Frame Classifier field is defined in Figure 9-303.

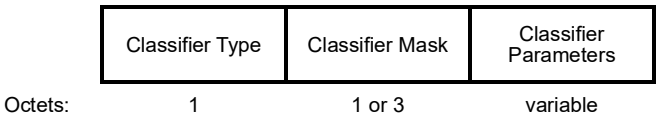

Figure 9-303—Frame Classifier field format

The Frame Classifier field comprises the following subfields: Classifier Type, Classifier Mask, and Classifier Parameters. The Classifier Type subfield specifies the type of classifier parameters in this TCLAS element as defined in Table 9-164.

Table 9-164—Frame classifier type

Classifier type	Classifier parameters
0	Ethernet parameters
1	TCP/UDP IP parameters
2	IEEE 802.1Q parameters
3	Filter Offset parameters
4	IP and higher layer parameters
5	IEEE 802.1D/Q parameters
6	IEEE 802.11 MAC header parameters
7	IEEE Std 802.11 downlink PV1 MPDU MAC header parameters (From DS field of the Frame Control field equal to 1)
8	IEEE Std 802.11 nondownlink PV1 MPDU MAC header parameters (From DS field of the Frame Control field equal to 0)
9	IEEE Std 802.11 PV1 MPDU Full Address MAC header parameters
10	IP extensions and higher layer parameters
11–255	Reserved

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When the classifier type is a value less than or equal to 5, but not equal to 3, the Classifier Mask subfield specifies a bitmap in which bits that have the value 1 identify a subset of the classifier parameters whose values need to match those of the corresponding parameters in a given MSDU for that MSDU to be classified to the TS of the affiliated TSPEC element. The bitmap is ordered from the LSB to the MSB, with each bit pointing to one of the classifier parameters of the same relative position as shown in this subclause based on classifier type. When there are more bits in the bitmap than classifier parameters that follow, the MSBs that do not point to any classifier parameters are reserved.

A Classifier Type subfield set to 6 applies only to frames with the Protocol Version subfield of the Frame Control field of the MAC header equal to 0.

A Classifier Type subfield set to 7 applies only to frames with the Protocol Version subfield of the Frame Control field of the MAC header equal to 1, the Type subfield of the Frame Control field of the MAC header equal to 0 or 1, and the From DS subfield of the Frame Control field of the MAC header equal to 1.

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A Classifier Type subfield set to 8 applies only to frames with the Protocol Version subfield of the Frame Control field of the MAC header equal to 1, the Type subfield of the Frame Control field of the MAC header equal to 0 or 1, and the From DS subfield of the Frame Control field of the MAC header equal to 0.

A Classifier Type subfield set to 9 applies only to frames with the Protocol Version subfield of the Frame Control field of the MAC header equal to 1 and the Type subfield of the Frame Control field of the MAC header equal to 3.

When the Classifier Type subfield is equal to 6, 7, 8, or 9, the Classifier Mask subfield is 3 octets in length and contains a sequence of 2-bit Classifier Mask Control subfields. Each Classifier Mask Control subfield applies to a specific target field of the MAC header of an MPDU and determines whether the target field is included in the comparison and whether an additional bitmask (the target field filter mask) is present. When the target field filter mask is present, it determines the bits of the target field that are used in the comparison.

The Classifier Mask Control subfield values are interpreted as follows:

— Setting the LSB of the two bits to 1 indicates the use of the corresponding MAC Header field for comparison, and setting the LSB of the two bits to 0 indicates the corresponding MAC header field is not used for comparison, and the corresponding Match Specification is not included in the Classifier.

— Setting the MSB of the two bits to 1 indicates the inclusion of the corresponding MAC Header Filter (a bit mask) in the corresponding Match Specification, and setting the MSB of the two bits to 0 indicates the MAC Header Filter is not included in the corresponding Match Specification and every bit of the Match Specification, if included in the Classifier Parameter, needs to be compared.

— If an optional MAC Header field needs to be compared, the LSB of the two bits in the Classifier Mask corresponding to the optional MAC header field is set to 1, and an MPDU that does not include the optional field is not a matching MPDU.

Table 9-165, Table 9-166, Table 9-167, and Table 9-168 specify the interpretation of the Classifier Mask Control subfield for each of the Classifier Type values 6, 7, 8, and 9, respectively.

Table 9-165—Classifier Mask for Classifier Type 6

Octet index	Bits index	Classifier parameters
0	B1B0	Frame Control
	B3B2	Duration/ID
	B5B4	Address 1
	B7B6	Address 2
1	B1B0	Address 3
	B3B2	Sequence Control
	B5B4	Address 4
	B7B6	QoS Control
2	B1B0	HT Control
	B3B2	Reserved
	B5B4	Reserved
	B7B6	Reserved

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Table 9-166—Classifier Mask for Classifier Type 7

Octet index	Bits index	Classifier parameters
0	B1B0	Frame Control
	B3B2	Address 1 (AID)
	B5B4	Address 2 (BSSID)
	B7B6	Sequence Control
1	B1B0	Address 3
	B3B2	Address 4
	B5B4	Reserved
	B7B6	Reserved
2	B1B0	Reserved
	B3B2	Reserved
	B5B4	Reserved
	B7B6	Reserved

Table 9-167—Classifier Mask for Classifier Type 8

Octet index	Bits index	Classifier parameters
0	B1B0	Frame Control
	B3B2	Address 1 (BSSID)
	B5B4	Address 2 (AID)
	B7B6	Sequence Control
1	B1B0	Address 3
	B3B2	Address 4
	B5B4	Reserved
	B7B6	Reserved
2	B1B0	Reserved
	B3B2	Reserved
	B5B4	Reserved
	B7B6	Reserved

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Table 9-168—Classifier Mask for Classifier Type 9

Octet index	Bits index	Classifier parameters
0	B1B0	Frame Control
	B3B2	Address 1
	B5B4	Address 2
	B7B6	Sequence Control
1	B1B0	Reserved
	B3B2	Reserved
	B5B4	Reserved
	B7B6	Reserved
2	B1B0	Reserved
	B3B2	Reserved
	B5B4	Reserved
	B7B6	Reserved

The map from the location of the Classifier Mask subfield to the target subfield is defined in Table 9-169.

Table 9-169—Map from location of Classifier Mask subfield to target subfield

Bit number	Target field
0–1	Frame Control
2–3	Duration/ID
4–5	Address 1
6–7	Address 2
8–9	Address 3
10–11	Sequence Control
12–13	Address 4
14–15	QoS Control
16–17	HT Control
18–23	Reserved

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For Classifier Type 0, the classifier parameters are the following parameters contained in an Ethernet frame header: Source Address, Destination Address, and Type ("Ethernet" [B9]). The endianness of the Type field is defined in "Ethernet" [B9]. The Frame Classifier field for Classifier Type 0 is defined in Figure 9-304. It has a length of 16 octets.

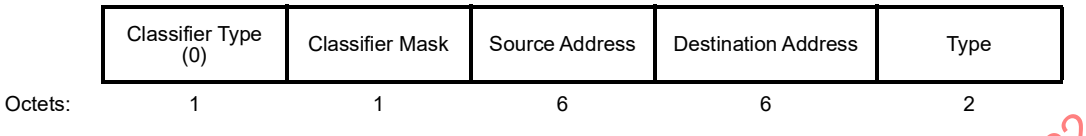

Figure 9-304—Frame Classifier field format of Classifier Type 0

For Classifier Type 1, frame classifier is defined for both IPv4 and IPv6, shown in Figure 9-305 and Figure 9-306, and distinguished by the Version field. Use of Classifier Type 1 for IPv6 is deprecated and replaced by Classifier Type 4. The subfields in the classifier parameters are represented and transmitted in the big-endian format. The classifier parameters are the following parameters:

- In the IP header: Source Address, Destination Address and Version.
- In a TCP or UDP header: Source Port and Destination Port, plus
- One of the following:
  - In an IPv4 header: Differentiated Services Code Point (DSCP) (IETF RFC 2474 [B30]) and Protocol, or
  - In an IPv6 header: Flow Label.

Figure 9-305—Frame Classifier field format of Classifier Type 1 for traffic over IPv4

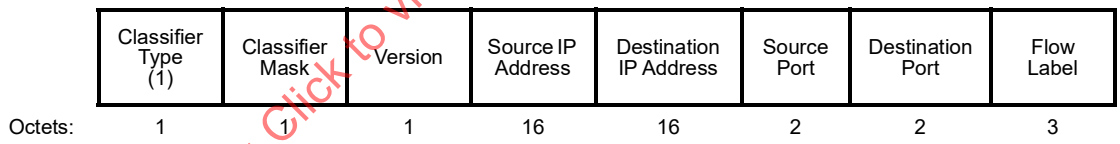

Figure 9-306—Frame Classifier field format of Classifier Type 1 for traffic over IPv6

The DSCP field contains a value in the 6 LSBs, and the 2 MSBs are set to 0. The 2 MSBs of the DSCP field are ignored for frame classification.

The value in the Version subfield is the value specified in IETF RFC 791 or IETF RFC 8200.

For Classifier Type 2, the Classifier Parameter is the IEEE 802.1Q-2003 VLAN Tag TCI. The endianness of the IEEE 802.1Q VLAN TCI field is defined in IEEE Std 802.1Q for the VLAN Tag TCI. The Frame Classifier field for Classifier Type 2 is defined in Figure 9-307. Classifier Type 2 is deprecated.

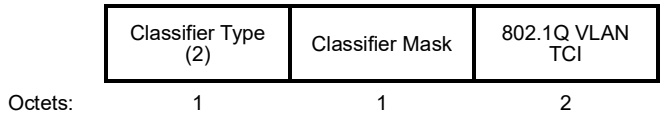

Figure 9-307—Frame Classifier field format of Classifier Type 2

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For Classifier Type 3, the classifier parameters are defined by a Filter Offset subfield, a Filter Value subfield and a Filter Mask subfield. The Frame Classifier subfield of Classifier Type 3 is defined in Figure 9-308. It has a variable length.

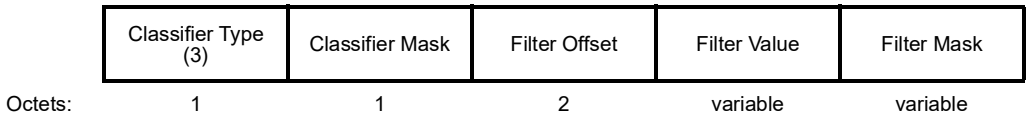

Figure 9-308—Frame Classifier field format of Classifier Type 3

The Classifier Mask subfield is reserved.

The Filter Offset subfield is set to the number of octets from the beginning of the MSDU or MMPDU at which the Filter Value is compared.

The length of the Filter Value and Filter Mask subfields is (*Length* – 5)/2, where *Length* is the value in the Length field of the TCLAS element.

The Filter Value subfield is an octet string that is compared to the MSDU or MMPDU content, beginning at the octet indicated by the Filter Offset.

The Filter Mask subfield is an octet string that is used to indicate the bits in the Filter Value subfield to be compared. The length of the Filter Mask subfield is equal to the length of the Filter Value subfield. A bit in the Filter Value subfield is compared only if the matching bit in the Filter Mask subfield is 1.

For Classifier Type 4, frame classifier is defined for both IPv4 and IPv6, shown in Figure 9-309 (with the Classifier Type subfield set to 4) and Figure 9-310, and distinguished by the Version subfield. The classifier parameters represent corresponding values in a received IPv4 or IPv6 frame and are defined in Table 9-170. The subfields in the classifier parameters are represented and transmitted in big-endian format.

Table 9-170—Classifier parameters for Classifier Type 4

Subfield	Included in IPv4	IPv4 field length (octets)	Included in IPv6	IPv6 field length (octets)
Version	Yes	1	Yes	1
Source IP Address	Yes	4	Yes	16
Destination IP Address	Yes	4	Yes	16
Source Port	Yes	2	Yes	2
Destination Port	Yes	2	Yes	2
DSCP	Yes	1	Yes	1
Protocol	Yes	1	No	n/a
Next Header	No	n/a	Yes	1
Flow Label	No	n/a	Yes	3

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The Frame Classifier subfield of Classifier Type 4 for traffic over IPv4 is shown in Figure 9-309.

	Classifier Type (4)	Classifier Mask	Version(4)	Source IP Address	Destination IP Address
Octets:	1	1	1	4	4
	Source Port	Destination Port	DSCP	Protocol	Reserved
Octets:	2	2	1	1	1

Figure 9-309—Frame Classifier subfield format of Classifier Type 4 for traffic over IPv4

The Frame Classifier subfield of Classifier Type 4 for traffic over IPv6 is shown in Figure 9-310.

	Classifier Type (4)	Classifier Mask	Version(6)	Source IP Address	Destination IP Address
Octets:	1	1	1	16	16
	Source Port	Destination Port	DSCP	Next Header	Flow Label
Octets:	2	2	1	1	3

Figure 9-310—Frame Classifier subfield format of Classifier Type 4 for traffic over IPv6

NOTE 1—Frame classification when extension headers are used is supported only if the TCLAS does not classify on ports (Classifier Mask has the Source and Destination Port bits set to 0).

The value in the Version subfield is the value specified in IETF RFC 791 or IETF RFC 8200.

The DSCP subfield contains the value as described in IETF RFC 2474 [B30] in the 6 least significant bits. The 2 most significant bits are reserved. For an IPv6 packet, this corresponds to the Traffic Class subfield of the IPv6 header.

The Source IP Address and Destination IP Address correspond to the identically named fields of the IPv4 and IPv6 headers.

The Source Port and Destination Port correspond to the identically named fields of various protocol headers that are encapsulated within an IPv4 or IPv6 packet.

The Next Header subfield contains the next encapsulated protocol which is either the value specified in the IPv4 header's Protocol field or the value in the Next Header field of the IPv6 header. In the presence of options in the IPv6 header, the Next Header field specifies the presence of one or more extension headers as registered in "IPv6 Extension Header Types" [B50] and defined by the corresponding IETF RFCs.

The Flow Label subfield contains the value in the 20 least significant bits. The 4 most significant bits are reserved.

NOTE 2—For example, the flow label 0x12345 is represented as the octet sequence 0x01, 0x23, 0x45.

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A TCLAS element is valid when the Classifier Mask Version bit is 1.

For Classifier Type 5 when used to match an IEEE 802.1D-2004 frame [B18], the classifier parameter is only the User Priority, and the DEI and VID parameters are ignored. For Classifier Type 5 when used to match an IEEE 802.1Q frame, the classifier parameters are: Priority Code Point, Drop Eligibility Indicator (DEI), and VLAN ID (VID).

The Frame Classifier field for Classifier Type 5 is defined in Figure 9-311.

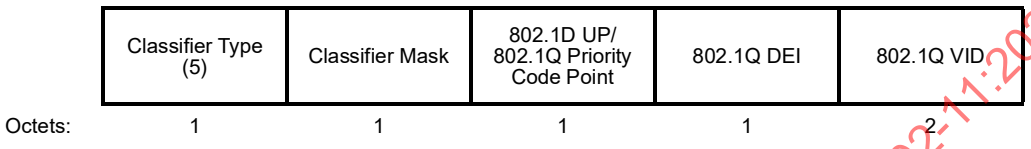

Figure 9-311—Frame Classifier field format of Classifier Type 5

The subfields in the classifier parameters are represented and transmitted in big-endian format.

The 802.1D UP/802.1Q Priority Code Point subfield contains the value to be matched to the appropriate type frame header in the 4 LSBs; the 4 MSBs are reserved.

The 802.1Q DEI subfield contains the value to match against an IEEE 802.1Q frame header, in the LSB; the 7 MSBs are reserved. When matching an IEEE 802.1D-2004 frame header, this subfield is ignored.

The 802.1Q VID subfield contains the value to match against an IEEE 802.1Q frame header, in the 12 LSBs; the 4 MSBs are reserved. When matching an IEEE 802.1D-2004 frame header, this subfield is ignored.

For Classifier Type 6, the format of the Frame Classifier field of a TCLAS element is shown in Figure 9-312.

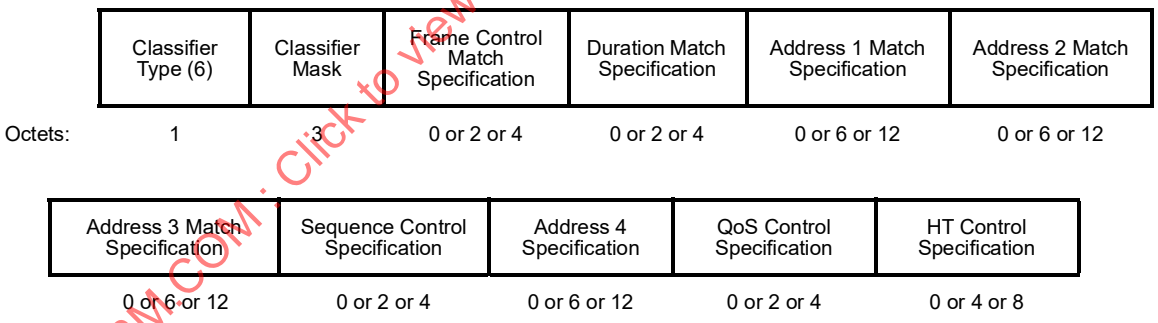

Figure 9-312—Frame Classifier field format of Classifier Type 6

For Classifier Type 6, the formats of the Frame Control Match Specification subfield, Duration/ID Match Specification subfield, Address 1 Match Specification subfield, Address 2 Match Specification subfield, Address 3 Match Specification subfield, Sequence Control Match Specification subfield, Address 4 Match Specification subfield, QoS Control Match Specification subfield and HT Control Match Specification subfield of the Frame Classifier field of a TCLAS element are shown in Figure 9-313, Figure 9-314, Figure 9-315, Figure 9-316, Figure 9-317, Figure 9-318, Figure 9-319, Figure 9-320, and Figure 9-321, respectively. The Match Specification subfield contains the match specification (i.e., the parameters) of the corresponding MAC header field with which an MPDU is compared. When the corresponding Filter Mask is not present, every bit in a Match Specification is compared; otherwise, only the bits with the same bit positions as the bits that are equal to 1 in the corresponding Filter Mask subfield are compared.

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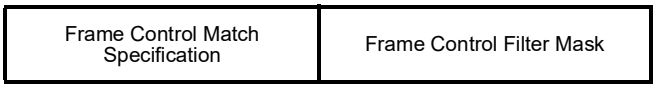

Figure 9-313—Frame Control Match Specification subfield format of Classifier Type 6, 7, 8, 9

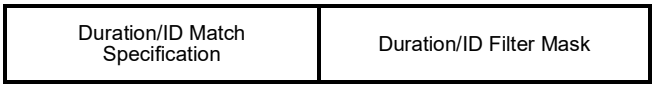

Figure 9-314—Duration/ID Match Specification subfield format of Classifier Type 6

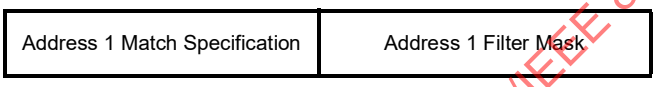

Figure 9-315—Address 1 Match Specification subfield format of Classifier Type 6, 8, 9

Figure 9-316—Address 2 Match Specification subfield format of Classifier Type 6, 7, 9

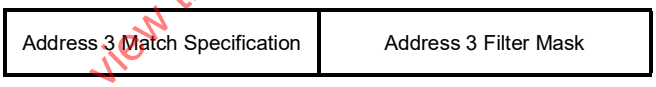

Figure 9-317—Address 3 Match Specification subfield format of Classifier Type 6, 7, 8

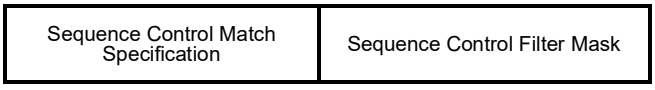

Figure 9-318—Sequence Control Match Specification subfield format of Classifier Type 6, 7, 8, 9

Figure 9-319—Address 4 Match Specification subfield format of Classifier Type 6, 7, 8

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QoS Control Match Specification	QoS Control Filter Mask
Octets: 2	0 or 2

Figure 9-320—QoS Control Match Specification subfield format of Classifier Type 6

HT Control Match Specification	HT Control Filter Mask
Octets: 4	0 or 4

Figure 9-321—HT Control Match Specification subfield format of Classifier Type 6

For Classifier Type 7, the format of the Frame Classifier field of a TCLAS element is shown in Figure 9-322.

	Classifier Type (7)	Classifier Mask	Frame Control Match Specification	Address 1 (SID) Match Specification	Address 2 Match Specification	Sequence Control Match Specification	Address 3 Match Specification	Address 4 Match Specification
Octets:	1	3	0, 2, or 4	0, 2, or 4	0, 6, or 12	0, 2, or 4	0, 6, or 12	0, 6, or 12

Figure 9-322—Frame Classifier field format of Classifier Type 7

For Classifier Type 7, the formats of the Frame Control Match Specification subfield, Address 1 (SID) subfield, Address 2 (BSSID) subfield, Sequence Control subfield, Address 3 subfield, and Address 4 subfield of the Frame Classifier field of a TCLAS element are shown in Figure 9-313, Figure 9-323, Figure 9-316, Figure 9-318, Figure 9-317, and Figure 9-319, respectively. The Match Specification subfield contains the match specification (i.e., the parameters) of the corresponding MAC header field with which an MPDU needs to be compared. When the corresponding Filter Mask subfield is not present, every bit in a Match Specification subfield needs to be compared; otherwise, only the bits with the same bit positions as the bits that are equal to 1 in the corresponding Filter Mask subfield are compared.

Address 1 (SID) Match Specification	Address 1 Filter Mask
Octets: 2	0, or 2

Figure 9-323—Address 1 (SID) Match Specification subfield format of Classifier Type 7

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For Classifier Type 8, the format of the Frame Classifier field of a TCLAS element is shown in Figure 9-324.

	Classifier Type (8)	Classifier Mask	Frame Control Match Specification	Address 1 (BSSID) Match Specification	Address 2 (SID) Match Specification	Sequence Control Match Specification	Address 3 Match Specification	Address 4 Match Specification
Octets:	1	3	0, 2, or 4	0, 6, or 12	0, 2, or 4	0, 2, or 4	0, 6, or 12	0, 6, or 12

Figure 9-324—Frame Classifier field format of Classifier Type 8

For Classifier Type 8, the formats of the Frame Control Match Specification subfield, Address 1 (BSSID) subfield, Address 2 (SID) subfield, Sequence Control subfield, and Address 3 subfield are shown in Figure 9-313, Figure 9-315, Figure 9-325, Figure 9-318, Figure 9-317, and Figure 9-319, respectively. The Match Specification subfield contains the match specification (i.e., the parameters) of the corresponding MAC header field with which an MPDU needs to be compared. When the corresponding Filter Mask subfield is not present, every bit in a Match Specification subfield needs to be compared; otherwise, only the bits with the same bit positions as the bits that are equal to 1 in the corresponding Filter Mask subfield are compared.

	Address 2(SID) Match Specification	Address 2 Filter Mask
Octets:	2	0, or 2

Figure 9-325—Address 2 (SID) Match Specification subfield format of Classifier Type 8

For Classifier Type 9, the format of the Frame Classifier field of a TCLAS element is shown in Figure 9-326.

	Classifier Type (9)	Classifier Mask	Frame Control Match Specification	Address 1 Match Specification	Address 2 Match Specification	Sequence Control Match Specification
Octets:	1	3	0, 2, or 4	0, 6, or 12	0, 6, or 12	0, 2, or 4

Figure 9-326—Frame Classifier field format of Classifier Type 9

For Classifier Type 9, the formats of the Frame Control Match Specification subfield, Address 1 subfield, Address 2 subfield, and Sequence Control subfield are shown in Figure 9-313, Figure 9-315, Figure 9-316, and Figure 9-318, respectively. The Match Specification subfield contains the match specification (i.e., the parameters) of the corresponding MAC header field with which an MPDU needs to be compared. When the corresponding Filter Mask subfield is not present, every bit in a Match Specification subfield needs to be compared; otherwise, only the bits with the same bit positions as the bits that are set to 1 in the corresponding Filter Mask subfield are compared.

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For Classifier Type 10, the Frame Classifier field for IP extensions and higher layer parameters is defined for packets using IPv4 and IPV6 as shown in Figure 9-327. The subfields in the classifier parameters are represented and transmitted in the big-endian format.

	Classifier Type (10)	Protocol Instance	Protocol Number or Next Header	Filter Value	Filter Mask
Octets:	1	1	1	variable	variable

Figure 9-327—Frame Classifier field format of Classifier Type 10 for packets using IPV4 or IPV6

The Protocol Instance subfield indicates the instance number of the protocol identified by the Protocol Number or Next Header subfield. A value of 0 in this field matches the first instance of the Protocol Number or Next Header. A value of 1 matches the second instance, and so on. The only value of Protocol Number or Next Header subfield that is allowed to appear more than once within an IP packet is the Destination Options extension header of IPv6.

The Protocol Number or Next Header subfield contains an IPv4 Protocol Number or an IPv6 Next Header value, which share a common interpretation also known as an IP Protocol Number. The Protocol Number or Next Header subfield value is compared against the Protocol field value of an IPv4 header and to all Next Header field values in an IPv6 packet. This is also true for an IPv6 packet that is encapsulated within an IPv4 packet. This matching operation is not maskable.

The lengths of the Filter Value and Filter Mask subfields are the same and are each equal to (Length – 4)/2 octets, where Length is the value in the Length field of the TCLAS element.

The Filter Value subfield is an octet string that is compared to the MSDU content, beginning at the first octet of the protocol information which is identified by the Protocol Number or Next Header subfield.

The Filter Mask subfield is an octet string that is used to indicate which bits in the Filter Value subfield are compared. A bit in the Filter Value subfield is compared only if the matching bit in the Filter Mask subfield is 1.

Figure 9-328 shows an example of how the Filter Value subfield is applied to an IPv4 packet.

When the Protocol Number or Next Header subfield value of the Frame Classifier matches the value in the Protocol subfield of the IPv4 header, in this case the identifier that corresponds to protocol XYZ, then the first Filter Value octet is compared to Protocol XYZ octet 0 and so on.

Figure 9-329 shows an example of how the Filter Value subfield is applied to an IPv6 packet that contains multiple extension headers.

When the Protocol Number or Next Header subfield value of the Frame Classifier matches the value of a Next Header field of any IPv6 Header or IPv6 Extension Header, then the first Filter Value octet is compared to the first octet of the header of of the payload that is identified by the matching Protocol Number or Next Header subfield value and so on. For example, if the Protocol Number or Next Header subfield value of a Frame Classifier of Classifier Type 10 contains the identifier for IPv6 Extension Header GHI, then this value matches the first entry of the seventh row in the figure and the Filter Value comparison begins at the first octet indicated on the ninth row of the figure. The comparison stops after the first match of a Next Header field.

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B0 B31

Version	IHL	DSCP	ECN	Total Length	
Identification				Flags	Fragment Offset
Time To Live		Protocol [containing the Identifier for Protocol XYZ]		Header Checksum	
Source IP Address					
Destination IP Address					
Options					
Protocol XYZ octet 0		Protocol XYZ octet 1		Protocol XYZ octet 2	Protocol XYZ octet 3
etc					

Figure 9-328—IPv4 packet example for Classifier Type 10

B0 B31

Version	Traffic Class	Flow Label	
Payload Length		Next Header [containing the identifier for Extension Header ABC]	Hop Limit
Source IP Address			
Destination IP Address			
Next Header [Extension Header ABC octet 0][containing the identifier for Extension Header DEF]	Extension Header ABC octet 1	Extension Header ABC octet 2	Extension Header ABC octet 3
Extension Header ABC octet 4	etc		
Next Header [Extension Header DEF octet 0][containing the identifier for Extension Header GHI]	Extension Header DEF octet 1	Extension Header DEF octet 2	Extension Header DEF octet 3
Extension Header DEF octet 4	etc		
Next Header [Extension Header GHI octet 0] [containing the identifier for Protocol XYZ]	Extension Header GHI octet 1	Extension Header GHI octet 2	Extension Header GHI octet 3
Extension Header GHI octet 4	etc		
Protocol XYZ octet 0	Protocol XYZ octet 1	Protocol XYZ octet 2	Protocol XYZ octet 3
etc			

Figure 9-329—IPv6 packet example for Classifier Type 10

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9.4.2.31 TS Delay element

The TS Delay element is used in an ADDTS Response frame transmitted by an HC and indicates the time after which the ADDTS can be retried; see 11.4.7. The TS Delay element is defined in Figure 9-330.

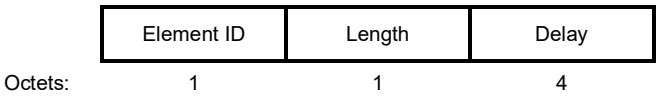

Figure 9-330—TS Delay element format

The Element ID and Length fields are defined in 9.4.2.1.

The Delay field specifies the amount of time, in TUs, a STA should wait before it reinitiates setup of a TS.

The Delay field is set to 0 when an AP does not expect to serve any TSPECs for an indeterminate time and does not know this time a priori.

9.4.2.32 TCLAS Processing element

The TCLAS Processing element is present in ADDTS Request, ADDTS Response, FMS Request, FMS Response, DMS Request, DMS Response, TFS Request and SCS Descriptor frames if there are multiple TCLAS elements associated with the request, response or descriptor. It is optionally present in the ADDTS Request and ADDTS Response frames if there are no TCLAS elements. Together with the TCLAS element(s), if present, it indicates how a PDU or MSDU should be processed by the classifier. The TCLAS Processing element is defined in Figure 9-331.

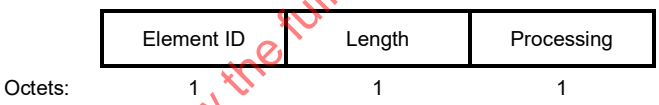

Figure 9-331—TCLAS Processing element format

The Element ID and Length fields are defined in 9.4.2.1.

The encoding of the Processing subfield is shown in Table 9-171.

Table 9-171—Encoding of Processing subfield

Processing subfield value	Meaning
0	PDU contents or MSDU parameters have to match to the parameters in all of the associated TCLAS elements.
1	PDU contents or MSDU parameters have to match to at least one of the associated TCLAS elements.
2	PDUs or MSDUs that do not belong to any other TS are classified to the TS for which this TCLAS Processing element is used. In this case, there are no associated TCLAS elements.
3–255	Reserved

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9.4.2.33 Schedule element

The Schedule element is transmitted by the HC to a STA to announce the schedule that the HC follows for admitted streams originating from or destined to that STA, or GCR-SP streams destined to that STA, in the future. The information in this element might be used by the STA for power management, internal scheduling, or any other purpose. The element information format is shown in Figure 9-332.

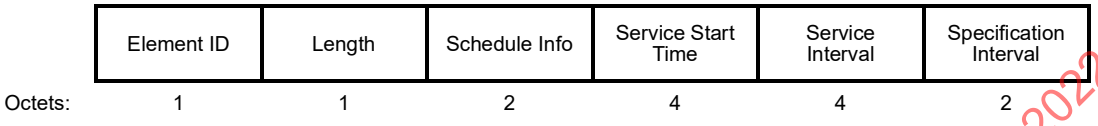

Figure 9-332—Schedule element format

The Element ID and Length fields are defined in 9.4.2.1.

The Schedule Info field is shown in Figure 9-333.

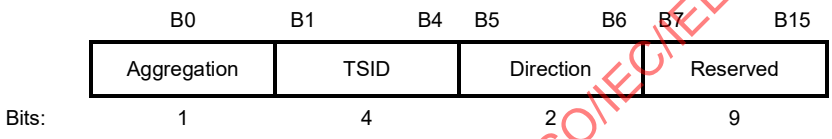

Figure 9-333—Schedule Info field format

The Aggregation subfield is set to 1 if the schedule is an aggregate schedule for all TSIDs associated with the STA to which the frame is directed. It is set to 0 otherwise. The TSID subfield contains a value allowed for a TSID, as defined in 9.2.4.5.2, and indicates the TSID for which this schedule applies. The TSID subfield is reserved when the Schedule element is included within a GCR Response subelement. The Direction subfield is defined in 9.4.2.29 and defines the direction of the TSPEC associated with the schedule. In a Schedule element sent within a GCR Response subelement, the Direction subfield is set to "Downlink." The TSID and Direction subfields are valid only when the Aggregation subfield is 0. If the Aggregation subfield is 1, the TSID and Direction subfields are reserved.

The Service Start Time field indicates the anticipated time, expressed in microseconds, when service starts and represents the lower order 4 octets of the TSF timer value at the start of the first SP. The AP uses this field to confirm or modify the service start time indicated in the TSPEC request.

The Service Interval field indicates the time, expressed in microseconds, between two successive SPs and represents the measured time from the start of one SP to the start of the next SP. If the Schedule element is included within a GCR Response subelement that has the GCR delivery method equal to GCR-SP, the Service Interval field set to 0 indicates the delivery method is GCR-A.

The Specification Interval field contains an unsigned integer that specifies the time interval, in TUs, to verify schedule compliance.

The HC can set the Service Start Time field and the Service Interval field to 0 (unspecified) for nonpowersaving STAs, except when the Schedule element is included within a GCR Response subelement that has the GCR delivery method equal to GCR-SP (see 11.21.16.3.8). When the Schedule element is included within a GCR Response subelement that has the GCR delivery method equal to GCR-SP, the Service Start Time field is not set to 0 and the Service Interval field might be set to 0.

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9.4.2.34 QoS Capability element

The QoS Capability element contains a number of subfields that are used to advertise optional QoS capabilities at a QoS STA. The QoS Capability element is defined in Figure 9-334.

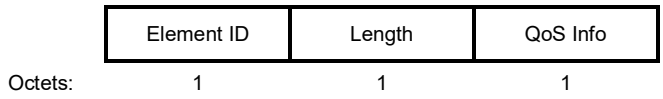

Figure 9-334—QoS Capability element format

The Element ID and Length fields are defined in 9.4.2.1.

The QoS Info field is defined in 9.4.1.17.

9.4.2.35 AP Channel Report element

The AP Channel Report element contains a list of channels where a STA is likely to find an AP. The format of the AP Channel Report element is shown in Figure 9-335. See 11.10.18 for details.

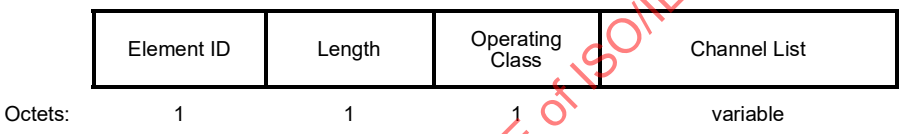

Figure 9-335—AP Channel Report element format

The Element ID and Length fields are defined in 9.4.2.1.

The Operating Class field contains an enumerated value from Annex E, specifying the operating class in which the Channel List field is valid. An AP Channel Report only reports channels for a single operating class. Multiple AP Channel Report elements are present when reporting channels in more than one operating class.

The Channel List field contains a variable number of octets, where each octet describes a single channel number. Channel numbering is dependent on Operating Class according to Annex E.

9.4.2.36 Neighbor Report element

The Neighbor Report element describes an AP. The format of the Neighbor Report element is shown in Figure 9-336.

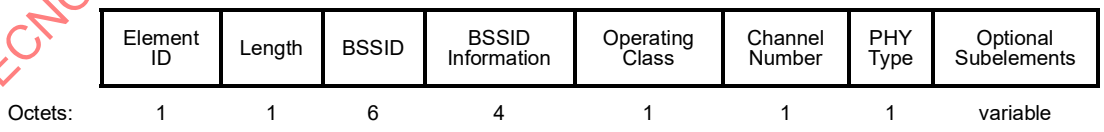

Figure 9-336—Neighbor Report element format

The Element ID and Length fields are defined in 9.4.2.1.

The value of the BSSID field is the BSSID of the BSS being reported. The subsequent fields in the Neighbor Report element pertain to this BSS.

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The BSSID Information field can be used to help determine neighbor service set transition candidates. The format of the BSSID Information field is shown in Figure 9-337.

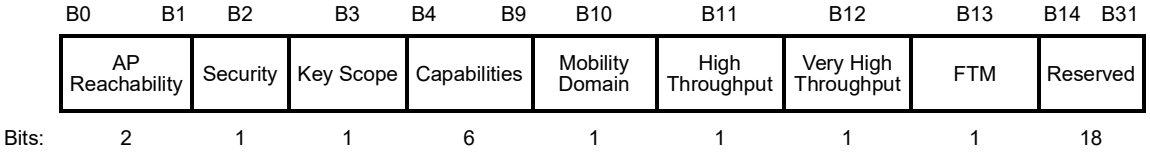

Figure 9-337—BSSID Information field format

The AP Reachability field indicates whether the AP identified by this BSSID is reachable by the STA that requested the neighbor report. For example, the AP identified by this BSSID is reachable for the exchange of preauthentication frames as described in 12.6.10.2. The values are shown in Table 9-172.

Table 9-172—Reachability field

Value	Reachability	Usage
0	Reserved	Not used.
1	Not Reachable	A station sending a preauthentication frame to the BSSID will not receive a response even if the AP indicated by the BSSID is capable of preauthentication.
2	Unknown	The AP is unable to determine if the value Reachable or Not Reachable is to be returned.
3	Reachable	The station sending a preauthentication frame to the BSSID can receive a response from an AP that is capable of preauthentication.

The Security bit, if 1, indicates that the AP identified by this BSSID supports the same security provisioning as used by the STA in its current association. If the bit is 0, it indicates either that the AP does not support the same security provisioning or that the security information is not available at this time.

The Key Scope bit, when set, indicates the AP indicated by this BSSID has the same authenticator as the AP sending the report. If this bit is 0, it indicates a distinct authenticator or the information is not available.

The Capabilities subfield contains selected capability information for the AP indicated by this BSSID. The bit fields within this subfield have the same meaning and are set to the equivalent bits within the Capability Information field (see 9.4.1.4) being sent in the beacons by the AP being reported. The format of the Capabilities subfield is shown in Figure 9-338.

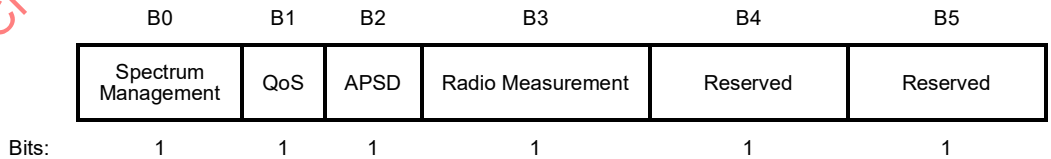

Figure 9-338—Capabilities subfield format

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The Mobility Domain bit is set to 1 to indicate that the AP represented by this BSSID is including an MDE in its Beacon frames and that the contents of that MDE are identical to the MDE advertised by the AP sending the report.

The High Throughput bit is set to 1 to indicate that the AP represented by this BSSID is an HT AP including the HT Capabilities element in its Beacons, and that the contents of that HT Capabilities element are identical to the HT Capabilities element advertised by the AP sending the report.

The Very High Throughput bit is set to 1 to indicate that the AP represented by this BSSID is a VHT AP and that the VHT Capabilities element, if included as a subelement in the report, is identical in content to the VHT Capabilities element included in the AP's Beacon.

The FTM field is set to 1 to indicate that the AP represented by this BSSID is an AP that has set the Fine Timing Measurement Responder field of the Extended Capabilities element to 1. The FTM field is set to 0 to indicate either that the reporting AP has dot11FineTimingMsmtRespActivated equal to false, or the reported AP has not set the Fine Timing Measurement Responder field of the Extended Capabilities element to 1 or that the Fine Timing Measurement Responder field of the reported AP is not available to the reporting AP at this time.

Bits 14–31 are reserved.

The Operating Class field indicates the channel set of the AP indicated by this BSSID. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing for the channel on which the Beacon frames are being transmitted for the BSS being reported. Valid operating classes are listed in Annex E.

The Channel Number field indicates the last known primary channel of the AP indicated by this BSSID. Channel number is defined within an operating class as shown in Annex E.

The PHY Type field indicates the PHY type of the AP indicated by this BSSID. It is an integer value coded according to the value of the dot11PHYType.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-173.

Table 9-173—Optional subelement IDs for Neighbor Report

Subelement ID	Name	Extensible
0	Reserved	
1	TSF Information	Yes
2	Condensed Country String	Yes
3	BSS Transition Candidate Preference	No
4	BSS Termination Duration	No
5	Bearing	No
6	Wide Bandwidth Channel	Yes
7–38	Reserved	
39	Measurement Report	Subelements

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Table 9-173—Optional subelement IDs for Neighbor Report *(continued)*

Subelement ID	Name	Extensible
40–44	Reserved	
45	HT Capabilities subelement	Yes
46–60	Reserved	
61	HT Operation subelement	Yes
62	Secondary Channel Offset subelement	No
63–65	Reserved	
66	Measurement Pilot Transmission	Subelements
67–69	Reserved	
70	RM Enabled Capabilities	Yes
71	Multiple BSSID	Subelements
72–190	Reserved	
191	VHT Capabilities	Yes
192	VHT Operation	Yes
193–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The TSF subelement contains TSF Offset and Beacon Interval subfields as shown in Figure 9-339.

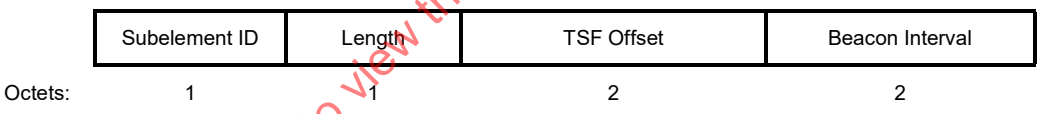

Figure 9-339—TSF subelement format

The Length field is defined in 9.4.3.

The TSF Offset subfield contains the neighbor AP's TSF timer offset. This is the time difference, in TUs, between the serving AP and a neighbor AP. This offset is given modulo the neighbor AP's Beacon Interval and rounded to the nearest TU boundary.

The Beacon Interval field is the beacon interval of the Neighbor AP indicated by this BSSID. This field is defined in 9.4.1.3 and in Figure 9-84.

The Condensed Country String subelement's Data field contains the first two octets of the value contained in dot11CountryString. This subelement is present only if the country of the neighbor AP indicated by the BSSID differs from the country of the AP that sent this neighbor report.

The Measurement Pilot Transmission subelement has the same format as the Measurement Pilot Transmission element (see 9.4.2.41). The Measurement Pilot Transmission subelement is not included if the reported AP is not transmitting Measurement Pilot frames or if the measurement pilot interval of the reported AP is unknown.

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A Measurement Report subelement with the Measurement Type field equal to LCI (see Table 9-125) is optionally present. If present, the subelement has the same format as the Measurement Report element with Measurement Type field equal to LCI.The subelement indicates the LCI of the neighbor STA and further includes the Z subelement, or the subelement indicates an unknown LCI (see 11.21.6.7). The Late, Incapable and Refused bits in the Measurement Report Mode field are set to 0. The Co-Located BSSID List subelement is present in the Measurement Report subelement of the Neighbor Report element, when there is at least one other BSS that is co-located within the same physical device as the reporting BSS.

A Measurement Report subelement with the Measurement Type field equal to Location Civic (see Table 9-125) is optionally present. If present, the subelement has the same format as the Measurement Report element with Measurement Type field equal to Location Civic, and the subelement indicates the civic address of the transmitting STA or an unknown civic address (see 11.21.6.7). The Late, Incapable and Refused bits in the Measurement Report Mode field are set to 0. The Co-Located BSSID List subelement is present in the Measurement Report subelement of the Neighbor Report element, when there is at least one other BSS which is co-located within the same physical device as the reporting BSS. When a Measurement Report subelement with Measurement Type field equal to LCI that includes a Co-Located BSSID List subelement is present, the Co-Located BSSID List subelement is not present in the Measurement Report subelement with Measurement Type field equal to Location Civic.

The HT Capabilities subelement is the same as the HT Capabilities element as defined in 9.4.2.55.

The HT Operation subelement is the same as the HT Operation element as defined in 9.4.2.56.

The Secondary Channel Offset subelement is the same as the Secondary Channel Offset element as defined in 9.4.2.19.

The RM Enabled Capabilities subelement has the same format as the RM Enabled Capabilities element (see 9.4.2.44).

The Multiple BSSID subelement has the same format as the Multiple BSSID element (see 9.4.2.45). The reference BSSID for the Multiple BSSID subelement is the BSSID field in the Neighbor Report element. This subelement is not present if the neighbor AP is not a member of a multiple BSSID set with two or more members or its membership is unknown. (see 11.10.14).

The format of the BSS Transition Candidate Preference subelement is shown in Figure 9-340.

	Subelement ID	Length	Preference
Octets:	1	1	1

Figure 9-340—BSS Transition Candidate Preference subelement format

The Length field is defined in 9.4.3.

The Preference field indicates the network preference for BSS transition to the BSS listed in this BSS Transition Candidate List Entries field in the BSS Transition Management Request frame, BSS Transition Management Query frame, and BSS Transition Management Response frame. The Preference field value is a number ranging from 0 to 255, as defined in Table 9-174, indicating an ordering of preferences for the BSS transition candidates for this STA. Additional details describing use of the Preference field are provided in 11.21.7.

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Table 9-174—Preference field values

Preference field value	Description
0	Excluded BSS; reserved when present in the BSS Transition Management Query or BSS Transition Management Response frames.
1–255	Relative values used to indicate the preferred ordering of BSSs, with 255 indicating the most preferred candidate and 1 indicating the least preferred candidate.

The BSS Termination TSF field contained in the BSS Termination Duration subelement is the TSF time of the BSS transmitting the neighbor report that corresponds to the time when termination of the neighbor BSS occurs. How the BSS determines the neighbor BSS termination time is out of scope of the standard. The format of the BSS Termination Duration subelement is shown in Figure 9-341.

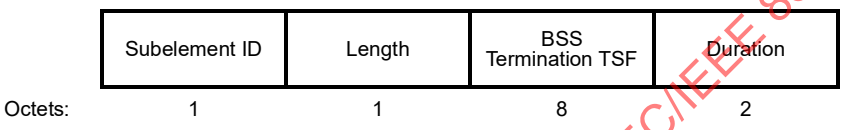

Figure 9-341—BSS Termination Duration subelement format

The Length field is defined in 9.4.3.

The BSS Termination TSF field indicates the value of the TSF timer when BSS termination will occur in the future. A BSS Termination TSF field set to 0 indicates that termination of the BSS will occur imminently. Prior to termination of the BSS, all associated STAs are disassociated by the AP.

The Duration field is an unsigned 2-octet integer that indicates the number of minutes for which the BSS is not present. A Duration field set to 0 is reserved. A Duration field set to 65 535 when the BSS is terminated for a period longer than or equal to 65 535 minutes.

The format of the Bearing subelement is shown in Figure 9-342.

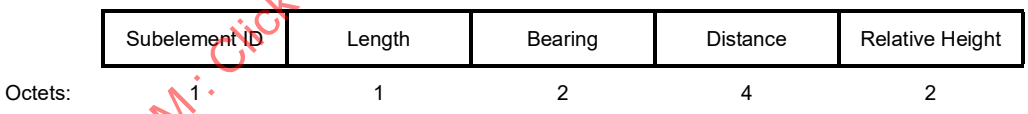

Figure 9-342—Bearing subelement format

The Length field is defined in 9.4.3.

The Bearing field specifies the direction that the neighbor, specified by the BSSID field in the Neighbor Report element, is positioned, relative to the reporting BSS and defined in relation to true north, increasing clockwise, measured in degrees from 0° to 359°. If the Bearing value is unknown, the subelement is not included.

The Distance field specifies the distance that the neighbor, specified by the BSSID field in the Neighbor Report element, is positioned relative to the reporting BSS as a 4-octet single precision floating point value represented by a binary32 floating point value as defined in IEEE Std 754-2008, with the least significant bit of the fraction occurring in bit 0 of the field, in meters. If the Distance field value is unknown the field is set to 0.

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The Relative Height field, defined by a 2s complement signed integer, specifies the relative height in meters that the neighbor is positioned, relative to the reporting BSS. If the relative height is unknown or at the same height as the reporting BSS, the field is 0.

The format of the Wide Bandwidth Channel subelement is shown in Figure 9-343.

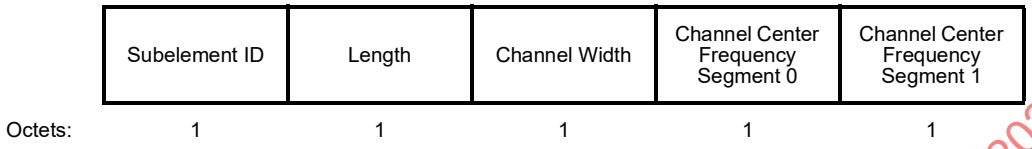

Figure 9-343—Wide Bandwidth Channel subelement format

The Length field is defined in 9.4.3.

The Channel Width, Channel Center Frequency Segment 0, and Channel Center Frequency Segment 1 subfields are defined in Table 9-175.

Table 9-175—HT/VHT Operation Information subfields

Field	Definition	Encoding
Channel Width	This field defines the BSS bandwidth (see 11.38.1).	Set to 0 for 20 MHz BSS bandwidth. Set to 1 for 40 MHz BSS bandwidth. Set to 2 for 80 MHz BSS bandwidth. Set to 3 for 160 MHz BSS bandwidth. Set to 4 for 80+80 MHz BSS bandwidth. Values in the range 5 to 255 are reserved.
Channel Center Frequency Segment 0	Defines the channel center frequency for an HT or VHT BSS or the frequency segment 0 channel center frequency for an 80+80 MHz VHT BSS. See 21.3.14.	For 20, 40, 80, or 160 MHz BSS bandwidth, indicates the channel center frequency index for the channel on which the HT or VHT BSS operates. For 80+80 MHz BSS bandwidth, indicates the channel center frequency index for the 80 MHz channel of frequency segment 0 on which the VHT BSS operates.
Channel Center Frequency Segment 1	Defines the frequency segment 1 channel center frequency for an 80+80 MHz VHT BSS. See 21.3.14.	For an 80+80 MHz BSS bandwidth, indicates the channel center frequency index of the 80 MHz channel of frequency segment 1 on which the VHT BSS operates. The channel center frequency index of segment 1 differs by more than 16 from the channel center frequency index of segment 0 (i.e., the channel center frequencies are more than 80 MHz apart). Reserved otherwise.

The VHT Capabilities subelement is the same as the VHT Capabilities element as defined in 9.4.2.157.

The VHT Operation subelement is the same as the VHT Operation element as defined in 9.4.2.158.

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

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9.4.2.37 RCPI element

The RCPI element indicates the received frame power level at the receiving STA as shown in Figure 9-344.

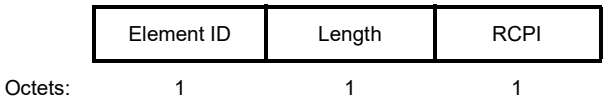

Figure 9-344—RCPI element format

The Element ID and Length fields are defined in 9.4.2.1.

The RCPI field contains an RCPI value, which is an indication of the received RF power in the selected channel for a received frame.

The value of the RCPI field is a monotonically increasing, logarithmic function of the received power level. The allowed values for the RCPI field are defined in Table 9-176, where P is the received power level in dBm.

Table 9-176—RCPI values

RCPI Value	Description
0	Represents $P < -109.5$ dBm
1–219	Power levels in the range $-109.5 \le P < 0$ are represented by RCPI $= \lfloor 2 \times (P + 110) \rfloor$
220	Represents $P \ge 0$ dBm
221–254	Reserved
255	Measurement not available

9.4.2.38 BSS Average Access Delay element

The BSS Average Access Delay element contains the AP Average Access Delay, which is a measure of load in the BSS and is available in both QoS APs and non-QoS APs. The format of the BSS Average Access Delay element is defined in Figure 9-345.

Figure 9-345—BSS Average Access Delay element format

The Element ID and Length fields are defined in 9.4.2.1.

The AP Average Access Delay is a scalar indication of the relative level of loading at an AP. A low value indicates more available capacity than a higher value. If the AP is not currently transmitting any DCF or EDCAF traffic, the AP Average Access Delay is set to 255. The values between 1 and 252 are a scaled representation of the average medium access delay for all DCF and EDCAF transmitted frames measured from the time the DCF or EDCAF MPDU is ready for transmission (i.e., begins CSMA/CA access) until the

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actual frame transmission start time. Non-QoS APs average the access delays for all DCF transmitted frames. QoS APs average the access delays for all EDCA transmitted frames of all ACs. The AP Average Access Delay values are scaled as follows:

0:	Access Delay < 8 μs
1:	8 μs ≤ Access Delay < 16 μs
2 ≤ n ≤ 14:	n × 8 μs ≤ Access Delay < (n + 1) × 8 μs
15:	120 μs ≤ Access Delay < 128 μs
16:	128 μs ≤ Access Delay < 144 μs
17 ≤ n ≤ 106:	(n × 16) – 128 μs ≤ Access Delay < ((n + 1) × 16) – 128 μs
107:	1 584 μs ≤ Access Delay < 1 600 μs
108:	1 600 μs ≤ Access Delay < 1 632 μs
109 ≤ n ≤ 246:	(n × 32) – 1 856 μs ≤ Access Delay < ((n + 1) × 32) – 1 856 μs
247:	6 048 μs ≤ Access Delay < 6 080 μs
248:	6 080 μs ≤ Access Delay < 8 192 μs
249:	8 192 μs ≤ Access Delay < 12 288 μs
250:	12 288 μs ≤ Access Delay < 16 384 μs
251:	16 384 μs ≤ Access Delay < 20 480 μs
252:	20 480 μs ≤ Access Delay < 24 576 μs
253:	24 576 μs ≤ Access Delay
254:	Service unable to access channel
255:	Measurement not available

The values 0–253 indicate the average access delay when one or more frames were transmitted during the measurement window. The value 254 indicates that the DCF is or the EDCAFs are currently unable to access the channel due to continuous carrier sense mechanism deferral and that no frames were transmitted during the measurement window. The AP measures and averages the medium access delay for all transmit frames using the DCF or the EDCAFs over a continuous 30 s measurement window. See 11.10.16 for accuracy requirements.

9.4.2.39 Antenna element

The Antenna element contains the Antenna ID field as shown in Figure 9-346.

	Element ID	Length	Antenna ID
Octets:	1	1	1

Figure 9-346—Antenna element format

The Element ID and Length fields are defined in 9.4.2.1.

The Antenna ID field contains the identifying number for the relevant antenna(s) or DMG antenna.

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For a non-DMG STA, the antenna ID identifies the antenna(s) used to transmit the frame the Antenna element is contained in, or the antenna(s) used to receive an earlier frame, depending on the frame the antenna ID is contained in. A specific antenna has an antenna ID between 1 and 254. The value 0 indicates that the antenna ID is unknown. The value 255 indicates that this transmission was made with multiple antennas, i.e., antennas were switched during the transmission. If during frame reception different antennas are used to receive the preamble and body, the antenna ID identifies the antenna that receives the frame body. In these cases, the value 255 is not used. Antenna IDs are assigned to each antenna and each antenna configuration as consecutive integers starting with 1. Each antenna ID number represents a unique antenna or unique configuration of multiple antennas characterized by a fixed relative position, a fixed relative direction, and a fixed peak gain for that position and direction.

For a DMG STA, the DMG antenna ID identifies the DMG antenna used to transmit the frame the Antenna element is contained in, or the DMG antenna used to receive an earlier frame, depending on the frame the DMG antenna ID is contained in. A specific DMG antenna has a DMG antenna ID between 0 and 3. DMG antenna IDs are assigned to each DMG antenna as consecutive integers starting with 0.

9.4.2.40 RSNI element

The RSNI element contains an RSNI value, as shown in Figure 9-347.

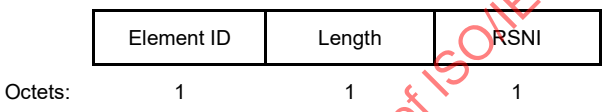

Figure 9-347—RSNI element format

The Element ID and Length fields are defined in 9.4.2.1.

The value of the RSNI field is in steps of 0.5 dB. RSNI is calculated by the ratio of the received signal power (RCPI-ANPI) to the noise plus interference power (ANPI) using the expression:

$$RSNI = (10 \times \log10((RCPI_{power} - ANPI_{power}) / ANPI_{power})+10) \times 2$$

where $RCPI_{power}$ and $ANPI_{power}$ indicate power domain values for RCPI and ANPI and not dB domain values. RSNI in dB is scaled in steps of 0.5 dB to obtain 8-bit RSNI values, which cover the range from –10 dB to +117 dB. The value 255 indicates that RSNI is not available. See 11.10.9.4 for details and procedures for measuring ANPI.

9.4.2.41 Measurement Pilot Transmission element

The Measurement Pilot Transmission element contains a Measurement Pilot Transmission field as shown in Figure 9-348.

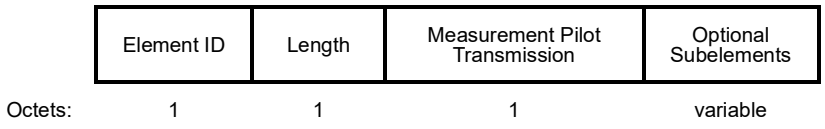

Figure 9-348—Measurement Pilot Transmission element format

The Element ID and Length fields are defined in 9.4.2.1.

The Measurement Pilot Transmission field contains the measurement pilot interval as specified in 9.4.1.18.

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The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-177.

Table 9-177—Optional subelement IDs for Measurement Pilot Transmission

Subelement ID	Name	Extensible
0–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.42 BSS Available Admission Capacity element

The BSS Available Admission Capacity element contains a list of Available Admission Capacity fields at different User Priorities and Access Categories as shown in Figure 9-349.

NOTE—The BSS Available Admission Capacity element is helpful for roaming QoS STAs to select a QoS AP that is likely to accept future admission control requests, but it does not provide an assurance that the HC will admit these requests.

	Element ID	Length	Available Admission Capacity Bitmask	Available Admission Capacity List
Octets:	1	1	2	2 × (total number of nonzero bits in Available Admission Capacity Bitmask)

Figure 9-349—BSS Available Admission Capacity element format

The Element ID and Length fields are defined in 9.4.2.1. The Length field is set to $2 + 2N_{nz}$, where N_{nz} equals the total number of nonzero bits in Available Admission Capacity Bitmask.

The Available Admission Capacity Bitmask field indicates the UP values that have an Available Admission Capacity specified in the Available Admission Capacity List field. The format of the Available Admission Capacity Bitmask is defined in Table 9-178.

Each bit in the Available Admission Capacity Bitmask is set to 1 to indicate that the Available Admission Capacity for the corresponding traffic type is present in the Available Admission Capacity List field. The bit is set to 0 to indicate that the Available Admission Capacity for the corresponding traffic type is not present in the Available Admission Capacity List field.

The Available Admission Capacity List comprises a sequence of Available Admission Capacity fields corresponding respectively to the nonzero bits in the Available Admission Capacity Bitmask field.

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Table 9-178—Available Admission Capacity Bitmask definition

Bit	Available Admission Capacity Reported
0	UP 0
1	UP 1
2	UP 2
3	UP 3
4	UP 4
5	UP 5
6	UP 6
7	UP 7
8	AC 0
9	AC 1
10	AC 2
11	AC 3
12–15	Reserved

Each Available Admission Capacity field is 2 octets long and contains an unsigned integer that specifies the amount of medium time available using explicit admission control for the corresponding UP or AC traffic, in units of 32 μs per 1 s. See 11.10.17 for furthers details.

9.4.2.43 BSS AC Access Delay element

The BSS AC Access Delay element contains an Access Category Access Delay field, as shown in Figure 9-350.

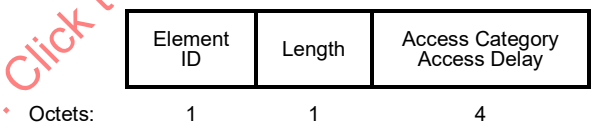

Figure 9-350—BSS AC Access Delay element format

The Element ID and Length fields are defined in 9.4.2.1.

The Access Category Access Delay field is formatted as four subfields as shown in Figure 9-351. The value of the AC Access Delay field is a scalar indication of the average access delay at a QoS AP for services for each of the indicated access categories. If the QoS AP is not currently transmitting any traffic using the indicated AC, the value of Average Access Delay field for that AC is set to 255. The values between 1 and 252 are a scaled representation of the average medium access delay for transmitted frames in the indicated AC measured from the time the EDCA MPDU is ready for transmission (i.e., begins CSMA/CA access) until the actual frame transmission start time. The AC Access Delay values are scaled as follows:

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0:	Access Delay < 8 μs
1:	8 μs ≤ Access Delay < 16 μs
2 ≤ n ≤ 14:	n × 8 μs ≤ Access Delay < (n + 1) × 8 μs
15:	120 μs ≤ Access Delay < 128 μs
16:	128 μs ≤ Access Delay < 144 μs
17 ≤ n ≤ 106:	(n × 16) – 128 μs ≤ Access Delay < ((n + 1) × 16) – 128 μs
107:	1584 μs ≤ Access Delay < 1600 μs
108:	1600 μs ≤ Access Delay < 1632 μs
109 ≤ n ≤ 246:	(n × 32) – 1856 μs ≤ Access Delay < ((n + 1) × 32) – 1856 μs
247:	6048 μs ≤ Access Delay < 6080 μs
248:	6080 μs ≤ Access Delay < 8192 μs
249:	8192 μs ≤ Access Delay < 12 288 μs
250:	12 288 μs ≤ Access Delay < 16 384 μs
251:	16 384 μs ≤ Access Delay < 20 480 μs
252:	20 480 μs ≤ Access Delay < 24 576 μs
253:	24 576 μs ≤ Access Delay
254:	Service unable to access channel
255:	Measurement not available

The values 0–253 indicate the average access delay when one or more frames were transmitted during the measurement window. The value 254 indicates that the EDCAF is currently unable to access the channel due to continuous carrier sense mechanism deferral to higher priority AC transmissions and that no frames were transmitted during the measurement window. The QoS AP measures and averages the medium access delay for all transmit frames of the indicated AC using EDCA mechanism over a continuous 30 s measurement window. See 11.10.16 for accuracy requirements.

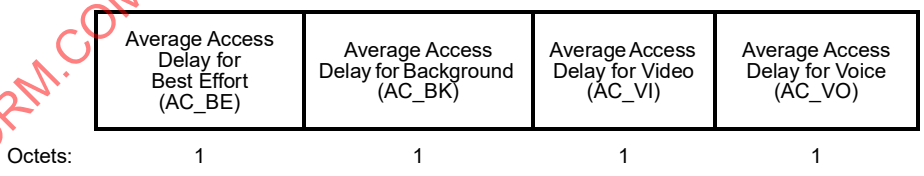

Figure 9-351—Access Category Access Delay subfield format

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9.4.2.44 RM Enabled Capabilities element

The RM Enabled Capabilities element signals support for radio measurements in a STA. The element is shown in Figure 9-352.

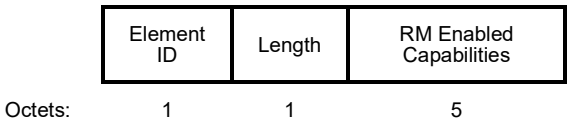

Figure 9-352—RM Enabled Capabilities element format

The Element ID and Length fields are defined in 9.4.2.1.

The RM Enabled Capabilities field is an octet string. Each subfield of this field indicates whether the corresponding capability listed in Table 9-179 is enabled.

Table 9-179—RM Enabled Capabilities definition

Bit position in the RM Enabled Capabilities field	Field name	Notes
0	Link Measurement Capability Enabled	A STA sets the Link Measurement Capability Enabled field to 1 when dot11RMLinkMeasurementActivated is true and sets it to 0 otherwise.
1	Neighbor Report Capability Enabled	A STA sets the Neighbor Report Capability Enabled field to 1 when dot11RMNeighborReportActivated is true and sets it to 0 otherwise.
2	Parallel Measurements Capability Enabled	A STA sets the Parallel Measurements Capability Enabled field to 1 when dot11RMParallelMeasurementsActivated is true and sets it to 0 otherwise.
3	Repeated Measurements Capability Enabled	A STA sets the Repeated Measurements Capability Enabled field to 1 when dot11RMRepeatedMeasurementsActivated is true and sets it to 0 otherwise.
4	Beacon Passive Measurement Capability Enabled	A STA sets the Beacon Passive Measurement Capability Enabled field to 1 when dot11RMBeaconPassiveMeasurementActivated is true and sets it to 0 otherwise.
5	Beacon Active Measurement Capability Enabled	A STA sets the Beacon Active Measurement Capability Enabled field to 1 when dot11RMBeaconActiveMeasurementActivated is true and sets it to 0 otherwise.
6	Beacon Table Measurement Capability Enabled	A STA sets the Beacon Table Measurement Capability Enabled field to 1 when dot11RMBeaconTableMeasurementActivated is true and sets it to 0 otherwise.
7	Beacon Measurement Reporting Conditions Capability Enabled	A STA sets the Beacon Measurement Reporting Conditions Capability Enabled field to 1 when dot11RMBeaconMeasurementReportingConditionsActivated is true and sets it to 0 otherwise.

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Table 9-179—RM Enabled Capabilities definition *(continued)*

Bit position in the RM Enabled Capabilities field	Field name	Notes
8	Frame Measurement Capability Enabled	A STA sets the Frame Measurement Capability Enabled field to 1 when dot11RMFrameMeasurementActivated is true and sets it to 0 otherwise.
9	Channel Load Measurement Capability Enabled	A STA sets the Channel Load Measurement Capability Enabled field to 1 when dot11RMChannelLoadMeasurementActivated is true and sets it to 0 otherwise.
10	Noise Histogram Measurement Capability Enabled	A STA sets the Noise Histogram Measurement Capability Enabled field to 1 when dot11RMNoiseHistogramMeasurementActivated is true and sets it to 0 otherwise.
11	Statistics Measurement Capability Enabled	A STA sets the Statistics Measurement Capability Enabled field to 1 when dot11RMStatisticsMeasurementActivated is true and sets it to 0 otherwise.
12	LCI Measurement Capability Enabled	A STA sets the LCI Measurement Capability Enabled field to 1 when dot11RMLCIMeasurementActivated is true and sets it to 0 otherwise.
13	LCI Azimuth Capability Enabled	A STA sets the LCI Azimuth Capability Enabled field to 1 when dot11RMLCIAzimuthActivated is true and sets it to 0 otherwise.
14	Transmit Stream/ Category Measurement Capability Enabled	A STA sets the Transmit Stream/Category Measurement Capability Enabled field to 1 when dot11RMTransmitStreamCategoryMeasurementActivated is true and sets it to 0 otherwise.
15	Triggered Transmit Stream/Category Measurement Capability Enabled	A STA sets the Triggered Transmit Stream/Category Measurement Capability Enabled field to 1 when dot11RMTriggeredTransmitStreamCategoryMeasurementActivated is true and sets it to 0 otherwise.
16	AP Channel Report Capability Enabled	A STA sets the AP Channel Report Capability Enabled field to 1 when dot11RMAPChannelReportActivated is true and sets it to 0 otherwise.
17	RM MIB Capability Enabled	A STA sets the RM MIB Capability Enabled field to 1 when dot11RMMIBActivated is true and sets it to 0 otherwise.
18–20	Operating Channel Max Measurement Duration	A STA sets the Operating Channel Max Measurement Duration field to equal dot11RMMaxMeasurementDuration. See 11.10.4.
21–23	Nonoperating Channel Max Measurement Duration	A STA sets the Nonoperating Channel Max Measurement Duration field to equal dot11RMNonOperatingChannelMaxMeasurementDuration. See 11.10.4.
24–26	Measurement Pilot Capability	A STA sets the Measurement Pilot Capability field to equal dot11RMMeasurementPilotActivated. See Table 11-10 in 11.10.15.

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Table 9-179—RM Enabled Capabilities definition *(continued)*

Bit position in the RM Enabled Capabilities field	Field name	Notes
27	Measurement Pilot Transmission Information Capability Enabled	A STA sets the Measurement Pilot Transmission Capability Enabled field to 1 when dot11RMMeasurementPilotTransmissionInformationActivated is true and sets it to 0 otherwise.
28	Neighbor Report TSF Offset Capability Enabled	A STA sets the Neighbor Report TSF Offset Capability Enabled field to 1 when dot11RMNeighborReportTSFOffsetActivated is true and sets it to 0 otherwise.
29	RCPI Measurement Capability Enabled	A STA sets the RCPI Measurement Capability Enabled field to 1 when dot11RMRCPIMeasurementActivated is true and sets it to 0 otherwise.
30	RSNI Measurement Capability Enabled	A STA sets the RSNI Measurement Capability Enabled field to 1 when dot11RMRSNIMeasurementActivated is true and sets it to 0 otherwise.
31	BSS Average Access Delay Capability Enabled	A STA sets the BSS Average Access Delay Capability Enabled field to 1 when dot11RMBSSAverageAccessDelayActivated is true and sets it to 0 otherwise (see NOTE).
32	BSS Available Admission Capacity Capability Enabled	A STA sets the BSS Available Admission Capacity Capability Enabled field to 1 when dot11RMBSSAvailableAdmissionCapacityActivated is true and sets it to 0 otherwise.
33	Antenna Capability Enabled	A STA sets the Antenna Capability Enabled field to 1 when dot11RMAntennaInformationActivated is true and sets it to 0 otherwise.
34	FTM Range Report Capability Enabled	A STA sets the FTM Range Report Capability Enabled field to 1 when dot11RMFineTimingMsmtRangeRepActivated is true and sets it to 0 otherwise.
35	Civic Location Measurement Capability Enabled	A STA sets the Civic Location Measurement Capability Enabled field to 1 when dot11RMCivicMeasurementActivated is true and sets it to 0 otherwise.
36–39	Reserved	

NOTE—At a QoS AP dot11RMBSSAverageAccessDelayActivated is true indicates that the AP BSS AC Access Delay capability is also enabled.

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9.4.2.45 Multiple BSSID element

The format of the Multiple BSSID element is shown in Figure 9-353.

	Element ID	Length	MaxBSSID Indicator	Optional Subelements
Octets:	1	1	1	variable

Figure 9-353—Multiple BSSID element format

The Element ID and Length fields are defined in 9.4.2.1.

The MaxBSSID Indicator field contains a value assigned to n, where 2^n is the maximum number of BSSIDs in the multiple BSSID set, including the reference BSSID (see 11.10.14). The maximum value of n is 8. The actual number of BSSIDs in the multiple BSSID set is not explicitly signaled. BSSID(i) corresponding to the i^{th} BSSID in the multiple BSSID set is derived as follows:

A0-A1-A2-A3-A4-A5 = Reference BSSID

$B = A5 \bmod 2^n$

$A5(i) = A5 - B + ((B + i) \bmod 2^n)$

BSSID(i) = A0-A1-A2-A3-A4-A5(i)

NOTE 1—For example, for n = 3 and Reference BSSID = 8c-fd-0f-7f-1e-f5:

A5 = f5
B = 5
A5(5) = f2 and BSSID(5) = 8c-fd-0f-7f-1e-f2
A5(2) = f7 and BSSID(2) = 8c-fd-0f-7f-1e-f7

NOTE 2—This definition uses the hexadecimal address representation defined in IEEE Std 802.

NOTE 3—The BSSID index as defined in 9.4.2.73 cannot be larger than 255, which effectively limits n to 8.

When the Multiple BSSID element is transmitted in a Beacon, DMG Beacon, or Probe Response frame, the reference BSSID is the BSSID field of the frame. The AP or DMG STA determines the number of Multiple BSSID elements. The AP or DMG STA does not fragment a nontransmitted BSSID profile subelement for a single BSSID across two Multiple BSSID elements unless the length of the nontransmitted BSSID profile subelement exceeds 255 octets. When the Multiple BSSID element is transmitted as a subelement in a Neighbor Report element, the reference BSSID is the BSSID field in the Neighbor Report element.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

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The Subelement ID field values for the defined subelements are shown in Table 9-180.

Table 9-180—Optional subelement IDs for Multiple BSSID

Subelement ID	Name	Extensible
0	Nontransmitted BSSID Profile	No
1–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Nontransmitted BSSID Profile subelement contains a list of elements for one or more APs or DMG STAs that have nontransmitted BSSIDs and is defined as follows:

— For each nontransmitted BSSID, the Nontransmitted BSSID Capability element (see 9.4.2.71) is the first element included, followed by a variable number of elements, in the order defined in Table 9-32 for a non-DMG non-S1G AP, Table 9-45 for a DMG AP or Table 9-46 for a S1G AP.

— The SSID element (see 9.4.2.2) and Multiple BSSID-Index element (see 9.4.2.73) are included in the Nontransmitted BSSID Profile subelement.

— The FMS Descriptor element is included in the Nontransmitted BSSID Profile subelement if the Multiple BSSID element is included in a Beacon frame.

— The Timestamp and Beacon Interval fields, DSSS Parameter Set, IBSS Parameter Set, Country, Channel Switch Announcement, Extended Channel Switch Announcement, Wide Bandwidth Channel Switch, Transmit Power Envelope, Supported Operating Classes, IBSS DFS, ERP Information, HT Capabilities, HT Operation, VHT Capabilities, VHT Operation, S1G Beacon Compatibility, Short Beacon Interval, S1G Capabilities, and S1G Operation elements are not included in the Nontransmitted BSSID Profile subelement; the values of these elements for each nontransmitted BSSID are always the same as the corresponding transmitted BSSID element values.

— When included in the Nontransmitted BSSID Profile subelement for this nontransmitted BSSID, the Non-Inheritance element (see 9.4.2.240) appears as the last element in the profile and carries a list of elements that are not inherited by this nontransmitted BSSID from the transmitted BSSID.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

The Multiple BSSID element is included in Beacon frames (as described in 9.3.3.2), in DMG Beacon frames (as described in 9.3.4.2), and Probe Response frames (as described in 9.3.3.10). The use of the Multiple BSSID element is described in 11.10.14. Nontransmitted BSSID advertisement procedures are described in 11.1.3.8.

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9.4.2.46 Mobility Domain element (MDE)

The MDE contains the MDID (Mobility Domain Identifier) field and the FT Capability and Policy field. The AP uses the MDE to advertise that it is included in the group of APs that constitute a mobility domain, to advertise its support for FT capability, and to advertise its FT policy information. The format for this element is shown in Figure 9-354.

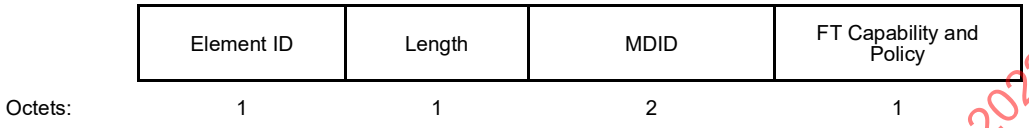

Figure 9-354—Mobility Domain element format

The Element ID and Length fields are defined in 9.4.2.1.

The MDID field is a 2-octet value that is an identifier that names a mobility domain.

The FT Capability and Policy field is 1 octet. The FT Capability and Policy field is defined in Figure 9-355.

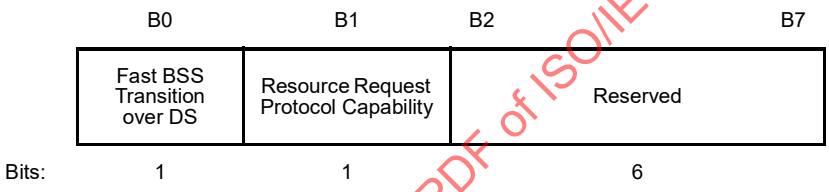

Figure 9-355—FT Capability and Policy field format

Bits 0–1 of the FT Capability and Policy field control the behavior of STAs performing fast BSS transitions (see 13.3). The STA might use information from the MDE to determine the transition methods recommended by the AP and protocols supported by the AP. The choice of executing any specific transition method is outside the scope of this standard.

If the Resource Request Protocol Capability subfield is 1, then the STA might perform the FT resource request protocol as described in 13.6.

When sent by a STA to a target AP, the FT Capability and Policy field matches the value advertised by that target AP. See 13.8.

9.4.2.47 Fast BSS Transition element (FTE)

The FTE includes information needed to perform the FT authentication sequence or FILS authentication during a fast BSS transition in an RSN. This element is shown in Figure 9-356.

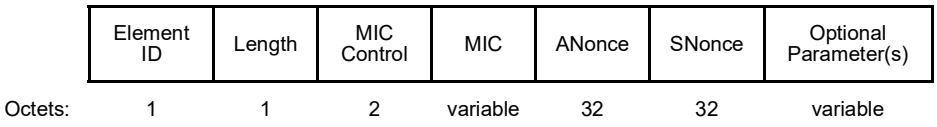

Figure 9-356—FTE format

The Element ID and Length fields are defined in 9.4.2.1.

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The MIC Control field is 2 octets and is defined in Figure 9-357.

Figure 9-357—MIC Control field format

The RSNXE Used subfield of the MIC Control field is used in the third and fourth messages of the FT authentication sequence to indicate whether the STA transmitting the frame containing the FTE includes an RSNXE in other frames. This subfield is set to 0 in other frames.

The Element Count subfield of the MIC Control field contains the number of elements that are included in the message integrity code (MIC) calculation.

When the Element Count subfield has a value greater than 0, the MIC field contains a MIC that is calculated using the algorithm specified in 13.8.4 and 13.8.5. Otherwise, the MIC field is set to 0.

The length of the MIC field depends on the negotiated AKM selector and is specific in Table 12-10.

The ANonce field contains a value chosen by the R1KH.

The SNonce field contains a value chosen by the S1KH.

The format of the Optional Parameter(s) field is shown in Figure 9-358.

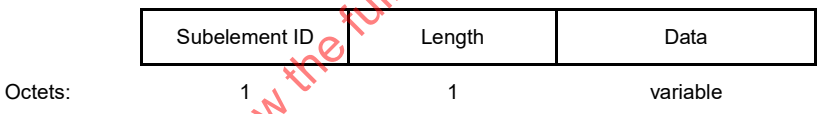

Figure 9-358—Optional Parameter(s) field format

The Subelement ID field is defined in Table 9-181:

Table 9-181—Subelement IDs

Value	Contents of Data field
0	Reserved
1	PMK-R1 key holder identifier (R1KH-ID)
2	GTK
3	PMK-R0 key holder identifier (R0KH-ID)
4	IGTK
5	Operating Channel Information (OCI)
6	BIGTK
7–255	Reserved

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R1KH-ID indicates the identity of the R1KH, which is used by the S0KH and the R0KH for deriving the PMK-R1s.

The GTK subelement contains the GTK, which is encrypted (see procedures in 13.8.5) and is defined in Figure 9-359.

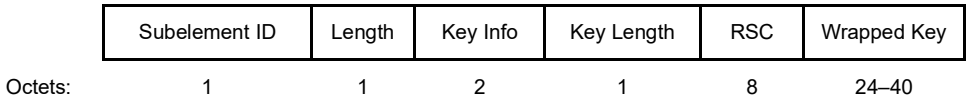

Figure 9-359—GTK subelement format

The GTK subelement Key Info subfield is defined in Figure 9-360.

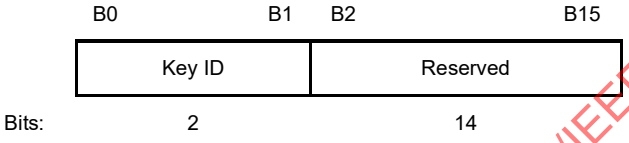

Figure 9-360—GTK subelement's Key Info subfield format

The Key Length field is the length of the Key field in octets, not including any padding (see 13.8.5).

The RSC field contains the current receive sequence counter (RSC) for the GTK being installed to allow a STA to identify replayed MPDUs. If the RSC is less than 8 octets in length, it is stored in the first octets and the remaining octets are set to 0. The least significant octet of the RSC is in the first octet of the RSC field. The RSC for TKIP is the TKIP sequence counter (TSC); for CCMP and GCMP it is the packet number (PN); see Table 12-8.

For WEP, the RSC value is reserved.

The Wrapped Key field contains the wrapped GTK as described in 13.8.5.

When sent by a non-AP STA, the R0KH-ID indicates the R0KH with which the S0KH negotiated the PMK-R0 it is using for this transition. When sent by an AP, the R0KH-ID indicates the R0KH that the S0KH will be using to generate a PMK-R0 security association. It is encoded following the conventions from 9.2.2.

The IGTK subelement contains the IGTK, used for protecting robust Management frames. The IGTK subelement format is shown in Figure 9-361.

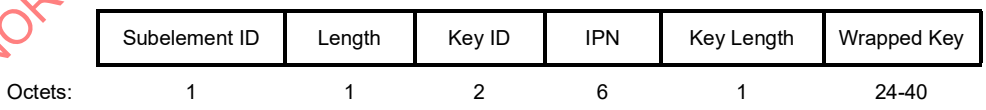

Figure 9-361—IGTK subelement format

The Key ID field indicates the value of the BIP key identifier.

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The IPN field contains the current RSC for the IGTK being installed, to allow a STA to identify replayed protected group addressed robust Management frames. The RSC for an IGTK is the IGTK packet number (IPN).

The Key Length field is the length of IGTK in octets, not including any padding (see 13.8.5).

The Wrapped Key field contains the wrapped IGTK being distributed.

The OCI subelement contains the operating channel information that is integrity protected (see procedures in 13.7) as defined in Figure 9-362.

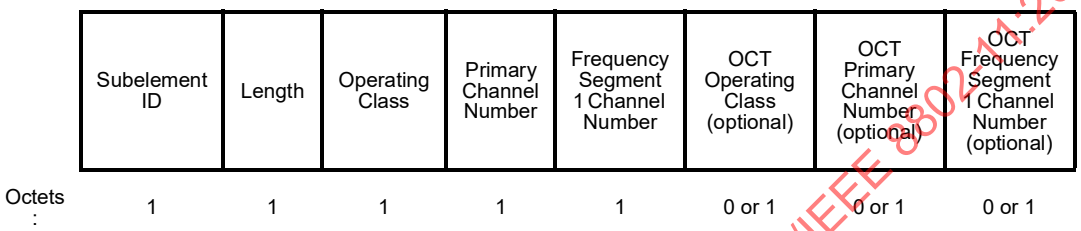

Figure 9-362—OCI subelement format

The definitions of the Operating Class, Primary Channel Number, Frequency Segment 1 Channel Number, OCT Operating Class, OCT Primary Channel Number and OCT Frequency Segment 1 Channel Number fields are the same as those described in 9.4.2.236.

The OCT Operating Class, OCT Primary Channel Number and OCT Frequency Segment 1 fields are present if the OCI subelement is contained in a frame sent using the OCT procedure, i.e., an MMPDU included in an MLME-OCTunnel.request or MLME-OCTunnel.response primitive (see 11.31.5); otherwise they are not present.

The BIGTK subelement contains the BIGTK, used for protecting Beacon frames. The BIGTK subelement format is shown in Figure 9-363.

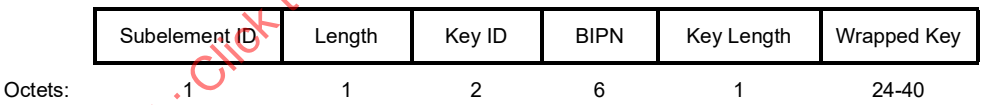

Figure 9-363—BIGTK subelement format

The Key ID field indicates the value of the BIGTK identifier.

The BIPN field contains the current RSC for the BIGTK being installed, to allow a STA to identify replayed Beacon frames. The RSC for a BIGTK is the BIGTK packet number (BIPN).

The Key Length field is the length of the BIGTK in octets, not including any padding (see 13.8.5).

The Wrapped Key field contains the wrapped BIGTK being distributed.

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9.4.2.48 Timeout Interval element (TIE)

The TIE specifies time intervals and timeouts. Figure 9-364 shows this element.

	Element ID	Length	Timeout Interval Type	Timeout Interval Value
Octets:	1	1	1	4

Figure 9-364—TIE format

The Element ID and Length fields are defined in 9.4.2.1.

The Timeout Interval Type field is defined in Table 9-182.

Table 9-182—Timeout Interval Type field value

Timeout Interval Type	Meaning	Units
0	Reserved	
1	Reassociation deadline interval	Time units (TUs)
2	Key lifetime interval	Seconds
3	Association Comeback time	Time units (TUs)
4	Time-to-Start (see 11.31.3.1)	Time units (TUs)
5–255	Reserved	

The Timeout Interval Value field contains an unsigned 32-bit integer. It is encoded according to the conventions in 9.2.2.

A reassociation deadline interval set to 0 indicates no deadline exists. A key lifetime interval set to 0 is reserved.

9.4.2.49 RIC Data element (RDE)

The RIC refers to a collection of elements that are used to express a resource request and to convey responses to the corresponding requests.

A RIC is a sequence of one or more Resource Requests, or a sequence of one or more Resource Responses. Each Resource Request or Response consists of an RDE, followed by one or more elements that describe that resource. See 13.11 for examples and procedures.

The RDE format is shown in Figure 9-365.

	Element ID	Length	RDE Identifier	Resource Descriptor Count	Status Code
Octets:	1	1	1	1	2

Figure 9-365—RDE format

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The Element ID and Length fields are defined in 9.4.2.1.

The RDE Identifier field has an arbitrary 8-bit value, chosen by the resource requester to uniquely identify the RDE within the RIC.

The Resource Descriptor Count field indicates the number of alternative Resource Descriptors that follow this RDE.

The Status Code field is used in Resource Responses to indicate the result of the request. Valid values for the Status Code field are given in 9.4.1.9. When an RDE is included in a Resource Request, the Status Code field is reserved.

9.4.2.50 RIC Descriptor element

The RIC Descriptor element is used with an RDE during a fast BSS transition to negotiate resources that are not otherwise described by elements. See 13.11 for procedures for including this element in a RIC.

Figure 9-366 shows the format of this element.

	Element ID	Length	Resource Type	Variable parameters
Octets:	1	1	1	variable

Figure 9-366—RIC Descriptor element format

The Element ID and Length fields are defined in 9.4.2.1.

The Resource Type field is defined in Table 9-183.

Table 9-183—Resource type code in RIC Descriptor element

Resource type value	Meaning	Variable parameters
1	Block Ack	Block Ack Parameter Set field value as defined in 9.4.1.13, Block Ack Timeout field value as defined in 9.4.1.14, and Block Ack Starting Sequence Control subfield value as defined in 9.3.1.7.
0, 2–255	Reserved	

Variable parameters contain any additional data based on the resource type.

9.4.2.51 DSE Registered Location element

A DSE Registered Location element includes DSE location configuration information (LCI), which contains latitude, longitude, and altitude information. The DSE Registered Location element format is shown in Figure 9-367.

	Element ID	Length	DSE Registered Location Information
Octets:	1	1	20

Figure 9-367—DSE Registered Location element format

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The Element ID and Length fields are defined in 9.4.2.1.

The structure and information fields are based on the LCI format described in IETF RFC 6225.

The DSE Registered Location Information field is shown in Figure 9-368.

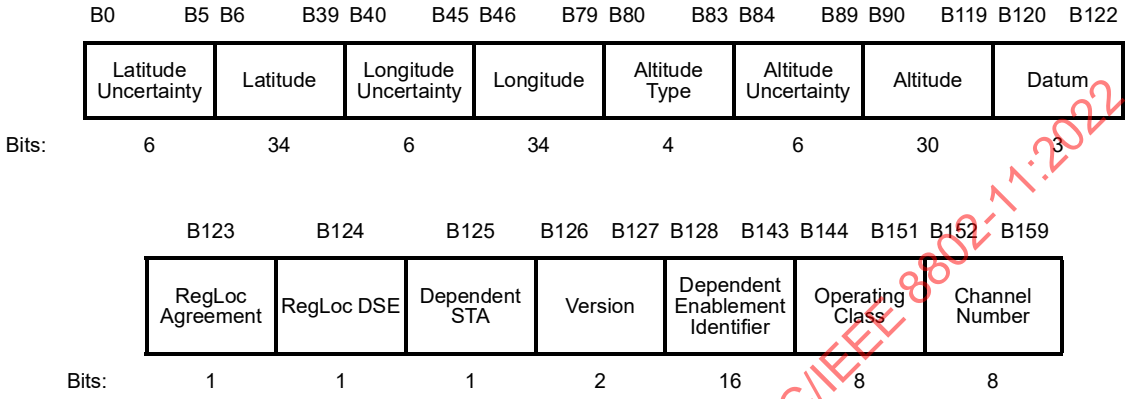

Figure 9-368—DSE Registered Location Information field format

The fields within the DSE Registered Location Information field are defined in section 2.2 of IETF RFC 6225 (July 2011) except as defined in this standard.

With an Altitude Type field set to 3 (i.e., height above ground is in meters), the altitude is defined to be in meters and is formatted in 2s complement, fixed-point, 22-bit integer part with 8-bit fraction.

The Datum field is defined in IETF RFC 6225, and the codes used are as defined in IETF RFC 6225.

The RegLoc Agreement bit field is set to 1 to report that the STA is operating within a national policy area or an international agreement area near a national border (see 11.11.3); otherwise, it is 0.

The RegLoc DSE bit field is set to 1 to report that the enabling STA is enabling the operation of STAs with DSE; otherwise, it is 0.

The Dependent STA bit field is set to 1 to report that the STA is operating with the enablement of the enabling STA whose LCI is being reported; otherwise, it is 0.

The Version field is defined in IETF RFC 6225, and the use is described in IETF RFC 6225.

The Dependent Enablement Identifier field is a value set by the enabling STA via the DSE Enablement frame; otherwise, it is set to 0.

The Operating Class field indicates the channel set for which the enablement request, report, or announcement applies. The Operating Class and Channel Number fields together specify the channel frequency and channel bandwidth for which the report applies. Valid values for the Operating Class field are shown in Annex E.

The Channel Number field indicates the channel number for which the enablement request, report, or announcement applies. The channel number is defined within an operating class as shown in Annex E.

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9.4.2.52 Extended Channel Switch Announcement element

The Extended Channel Switch Announcement element is used by an AP, PCP, IBSS STA, or mesh STA to advertise when the BSS is changing to a new channel in the same or a new operating class. The announcement includes both the operating class and the channel number of the new channel. The element is present only when an extended channel switch is pending. The format of the Extended Channel Switch Announcement element is shown in Figure 9-369.

	Element ID	Length	Channel Switch Mode	New Operating Class	New Channel Number	Channel Switch Count
Octets:	1	1	1	1	1	1

Figure 9-369—Extended Channel Switch Announcement element format

The Element ID and Length fields are defined in 9.4.2.1.

The Channel Switch Mode field indicates any restrictions on transmission until a channel switch. An AP, PCP, or an IBSS STA sets the Channel Switch Mode field to either 0 or 1 on transmission as specified in 11.8.8.2 and 11.8.8.3. The Channel Switch Mode field is reserved in an MBSS.

The New Operating Class field is set to the number of the operating class after the channel switch, as defined in Annex E.

The New Channel Number field is set to the number of the channel after the channel switch. The channel number is a channel from the STA's new operating class as defined in Annex E.

For nonmesh STAs, the Channel Switch Count field indicates the number of target beacon transmission times (TBTTs) until the STA sending the Channel Switch Count field switches to the new channel. A Channel Switch Count field set to 1 indicates that the switch occurs immediately before the next TBTT. A Channel Switch Count field set to 0 indicates that the switch occurs any time after the frame containing the Channel Switch Count field is transmitted.

For mesh STAs, the Channel Switch Count field is encoded as an octet with bits 6 to 0 set to the time, in units of 2 TU when the MSB (bit 7) is 0, or in units of 100 TU when the MSB (bit 7) is 1, until the mesh STA sending the Channel Switch Count field switches to the new channel. Bits 6 to 0 set to 0 indicates that the switch occurs at any time after the frame containing the Channel Switch Count field is transmitted. For example, a 200 TU channel switch time is encoded as X'82' and a 10 TU channel switch time is encoded as X'05'.

9.4.2.53 Supported Operating Classes element

The Supported Operating Classes element is used by a STA to advertise the operating classes within which it is currently configured to operate. The format of the Supported Operating Classes element is shown in Figure 9-370.

	Element ID	Length	Current Operating Class	Operating Classes	Current Operating Class Extension Sequence (optional)	Operating Class Duple Sequence (optional)
Octets:	1	1	1	variable	variable	variable

Figure 9-370—Supported Operating Classes element format

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The Element ID and Length fields are defined in 9.4.2.1.

The Current Operating Class field, concatenated with the Current Operating Class Extension field within the Current Operating Class Extension Sequence field if present, indicates the operating class in use for transmission and reception. If the operating class in use is a single octet, the Current Operating Class Extension Sequence field is not present. If the operating class in use is more than a single octet, then the Current Operating Class Extension Sequence field is present, and the concatenation of the Current Operating Class field with the Current Operating Class Extension Sequence field comprises N (where $N \geq 0$) Operating Class octets with an 80+ behavior limit followed by one Operating Class octet without an 80+ behavior limit (as defined in Annex E).

The Operating Classes field lists, in descending order of preference, all 1-octet operating classes within which the STA is currently configured to operate. The Operating Classes field terminates immediately before a OneHundredAndThirty Delimiter (see Figure 9-371), a Zero Delimiter (see Figure 9-372), or the end of the element.

The format of the optional Current Operating Class Extension Sequence field is shown in Figure 9-371.

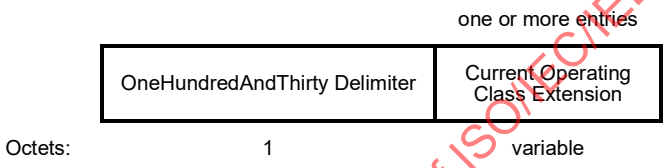

Figure 9-371—Current Operating Class Extension Sequence field format

The OneHundredAndThirty Delimiter field is set to 130.

The Current Operating Class Extension field comprises N (where $N \geq 0$) Operating Class octets with an 80+ behavior limit followed by one Operating Class octet without an 80+ behavior limit (as defined in Annex E).

The format of the Operating Class Duple Sequence field is shown in Figure 9-372.

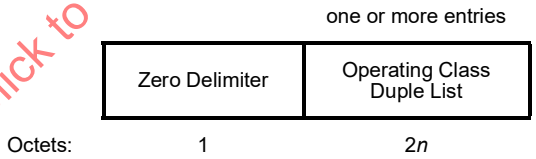

Figure 9-372—Operating Class Duple Sequence field format

The Zero Delimiter element is set to 0.

The Operating Class Duple List subfield lists all 2-octet operating classes within which the STA is currently configured to operate. Each operating class in the Operating Class Duple List subfield contains an Operating Class octet with an 80+ behavior limit followed by one Operating Class octet without an 80+ behavior limit (as defined in Annex E). Operating classes are transmitted in ascending order using the first octet in the operating class as the primary sort key and then the second octet in the operating class as the secondary sort key. If there are no 2-octet operating classes within which the STA is currently configured to operate, then the Operating Class Duple Sequence field is omitted from the Supported Operating Classes element. The Operating Class Duple List subfield terminates immediately before another zero octet or the end of the element.

The use of this element is described in 11.9.2 and 11.10.9.1.

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9.4.2.54 Management MIC element

The MME provides message integrity and protects group addressed robust Management frames and protected Beacon frames from forgery and replay. Figure 9-373 shows the MME format.

Figure 9-373—Management MIC element format

The Element ID and Length fields are defined in 9.4.2.1.

The Key ID field identifies the IGTK or BIGTK used to compute the MIC. Bits 0–11 define a value in the range 0–4095. Bits 12–15 are reserved. The IGTK Key ID is either 4 or 5. The BIGTK Key ID is either 6 or 7. The remaining Key IDs are reserved.

The IPN/BIPN field contains a 6-octet value, interpreted as an unsigned integer and used to detect replay of protected group addressed robust Management frames and protected Beacon frames. For protected group addressed robust Management frames, the IPN/BIPN field contains the IPN. For protected Beacon frames, the IPN/BIPN field contains the BIPN.

The MIC field contains a message integrity code calculated over the robust Management frame or protected Beacon frame as specified in 12.5.4.5 and 12.5.4.6. The length of the MIC field depends on the specific cipher negotiated and is either 8 octets (for BIP-CMAC-128) or 16 octets (for BIP-CMAC-256, BIP-GMAC-128, and BIP-GMAC-256).

9.4.2.55 HT Capabilities element

9.4.2.55.1 HT Capabilities element structure

An HT STA declares that it is an HT STA by transmitting the HT Capabilities element.

The HT Capabilities element contains a number of fields that are used to advertise optional HT capabilities of an HT STA. The HT Capabilities element is present in Beacon, Association Request, Association Response, Reassociation Request, Reassociation Response, Probe Request, Probe Response, Mesh Peering Open, and Mesh Peering Close frames. The HT Capabilities element is defined in Figure 9-374.

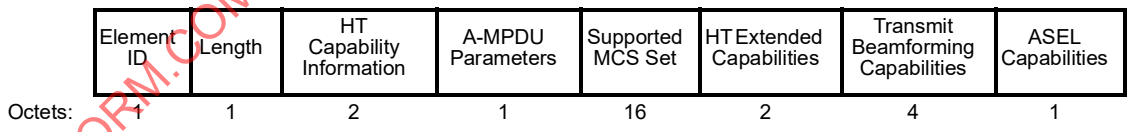

Figure 9-374—HT Capabilities element format

The Element ID and Length fields are defined in 9.4.2.1.

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9.4.2.55.2 HT Capability Information field

The HT Capability Information field of the HT Capabilities element contains capability information bits. The structure of this field is defined in Figure 9-375.

Figure 9-375—HT Capability Information field format

The subfields of the HT Capability Information field are defined in Table 9-184.

Table 9-184—Subfields of the HT Capability Information field

Subfield	Definition	Encoding
LDPC Coding Capability	Indicates support for receiving LDPC coded PPDUs	Set to 0 if not supported Set to 1 if supported
Supported Channel Width Set	Indicates the channel widths supported by the STA. See 11.15.	Set to 0 if only 20 MHz operation is supported Set to 1 if both 20 MHz and 40 MHz operation is supported This field is reserved when the transmitting or receiving STA is operating in an operating class that includes 20 in the Channel spacing (MHz) column of the appropriate table in Annex E.
SM Power Save	Indicates the spatial multiplexing power save mode that is in operation immediately after (re)association. See 11.2.6.	Set to 0 for static SM power save mode Set to 1 for dynamic SM power save mode Set to 3 for SM power save disabled or not supported The value 2 is reserved Only valid in a (Re)Association Request frame sent to an AP. Otherwise this subfield is set to 0 or 3 upon transmission and is ignored upon reception. NOTE—This subfield indicates the operational state immediately after (re)association as well as (if not set to 3) a capability.
HT-Greenfield	Indicates support for the reception of PPDUs with HT-greenfield format. See 19.1.4.	Set to 0 if not supported Set to 1 if supported

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Table 9-184—Subfields of the HT Capability Information field *(continued)*

Subfield	Definition	Encoding
Short GI for 20 MHz	Indicates short GI support for the reception of HT PPDUs transmitted with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 and, for a VHT STA, for the reception of VHT PPDUs transmitted with the TXVECTOR parameter CH_BANDWIDTH equal to CBW20	Set to 0 if not supported Set to 1 if supported
Short GI for 40 MHz	Indicates short GI support for the reception of HT PPDUs transmitted with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40 and, for a VHT STA, for the reception of VHT PPDUs transmitted with the TXVECTOR parameter CH_BANDWIDTH equal to CBW40	Set to 0 if not supported Set to 1 if supported
Tx STBC	Indicates support for the transmission of PPDUs using STBC	Set to 0 if not supported Set to 1 if supported This field is reserved for a mesh STA.
Rx STBC	Indicates support for the reception of PPDUs using STBC	Set to 0 for no support Set to 1 for support of one spatial stream Set to 2 for support of one and two spatial streams Set to 3 for support of one, two and three spatial streams This field is reserved for a mesh STA.
Maximum A-MSDU Length	Indicates maximum A-MSDU length. See 10.11.	Set to 0 for 3839 octets Set to 1 for 7935 octets
DSSS/CCK Mode in 40 MHz	Indicates the BSS is operating in a mode that allows transmission of DSSS/CCK PPDUs, when the operating channel width is 40 MHz. See 11.15.	In Beacon and Probe Response frames: Set to 0 if the BSS is operating in a mode that does not allow transmission of DSSS/CCK PPDUs Set to 1 if the BSS is operating in a mode that allows transmission of DSSS/CCK PPDUs Otherwise: Set to 0 if the STA supports neither transmission nor reception of DSSS/CCK PPDUs when the operating channel width is 40 MHz Set to 1 if the STA supports transmission and reception of DSSS/CCK PPDUs when the operating channel width is 40 MHz See 11.15.8 for operating rules
Forty MHz Intolerant	Indicates whether APs receiving this information or reports of this information are required to prohibit 40 MHz transmissions (see 11.15.12).	Set to 1 by an HT STA to prohibit a receiving AP from operating that AP's BSS as a 20/40 MHz BSS; otherwise, set to 0.

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9.4.2.55.3 A-MPDU Parameters field

The structure of the A-MPDU Parameters field of the HT Capabilities element is shown in Figure 9-376.

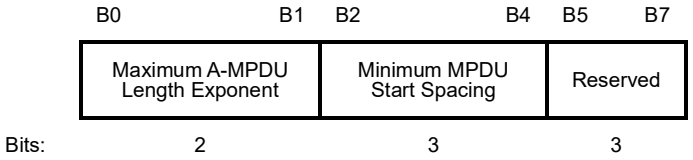

Figure 9-376—A-MPDU Parameters field format

The subfields of the A-MPDU Parameters field are defined in Table 9-185.

Table 9-185—Subfields of the A-MPDU Parameters field

Subfield	Definition	Encoding
Maximum A-MPDU Length Exponent	Indicates the maximum length of A-MPDU that the STA can receive.	The length defined by this field is equal to $2^{(13 + \text{Maximum A-MPDU Length Exponent})} - 1$ octets.
Minimum MPDU Start Spacing	Determines the minimum time between the start of adjacent MPDUs within an A-MPDU that the STA can receive, measured at the PHY SAP. See 10.12.3.	Set to 0 for no restriction Set to 1 for 1/4 μs Set to 2 for 1/2 μs Set to 3 for 1 μs Set to 4 for 2 μs Set to 5 for 4 μs Set to 6 for 8 μs Set to 7 for 16 μs

9.4.2.55.4 Supported MCS Set field

The Supported MCS Set field of the HT Capabilities element indicates the HT-MCSs a STA supports.

An MCS is identified by an MCS index, which is represented by an integer in the range 0 to 76. The interpretation of the MCS index (i.e., the mapping from MCS to data rate) is PHY dependent. For the HT PHY, see 19.5.

The structure of the MCS Set field is defined in Figure 9-377.

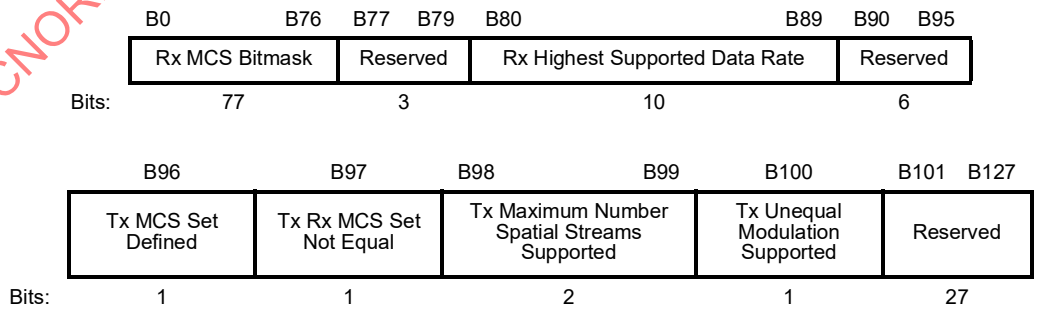

Figure 9-377—Supported MCS Set field format

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The Rx MCS Bitmask subfield of the Supported MCS Set field defines a set of MCS index values, where bit B0 corresponds to MCS 0 and bit B76 corresponds to MCS 76.

NOTE—An HT STA includes the mandatory MCS values defined in 19.1 in the Rx MCS Bitmask subfield.

The Rx Highest Supported Data Rate subfield of the Supported MCS Set field defines the highest HT PPDU data rate that the STA is able to receive, in units of 1 Mb/s in the range 1 to 1023. If the maximum data rate expressed in Mb/s is not an integer, then the value is rounded down to the next integer. The value 0 indicates that this subfield does not specify the HT PPDU highest data rate that the STA is able to receive; see 10.6.6.5.3.

The Tx MCS Set Defined, Tx Rx MCS Set Not Equal, Tx Maximum Number Spatial Streams Supported, and Tx Unequal Modulation Supported subfields of the Supported MCS Set field indicate the transmit-supported MCS set, as defined in Table 9-186.

Table 9-186—Transmit MCS Set

Condition	Tx MCS Set Defined	Tx Rx MCS Set Not Equal	Tx Maximum Number Spatial Streams Supported	Tx Unequal Modulation Supported
No Tx MCS set is defined	0	0	0	0
The Tx MCS set is defined and is equal to the Rx MCS set	1	0	0	0
The Tx MCS set is defined and is not necessarily equal to the Rx MCS set	1	1	Indicates the maximum number of spatial streams supported when transmitting: Set to 0 for 1 spatial stream Set to 1 for 2 spatial streams Set to 2 for 3 spatial streams Set to 3 for 4 spatial streams	Indicates whether transmit unequal modulation (UEQM) is supported: Set to 0 for UEQM not supported Set to 1 for UEQM supported

9.4.2.55.5 HT Extended Capabilities field

The structure of the HT Extended Capabilities field of the HT Capabilities element is defined in Figure 9-378.

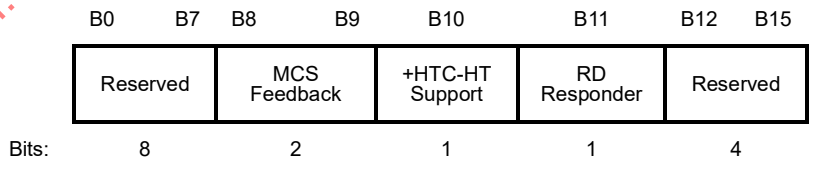

Figure 9-378—HT Extended Capabilities field format

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The subfields of the HT Extended Capabilities field are defined in Table 9-187.

Table 9-187—Subfields of the HT Extended Capabilities field

Subfield	Definition	Encoding
MCS Feedback	Indicates whether the STA can provide MFB	Set to 0 (No Feedback) if the STA does not provide MFB Set to 2 (Unsolicited) if the STA provides only unsolicited MFB Set to 3 (Both) if the STA can provide MFB in response to MRQ (either Delayed or Immediate, see 10.32.1) as well as unsolicited MFB The value 1 is reserved
+HTC-HT Support	Indicates support of the HT variant HT Control field. See 10.8	Set to 0 if not supported Set to 1 if supported
RD Responder	Indicates support for acting as a reverse direction responder, i.e., the STA might use an offered RDG to transmit data to an RD initiator using the reverse direction protocol described in 10.29.	Set to 0 if not supported Set to 1 if supported

9.4.2.55.6 Transmit Beamforming Capabilities

The structure of the Transmit Beamforming Capabilities field is defined in Figure 9-379.

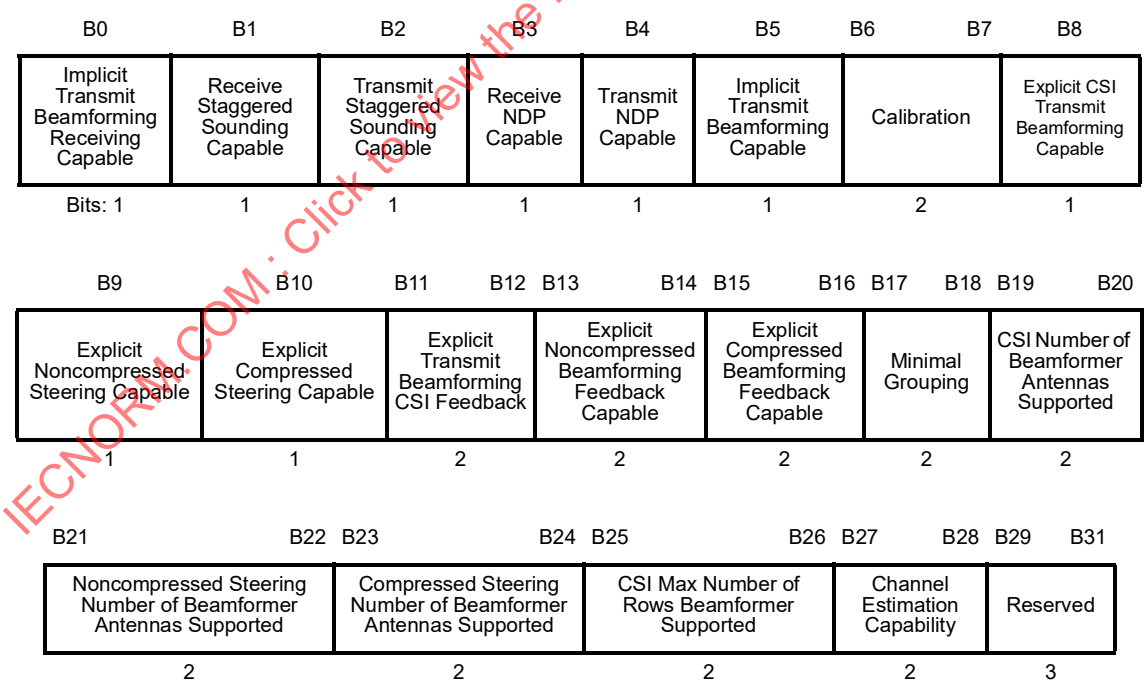

Figure 9-379—Transmit Beamforming Capabilities field format

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The subfields of the Transmit Beamforming Capabilities field are defined in Table 9-188.

Table 9-188—Subfields of the Transmit Beamforming Capabilities field

Subfield	Definition	Encoding
Implicit Transmit Beamforming Receiving Capable	Indicates whether this STA can receive Transmit Beamforming steered frames using implicit feedback	Set to 0 if not supported Set to 1 if supported
Receive Staggered Sounding Capable	Indicates whether this STA can receive staggered sounding frames.	Set to 0 if not supported Set to 1 if supported
Transmit Staggered Sounding Capable	Indicates whether this STA can transmit staggered sounding frames.	Set to 0 if not supported Set to 1 if supported
Receive NDP Capable	Indicates whether this receiver can interpret null data PPDUs as sounding frames.	Set to 0 if not supported Set to 1 if supported
Transmit NDP Capable	Indicates whether this STA can transmit null data PPDUs as sounding frames.	Set to 0 if not supported Set to 1 if supported
Implicit Transmit Beamforming Capable	Indicates whether this STA can apply implicit transmit beamforming.	Set to 0 if not supported Set to 1 if supported
Calibration	Indicates whether the STA can participate in a calibration procedure initiated by another STA that is capable of generating an immediate response sounding PPDU and can provide a CSI report in response to a sounding PPDU.	Set to 0 if not supported Set to 1 if the STA can respond to a calibration request using the CSI report, but cannot initiate calibration The value 2 is reserved Set to 3 if the STA can both initiate and respond to a calibration request
Explicit CSI Transmit Beamforming Capable	Indicates whether this STA can apply transmit beamforming using CSI explicit feedback in its transmission	Set to 0 if not supported Set to 1 if supported
Explicit Noncompressed Steering Capable	Indicates whether this STA can apply transmit beamforming using noncompressed beamforming feedback matrix explicit feedback in its transmission	Set to 0 if not supported Set to 1 if supported
Explicit Compressed Steering Capable	Indicates whether this STA can apply transmit beamforming using compressed beamforming feedback matrix explicit feedback in its transmission	Set to 0 if not supported Set to 1 if supported
Explicit Transmit Beamforming CSI Feedback	Indicates whether this receiver can return CSI explicit feedback.	Set to 0 if not supported Set to 1 for delayed feedback Set to 2 for immediate feedback Set to 3 for delayed and immediate feedback

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Table 9-188—Subfields of the Transmit Beamforming Capabilities field *(continued)*

Subfield	Definition	Encoding
Explicit Noncompressed Beamforming Feedback Capable	Indicates whether this receiver can return noncompressed beamforming feedback matrix explicit feedback.	Set to 0 if not supported Set to 1 for delayed feedback Set to 2 for immediate feedback Set to 3 for delayed and immediate feedback
Explicit Compressed Beamforming Feedback Capable	Indicates whether this receiver can return compressed beamforming feedback matrix explicit feedback.	Set to 0 if not supported Set to 1 for delayed feedback Set to 2 for immediate feedback Set to 3 for delayed and immediate feedback
Minimal Grouping	Indicates the minimal grouping used for explicit feedback reports	Set to 0 if the STA supports groups of 1 (no grouping) Set to 1 indicates groups of 1, 2 Set to 2 indicates groups of 1, 4 Set to 3 indicates groups of 1, 2, 4
CSI Number of Beamformer Antennas Supported	Indicates the maximum number of beamformer antennas the HT beamformee can support when CSI feedback is required	Set to 0 for single Tx antenna sounding Set to 1 for 2 Tx antenna sounding Set to 2 for 3 Tx antenna sounding Set to 3 for 4 Tx antenna sounding
Noncompressed Steering Number of Beamformer Antennas Supported	Indicates the maximum number of beamformer antennas the HT beamformee can support when noncompressed beamforming feedback matrix is required	Set to 0 for single Tx antenna sounding Set to 1 for 2 Tx antenna sounding Set to 2 for 3 Tx antenna sounding Set to 3 for 4 Tx antenna sounding
Compressed Steering Number of Beamformer Antennas Supported	Indicates the maximum number of beamformer antennas the HT beamformee can support when compressed beamforming feedback matrix is required	Set to 0 for single Tx antenna sounding Set to 1 for 2 Tx antenna sounding Set to 2 for 3 Tx antenna sounding Set to 3 for 4 Tx antenna sounding
CSI Max Number of Rows Beamformer Supported	Indicates the maximum number of rows of CSI explicit feedback from the HT beamformee or calibration responder or transmit ASEL responder that an HT beamformer or calibration initiator or transmit ASEL initiator can support when CSI feedback is required.	Set to 0 for a single row of CSI Set to 1 for 2 rows of CSI Set to 2 for 3 rows of CSI Set to 3 for 4 rows of CSI
Channel Estimation Capability	Indicates the maximum number of space-time streams (columns of the MIMO channel matrix) for which channel dimensions can be simultaneously estimated when receiving an NDP sounding PPDU or the extension portion of the HT Long Training fields (HT-LTFs) in a staggered sounding PPDU. See NOTE.	Set 0 for 1 space-time stream Set 1 for 2 space-time streams Set 2 for 3 space-time streams Set 3 for 4 space-time streams

NOTE—The maximum number of space-time streams for which channel coefficients can be simultaneously estimated using the HT-LTFs corresponding to the data portion of the PPDU is limited by the Rx MCS Bitmask subfield of the Supported MCS Set field and by the Rx STBC subfield of the HT Capability Information field. Both fields are part of the HT Capabilities element.

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9.4.2.55.7 ASEL Capability field

The structure of the ASEL Capability field of the HT Capabilities element is defined in Figure 9-380.

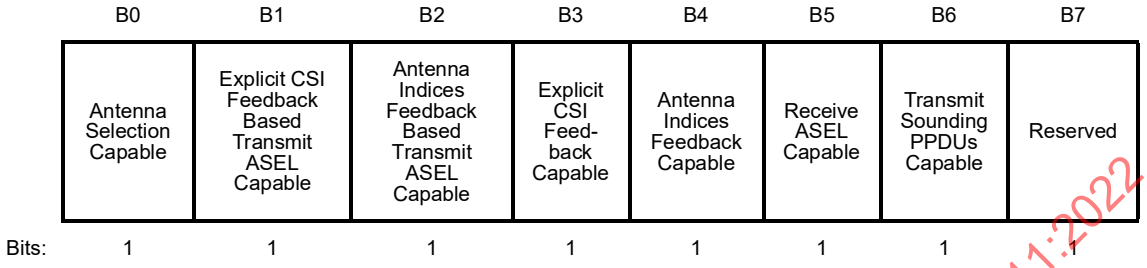

Figure 9-380—ASEL Capability field format

The subfields of the ASEL Capability field are defined in Table 9-189.

Table 9-189—ASEL Capability field subfields

Subfield	Definition	Encoding
Antenna Selection Capable	Indicates whether this STA supports ASEL	Set to 0 if not supported Set to 1 if supported
Explicit CSI Feedback Based Transmit ASEL Capable	Indicates whether this STA supports transmit ASEL based on explicit CSI feedback	Set to 0 if not supported Set to 1 if supported
Antenna Indices Feedback Based Transmit ASEL Capable	Indicates whether this STA supports transmit ASEL based on antenna indices feedback	Set to 0 if not supported Set to 1 if supported
Explicit CSI Feedback Capable	Indicates whether this STA can compute CSI and provide CSI feedback in support of ASEL	Set to 0 if not supported Set to 1 if supported
Antenna Indices Feedback Capable	Indicates whether this STA can compute an antenna indices selection and return an antenna indices selection in support of ASEL	Set to 0 if not supported Set to 1 if supported
Receive ASEL Capable	Indicates whether this STA supports receive ASEL	Set to 0 if not supported Set to 1 if supported
Transmit Sounding PPDUs Capable	Indicates whether this STA can transmit sounding PPDUs for ASEL training on request	Set to 0 if not supported Set to 1 if supported

9.4.2.56 HT Operation element

The operation of HT STAs in the BSS is controlled by the HT Operation element. The structure of this element is defined in Figure 9-381.

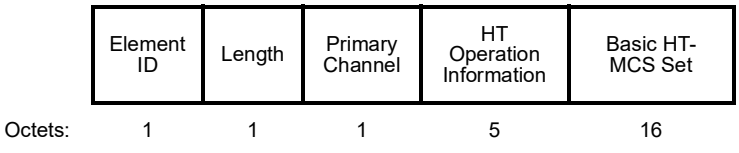

Figure 9-381—HT Operation element format

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The Element ID and Length fields are defined in 9.4.2.1.

The structure of the HT Operation Information field is shown in Figure 9-382.

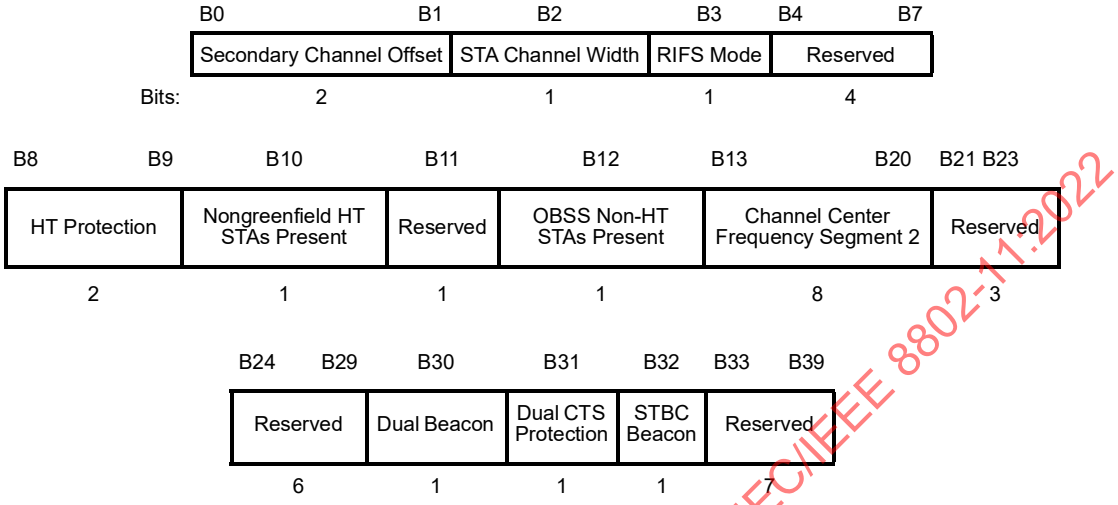

Figure 9-382—HT Operation Information field format

The Primary Channel field, subfields of the HT Operation Information field, and the Basic HT-MCS Set field are defined in Table 9-190. The "Reserved in IBSS?" column indicates whether each field is reserved (Y) or not reserved (N) when this element is present in a frame transmitted within an IBSS. The "Reserved in MBSS?" column indicates whether each field is reserved (Y) or not reserved (N) when this element is present in a frame transmitted within an MBSS.

Table 9-190—HT Operation element fields and subfields

Field	Definition	Encoding	Reserved in IBSS?	Reserved in MBSS?
Primary Channel	Indicates the channel number of the primary channel. See 11.15.2.	Channel number of the primary channel	N	N
Secondary Channel Offset	Indicates the offset of the secondary channel relative to the primary channel.	Set to 1 (SCA) if the secondary channel is above the primary channel Set to 3 (SCB) if the secondary channel is below the primary channel Set to 0 (SCN) if no secondary channel is present The value 2 is reserved	N	N

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Table 9-190—HT Operation element fields and subfields *(continued)*

Field	Definition	Encoding	Reserved in IBSS?	Reserved in MBSS?
STA Channel Width	Defines the channel widths that can be used to transmit to the STA. See 11.15.12	Set to 0 for a 20 MHz channel width Set to 1 allows use of any channel width in the Supported channel width set This field is reserved when the transmitting or receiving STA is operating in an operating class that does not include a value of PrimaryChannelLowerBehavior or PrimaryChannelUpperBehavior in the behavior limits set as specified in Annex E. See NOTE 1.	N	N
RIFS Mode	Indicates whether the use of reduced interframe space is permitted within the BSS. See 10.3.2.3.2 and 10.27.3.3	Set to 0 if use of RIFS is prohibited Set to 1 if use of RIFS is permitted	Y	Y
HT Protection	Indicates protection requirements of HT transmissions. See 10.27.3.	Set to 0 for no protection mode Set to 1 for nonmember protection mode Set to 2 for 20 MHz protection mode Set to 3 for non-HT mixed mode	Y	N
Nongreenfield HT STAs Present	AP indicates if any HT STAs that are not HT-greenfield capable have associated. Mesh STA indicates if it establishes a mesh peering with an HT STA that is not HT-greenfield capable. Determines when a non-AP STA should use HT-greenfield protection. Present in Beacon and Probe Response frames transmitted by an AP or mesh STA. Otherwise reserved. See 10.27.3.1.	Set to 0 if all HT STAs that are associated are HT-greenfield capable or all HT peer mesh STAs are HT-greenfield capable Set to 1 if one or more HT STAs that are not HT-greenfield capable are associated or one or more HT peer mesh STAs are not HT-greenfield capable	Y	N

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Table 9-190—HT Operation element fields and subfields *(continued)*

Field	Definition	Encoding	Reserved in IBSS?	Reserved in MBSS?
OBSS Non-HT STAs Present	Indicates if the use of protection for non-HT STAs by overlapping BSSs is determined to be desirable. If the BSS is operating in an operating class for which the behavior limits set listed in Annex E includes the DFS_50_100_Behavior, this field indicates if there exist any non-HT OBSSs and whether HT-greenfield transmissions are allowed. Present in Beacon and Probe Response frames transmitted by an AP. Otherwise reserved. See 10.27.3.4 and 11.8.8.5.	If not operating in an operating class for which the behavior limits set listed in Annex E includes the value DFS_50_100_Behavior: Set to 1 if the use of protection for non-HT STAs by OBSSs is determined to be desirable. See NOTE 2. Set to 0 otherwise. If operating in an operating class for which the behavior limits set listed in Annex E includes the value DFS_50_100_Behavior: Set to 1 if there exists one or more non-HT OBSSs. Indicates that HT-greenfield transmissions are disallowed in the BSS. Set to 0 otherwise.	Y	Y
Channel Center Frequency Segment 2	Defines the channel center frequency for a 160 or 80+80 MHz BSS bandwidth with NSS support less than Max VHT NSS. See 21.3.14, 11.38 and 9.4.2.157.3.	For a STA with dot11VHTExtendedNSSBWCapable equal to true: See Table 9-272, otherwise this field is set to 0. NOTE—This subfield is not used in a non-VHT HT STA.	N	N
Dual Beacon	Indicates whether the AP transmits an STBC beacon. The use of the dual beacon mechanism is obsolete.	Set to 0 if no STBC beacon is transmitted Set to 1 if an STBC beacon is transmitted by the AP	Y	Y
Dual CTS Protection	Dual CTS protection is used by the AP to set a NAV at STAs that do not support STBC and at STAs that can associate solely through the STBC beacon. See 10.3.2.10. The use of the dual CTS mechanism is obsolete.	Set to 0 if dual CTS protection is not required Set to 1 if dual CTS protection is required	Y	Y
STBC Beacon	Indicates whether the beacon containing this element is a primary or an STBC beacon. The STBC beacon has half a beacon period shift relative to the primary beacon. Defined only in a Beacon frame transmitted by an AP. Otherwise reserved. See 11.1.3.2.	Set to 0 in a primary beacon Set to 1 in an STBC beacon	Y	Y

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Table 9-190—HT Operation element fields and subfields *(continued)*

Field	Definition	Encoding	Reserved in IBSS?	Reserved in MBSS?
Basic HT-MCS Set	Indicates the HT-MCS values that are supported by all HT STAs in the BSS. Present in Beacon, Probe Response, Mesh Peering Open and Mesh Peering Confirm frames. Otherwise reserved.	A bitmap where a bit is set to 1 to indicate support for that MCS and 0 otherwise, where bit 0 corresponds to MCS 0. MCS values are defined in 9.4.2.55.4.	N	N
NOTE 1—Any change of STA Channel Width field does not impact the HT Protection field. NOTE 2—Examples of when this bit might be set to 1 include, but are not limited to, the following situations: a) One or more non-HT STAs are associated b) A non-HT BSS is overlapping (a non-HT BSS might be detected by the reception of a Beacon or Probe Response frame that does not include an HT Capabilities element)				

9.4.2.57 20/40 BSS Intolerant Channel Report element

The 20/40 BSS Intolerant Channel Report element contains a list of channels on which a STA has found conditions that disallow the use of a 20/40 MHz BSS. The format of the 20/40 BSS Intolerant Channel Report element is shown in Figure 9-383.

	Element ID	Length	Operating Class	Channel List
Octets:	1	1	1	variable

Figure 9-383—20/40 BSS Intolerant Channel Report element format

The Element ID and Length fields are defined in 9.4.2.1.

The Operating Class field of the 20/40 MHz BSS Intolerant Channel Report element contains an enumerated value from Annex E, encoded as an unsigned integer, specifying the operating class in which the Channel List field is valid. If the operating class is "unknown" as described in 11.15.12, the Operating Class field is set to 0. A 20/40 BSS Intolerant Channel Report only reports channels for a single operating class. Multiple 20/40 BSS Intolerant Channel Report elements are used to report channels in more than one operating class.

The Channel List field of the 20/40 MHz BSS Intolerant Channel Report element contains a variable number of octets, where each octet describes a single channel number. Channel numbering is dependent on operating class according to Annex E.

A 20/40 BSS Intolerant Channel Report element includes only channels that are valid for the regulatory domain in which the STA transmitting the element is operating and that are consistent with the Country element transmitted by the AP of the BSS of which it is a member.

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9.4.2.58 Overlapping BSS Scan Parameters element

The Overlapping BSS Scan Parameters element is used by an AP to indicate the values to be used by BSS members when performing OBSS scan operations. The format of the Overlapping BSS Scan Parameters element is shown in Figure 9-384.

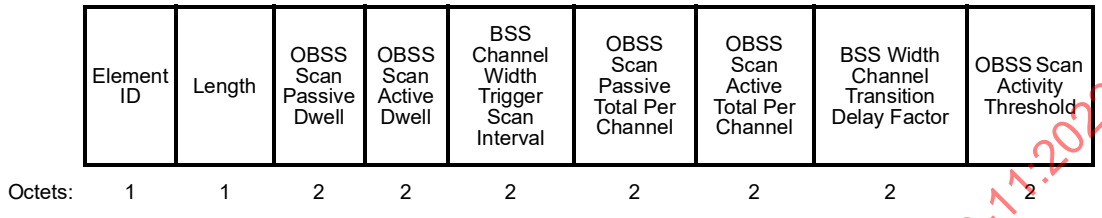

Figure 9-384—Overlapping BSS Scan Parameters element format

The Element ID and Length fields are defined in 9.4.2.1.

The OBSS Scan Passive Dwell field contains a value in TUs, encoded as an unsigned integer, that a receiving STA uses to set dot11OBSSScanPassiveDwell as described in 11.15.5.

The OBSS Scan Active Dwell field contains a value in TUs, encoded as an unsigned integer, that a receiving STA uses to set dot11OBSSScanActiveDwell as described in 11.15.5.

The BSS Channel Width Trigger Scan Interval field contains a value in seconds, encoded as an unsigned integer, that a receiving STA uses to set dot11BSSWidthTriggerScanInterval as described in 11.15.5.

The OBSS Scan Passive Total Per Channel field contains a value in TUs, encoded as an unsigned integer, that a receiving STA uses to set dot11OBSSScanPassiveTotalPerChannel as described in 11.15.5.

The OBSS Scan Active Total Per Channel field contains a value in TUs, encoded as an unsigned integer, that a receiving STA uses to set dot11OBSSScanActiveTotalPerChannel as described in 11.15.5.

The BSS Width Channel Transition Delay Factor field contains an integer value that a receiving STA uses to set dot11BSSWidthChannelTransitionDelayFactor as described in 11.15.5.

The OBSS Scan Activity Threshold field contains a value in hundredths of percent, encoded as an unsigned integer, that a receiving STA uses to set dot11OBSSScanActivityThreshold as described in 11.15.5.

The use of each of these parameters is described in 11.15.5.

9.4.2.59 20/40 BSS Coexistence element

The 20/40 BSS Coexistence element is used by STAs to exchange information that affects 20/40 BSS coexistence.

The 20/40 BSS Coexistence element is formatted as shown in Figure 9-385.

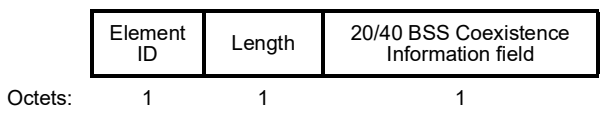

Figure 9-385—20/40 BSS Coexistence element format

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The Element ID and Length fields are defined in 9.4.2.1.

The structure of the 20/40 BSS Coexistence Information field is shown in Figure 9-386.

	B0	B1	B2	B3	B4	B5 B7
	Information Request	Forty MHz Intolerant	20 MHz BSS Width Request	OBSS Scanning Exemption Request	OBSS Scanning Exemption Grant	Reserved
Bits:	1	1	1	1	1	3

Figure 9-386—20/40 BSS Coexistence Information field format

The Information Request field is used to indicate that a transmitting STA is requesting the recipient to transmit a 20/40 BSS Coexistence Management frame with the transmitting STA as the recipient.

The Forty MHz Intolerant field is set to 1 to prohibit an AP that receives this information or reports of this information from operating a 20/40 MHz BSS. When equal to 0, it does not prohibit a receiving AP from operating a 20/40 MHz BSS. This field is used for inter-BSS communication. The definition of this field is the same as the definition of the Forty MHz Intolerant field in the HT Capabilities element (see 9.4.2.55), and its operation is described in 11.15.11.

The 20 MHz BSS Width Request field is set to 1 to prohibit a receiving AP from operating its BSS as a 20/40 MHz BSS. Otherwise, it is set to 0. This field is used for intra-BSS communication. The operation of this field is described in 11.15.12.

The OBSS Scanning Exemption Request field is set to 1 to indicate that the transmitting non-AP STA is requesting the BSS to allow the STA to be exempt from OBSS scanning. Otherwise, it is set to 0. The OBSS Scanning Exemption Request field is reserved when transmitted by an AP. The OBSS Scanning Exemption Request field is reserved when a 20/40 BSS Coexistence element is included in a group addressed frame.

The OBSS Scanning Exemption Grant field is set to 1 by an AP to indicate that the receiving STA is exempted from performing OBSS Scanning. Otherwise, it is set to 0. The OBSS Scanning Exemption Grant field is reserved when transmitted by a non-AP STA. The OBSS Scanning Exemption Grant field is reserved when a 20/40 BSS Coexistence element is included in a group addressed frame.

9.4.2.60 Time Advertisement element

The Time Advertisement element, shown in Figure 9-387, specifies fields describing the source of time corresponding to a time standard, an external clock (external time source), an estimate of the offset between that time standard and the TSF timer, and an estimate of the standard deviation of the error in the offset estimate. This information is used by a receiving STA to align its own estimate of the time standard based on that of another STA.

	Element ID	Length	Timing Capabilities	Time Value (optional)	Time Error (optional)	Time Update Counter (optional)
Octets:	1	1	1	0 or 10	0 or 5	0 or 1

Figure 9-387—Time Advertisement element format

The Element ID and Length fields are defined in 9.4.2.1.

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The Timing Capabilities field specifies the STA's source and encoding of the Time Value field. The encoding of the Timing Capabilities field is specified in Table 9-191.

Table 9-191—Encoding of the Timing Capabilities field

Value	Usage
0	No standardized external time source
1	Timestamp offset based on UTC (see ITU-R Recommendation TF.460-6 (2002) [B53]). The Timestamp offset value in nanoseconds is defined to be 0 at the beginning of the first nanosecond of the first day of the year 1958.
2	UTC time at which the TSF timer is 0.
3–255	Reserved

When the Timing Capabilities field is 0, only the Element ID, Length, and Timing Capabilities fields are included in the Time Advertisement element.

When the Timing Capabilities is 1, the following additional fields are included in the Time Advertisement element:

— Time Value field, a 2s complement integer in nanoseconds that, when added to the Timestamp present in the same transmitted frame, gives the receiving STA an estimate of the time standard at the time the frame was transmitted. The Timestamp is derived from the TSF Timer as defined in 11.19.

— Time Error field, which is set to an unsigned integer in nanoseconds that defines the standard deviation of the error in the Time Value estimate. The Time Error field is set to all 1s to indicate that the error is unknown.

When the Timing Capabilities field is 2, the following fields are included in the Time Advertisement element:

— The Time Value field is the UTC time at which the TSF Timer is 0, given that the TSF Timer units are 1 microsecond units as defined in 11.1.3. The format, including all subfields is shown in Table 9-192. For any subfield not known in the Time Value field, the subfield value is 0.

— The Time Error field is an unsigned integer in milliseconds that defines the standard deviation of the error in the Time Value estimate.

— The Time Update Counter field is a modulo 256 counter that increments each time the AP updates the Time Value UTC at which the TSF Timer is 0.

Table 9-192—Time Value field format when Timing Capabilities is 2

Octet	Description
0–1	Year (0–65 534)
2	Month (0–12)
3	Day of month (0–31)
4	Hours (0–23)
5	Minutes (0–59)
6	Seconds (0–59)
7–8	Milliseconds (0–999)
9	Reserved

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9.4.2.61 Link Identifier element

The Link Identifier element contains information that identifies a TDLS direct link. The element information format is defined in Figure 9-388.

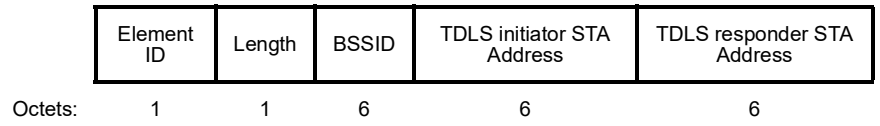

Figure 9-388—Link Identifier element format

The Element ID and Length fields are defined in 9.4.2.1.

The BSSID field is set to the BSSID of the BSS of which the TDLS initiator STA is a member.

The TDLS initiator STA Address field is set to the TDLS initiator STA's MAC address.

The TDLS responder STA Address field is set to the TDLS responder STA's MAC address.

9.4.2.62 Wakeup Schedule element

The Wakeup Schedule element contains information regarding the periodic wakeup schedule for TDLS peer PSM. The element format is defined in Figure 9-389.

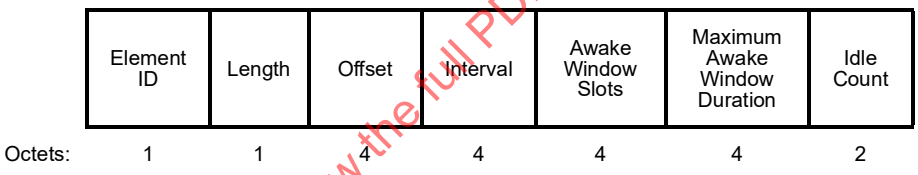

Figure 9-389—Wakeup Schedule element format

The Element ID and Length fields are defined in 9.4.2.1.

The Offset field is the time in microseconds between TSF 0 and the start of a first Awake Window. See 11.2.3.12.

The Interval field is set to the time in microseconds between the start of two successive Awake Windows. See 11.2.3.12.

The Awake Window Slots field is set to the duration of the Awake Window in units of backoff slots (see 10.23.2.4). See 11.2.3.12.

The Maximum Awake Window Duration field is set to the maximum duration of the Awake Window, in units of microseconds. See 11.2.3.12.

The Idle Count field is set to the number of consecutive Awake Windows during which no individually addressed frame is received from the TDLS peer STA before a TDLS peer STA deletes the wakeup schedule. See 11.2.3.12.

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9.4.2.63 Channel Switch Timing element

The Channel Switch Timing element contains information regarding the channel switch timing. The element is defined in Figure 9-390.

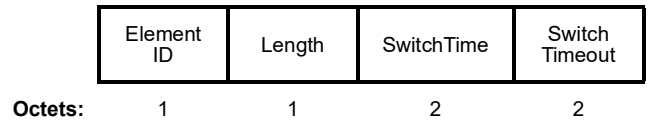

Figure 9-390—Channel Switch Timing element format

The Element ID and Length fields are defined in 9.4.2.1.

The Switch Time field is set to the time it takes for a STA sending the Channel Switch Timing element to switch channels, in units of microseconds.

The Switch Timeout field is set to a time in units of microseconds. The STA sending the Channel Switch Timing element waits for the first Data frame exchange on the off-channel for Switch Timeout microseconds before switching back to base channel. The time is measured from the end of the last symbol of the Ack frame that is transmitted in response to TDLS Channel Switch Response frame, as seen on the WM.

9.4.2.64 PTI Control element

The PTI Control element contains information regarding the traffic buffered at the TPU buffer STA for the TPU sleep STA at the time a TDLS Peer Traffic Indication frame is transmitted by the TPU buffer STA. The element is optionally included in the TDLS Peer Traffic Indication frame. The element is defined in Figure 9-391.

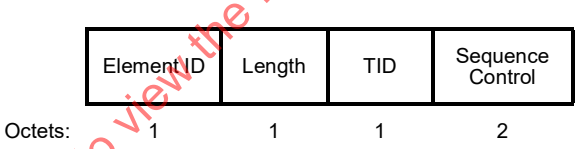

Figure 9-391—PTI Control element format

The Element ID and Length fields are defined in 9.4.2.1.

The TID field contained in the PTI Control element is set to the TID of the latest MPDU that has been transmitted over the TDLS direct link to the TPU sleep STA that is the destination of the TDLS Peer Traffic Indication frame that contains the PTI Control element. See 11.2.3.13.

The Sequence Control field is defined in 9.2.4.4. The Sequence Control field contained in the PTI Control element is set to the sequence number of the latest MPDU that has been transmitted over the TDLS direct link to the TPU sleep STA that is the destination of the TDLS Peer Traffic Indication frame that contains the PTI Control element. See 11.2.3.13.

9.4.2.65 TPU Buffer Status element

The TPU Buffer Status element contains information regarding the traffic buffered at the TPU buffer STA for the TPU sleep STA at the time a TDLS Peer Traffic Indication frame is transmitted by the TPU buffer STA. The element is included in the TDLS Peer Traffic Indication frame. The element is defined in Figure 9-392.

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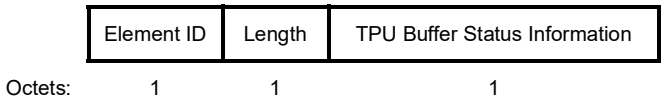

Figure 9-392—TPU Buffer Status element format

The Element ID and Length fields are defined in 9.4.2.1.

The TPU Buffer Status Information field is defined in Figure 9-393

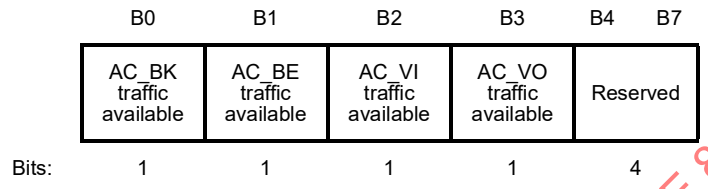

Figure 9-393—TPU Buffer Status Information field format

The AC_BK traffic available field is one bit in size and is set to 1 if AC_BK contains traffic buffered for the TPU sleep STA to which the TPU Buffer Status element will be transmitted and is set to 0 otherwise.

The AC_BE traffic available field is one bit in size and is set to 1 if AC_BE contains traffic buffered for the TPU sleep STA to which the TPU Buffer Status element will be transmitted and is set to 0 otherwise.

The AC_VI traffic available field is one bit in size and is set to 1 if AC_VI contains traffic buffered for the TPU sleep STA to which the TPU Buffer Status element will be transmitted and is set to 0 otherwise.

The AC_VO traffic available field is one bit in size and is set to 1 if AC_VO contains traffic buffered for the TPU sleep STA to which the TPU Buffer Status element will be transmitted and is set to 0 otherwise.

9.4.2.66 Event Request element

9.4.2.66.1 Event Request definition

The Event Request element contains a request to the receiving STA to perform the specified event action. The format of the Event Request element is shown in Figure 9-394.

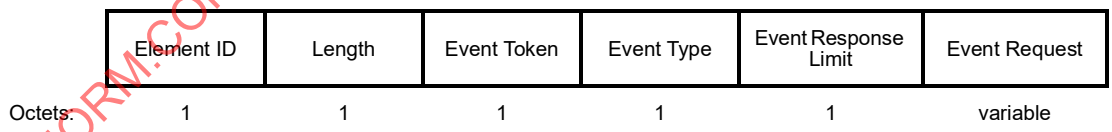

Figure 9-394—Event Request element format

The Element ID and Length fields are defined in 9.4.2.1.

The Event Token field is a nonzero number that is unique among the Event Request elements sent to each destination MAC address for which a corresponding Event Report element has not been received.

The Event Type field is a number that identifies the type of event request. The values of the Event Type field are defined in Table 9-193.

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Table 9-193—Event Type field definitions for event requests and reports

Name	Event Type
Transition	0
RSNA	1
Peer-to-peer link	2
WNM log	3
Reserved	4–220
Vendor Specific	221
Reserved	222–255

The Event Response Limit field contains the maximum number of requested Event Reports to be included in the Event Report element. The field is set to 0 to indicate that no limit is set on the number of Event Reports to be included in the Event Report element.

The Event Request field contains the event request corresponding to the event type, as described in 9.4.2.66.2 to 9.4.2.66.4. The Event Request field is not present when requesting a WNM log report.

The Event Request element is included in an Event Request frame, as described in 9.6.13.2. The use of the Event Request element and Event Request frame is described in 11.21.2.

9.4.2.66.2 Transition event request

The Event Request field corresponding to the Transition event request contains zero or more Transition Event Request subelements. A transition event is a STA movement or attempted movement from one BSS (the source BSS) in one ESS to another BSS (the target BSS) within the same ESS.

The Transition Event subelements specify the conditions in which a Transition Event Report is sent by a STA. The set of valid Transition Event Request subelements is defined in Table 9-194.

Table 9-194—Transition Event Request subelement

Transition Event Request subelement	Subelement ID
Transition Target BSSID	0
Transition Source BSSID	1
Transition Time Threshold	2
Transition Result	3
Frequent Transition	4
Reserved	5–255

The Transition Target BSSID subelement is used to request that a Transition Event Report includes the transition event entry when the target BSSID is equal to the specific BSSID in the Target BSSID field.

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Excluding this subelement from the Event Request element indicates a request for transition events for all target BSSIDs. The format of the Transition Target BSSID subelement is shown in Figure 9-395.

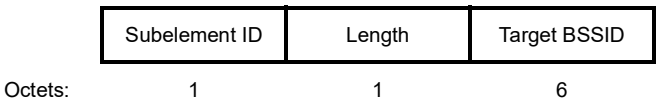

Figure 9-395—Transition Target BSSID subelement format

The Subelement ID field is equal to the Transition Target BSSID value in Table 9-194.

The Length field is defined in 9.4.3.

The Target BSSID field contains a 6-octet BSSID.

The Transition Source BSSID subelement is used to request that a Transition Event Report includes the transition event entry when the source BSSID is equal to the BSSID specified in the Source BSSID field. Excluding this subelement from the Event Request element indicates a request for transition events for all source BSSIDs. The format of the Transition Source BSSID subelement is shown in Figure 9-396.

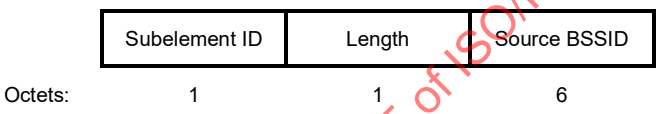

Figure 9-396—Transition Source BSSID subelement format

The Subelement ID field is equal to the Transition Source BSSID value in Table 9-194.

The Length field is defined in 9.4.3.

The Source BSSID field contains a 6-octet BSSID.

The Transition Time Threshold subelement is used to request that a Transition Event Report includes the transition event entry when the transition time is greater than or equal to the Transition Time Threshold value. The format of the Transition Time Threshold subelement is shown in Figure 9-397.

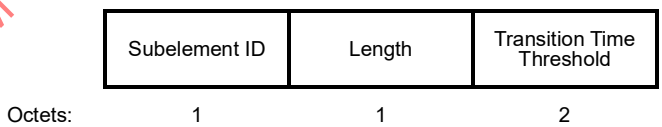

Figure 9-397—Transition Time Threshold subelement format

The Subelement ID field is equal to the Transition Time Threshold value in Table 9-194.

The Length field is defined in 9.4.3.

The Transition Time Threshold field contains a value representing the Transition Time to be used as the threshold value for the Transition Time condition in TUs. The Transition Time is defined in 11.21.2.2.

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The Transition Result subelement is used to request that a Transition Event Report includes the transition event entry that matches the transition result defined by this subelement. The format of Transition Result subelement is shown in Figure 9-398.

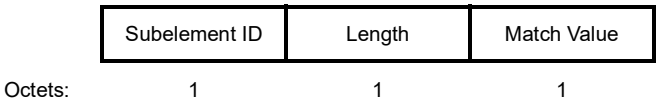

Figure 9-398—Transition Result subelement format

The Subelement ID field is equal to the Transition Result value in Table 9-194.

The Length field is defined in 9.4.3.

The Match Value field is set with each bit as defined in Figure 9-399 to request that the specified transition results that match the bit descriptions are included in the Transition Event report.

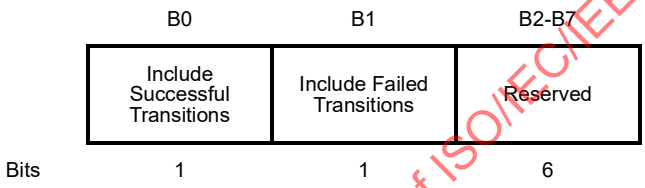

Figure 9-399—Match Value field definitions

The Frequent Transition subelement is used to request that an alerting Transition Event report be generated when the total transition count during the specified time period is greater than or equal to the value given in Frequent Transition Count Threshold field. The format of the Frequent Transition subelement is shown in Figure 9-400.

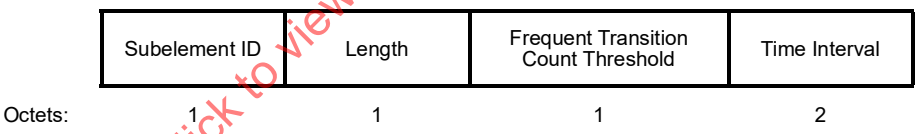

Figure 9-400—Frequent Transition subelement format

The Subelement ID field is equal to the Frequent Transition value in Table 9-194.

The Length field is defined in 9.4.3.

The Frequent Transition Count Threshold field containing the number of transitions in the measurement duration after which a Transition Event Report is generated.

The Time Interval field is the time interval in TUs during which the STA determines if the Frequent Transition Count Threshold is exceeded.

9.4.2.66.3 RSNA event request

The Event Request field corresponding to an RSNA event request contains zero or more RSNA Event Request subelements.

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The subelement format and ordering of subelements are defined in 9.4.3. The set of valid RSNA Event Request subelements is defined in Table 9-195.

Table 9-195—RSNA Event Request subelement

RSNA Event Request subelement	Subelement ID
RSNA Target BSSID	0
Authentication Type	1
EAP Method	2
RSNA Result	3
Reserved	4–255

The RSNA subelements specify reporting conditions for RSNA Event Reports.

The RSNA Target BSSID subelement identifies the BSS at which an RSNA Event establishment was attempted. Excluding this subelement from the Event Request element indicates a request for transition events for all source BSSIDs. The format of the RSNA Target BSSID subelement is shown in Figure 9-401.

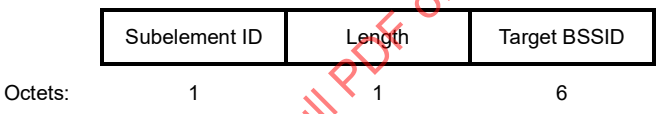

Figure 9-401—RSNA Target BSSID subelement format

The Subelement ID field is equal to the RSNA Target BSSID value in Table 9-195.

The Length field is defined in 9.4.3.

The Target BSSID field contains a 6-octet BSSID.

The Authentication Type subelement is used to request that an RSNA Event Report includes the RSNA event entry when the Authentication Type is equal to the authentication type specified in the Authentication Type field. The format of the Authentication Type subelement is shown in Figure 9-402.

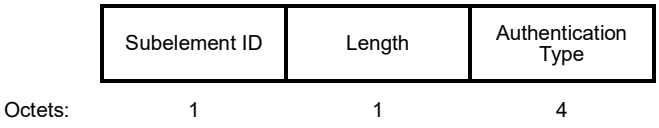

Figure 9-402—Authentication Type subelement format

The Subelement ID field is equal to the Authentication Type value in Table 9-195.

The Length field is defined in 9.4.3.

The Authentication Type field contains one of the AKM suite selectors defined in Table 9-151 in 9.4.2.24.3.

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The EAP Method subelement is used to request that an RSNA Event Report includes the RSNA event entry when the EAP Method is equal to the EAP method specified in the EAP Method field. The format of the EAP Method subelement is shown in Figure 9-403.

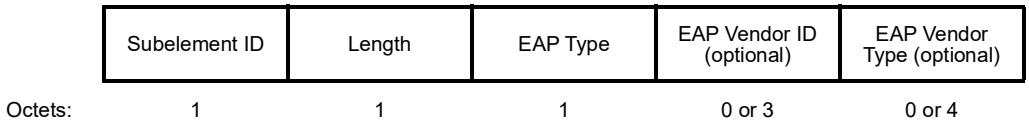

Figure 9-403—EAP Method subelement format

The Subelement ID field is equal to the EAP Method value in Table 9-195.

The Length field is defined in 9.4.3.

The EAP Type field contains a value that identifies a single EAP method and is any valid IANA assigned EAP type.

The EAP Vendor ID field contains a value that identifies the EAP Vendor. The EAP Vendor ID field is included when EAP Type field is 254 and is excluded otherwise.

The EAP Vendor Type field contains a value that identifies the EAP Type as defined by the vendor. The EAP Vendor Type field is included when EAP Type field is 254 and is excluded otherwise.

The RSNA Result subelement is used to request that an RSNA Event Report includes the RSNA event entry that matches the transition result defined by this subelement. The format of RSNA Result subelement is shown in Figure 9-404.

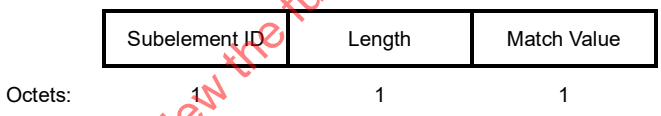

Figure 9-404—RSNA Result subelement format

The Subelement ID field is equal to the RSNA Result value in Table 9-195.

The Length field is defined in 9.4.3.

The Match Value field bits are set as defined in Figure 9-405 to request that the specified RSNA results that match that bit descriptions are included in the RSNA Event report.

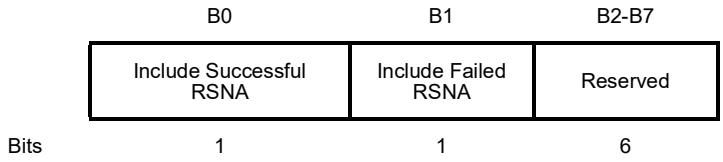

Figure 9-405—Match Value field definitions

9.4.2.66.4 Peer-to-peer link event request

The Event Request field corresponding to peer-to-peer link event request contains zero or more Peer-to-Peer Link Event Request subelements.

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The Peer-to-Peer Link Event Request subelements are defined to have a common format consisting of a 1-octet Subelement ID field, a 1-octet Length field, and a variable length subelement specific information field. The set of valid Peer-to-Peer Link Event Request subelements is defined in Table 9-196.

Table 9-196—Peer-to-Peer Link Event Request subelement

Peer-to-Peer Link Event Request subelement	Subelement ID
Peer Address	0
Channel Number	1
Reserved	2–255

The Peer-to-Peer Link Event Request subelements specify reporting conditions for peer-to-peer link event reporting.

The Peer Address subelement identifies the peer STA, BSS, or IBSS of the peer-to-peer links to be reported. Excluding this subelement from the Event Request element indicates a request for peer-to-peer link events for any peer STA, any BSS, and any IBSS. The format of the Peer Address subelement is shown in Figure 9-406.

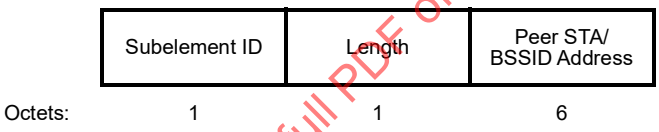

Figure 9-406—Peer Address subelement format

The Subelement ID field is equal to the Peer Address value in Table 9-196.

The Length field is defined in 9.4.3.

The Peer STA/BSSID Address field contains a 6-octet MAC address of a peer STA or a BSSID for peer-to-peer links in an IBSS. If the indicated address matches the Address 1 field of the MAC header contents (see Table 9-30), then the address is a peer STA address for a TDLS or IBSS. If the indicated address matches the Address 3 field of the MAC header contents, then the address is a BSSID for the Direct Link in an infrastructure BSS or for the IBSS.

The Channel Number subelement(s) identify the channel for the peer-to-peer links to be reported. Excluding this subelement from the Event Request element indicates a request for peer-to-peer link events for any channel. The format of the Channel Number subelement is shown in Figure 9-407. The identified channel is indicated by N+1 Channel Number subelements where the first N subelements contain an Operating Class octet with an 80+ behavior limit and the last subelement contains an Operating Class octet without an 80+ behavior limit (as defined in Annex E).

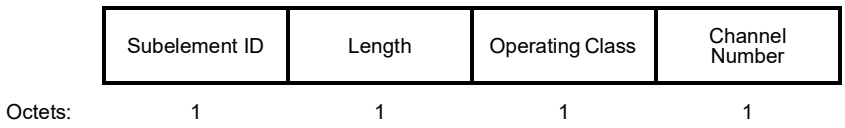

Figure 9-407—Channel Number subelement format

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The Subelement ID field is equal to the Channel Number value in Table 9-196.

The Length field is defined in 9.4.3.

The Operating Class field indicates the channel set of the peer-to-peer link to be used for the peer-to-peer link event report. Operating Classes are defined in Annex E.

The Channel Number field indicates the channel number or (if the corresponding operating class in Annex E has "—" in the channel set column) the center frequency index of the frequency segment containing the primary channel of the peer-to-peer link events requested and included in the peer-to-peer link event report. A Channel Number of 0 in all *N*+1 Channel Number subelements indicates a request to report any peer-to-peer link event for any supported channel in the specified filtering Operating Class.

9.4.2.66.5 Vendor specific event request

The Event Request field corresponding to a vendor specific event request contains zero or more Vendor Specific subelements. The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.25).

9.4.2.67 Event Report element

9.4.2.67.1 Event Report definition

The Event Report element is used by a STA to report an event. The format of the Event Report element is shown in Figure 9-408.

	Element ID	Length	Event Token	Event Type	Event Report Status
Octets:	1	1	1	1	1

	Event TSF (optional)	UTC Offset (optional)	Event Time Error (optional)	Event Report (optional)
Octets:	0 or 8	0 or 10	0 or 5	variable

Figure 9-408—Event Report element format

The Element ID and Length fields are defined in 9.4.2.1.

The Event Token field is the Event Token in the corresponding Event Request element. If the Event Report element is being sent autonomously then the Event Token is 0.

The Event Type field is a number that identifies the type of event report. The values of the Event Type field are defined in Table 9-193.

The Event Report Status field is a value in Table 9-197, indicating the STA's response to the Event Request.

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Table 9-197—Event Report Status

Event Report Status	Description
0	Successful
1	Request failed
2	Request refused
3	Request incapable
4	Detected frequent transition
5–255	Reserved

The Event TSF, UTC Offset, Event Time Error, and Event Report fields are present only when the Event Report Status field is 0.

The Event TSF field is TSF value when the STA logged the event.

The UTC Offset field is the UTC value that corresponds to the UTC time when the TSF timer is equal to 0. If the UTC Offset is unknown, the field is 0.

The Event Time Error field is the UTC standard deviation, as described in 9.4.2.60, that corresponds to the TSF value logged for the event. If the Event Time Error is unknown, the field is 0.

The Event Report field contains the specification of a single event report, as described in 9.4.2.67.2 to 9.4.2.67.5.

The Event Report element is included in an Event Report frame, as described in 9.6.13.3. The use of the Event Report element and frame is described in 11.21.2.

9.4.2.67.2 Transition event report

The format of the Event Report field corresponding to a Transition event report is shown in Figure 9-409.

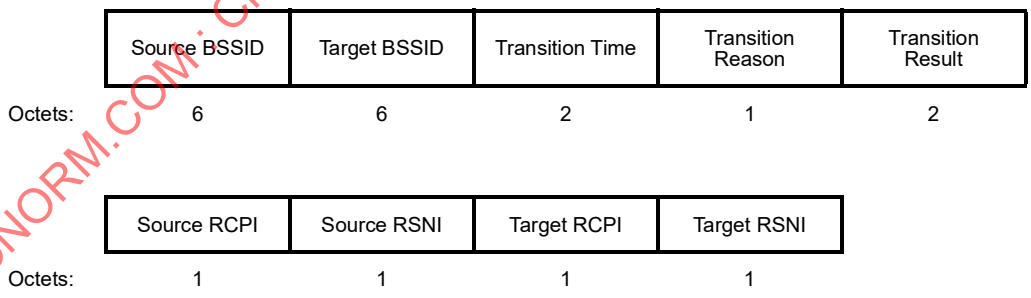

Figure 9-409—Event Report format for Transition event

The Source BSSID field contains the 6-octet BSSID address of the associated AP prior to the attempted transition.

The Target BSSID field contains the 6-octet BSSID address of the AP that is the target of the attempted transition.

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The Transition Time field contains the transition time in TUs. The transition time is defined in 11.21.2.2.

The Transition Reason field indicates the reason why a transition attempt occurred and contains one of the values in Table 9-198.

Table 9-198—Transition and Transition Query reasons

Transition Reason value	Description
0	Unspecified
1	Excessive frame loss rates and/or poor conditions
2	Excessive delay for current traffic streams
3	Insufficient QoS capacity for current traffic streams (TSPEC rejected)
4	First association to ESS (the association initiated by an Association Request frame instead of a Reassociation Request frame)
5	Load balancing
6	Better AP found
7	Deauthenticated or Disassociated from the previous AP
8	AP failed IEEE 802.1X EAP Authentication
9	AP failed 4-way handshake
10	Received too many replay counter failures
11	Received too many data MIC failures
12	Exceeded maximum number of retransmissions
13	Received too many broadcast disassociations
14	Received too many broadcast deauthentications
15	Previous transition failed
16	Low RSSI
17	Roam from a non-IEEE-802.11 system
18	Transition due to received BSS Transition Request frame
19	Preferred BSS transition candidate list included
20	Leaving ESS
21–255	Reserved

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The Transition Result field contains the result of the attempted transition and is one of the status codes specified in Table 9-50 in 9.4.1.9.

The Source RCPI field indicates the received channel power of the most recently measured frame from the Source BSSID before the STA reassociates to the Target BSSID. The Source RCPI is a logarithmic function of the received signal power, as defined in 9.4.2.37.

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The Source RSNI field indicates the received signal-to-noise indication of the most recently measured frame from the Source BSSID before the STA reassociates to the Target BSSID. The Source RSNI is a logarithmic function of the signal-to-noise ratio, as defined in 9.4.2.40.

The Source BSSID, Source RCPI, and Source RSNI fields are set to 0 if the transition is initiated by an Association Request frame.

The Target RCPI field indicates the received channel power of the first measured frame just after the STA reassociates to the Target BSSID. If association with the Target BSSID failed, the Target RCPI field indicates the received channel power of the most recently measured frame from the Target BSSID. The Target RCPI is a logarithmic function of the received signal power, as defined in 9.4.2.37.

The Target RSNI field indicates the received signal-to-noise indication of the first measured frame just after the STA reassociates to the Target BSSID. If association with the Target BSSID failed, the Target RCPI field indicates the received signal-to-noise indication of the most recently measured frame from the Target BSSID. The Target RSNI is a logarithmic function of the signal-to-noise ratio, as defined in 9.4.2.40.

9.4.2.67.3 RSNA event report

The format of the Event Report field corresponding to an RSNA event report is shown in Figure 9-410.

	Target BSSID	Authentication Type	EAP Method	RSNA Result	RSNE
Octets:	6	4	1 or 8	2	variable

Figure 9-410—Event Report format for RSNA event

The Target BSSID field contains the 6-octet BSSID address of the AP accepting the authentication attempt.

The Authentication Type field contains the Authentication type in use at the time of the authentication attempt and is one of the AKM suite selectors defined in Table 9-151 in 9.4.2.24.3.

When the Authentication Type field is either 00-0F-AC:1 (Authentication negotiated over IEEE Std 802.1X or using PMKSA caching as defined in 12.6.10.3) or 00-0F-AC:3 (AKM suite selector for fast BSS transition as defined in 12.6.3), the EAP Method field contains the IANA assigned EAP type. The EAP type contains either the legacy type (1 octet) or the expanded type (1 octet type = 254, 3-octet Vendor ID, 4-octet Vendor-Type). The EAP Method field is 0 otherwise. The EAP Method field is a single octet set to 0 otherwise.

The RSNA Result field contains the result of the RSNA establishment attempt and is one of the status codes specified in Table 9-50 in 9.4.1.9.

The RSNE field contains the entire contents of the negotiated RSNE at the time of the authentication attempt. The maximum length of the RSNE field is less than the maximum length of an RSNE, as defined in 9.4.2.24. If the length of the RSNE included here exceeds the maximum length of the RSNE field, the RSNE is truncated to the maximum length allowed for the RSNE field.

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9.4.2.67.4 Peer-to-peer link event report

The format of the Event Report field corresponding to a peer-to-peer link event report is shown in Figure 9-411.

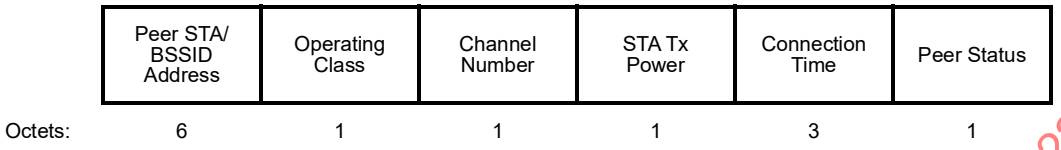

Figure 9-411—Event Report format for peer-to-peer link event

A peer-to-peer link is defined to be either a Direct Link within a QoS BSS, a TDLS, or a STA-to-STA communication in an IBSS.

The Peer STA/BSSID Address field contains a 6-octet MAC address. If this event is for a peer-to-peer link in an infrastructure BSS, this field contains the MAC address of the peer STA. If this event is for a peer-to-peer link in an IBSS, this field contains the BSSID.

The Operating Class field indicates the channel set of the peer-to-peer link. Valid values of the Operating Class are shown in Annex E.

The Channel Number field indicates the peer-to-peer channel number of the peer-to-peer link. The Channel Number is defined within an Operating Class as shown in Annex E.

The STA Tx Power field indicates the target transmit power at the antenna (i.e., EIRP) in dBm with a tolerance of ± 5 dB of the lowest basic rate of the reporting STA.

The Connection Time field contains the connection time in seconds. If the Peer Status is 0, this field indicates the duration of the Direct Link. If the Peer Status field is 1, this field indicates the time difference from the time the Direct Link was established to the time at which the reporting STA generated the event report. If the Peer Status field is 2, this field indicates the duration of the IBSS membership. If the Peer Status is 3, this field indicates the time difference from the time the STA joined the IBSS to the time at which the reporting STA generated the event report. See 11.21.2.4.

The Peer Status field indicates the Peer link connection status as indicated in Table 9-199.

Table 9-199—Peer Status definitions

Peer Status	Description
0	Direct Link terminated
1	Direct Link active
2	IBSS membership terminated
3	IBSS membership active
4–255	Reserved

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9.4.2.67.5 WNM log event report

The format of the Event Report field corresponding to a WNM log event report is shown in Figure 9-412.

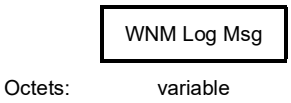

Figure 9-412—Event Report format for WNM log event

The WNM Log Msg field contains the entire syslog message, consisting of the PRI, HEADER, and MSG portion of a WNM log message as described in IETF RFC 5424. The TAG field of the MSG portion of the message is a 17-octet string containing the ASCII representation of the STA MAC address using hexadecimal notation with colons between octets. The octet containing the Individual/Group bit occurs last, and that bit is in the least significant position within that octet. See 11.21.2.5.

NOTE—For example, the TAG field for a STA with MAC address AC-DE-48-12-7B-80 is "80:7B:12:48:DE:AC" or "80:7b:12:48:de:ac".

9.4.2.67.6 Vendor Specific event report

The Event Report field corresponding to Vendor Specific event report contains zero or more Vendor Specific subelements. The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.25).

9.4.2.68 Diagnostic Request element

9.4.2.68.1 Diagnostic Request definition

The Diagnostic Request element contains a request that the receiving STA undertake the specified diagnostic action. The format of the Diagnostic Request element is shown in Figure 9-413.

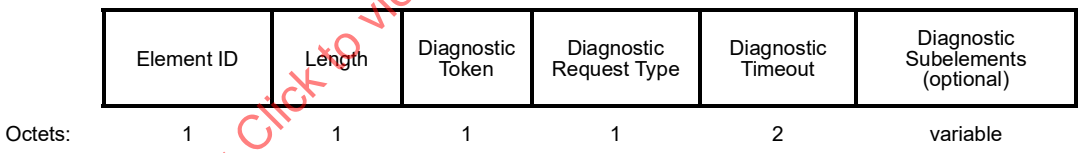

Figure 9-413—Diagnostic Request element format

The Element ID and Length fields are defined in 9.4.2.1.

The Diagnostic Token field is a number that is unique among the Diagnostic Request elements sent to each destination MAC address for which a corresponding Diagnostic Report element has not been received.

The Diagnostic Request Type field is a number that identifies a type of diagnostic request. The values of Diagnostic Request Types are shown in Table 9-200.

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Table 9-200—Diagnostic Request/Report Type definitions

Name	Diagnostic Type values
Cancel Diagnostic Request	0
Manufacturer Information STA Report	1
Configuration Profile	2
Association Diagnostic	3
IEEE 802.1X Authentication Diagnostic	4
Reserved	5–220
Vendor Specific	221
Reserved	222–255

The Diagnostic Timeout field contains the time, in seconds, after which no response is returned.

The Diagnostic Subelements field contains zero or more diagnostic subelements depending on the specific Diagnostic Request Type, as defined in 9.4.2.68.2 to 9.4.2.68.4.

The Cancel Diagnostic Request, Manufacturer Information STA Report, and Configuration Profile Diagnostic Request elements carry no Diagnostic subelements.

The Diagnostic Request element is included in a Diagnostic Request frame, as described in 9.6.13.4. The use of Diagnostic Request element and frames is described in 11.21.3.

9.4.2.68.2 Association Diagnostic request

The Diagnostic Subelements field corresponding to an Association Diagnostic request type is shown in Table 9-201. The corresponding Diagnostic subelements are defined in 9.4.2.68.5.

Table 9-201—Association Diagnostic request contents

Order	Subelement
1	AP Descriptor
2	Profile ID

9.4.2.68.3 IEEE 802.1X Authentication Diagnostic request

The Diagnostic Subelements field corresponding to an IEEE 802.1X Authentication Diagnostic request type is shown in Table 9-202. The corresponding Diagnostic subelements are defined in 9.4.2.68.5.

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Table 9-202—IEEE 802.1X Authentication Diagnostic request contents

Order	Subelement
1	AP Descriptor
2	EAP Method
3	Credential Type
4	Profile ID

9.4.2.68.4 Vendor Specific diagnostic request

The Diagnostic Subelements field corresponding to a Diagnostic Request element of type Vendor Specific diagnostic request contains zero or more Vendor Specific subelements. The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25).

9.4.2.68.5 Diagnostic subelement descriptions

The following text describes the various subelements that are optionally included in Diagnostic Subelements field of a Diagnostic Request element (9.4.2.68) or a Diagnostic Report element (9.4.2.69). The format of a Diagnostic subelement is shown in Figure 9-414.

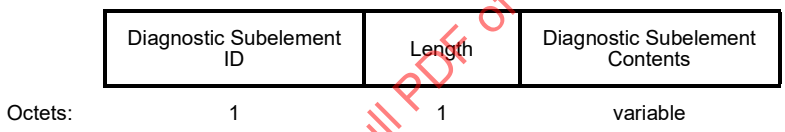

Figure 9-414—Diagnostic subelement format

The Diagnostic Subelement ID field indicates the Diagnostic subelement ID and is any allocated value in Figure 9-203.

Table 9-203—Diagnostic subelement ID values

Subelement ID	Subelement name
0	Credential Type
1	AKM Suite
2	AP Descriptor
3	Antenna Type
4	Cipher Suite
5	Collocated Radio Type
6	Device Type
7	EAP Method
8	Firmware Version
9	MAC Address
10	Manufacturer ID String
11	Manufacturer Model String

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Table 9-203—Diagnostic subelement ID values *(continued)*

Subelement ID	Subelement name
12	Manufacturer OI
13	Manufacturer Serial Number String
14	Power Save Mode
15	Profile ID
16	Supported Operating Classes
17	Status Code
18	SSID
19	Tx Power Capability
20	Certificate ID
21–220	Reserved
221	Vendor Specific
221–255	Reserved

The Length field is the length in octets of the Diagnostic Subelement Contents field.

The values of the Diagnostic Subelement Contents field are described in the following paragraphs.

The format for the Credential Type subelement is shown in Figure 9-415.

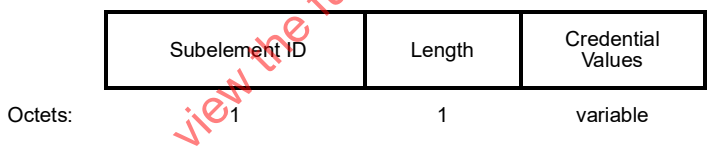

Figure 9-415—Credential Type subelement format

The Credentials Values field indicates one or more types of credential. Each value is chosen from those shown in Table 9-204.

Table 9-204—Credentials values

Value	Description
0	None
1	Preshared key
2	Username and password
3	X.509 certificate
4	Other certificate
5	One time password
6	Token
7–255	Reserved

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The format for the AKM Suite subelement is shown in Figure 9-416.

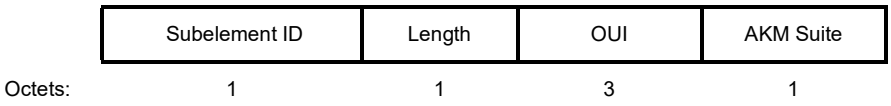

Figure 9-416—AKM Suite subelement format

The OUI and AKM Suite fields identify the authentication method, and the AKM suite selector is one of the values in Table 9-151 in 9.4.2.24.3.

The format of the AP descriptor subelement is shown in Figure 9-417.

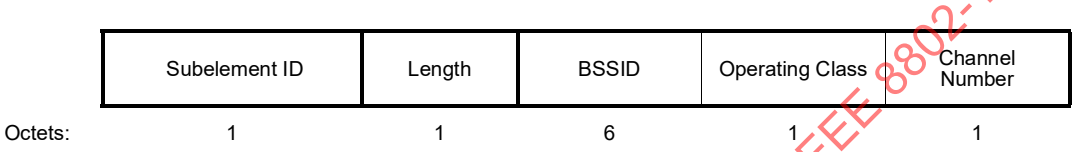

Figure 9-417—AP Descriptor subelement format

The set of current operating classes and channel widths of the AP is indicated by *N*+1 AP descriptor subelements where the first *N* subelements contain an Operating Class octet with an 80+ behavior limit and the last subelement contains an Operating Class octet without an 80+ behavior limit (as defined in Annex E).

NOTE 1—An 80+80 MHz AP sends four AP descriptor subelements for 20/40 MHz, 80 MHz, 80+ MHz (for the secondary 80 MHz frequency segment), and 80 MHz (for the primary 80 MHz frequency segment).

The BSSID field identifies the BSS indicated in the AP Descriptor subelement, as described in 9.2.4.3.4.

The Operating Class field contains an enumerated value from Annex E that identifies the mapping from Channel Number to frequency.

The Channel Number field indicates a current operating channel or (if the corresponding operating class in Annex E has "—" in the channel set column) the center frequency index of the frequency segment containing the primary channel, of the AP identified by the BSSID in the AP Descriptor subelement.

The format for the Antenna Type subelement is shown in Figure 9-418.

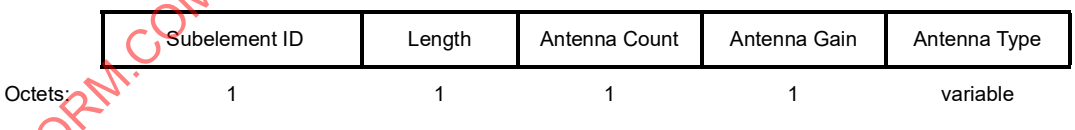

Figure 9-418—Antenna Type subelement format

The Antenna Count field contains the number of antennas of the indicated antenna type and antenna gain pair. The Antenna Count field value 0 is reserved.

The Antenna Gain field contains the peak gain, in dBi, of the antenna.

The Antenna Type field contains an ASCII string (truncated to 251 octets if required) describing the manufacturer's type information (i.e., a series of letters/numbers) of the antenna(s) or DMG antenna connected to the wireless adapter.

NOTE 2—Beamforming antennas for a non-DMG STA might have several antenna IDs, depending on antenna bearing.

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The format for the Cipher Suite subelement is shown in Figure 9-419.

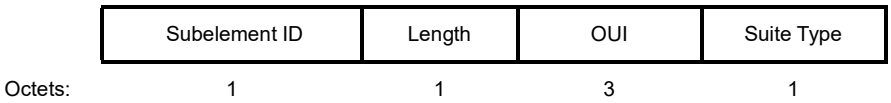

Figure 9-419—Cipher Suite subelement format

The OUI and Suite Type fields identify the cipher suite, and the cipher suite selector is one of the values in Table 9-149.

The format for the Collocated Radio Type subelement is shown in Figure 9-420.

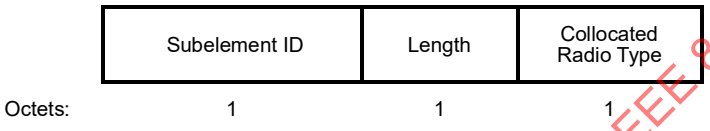

Figure 9-420—Collocated Radio Type subelement format

The Collocated Radio Type subelement indicates the type of collocated radio and is one of the values in Table 9-205. The method that a STA uses to obtain the information on the collocated radio is out of the scope of this standard.

Table 9-205—Collocated Radio Type

Collocated Radio Type	Value
Reserved	0
Cellular	1
Cordless	2
GPS	3
IEEE 802.11™	4
IEEE 802.15™	5
IEEE 802.16™	6
IEEE 802.20™	7
IEEE 802.22™	8
Digital Audio Broadcasting	9
Digital Video Broadcasting	10
Reserved	11–255

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The Device Type subelement reports the type of device in which the IEEE 802.11 STA resides. The format of the Device Type subelement is shown in Figure 9-421.

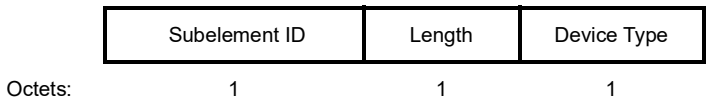

Figure 9-421—Device Type subelement format

The Device Type field indicates the category of device. The numerical assignment to each device type category is defined in Table 9-206.

Table 9-206—Device Type definitions

Device Type	Value
Reserved	0
Reference Design	1
Access Point or Wireless Router for Home or Small Office	2
Enterprise Access Point	3
Cable, DSL, or Other Broadband Gateway	4
Digital Still Camera	5
Portable Video Camera	6
Networked Web Camera	7
Digital Audio—Stationary	8
Digital Audio—Portable	9
Set-Top Box, Media Extender, Media Server (includes players & recorders)	10
Display Device (television, monitor, picture frame)	11
Game Console or Game Console Adapter	12
Gaming Device—Portable	13
Media Server or Media Adapter	14
Network Storage Device	15
External Card	16
Internal Card	17
Ultra-Mobile PC	18
Notebook Computer	19
PDA (Personal Digital Assistant)	20
Printer or Print Server (includes scanner and/or fax capability)	21
Phone—Dual-Mode	22

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Table 9-206—Device Type definitions *(continued)*

Device Type	Value
Phone—Single-Mode	23
Smartphone—Dual-Mode	24
Smartphone—Single-Mode	25
Reserved	26-220
Other devices	221
Reserved	222–255

The format for the EAP Method subelement is shown in Figure 9-422.

	Subelement ID	Length	EAP Type	EAP Vendor ID (optional)	EAP Vendor Type (optional)
Octets:	1	1	1	0 or 3	0 or 4

Figure 9-422—EAP Method subelement format

The EAP Type field contains a value that identifies a single EAP method and is any valid IANA assigned EAP type.

The EAP Vendor ID field contains a value that identifies the EAP Vendor. The EAP Vendor ID field is included when EAP Type field is 254 and is excluded otherwise.

The EAP Vendor Type field contains a value that identifies the EAP Type as defined by the vendor. The EAP Vendor Type field is included when EAP Type field is 254 and is excluded otherwise.

The format for the Firmware Version subelement is shown in Figure 9-423.

	Subelement ID	Length	Firmware Version
Octets:	1	1	variable

Figure 9-423—Firmware Version subelement format

This Firmware Version field contains an ASCII string identifying the version of firmware currently installed on the wireless network adaptor.

The format for the MAC Address subelement is shown in Figure 9-424.

	Subelement ID	Length	MAC Address
Octets:	1	1	6

Figure 9-424—MAC Address subelement format

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This MAC Address field contains the 6-octet IEEE 802 MAC address of the STA.

The format for the Manufacturer ID String subelement is shown in Figure 9-425.

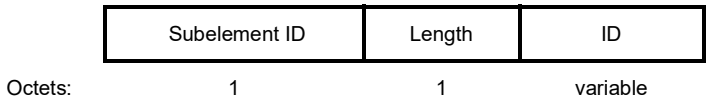

Figure 9-425—Manufacturer ID String subelement format

The ID field contains an ASCII string indicating the manufacturer identifier of the wireless network adaptor.

The format for the Manufacturer Model String subelement is shown in Figure 9-426.

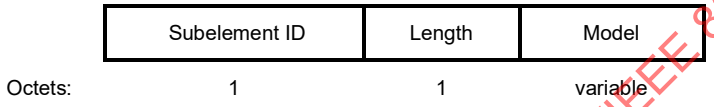

Figure 9-426—Manufacturer Model String subelement format

The Model field contains an ASCII string indicating the model of the wireless network adaptor.

The format for the Manufacturer OI subelement is shown in Figure 9-427.

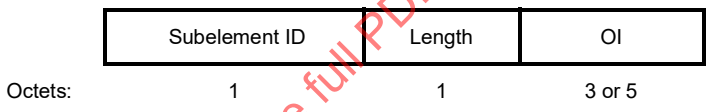

Figure 9-427—Manufacturer OI subelement format

The OI field contains an organization identifier, as defined in 9.4.1.31.

The format for the Manufacturer Serial Number String subelement is shown in Figure 9-428.

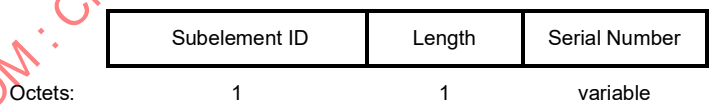

Figure 9-428—Manufacturer Serial Number String subelement format

The Serial Number field contains an ASCII string indicating the serial number of the wireless network adaptor.

The format for the Power Save Mode subelement is shown in Figure 9-429.

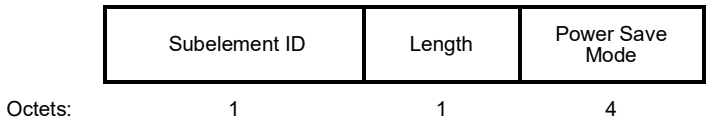

Figure 9-429—Power Save Mode subelement format

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The Power Save Mode field is a bitmap field that indicates the power save mode(s) in use by the STA, as defined in Table 9-207.

Table 9-207—Power Save Mode definition

Power Save Mode	Bit
Unknown	0
None	1
PS mode (ReceiveDTIMs=1, see 11.2.3)	2
PS mode (ReceiveDTIMs=0, see 11.2.3)	3
U-APSD (see 11.2.3.5)	4
S-APSD (see 11.2.3.5)	5
U-PSMP (see 10.30	6
S-PSMP (see 10.30)	7
SM power save (see 11.2.6)	8
WNM sleep mode (see 11.2.3.16)	9
FMS (see 11.2.3.14)	10
TIM broadcast (see 11.2.3.15)	11
TFS (see 11.21.12)	12
TPU (see 11.2.3.13)	13
TDLS peer PSM (see 11.2.3.12)	14
TXOP power save mode	15
Reserved	16–31

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The format for the Profile ID subelement is shown in Figure 9-430.

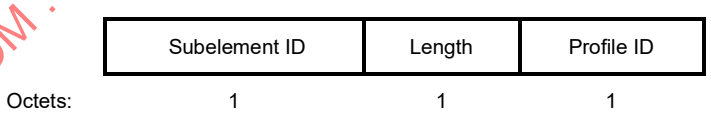

Figure 9-430—Profile ID subelement format

The Profile ID field contains a unique identifier for referencing a configuration profile available on a device. The identifier is uniquely associated to a single configuration profile on the device sending the identifier.

The format for the Supported Operating Classes subelement is shown in Figure 9-431.

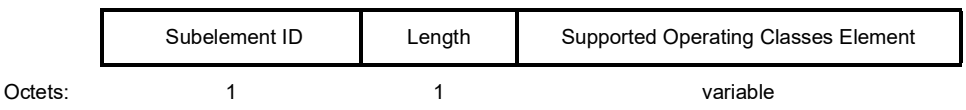

Figure 9-431—Supported Operating Classes subelement format

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The Supported Operating Classes Element field contains the Supported Operating Classes element, as defined in 9.4.2.53.

The format for the Status Code subelement is shown in Figure 9-432.

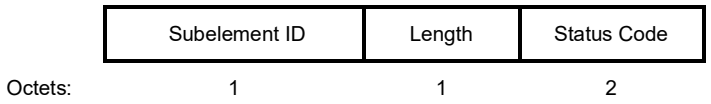

Figure 9-432—Status Code subelement format

The Status Code field contains the final IEEE 802.11 Status code, as defined in Table 9-50 in 9.4.1.9, received at the end of the applicable operation.

The format for the SSID subelement is shown in Figure 9-433.

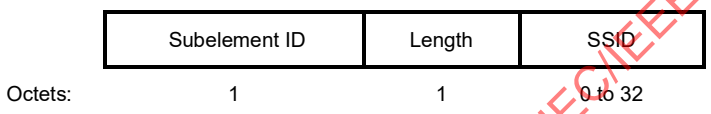

Figure 9-433—SSID subelement format

The SSID field contains a service set identifier with a maximum length of 32 octets, as defined in 9.4.2.2.

The format for the Tx Power Capability subelement is shown in Figure 9-434.

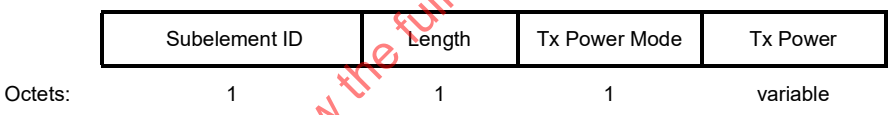

Figure 9-434—Tx Power Capability subelement format

The Tx Power Mode field identifies the transmit power mode of the non-AP STA and is one of the values in Table 9-208.

Table 9-208—Tx Power Modes

Tx Power Mode	Value
Discrete	0
Range	1
Reserved	2–255

The Tx Power field indicates the target transmit power level(s) at the antenna(s) or DMG antenna(s) (i.e., EIRP), where the actual power is within ± 5 dB to the target. Each transmit power level is encoded in a single octet as a 2s complement value in dBm, rounded to the nearest integer. If the Tx Power Mode field is 0, then the Tx Power field contains one or more transmit power levels in increasing numerical order. If the Tx Power Mode field is 1, the Tx Power field contains the STA's minimum and nonzero maximum transmit power levels, in that order.

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The format for the Certificate ID subelement is shown in Figure 9-435.

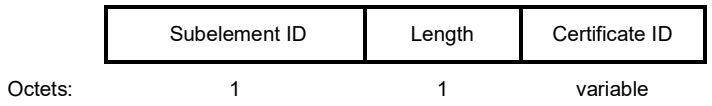

Figure 9-435—Certificate ID subelement format

The Certificate ID field contains a UTF-8 string indicating an identifier assigned to the STA in a manner outside the scope of the standard. The Certificate ID typically takes the form of "WFA3991" and might be used by a receiving STA to look up the certificate assigned to that ID.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25).

9.4.2.69 Diagnostic Report element

9.4.2.69.1 Diagnostic report definition

The Diagnostic Report element contains a Diagnostic report. The format of the Diagnostic Report element is shown in Figure 9-436.

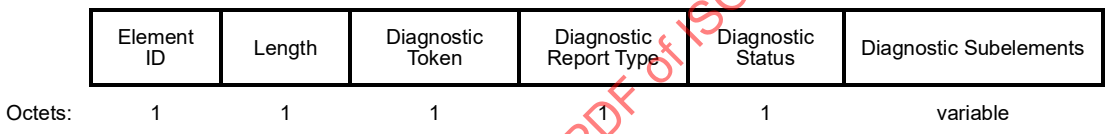

Figure 9-436—Diagnostic Report element format

The Element ID and Length fields are defined in 9.4.2.1.

The Diagnostic Token field is the Diagnostic Token in the corresponding Diagnostic Request element.

The Diagnostic Report Type field is a number that identifies the Diagnostic report. The Diagnostic Report Types are defined in Table 9-200.

The Diagnostic Status field is a value in Table 9-197 (see 9.4.2.67), indicating the STA's response to the diagnostic request indicated by the diagnostic token.

The Diagnostic Subelements field contains the results of the diagnostic request.

The Diagnostic Subelements field contains the diagnostic subelement values, defined in 9.4.2.68.5 corresponding to the Diagnostic Report Type field value.

The Diagnostic Report element is included in a Diagnostic Report frame, as described in 9.6.13.5. The use of Diagnostic Report element and frames is described in 11.21.3.

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9.4.2.69.2 Manufacturer Information STA Report

The contents of the Diagnostic Subelements field of a Diagnostic Report element of type Manufacturer Information STA Report is shown in Table 9-209. The corresponding Diagnostic subelements are defined in 9.4.2.68.5.

Table 9-209—Manufacturer Information STA report contents

Order	Subelement
1	Manufacturer OI
2	Manufacturer ID string
3	Manufacturer model string
4	Manufacturer serial number string
6	Firmware Version
7	Antenna Type
8	Collocated Radio Type
9	Device Type
10	Certificate ID

9.4.2.69.3 Configuration Profile report

The contents of the Diagnostic Subelements field of a Diagnostic Report element of type Configuration Profile is shown in Table 9-210. The corresponding Diagnostic subelements are defined in 9.4.2.68.5.

Table 9-210—Configuration Profile report contents

Order	Subelement
1	Profile ID
2	Supported Operating Classes
3	Tx Power
4	Cipher Suite
5	AKM Suite
6	EAP Method
7	Credential Type
8	SSID
9	Power Save Mode

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9.4.2.69.4 Association Diagnostic report

The contents of the Diagnostic Subelements field of a Diagnostic Report element of type Association Diagnostic is shown in Table 9-211. The corresponding Diagnostic subelements are defined in 9.4.2.68.5.

Table 9-211—Association Diagnostic report contents

Order	Subelement
1	AP Descriptor
2	Status Code

9.4.2.69.5 IEEE 802.1X Authentication Diagnostic report

The contents of the Diagnostic Subelements field of a Diagnostic Report element of type IEEE 802.1X Authentication Diagnostic is shown in Table 9-212. The corresponding Diagnostic subelements are defined in 9.4.2.68.5.

Table 9-212—IEEE 802.1X Authentication Diagnostic report contents

Order	Subelement
1	AP Descriptor
2	EAP Method
3	Credential Type
4	Status Code

9.4.2.69.6 Vendor Specific diagnostic report

The contents of the Diagnostic subelements field of a Diagnostic Report element of type Vendor Specific contains zero or more Vendor Specific subelements that have the same formats as Vendor Specific elements in 9.4.2.25.

9.4.2.70 Location Parameters element

9.4.2.70.1 Location Parameters definition

The Location Parameters element is used for location services. The format of this element is shown in Figure 9-437.

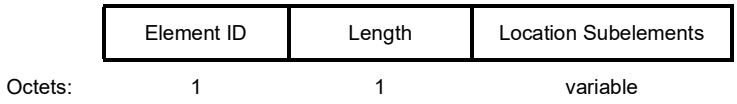

Figure 9-437—Location Parameters element format

The Element ID and Length fields are defined in 9.4.2.1.

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The Location Subelements field contains one or more Location subelements described in Table 9-213.

Table 9-213—Optional subelement IDs for Location Parameters

Subelement ID	Subelement name
1	Location Indication Parameters (see 9.4.2.70.2)
2	Location Indication Channels (see 9.4.2.70.3)
3	Location Status (see 9.4.2.70.4)
4	Radio (see 9.4.2.70.5)
5	Motion (see 9.4.2.70.6)
6	Location Indication Broadcast Data Rate (see 9.4.2.70.7)
7	Time of Departure (see 9.4.2.70.8)
8	Location Indication Options (see 9.4.2.70.9)
9–220	Reserved
221	Vendor Specific (see 9.4.2.25)
222–255	Reserved

The Location Parameters element is included in Location Configuration Request frames, as described in 9.6.13.6; Location Configuration Response frames, as described in 9.6.13.7; and Location Track Notification frames, as described in 9.6.7.17. The use of the Location Parameters element is described in 11.21.4.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.4.2.70.2 Location Indication Parameters subelement

The Location Indication Parameters subelement contains STA location reporting characteristics. The format of the Location Indication Parameters subelement is shown in Figure 9-438.

	Subelement ID	Length	Indication Multicast Address	Report Interval Units	Normal Report Interval	Normal Number of Frames per Channel
Octets:	1	1	6	1	2	1

	In-Motion Report Interval	In-Motion Number of Frames per Channel	Burst Inter-frame Interval	Tracking Duration	ESS Detection Interval
Octets:	2	1	1	1	1

Figure 9-438—Location Indication Parameters subelement format

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The Subelement ID field is defined in Table 9-213.

The Length field is defined in 9.4.3.

Except in Location Track Notification frames sent in an IBSS, the Indication Multicast Address field specifies the destination address to which the Location Track Notification frames are sent. This field is a locally administered group address formed according to the procedure defined in 11.21.4.1. The field is reserved when Location Track Notification frames are transmitted in an IBSS.

The Report Interval Units field contains the units used for the Normal Report Interval field and In-Motion Report Interval field, as indicated in Table 9-214.

Table 9-214—Report Interval Units field

Report Interval Units	Description
0	Hours
1	Minutes
2	Seconds
3	Milliseconds
4–255	Reserved

The Normal Report Interval field is the time interval, expressed in the units indicated in the Report Interval Units field, at which the reporting STA is expected to transmit one or more Location Track Notification frames if either dot11MotionDetectionActivated is false or the STA is stationary. The STA does not transmit Location Track Notification frames when the value of the Normal Report Interval field is 0.

The Normal Number of Frames per Channel field is the number of Location Track Notification frames per channel sent or expected to be sent by the STA at each Normal Report Interval.

Motion is the act or process of moving, or a particular action or movement relative to the point at which the STA is configured to send Location Track Notification frames. Motion might be detected using one of the following criteria:

— Detection of speed that is greater or equal to 0.5 m/s.
— Detection of movement or vibration, for example by a ball-in-tube sensor or accelerometer or other means.

The exact criteria and mechanism to detect motion is out of scope for this standard.

The In-Motion Report Interval field is the time interval, expressed in the units indicated in the Report Interval Units field, at which the STA reports its location by sending a Location Track Notification frame when the reporting STA is in motion. If dot11MotionDetectionActivated is false, this field is 0.

The In-Motion Number of Frames per Channel field is the number of Location Track Notification frames per channel sent or expected to be sent by the STA at each In-Motion Report Interval. If dot11MotionDetectionActivated is false, this field is 0.

The Burst Inter-frame Interval field is the target time interval, expressed in milliseconds, between the transmissions of each of the Normal or In-Motion frames on the same channel. The Burst Inter-frame interval value is 0 to indicate that frames are transmitted with no target inter-frame delay.

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The Tracking Duration field is the amount of time, in minutes, that a STA sends the Location Track Notification frames. The duration starts as soon as the STA sends a Location Configuration Response frame with a Location Status value of Success. If the Tracking Duration value is a nonzero value the STA sends Location Track Notification frames, based on the Normal and In-Motion Report Interval field values, until the duration ends. If the Tracking Duration is 0 the STA continuously sends Location Track Notification frames as defined by Normal and In-Motion Report Interval field values until transmission is terminated based on the procedures detailed in 11.21.4.2.

The ESS Detection Interval field is the periodicity, in minutes, that a STA checks for beacons transmitted by one or more APs belonging to the same ESS that configured the STA. If no beacons from the ESS are received for this period, the STA terminates transmission of Location Track Notification frames, as described in the procedures detailed in 11.21.4.2. The ESS Detection Interval field is not used when the ESS Detection Interval field value is 0.

9.4.2.70.3 Location Indication Channels subelement

The Location Indication Channels subelement contains location reporting channel information. The format of the Location Indication Channels subelement format is shown in Figure 9-439.

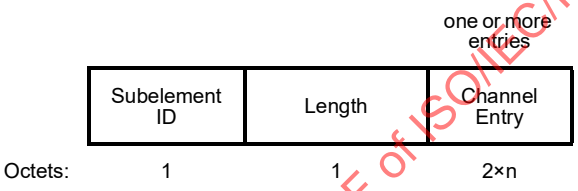

Figure 9-439—Location Indication Channels subelement format

The Subelement ID field is defined in Table 9-213.

The Length field is defined in 9.4.3.

The Channel Entry field includes one or more Operating Class and Channel fields (see Figure 9-106).

The Operating Class subfield of the Operating Class and Channel field indicates the frequency band on which a STA transmits Location Track Notification frames.

The Channel subfield of the Operating Class and Channel field indicates a channel number on which a STA sends or an ESS expects to receive Location Track Notification frames.

The Operating Class and Channel fields can be grouped together to identify a noncontiguous channel. A noncontiguous channel is indicated by a group of N+1 Operating Class and Channel fields where the first N Operating Class and Channel fields contain an Operating Class subfield with an 80+ behavior limit and the last Operating Class and Channel field in the group contains an Operating Class subfield without an 80+ behavior limit (as defined in Annex E).

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9.4.2.70.4 Location Status subelement

The Location Status subelement provides the result of a Location Request or Location Configuration Request frame. The format of the Location Status subelement is shown in Figure 9-440.

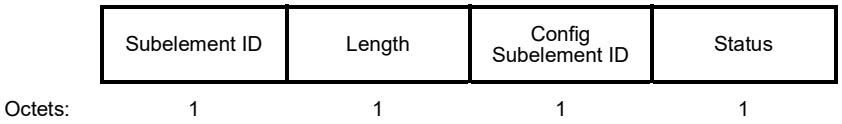

Figure 9-440—Location Status subelement format

The Subelement ID field is defined in Table 9-213.

The Length field is defined in 9.4.3.

The Config Subelement ID field is a specific Location Parameters subelement ID transmitted in a Location Configuration Request frame as defined in Table 9-213.

A Location Status subelement is included for each configuration subelement in the Location Configuration Request frame, except when all status values are the same. When all status values are the same, one Location Status subelement is included with the Config subelement ID set to 0 in the Location Configuration Response frame.

The Status field identifies the result of the Location Request frame and is one of the values in Table 9-197.

9.4.2.70.5 Radio subelement

The Radio subelement contains radio information. The format of the Radio subelement is shown in Figure 9-441.

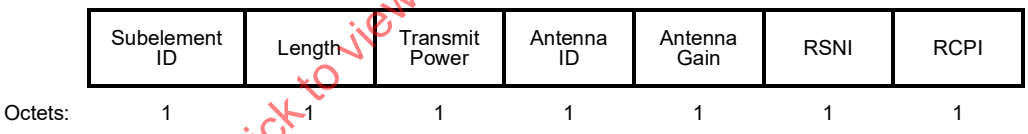

Figure 9-441—Radio subelement format

The Subelement ID field is defined in Table 9-213.

The Length field is defined in 9.4.3.

The Transmit Power field is the transmit power used to transmit the current Location Track Notification frame containing the Location Parameters element with the Radio subelement and is a 2s complement signed integer, reported as an EIRP in dBm. A Transmit Power field set to –128 indicates that the transmit power is unknown. The tolerance for the transmit power value reported in the Radio subelement is ± 5 dB. This tolerance is defined as the maximum possible difference, in decibels, between the reported power value and the total transmitted power across all antennas of the STA, which are measured when transmitting Location Request frames.

The Antenna ID field is the identifying number for the antenna or DMG antenna used to transmit the Location Request frame. The antenna ID or DMG antenna ID is defined in 9.4.2.39.

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The Antenna Gain field is the antenna gain of the antenna (or group of antennas) over which the Location Track Notification frame is transmitted and is a 2s complement signed integer, reported in dB. An Antenna Gain field set to –128 indicates that the antenna gain is unknown.

The RSNI field contains the RSNI value measured against the most recently received Location Configuration Request frame requesting that a Radio subelement be included in the Location Track Notification frame. The RSNI value is defined in 9.4.2.40. A RSNI field set to 255 indicates that the RSNI value is unknown or is not used.

The RCPI field contains the RCPI value measured against the most recently received Location Configuration Request frame requesting that a Radio subelement be included in the Location Track Notification frame. The RCPI value is defined in 9.4.2.37. A RCPI field set to 255 indicates that the RCPI value is unknown or is not used.

9.4.2.70.6 Motion subelement

The Motion subelement contains motion information. The format of the Motion subelement is shown in Figure 9-442.

	Subelement ID	Length	Motion Indicator	Bearing	Speed Units	Horizontal Speed	Vertical Speed
Octets:	1	1	1	2	1	2	2

Figure 9-442—Motion subelement format

The Subelement ID field is defined in Table 9-213.

The Length field is defined in 9.4.3.

The Motion Indicator field is defined in Table 9-215. The mechanism that a STA uses to determine the value or transitions from one value to another of the Motion Indicator field is beyond the scope of the standard.

Table 9-215—Motion Indicator field

Motion Indicator value	Description
0	Stationary: the device is stationary and not in motion.
1	Start of motion: the device was stationary and is now in motion.
2	In motion: the device is and has been in motion.
3	End of motion: the device was in motion and is now stationary.
4	Unknown: information related to motion is unknown.
5–255	Reserved

The Bearing field, defined by a 2-octet unsigned integer, specifies the direction that the STA is traveling with relation to true north, increasing clockwise, measured in degrees from 0° to 359°. If the Bearing value is unknown, the field is 65 535.

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The Speed Units field contains the units for both Horizontal and Vertical Speed field, as defined in Table 9-216.

Table 9-216—Speed Units

Speed Units value	Description
0	Centimeters per second
1	Meters per second
2–255	Reserved

The Horizontal Speed field contains the horizontal speed of the STA expressed in the units indicated in the Speed Units field. If the Horizontal Speed value is unknown, the field is 65 535.

The Vertical Speed field is a 2s complement signed integer indicating the vertical speed of the STA expressed in the units indicated in the Speed Units field. If the Vertical Speed value is unknown or greater than 32 766, the field is 32 767. If the Vertical Speed value is less than –32 767, the field is –32 768.

The Motion subelement field values are valid at the time of transmission of the Location Track Notification frame containing the subelement.

9.4.2.70.7 Location Indication Broadcast Data Rate subelement

The Location Indication Broadcast Data Rate subelement contains location reporting transmission rate information. The format of the Location Indication Broadcast Data Rate subelement format is shown in Figure 9-443.

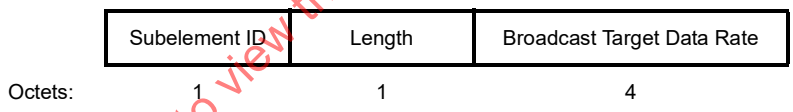

Figure 9-443—Location Indication Broadcast Data Rate subelement format

The Subelement ID field is defined in Table 9-213.

The Length field is defined in 9.4.3.

The Broadcast Target Data Rate field specifies the target data rate at which the STA transmits Location Track Notification frames. The Broadcast Target Data Rate field format is specified by the Rate Identification field defined in 9.4.1.32. A Broadcast Target Data Rate field set to 0 indicates the STA transmits Location Track Notification frames at a rate chosen by the STA transmitting the Location Track Notification frames.

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9.4.2.70.8 Time of Departure subelement

The Time of Departure subelement contains time of departure information for the Location Track Notification frame including the subelement. The format of the Time of Departure subelement is shown in Figure 9-444.

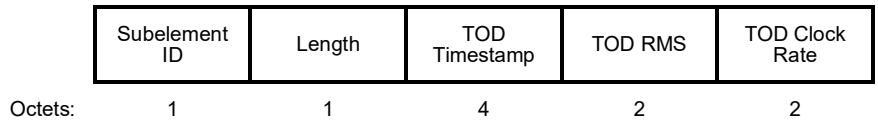

Figure 9-444—Time of Departure subelement format

The Subelement ID field is defined in Table 9-213.

The Length field is defined in 9.4.3.

The TOD Timestamp field specifies when the first frame energy is sent by the transmitting port in units equal to 1/TOD Clock Rate, where the TOD Clock Rate is specified in the TOD Clock Rate field. The reported TOD timestamp value is determined from the TIME_OF_DEPARTURE parameter within the PHY-TXSTART.confirm primitive.

The TOD RMS field specifies the RMS time of departure error in units equal to 1/TOD Clock Rate, where the TOD Clock Rate is specified in the TOD Clock Rate field, where the time of departure error equals the difference between the TOD Timestamp field and the time of departure measured by a reference entity using a clock synchronized to the start time and mean frequency of the local PHY entity's clock. The TOD RMS field is determined from aTxPHYTxStartRMS in units equal to 1/TOD Clock Rate, where the TOD Clock Rate is specified in the TOD Clock Rate field.

The TOD Clock Rate field contains the clock rate used to generate the TOD timestamp value reported in the TOD Timestamp field, and it is specified in units of MHz.

9.4.2.70.9 Location Indication Options subelement

The Location Indication Options subelement contains the options for the STA when transmitting the Location Track Notification frame. The format of the Location Indication Options subelement is shown in Figure 9-445.

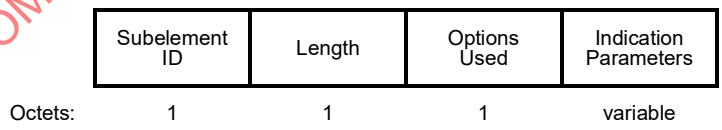

Figure 9-445—Location Indication Options subelement format

The Subelement ID field is defined in Table 9-213.

The Length field is defined in 9.4.3.

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The Options Used field specifies the Indication Parameter fields in the Location Indication Options subelement that are used. The format of the Options Used field is shown in Figure 9-446.

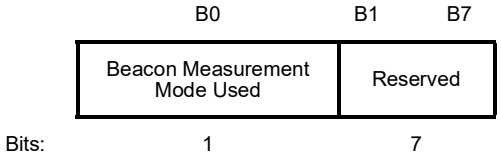

Figure 9-446—Options Used field format

The Indication Parameters field defines a sequence of optional fields that are included in the Location Indication Options subelement based on the Options Used field value. The value of the Indication Parameters field is defined in Table 9-217.

Table 9-217—Indication Parameter values

Order	Field length	Field	Description
1	1	Beacon Measurement Mode	The Beacon Measurement Mode field is the mode of beacon measurement, as defined in Table 9-103. The results of the beacon measurement are included in the Location Track Notification frame, as described in 9.6.7.17 and 11.21.4.2.
2–8		Reserved	

9.4.2.71 Nontransmitted BSSID Capability element

The format of the Nontransmitted BSSID Capability element when transmitted by a non-DMG STA is shown in Figure 9-447.

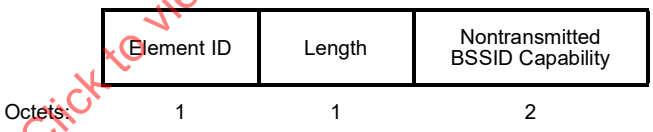

Figure 9-447—Nontransmitted BSSID Capability element format (non-DMG STA)

The format of the Nontransmitted BSSID Capability element when transmitted by a DMG STA is shown in Figure 9-448.

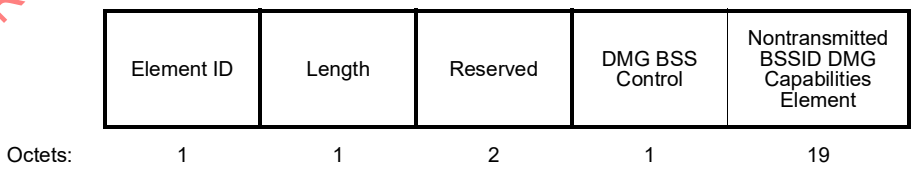

Figure 9-448—Nontransmitted BSSID Capability element format (DMG STA)

When transmitted by a DMG STA, the Nontransmitted BSSID Capability element includes the DMG BSS Control and the Nontransmitted BSSID DMG Capabilities Element fields.

The Element ID and Length fields are defined in 9.4.2.1.

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The Nontransmitted BSSID Capability field contains the contents of the Capability Information field (defined in 9.4.1.4) in beacons for the BSS.

The Nontransmitted BSSID Capability element is included in the Nontransmitted BSSID Profile subelement of the Multiple BSSID element defined in 9.4.2.45. The use of the Multiple BSSID element is described in 11.10.14 and Nontransmitted BSSID advertisement procedures are described in 11.1.3.8.

The DMG BSS Control field is defined in Figure 9-449.

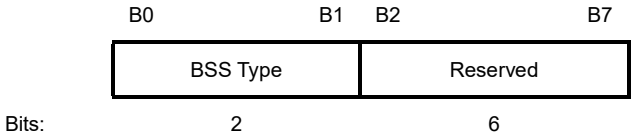

Figure 9-449—DMG BSS Control field format

The BSS Type field is defined in 9.4.1.46.

The Nontransmitted BSSID DMG Capabilities Element field contains the DMG Capabilities element of the DMG STA.

9.4.2.72 SSID List element

The format of the SSID List element is shown in Figure 9-450.

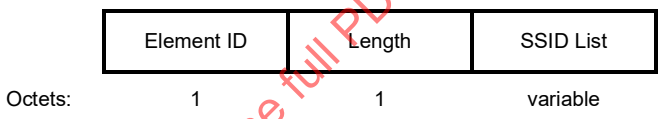

Figure 9-450—SSID List element format

The Element ID and Length fields are defined in 9.4.2.1.

The SSID List field is a list of SSID elements for which the STA is requesting information.

The SSID List element is included in Probe Request frames, as described in 9.3.3.9. The use of the SSID List element and frames is described in 11.1.4.

9.4.2.73 Multiple BSSID-Index element

The format of the Multiple BSSID-Index element is shown in Figure 9-451.

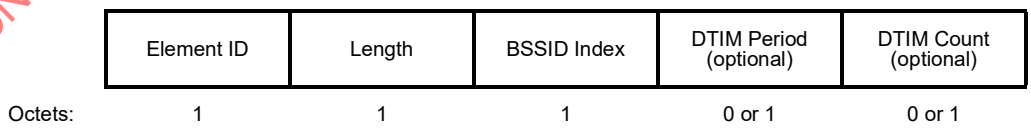

Figure 9-451—Multiple BSSID-Index element format

The Element ID and Length fields are defined in 9.4.2.1.

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The BSSID Index field is a value between 1 and $2^n - 1$ that identifies the nontransmitted BSSID, where n is a nonzero, positive integer value.

The DTIM Period field indicates the DTIM period for the BSSID. This field is not present when the Multiple BSSID-Index element is included in the Probe Response frame.

The DTIM Count field indicates the DTIM count for the BSSID. This field is not present when the Multiple BSSID-Index element is included in the Probe Response frame.

The Multiple BSSID-Index element is included in the nontransmitted BSSID profile element, as described in 11.1.3.8. The use of the Multiple BSSID element and frames is described in 11.10.14.

9.4.2.74 FMS Descriptor element

The FMS Descriptor element defines information about group addressed BUs buffered at the AP. It is present in the Beacon frames when dot11FMSActivated is true. The format of the FMS Descriptor element is shown in Figure 9-452.

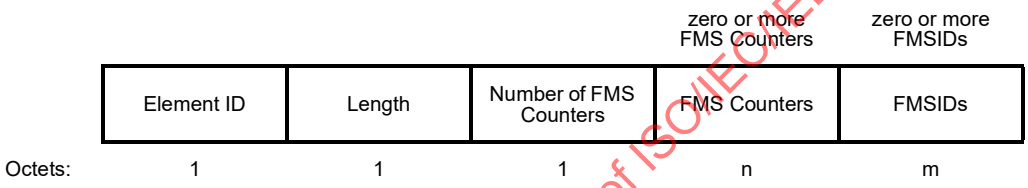

Figure 9-452—FMS Descriptor element format

The Element ID and Length fields are defined in 9.4.2.1.

The Number of FMS Counters field defines the number of FMS Counter fields that are contained in the FMS Counters field in the FMS Descriptor element.

The FMS Counters field contains zero or more FMS Counter fields. The format of the FMS Counter field is shown in Figure 9-453. When one or more FMS streams are accepted at the AP, at least one FMS counter is present in the FMS Descriptor element. A maximum of eight FMS counters are permitted. The FMS counters are used by the non-AP STA to identify the DTIM beacon after which group addressed BUs assigned to a particular delivery interval are transmitted. A single FMS counter is shared by all FMS streams that use the same delivery interval.

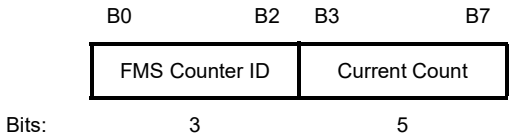

Figure 9-453—FMS Counter field format

The FMS Counter ID field is a 3- bit value that represents the counter ID assigned by the AP for a particular FMS stream.

The Current Count field indicates how many DTIM Beacon frames (including the current one) appear before the next DTIM Beacon frame after which the group addressed BUs assigned to a particular delivery interval are scheduled to be transmitted.

The FMSIDs field contains zero or more FMSIDs. Each FMSID is a 1-octet identifier assigned by the AP.

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Inclusion of an FMSID indicates the AP has buffered BUs for the corresponding group addressed stream that is scheduled for transmission immediately after the DTIM Beacon frame.

The FMS Descriptor element is included in Beacon frames, as described in 9.3.3.2. The use of the FMS Descriptor element and frames is described in 11.2.3.14.

9.4.2.75 FMS Request element

The FMS Request element defines information about the group addressed frames being requested by the non-AP STA. The format of FMS Request element is shown in Figure 9-454.

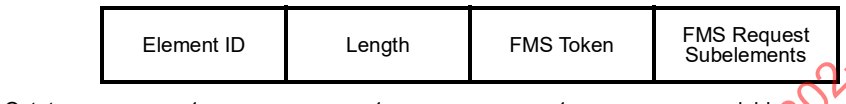

Figure 9-454—FMS Request element format

The Element ID and Length fields are defined in 9.4.2.1.

The FMS Token field contains a unique identifier for the FMS Stream Set that is the set of FMS subelements specified in the request. If this is a new request, then the FMS Token field is set to 0. Otherwise, the FMS Token field is set to the value assigned by the AP in the FMS Response element.

The FMS Request Subelements field contains one or more FMS Request subelements described in Table 9-218.

Table 9-218—Optional subelement IDs for FMS Request subelements

Subelement ID	Subelement name
0	Reserved
1	FMS subelement
2–220	Reserved
221	Vendor Specific subelement
222–255	Reserved

The format of the FMS subelement is shown in Figure 9-455.

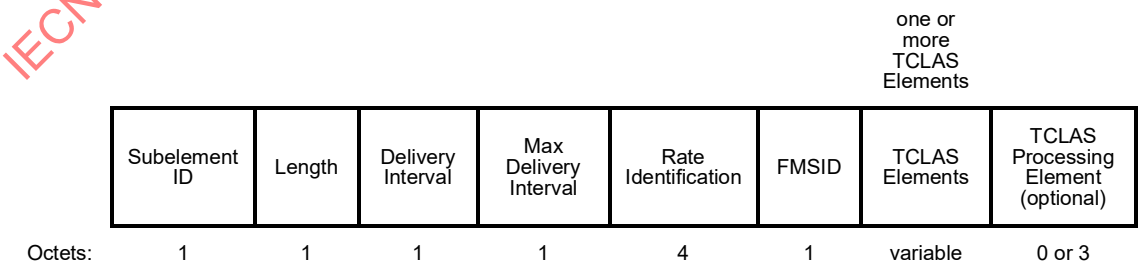

Figure 9-455—FMS subelement format

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The Subelement ID field is 1 to uniquely identify this subelement as the FMS subelement.

The Length field is defined in 9.4.3.

The Delivery Interval field defines the periodicity of stream transmission in units of DTIMs. The default value is 1. The value set to 0 indicates that requesting non-AP STA does not use the FMS stream identified by the TCLAS elements anymore.

The Max Delivery Interval field defines the maximum delivery interval the non-AP STA supports for the requested stream in units of DTIMs. The value set to 0 indicates that the non-AP STA is willing to accept any maximum delivery interval supported by the AP.

The Rate Identification field specifies the data rate as described in 9.4.1.32, at which the STA requests to receive group addressed frames. If the STA does not request a particular multicast rate, the Rate Identification field is 0.

The FMSID field contains a unique identifier for this stream. If this is a new request, the FMSID field is reserved. Otherwise, the FMSID is set to the value assigned by the AP in the FMS Response element.

The TCLAS Elements field contains one or more TCLAS elements to specify the traffic filter as defined in 9.4.2.30. The number of TCLAS elements is limited and the total size of the FMS Request element is less than or equal to 255 octets.

The TCLAS Processing Element field is optionally present and defines how multiple TCLAS elements are processed as defined in 9.4.2.32.

The FMS Request element is included in FMS Request frames, as described in 9.6.13.11. The use of the FMS Request element and frames is described in 11.2.3.14.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25).

9.4.2.76 FMS Response element

The FMS Response element provides information about the delivery of group addressed frames. The format of the FMS Response element is shown in Figure 9-456.

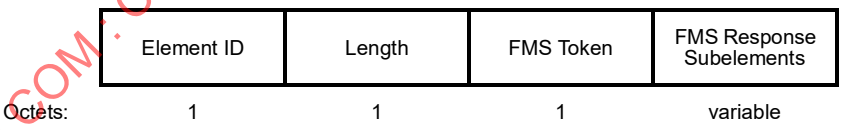

Figure 9-456—FMS Response element format

The Element ID and Length fields are defined in 9.4.2.1.

The FMS Token field is assigned by the AP for the set of FMS streams that share the counter identified by the FMS Counter ID maintained in the AP.

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The FMS Response Subelements field contains one or more FMS Response subelements described in Table 9-219.

Table 9-219—Optional subelement IDs for FMS Response subelements

Subelement ID	Subelement name
0	Reserved
1	FMS Status subelement
2	TCLAS Status subelement
3–220	Reserved
221	Vendor Specific subelement
222–255	Reserved

The format of the FMS Status subelement is shown in Figure 9-457.

	Subelement ID	Length	Element Status	Delivery Interval	Max Delivery Interval	FMSID	FMS Counter	Rate Identification	Multicast Address
Octets:	1	1	1	1	1	1	1	4	6

Figure 9-457—FMS Status subelement format

The Subelement ID field is 1 to uniquely identify this subelement as the FMS Status subelement.

The Length field is defined in 9.4.3.

The Element Status field indicates the status of STA's requested delivery interval, as indicated in Table 9-220, provided by the AP.

Table 9-220—FMS Element Status and TFS Response Status definition

Value	Description
0	Accept
1	Deny, due to request format error or ambiguous classifier.
2	Deny, due to lack of resources on the AP.
3	Deny, due to requested classifier(s) matching 2 or more existing streams on different intervals.
4	Deny, by policy, requested stream or filter is not permitted to participate in the service.
5	Deny, reason unspecified.
6	Alternate proposed, due to existing stream with different delivery interval.
7	Alternate proposed, due to policy limits on the AP.
8	Alternate proposed, because the AP changed the delivery interval.
9	Multicast rate changes not allowed.

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Table 9-220—FMS Element Status and TFS Response Status definition *(continued)*

Value	Description
10	Terminate, due to an AP policy change.
11	Terminate, due to lack of resources of the AP.
12	Terminate, due to other FMS stream with higher priority.
13	Alternate proposed, because the AP changed the maximum delivery interval.
14	Alternate proposed, because the AP is unable to provide requested TCLAS-based classifiers.
15–255	Reserved

The Delivery Interval field defines the minimum integer of DTIM periods between successive transmissions of frames for the stream corresponding to that FMSID.

The Max Delivery Interval field defines the maximum delivery interval the AP uses for the stream corresponding to FMSID. The value set to 0 indicates that the AP has no maximum delivery interval for the stream identified by FMSID.

The FMSID field is assigned by the AP and provides a unique identifier for this stream within the BSS.

The format of the FMS Counter field is shown in Figure 9-453. The FMS Counter ID field of the FMS Counter field is defined in 9.4.2.74. The Current Count field of the FMS Counter field is reserved in the FMS Status subelement.

The Rate Identification field specifies the data rate as described in 9.4.1.32 to be used for the multicast service. If the Rate Identification field is set to 0 then the data rate is undefined.

The Multicast MAC Address field contains the MAC address of the multicast traffic to which this FMS response relates.

The format of the TCLAS Status subelement is shown in Figure 9-458.

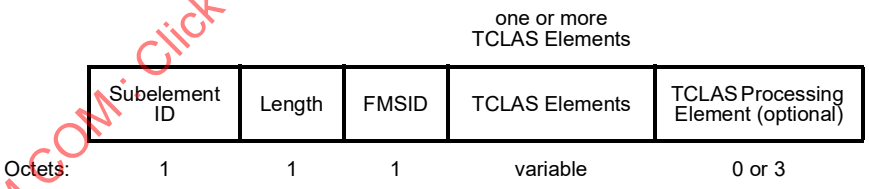

Figure 9-458—TCLAS Status subelement format

The Subelement ID field is 2 to uniquely identify this subelement as the TCLAS Status subelement.

The Length field is defined in 9.4.3.

The FMSID field is assigned by the AP and provides a unique identifier for this stream within the BSS.

The TCLAS Elements field contains one or more TCLAS elements to specify the traffic filter as defined in 9.4.2.30. The number of TCLAS elements is limited and the total size of the FMS Response element is less than or equal to 255 octets.

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The TCLAS Processing Element field is optionally present and defines how multiple TCLAS elements are processed as defined in 9.4.2.32.

The FMS Response element is included in FMS Response frames, as described in 9.6.13.12. The use of the FMS Response element and frames is described in 11.2.3.14.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.25).

9.4.2.77 QoS Traffic Capability element

The QoS Traffic Capability element provides information about types of traffic generated by a non-AP QoS STA and is used by a QoS AP to indicate the access categories of associated non-AP QoS STAs. The format of the QoS Traffic Capability element is shown in Figure 9-459.

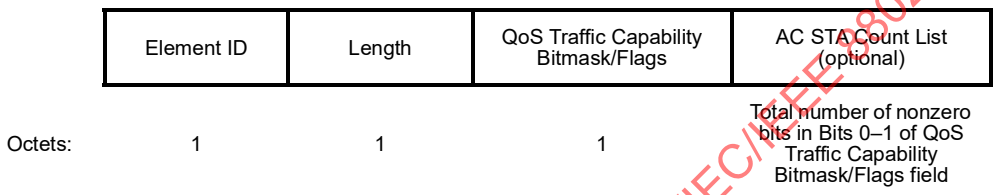

Figure 9-459—QoS Traffic Capability element format

The Element ID and Length fields are defined in 9.4.2.1. The Length field is set to 1 + *n*, where *n* equals the total number of nonzero bits in Bits 0–1 of the QoS Traffic Capability Bitmask/Flags field.

The format of QoS Traffic Capability Bitmask/Flags field is defined in Table 9-221.

Table 9-221—QoS Traffic Capability Bitmask/Flags definition

Bit	Description
0	AC_VO
1	AC_VI
2	Reserved
3	Reserved
4	UP 4 Traffic
5	UP 5 Traffic
6	UP 6 Traffic
7	Reserved

Bits 0–1 serve as QoS Traffic Capability Bitmask. The bitmask indicates the AC values that have the station count specified in the following AC STA Count List. An AP sets the bit to 1 to indicate that the station count for the corresponding AC is present in the AC STA Count List field. An AP sets the bit to 0 to indicate that the station count for the corresponding AC is not present in the AC STA Count List field. Bits 0–1 are reserved in a transmission to an AP.

Bits 4–6 serve as QoS Traffic Capability Flags. Each of Bits 4–6 serves as a flag for a non-AP STA to indicate application requirements about the user priorities of the traffic it generates. A non-AP STA sets the

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bit to 1 to indicate the existence of an application that requires generation of traffic belonging to the corresponding user priority (UP). A non-AP STA sets the bit to 0 to indicate that such application does not exist. Bits 4–6 are reserved in a transmission from an AP.

Bits 2–3 and Bit 7 are reserved.

The AC STA Count List field comprises a sequence of STA Count fields corresponding to the nonzero bits in the Bits 0–1 of the QoS Traffic Capability Bitmask/Flags field. Each STA Count field is 1 octet long and contains an unsigned integer. The STA Count field specifies the number of associated QoS STAs that have indicated QoS traffic capability of the corresponding AC. If the number of STAs is greater than 255, the STA Count field is 255. The AC STA Count List field is present only when the QoS AP transmits the QoS Traffic Capability element.

The QoS Traffic Capability element is included in Beacon frames, as described in 9.3.3.2; Probe Response frames, as described in 9.3.3.10; Association Request frames, as described in 9.3.3.5; and Reassociation Request frames, as described in 9.3.3.7.

9.4.2.78 BSS Max Idle Period element

The BSS Max Idle Period element contains the time period a non-AP STA can refrain from transmitting frames to the AP before the AP disassociates the STA due to inactivity. The format of the BSS Max Idle Period element is shown in Figure 9-460.

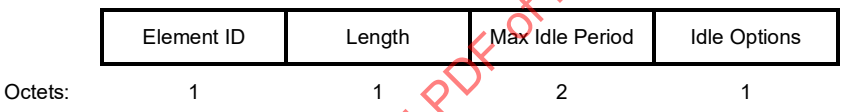

Figure 9-460—BSS Max Idle Period element format

The Element ID and Length fields are defined in 9.4.2.1.

The BSSMaxIdlePeriod parameter indicates the idle timeout limit, as described in 11.21.13. The time period is specified in units of 1000 TUs. The value of 0 is reserved. In a non-S1G STA, the Max Idle Period field is an unsigned integer that contains the value of the parameter BSSMaxIdlePeriod. In an S1G STA, the two MSBs of the Max Idle Period field contain the Unified Scaling Factor subfield and the remaining 14 bits contain the Unscaled Interval subfield (see Figure 9-89). In an S1G STA, the BSSMaxIdlePeriod parameter used by the MLME primitives is in units of 1000 TUs and is equal to the value of the Unscaled Interval subfield, multiplied by the scaling factor that corresponds to the value indicated in the Unified Scaling Factor subfield. The Unified Scaling Factor subfield encoding is defined in Table 9-48.

The Idle Options field indicates the options associated with the BSS Idle capability. The Idle Options field is shown in Figure 9-461.

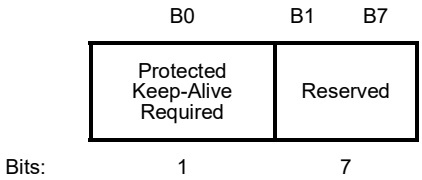

Figure 9-461—Idle Options field format

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The Protected Keep-Alive Required subfield is set to 1 to indicate that only a protected frame indicates activity. The Protected Keep-Alive Required subfield is set to 0 to indicate that either an unprotected or a protected frame indicates activity.

The BSS Max Idle Period element is included in Association Request and Response frames, as described in 9.3.3.5 and 9.3.3.6, and Reassociation Request and Response frames, as described in 9.3.3.7 and 9.3.3.8. The use of the BSS Max Idle Period element and frames is described in 11.21.13.

9.4.2.79 TFS Request element

The TFS Request element defines information about the traffic filters that are enabled at the AP for the requesting non-AP STA. The format of the TFS Request element is defined in Figure 9-462.

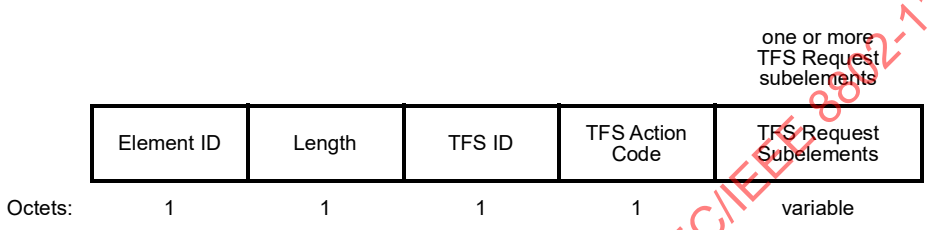

Figure 9-462—TFS Request element format

The Element ID and Length fields are defined in 9.4.2.1.

The TFS ID field is assigned by the STA and provides a unique identifier for the traffic filter set specified by the TFS Request Subelements field.

The TFS Action Code field defines the actions taken at the AP when a frame matches a traffic filter set. The functions of the bits in this field are shown in Table 9-222.

Table 9-222—TFS Action Code field values

Bit(s)	Name	Notes
0	Delete After Match	Setting this field to 1 for any traffic filter set indicates all traffic filter sets established at the AP for the non-AP STA are deleted when a frame matches any of the traffic filter sets established for the non-AP STA. Setting this field to 0 indicates no deletion of the traffic filter set upon a match.
1	Notify	Setting this field to 1 indicates the STA requests to be sent a TFS Notify frame upon the first frame matching to the traffic filter set or the first frame match after the AP receives a Notify Response frame containing the corresponding TFS ID. Setting this field to 0 indicates the AP does not send a TFS Notify frame to the requesting STA.
2–7	Reserved	All other bits are reserved.

The TFS Request Subelements field contains one or more TFS Request subelements described in Table 9-223. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-223. Each TFS Request subelement specifies one traffic filter. Using multiple TFS Request subelements in a TFS Request element is the equivalent to a logical AND operation on the match conditions of each TFS Request subelement.

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Table 9-223—Optional subelement IDs for TFS Request parameters

Subelement ID	Subelement name
1	TFS subelement
221	Vendor Specific subelement
0, 2 to 220, 222 to 255	Reserved

In a TFS Response element, the number of the response subelements is the same as the number of the TFS Request subelements in the corresponding TFS Request element, where the TFS Response subelements appear in the same order as the corresponding TFS Request subelements in the corresponding TFS Request frame.

The format of the TFS subelement is shown in Figure 9-463.

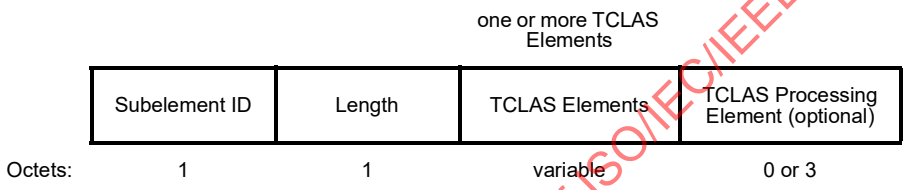

Figure 9-463—TFS subelement format

The Subelement ID field uniquely identifies this subelement to be the TFS subelement.

The Length field is defined in 9.4.3.

The TCLAS Elements field contains one or more TCLAS elements, each specifying a set of filtering parameters as defined in 9.4.2.30. The number of TCLAS elements is limited and the total size of the TFS Request element is less than 255 octets.

The TCLAS Processing Element field is optionally present and defines how multiple TCLAS elements are processed as defined in 9.4.2.32.

The format of the Vendor Specific subelement for a TFS Request element is shown in Figure 9-464.

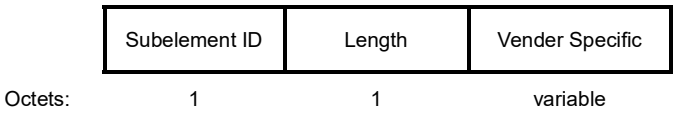

Figure 9-464—TFS Request Vendor Specific subelement format

The Subelement ID field uniquely identifies this subelement to be the TFS Request subelement.

The Length field is defined in 9.4.3.

The Vendor Specific field contains the vendor specific information.

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The TFS Request element is included in TFS Request frames, as described in 9.6.13.15, and WNM Sleep Mode Request frames, as described in 9.6.13.19. The use of the TFS Request element and frames is described in 11.21.12.

9.4.2.80 TFS Response element

The TFS Response element defines information about the status of the requested filtering parameters. The format of the TFS Response element is defined in Figure 9-465.

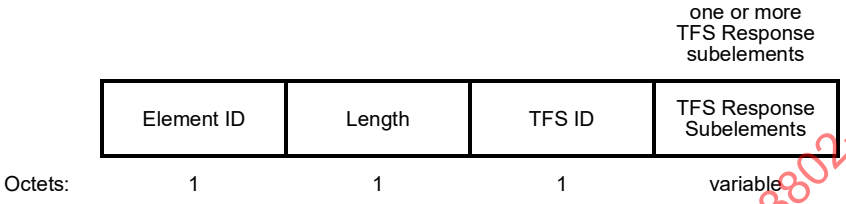

Figure 9-465—TFS Response element format

The Element ID and Length fields are defined in 9.4.2.1.

The TFS ID field indicates the unique ID for the TFS traffic filter set.

The TFS Response Subelements field contains one or more TFS Response subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-224.

In a TFS Response element, the number of the response subelements is the same as the number of the TFS Request subelements in the corresponding TFS Request element, where the TFS Response subelements appear in the same order as the corresponding TFS Request subelements in the corresponding TFS Request frame.

Table 9-224—Optional subelement IDs for TFS Response parameters

Subelement ID	Subelement name
1	TFS Status subelement
221	Vendor Specific subelement
0, 2–220, 222–255	Reserved

A TFS Status subelement contains the information as defined in Figure 9-466.

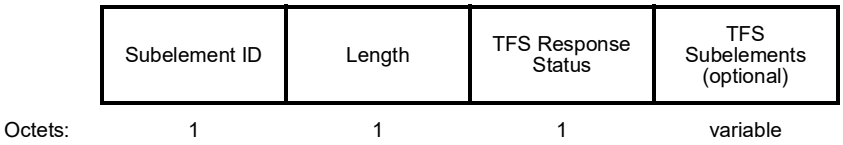

Figure 9-466—TFS Status subelement format

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The Length field is defined in 9.4.3.

The TFS Response Status field indicates the status returned by the AP responding to the STA's requested traffic filter, as indicated in Table 9-220.

If present, the TFS Subelements field contains one or more TFS Request subelements containing the alternative filtering parameters preferred by the AP.

The format of the Vendor Specific subelement for a TFS Response element is shown in Figure 9-467.

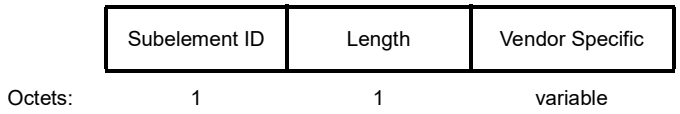

Figure 9-467—TFS Response Vendor Specific subelement format

The Subelement ID field uniquely identifies this subelement to be the TFS Response subelement.

The Length field is defined in 9.4.3.

The Vendor Specific field contains the vendor specific information.

The TFS Response element is included in TFS Response frames, as described in 9.6.13.16, and WNM Sleep Mode Response frames, as described in 9.6.13.20. The use of the TFS Response element and frames is described in 11.21.12.

9.4.2.81 WNM Sleep Mode element

The WNM Sleep Mode element is used to enter and exit the WNM sleep mode. The format of the WNM Sleep Mode element is shown in Figure 9-468.

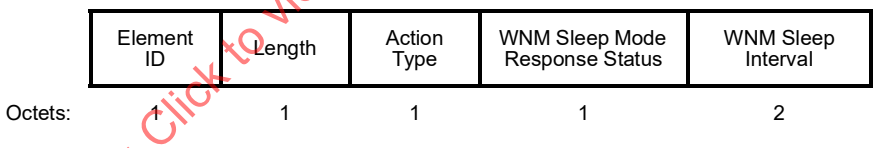

Figure 9-468—WNM Sleep Mode element format

The Element ID and Length fields are defined in 9.4.2.1.

The Action Type field is a number that identifies the type of WNM sleep mode request and response. The Action Types are shown in Table 9-225.

Table 9-225—Action Type definitions

Name	Action Type value
Enter WNM sleep mode	0
Exit WNM sleep mode	1
Reserved	2–255

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The WNM Sleep Mode Response Status field indicates the status returned by the AP responding to the non-AP STA's WNM sleep mode request as defined in Table 9-226. This field is valid only in the WNM Sleep Mode element in a WNM Sleep Mode Response frame and is reserved otherwise.

Table 9-226—WNM Sleep Mode Response Status definition

Value	Description
0	Enter/Exit WNM sleep mode Accept.
1	Exit WNM sleep mode Accept, GTK/IGTK/BIGTK update required.
2	Denied. The AP is unable to perform the requested action.
3	Denied temporarily. The AP is unable to perform the requested action at the current time. The request can be submitted again at a later time.
4	Denied. Due to the pending key expiration.
5	Denied. The requested action was not granted due to other WNM services in use by the requesting STA.
6–255	Reserved

The WNM Sleep Interval field is reserved if the Action Type field is 1.

The WNM Sleep Interval field indicates to the AP how often a STA in WNM sleep mode wakes to receive Beacon frames, defined as the number of DTIM intervals. The value set to 0 indicates that the requesting non-AP STA does not wake up at any specific interval. In a non-S1G STA, the WNM Sleep Interval field is an unsigned integer. In an S1G STA, the two MSBs of the WNM Sleep Interval field contain the Unified Scaling Factor subfield and the remaining 14 bits contain the Unscaled Interval subfield (see Figure 9-89). In an S1G STA, the WNM sleep interval is equal to the value of the Unscaled Interval subfield, multiplied by the scaling factor that corresponds to the value indicated in the Unified Scaling Factor subfield. The Unified Scaling Factor subfield encoding is defined in Table 9-48.

The WNM Sleep Mode element is included in WNM Sleep Mode Request frames, as described in 9.6.13.19, and WNM Sleep Mode Response frames, as described in 9.6.13.20. The use of the WNM Sleep Mode element and frames is described in 11.2.3.16.

9.4.2.82 TIM Broadcast Request element

The TIM Broadcast Request element contains information about the periodic TIM broadcast being requested by the non-AP STA. The format of the TIM Broadcast Request element is shown in Figure 9-469.

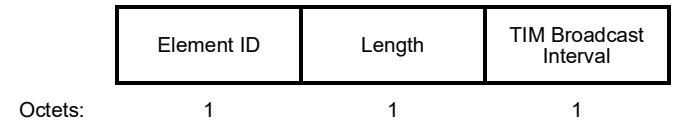

Figure 9-469—TIM Broadcast Request element format

The Element ID and Length fields are defined in 9.4.2.1.

The TIM Broadcast Interval field is the number of beacon periods between TIM frame transmissions. A TIM Broadcast Interval field set to 0 terminates the use of TIM Broadcast for the requesting station.

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The TIM Broadcast Request element is included in TIM Broadcast Request frames, as described in 9.6.13.21; Association Request frames, as described in 9.3.3.5; and Reassociation Request frames, as described in 9.3.3.7. The use of the TIM Broadcast Request element and frames is described in 11.2.3.15.

9.4.2.83 TIM Broadcast Response element

The TIM Broadcast Response element contains information about the periodic TIM broadcast by the AP. The format of the TIM Broadcast Response element is shown in Figure 9-470.

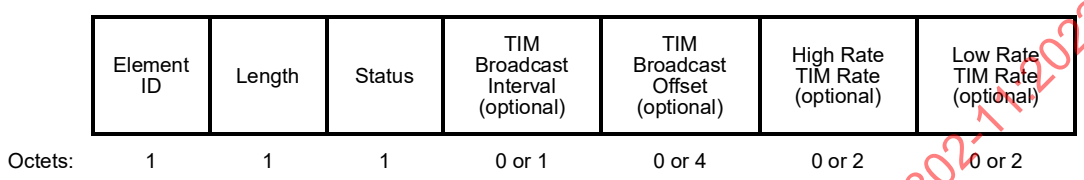

Figure 9-470—TIM Broadcast Response element format

The Element ID and Length fields are defined in 9.4.2.1.

The Status field indicates the status of the AP responding to the STA's requested delivery interval, as indicated in Table 9-227.

Table 9-227—Status field values

Field value	Description
0	Accept
1	Accept, timestamp present in TIM frames
2	Denied
3	Overridden
4	Overridden, timestamp present in TIM frames
5–255	Reserved

When the Status field is 0, 1, 3 or 4, the TIM Broadcast Interval field, TIM Broadcast Offset field, High Rate TIM Rate field, and Low Rate TIM Rate field are included in the TIM Broadcast Response element.

The TIM Broadcast Interval field contains the number of beacon periods between scheduled TIM frame transmissions.

The TIM Broadcast Offset field contains the offset in microseconds with a tolerance of ± 4 μs relative to the TBTT for which a TIM frame is scheduled for transmission. The field contains a 2s complement signed integer.

The High Rate TIM Rate field provides an indication of the rate that is used to transmit the high data rate TIM frame, in units of 0.5 Mb/s. Setting this field to 0 indicates that the high data rate TIM frame is not transmitted.

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The Low Rate TIM Rate field provides an indication of the rate that is used to transmit the low data rate TIM frame, in units of 0.5 Mb/s. The value 0 is reserved.

The TIM Broadcast Response element is included in TIM Broadcast Response frames, as described in 9.6.13.22; Association Response frames, as described in 9.3.3.6; and Reassociation Response frames, as described in 9.3.3.8. The use of the TIM Broadcast Response element and frames is described in 11.2.3.15.

9.4.2.84 Collocated Interference Report element

The Collocated Interference Report element contains some characteristics of the reported collocated interference. The Collocated Interference Report element is defined in Figure 9-471.

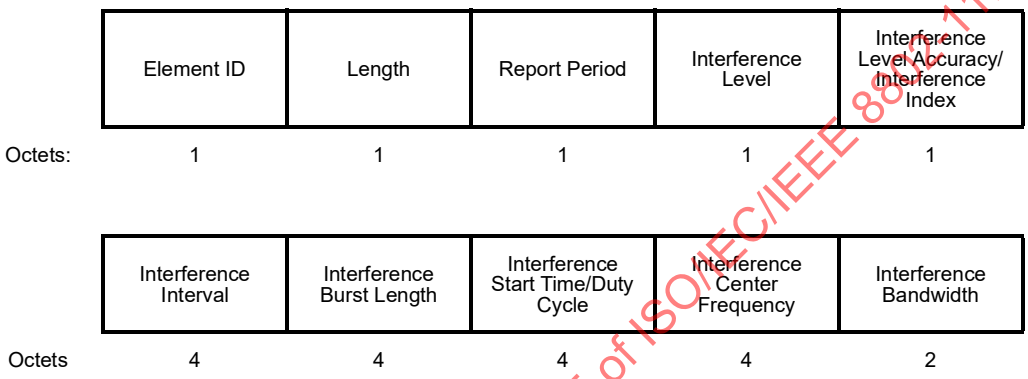

Figure 9-471—Collocated Interference Report element format

The Element ID and Length fields are defined in 9.4.2.1.

The Report Period field contains an unsigned integer value in units of 200 TUs. If the Report Period field is a value that is greater than 0, then the reporting is periodic, and the field contains the period of sending the report. If the Report Period field is 0, then the reporting is not periodic, and a report is generated when the STA knows of a change in the collocated interference. See 11.21.9 for further details.

The Interference Level field is a 2s complement signed integer indicating the maximum level of the collocated interference power in units of dBm over all receive chains averaged over a 4 μs period during an interference period and across interference bandwidth. When the interference level is unknown, the field is +127 dBm. When the interference level is equal or greater than 126 dBm, the field is +126 dBm. If no collocated interference is present the field is –128 dBm. When the interference level is equal or lower than –127 dBm, the field is –127 dBm. The interference level is referenced to the antenna connector (see "antenna connector" in 3.1) used for reception, like RCPI.

The Interference Level Accuracy/Interference Index field is shown in Figure 9-472.

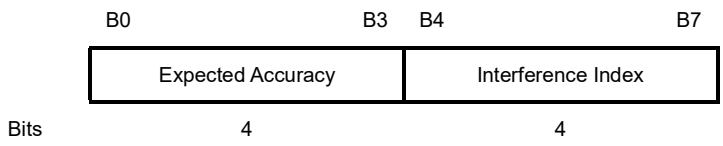

Figure 9-472—Interference Level Accuracy/Interference Index field format

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The Expected Accuracy field represents an unsigned integer indicating the expected accuracy of the estimate of interference in dB with 95% confidence interval. If the Interference Level field is X (dBm) and the expected accuracy field is Y (dB), the actual interference level is in the range X – Y to X + Y with the probability of 95%. The range of expected accuracy is from 0 dB to 14 dB. If accuracy is unknown or greater than 14 dB, then the Expected Accuracy field is 15.

The Interference Index field indicates the interference index that is unique for each type of interference source. The field set to 0 indicates that no collocated interference is present. See 11.21.9 for further details.

The Interference Interval field indicates the interval between two successive periods of interference in microseconds. When the interval between two successive periods of interference is variable the field is 2^{32}–1. When the interval between two successive periods of interference is equal or greater than 2^{32}– 2, the field is 2^{32}– 2. If no collocated interference is present, the field is 0.

The Interference Burst Length field indicates the duration of each period of interference in microseconds. When the duration of each period of interference is variable the field is 2^{32}– 1. When the duration of each period of interference is equal or greater than 2^{32}– 2, the field is 2^{32}– 2. If no collocated interference is present, the field is 0.

The Interference Start Time/Duty Cycle field contains the least significant 4 octets (i.e., B0–B31) of the TSF timer at the start of the interference burst. When either the Interference Interval or the Interference Burst Length fields are set to 2^{32}– 1, this field indicates the average duty cycle. The average duty cycle value is defined as follows:

$$\text{Average duty cycle} = \left\lfloor (2^{32} - 2) \times \frac{T_B}{T_I} + 0.5 \right\rfloor$$

where

T_B is the average interference burst length
T_I is the average interference interval

When the interference is nonperiodic or no collocated interference is present, the Interference Start Time field is 0.

The Interference Center Frequency field indicates the center frequency of interference in units of 5 kHz. When center frequency is unknown, the center frequency of the STA's operating channel is reported. If no collocated interference is present the field is 0.

The Interference Bandwidth field indicates the bandwidth in units of 5 kHz at the –3 dB roll-off point of the interference signal. When bandwidth of the interference signal is unknown, the field is 65 535. When bandwidth of the interference signal is equal or greater than 65 534 the field is 65 534. If no collocated interference is present, the field is 0.

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9.4.2.85 Channel Usage element

The Channel Usage element defines the channel usage information for BSSs that are not infrastructure BSSs or an off channel TDLS direct link. The format of the Channel Usage element is shown in Figure 9-473.

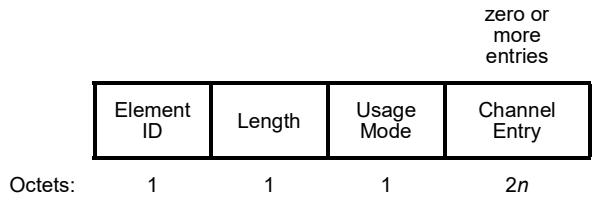

Figure 9-473—Channel Usage element format

The Element ID and Length fields are defined in 9.4.2.1.

The Usage Mode field is a number that identifies the usage of the recommended channels listed in the Operating Class/Channel Number pair fields. The Usage Mode definitions are shown in Table 9-228.

Table 9-228—Usage Mode definitions

Value	Usage Mode
0	Noninfrastructure IEEE 802.11 network
1	Off-channel TDLS direct link
2–255	Reserved

The Channel Entry field includes zero or more Operating Class and Channel fields. The format of the Operating Class and Channel fields is defined in 9.4.1.22. Operating Class and Channel fields can be grouped together to identify a noncontiguous channel as described in 9.4.2.70.3.

The Channel Usage element can be included in Probe Request frames, as described in 9.3.3.9; Probe Response frames, as described in 9.3.3.10; Channel Usage Request frames, as described in 9.6.13.24; and Channel Usage Response frames, as described in 9.6.13.25. The use of the Channel Usage element and frames is described in 11.21.15.

9.4.2.86 Time Zone element

The Time Zone element contains the local time zone of the AP. The format of the Time Zone element is shown in Figure 9-474.

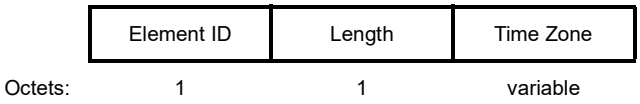

Figure 9-474—Time Zone element format

The Element ID and Length fields are defined in 9.4.2.1.

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The format of the Time Zone field is as specified in 8.3 of IEEE Std 1003.1-2004:

stdoffset[dst[offset][,start[/time],end[/time]]]

The length of the field is no less than 4 octets and no more than TZNAME_MAX, as defined in IEEE Std 1003.1-2004. The Time Zone field represents the time zone at the AP's location. The encoding of the field is in ASCII characters as shown in the following Example-1.

Example-1: EST5

Example-2: EST5EDT4,M3.2.0/02:00,M11.1.0/02:00

In the Example-2, the string is interpreted as a time zone that is normally five hours behind UTC, and four hours behind UTC during daylight saving time (DST), which runs from the second Sunday in March at 02:00 local time to the first Sunday in November at 02:00 local time. Normally, the time zone is abbreviated "EST" but during DST it is abbreviated "EDT."

9.4.2.87 DMS Request element

The DMS Request element defines information about the group addressed frames to be transmitted as individual addressed frames. The format of the DMS Request element is shown in Figure 9-475.

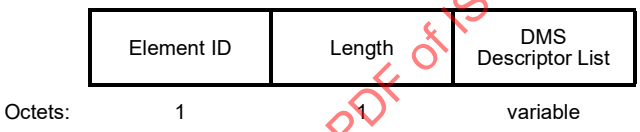

Figure 9-475—DMS Request element format

The Element ID and Length fields are defined in 9.4.2.1.

The DMS Descriptor List field contains one or more DMS Descriptors. The format of the DMS Descriptor is defined in Figure 9-476.

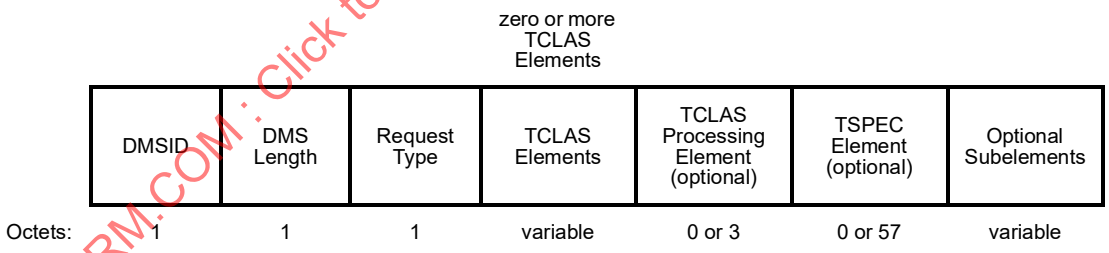

Figure 9-476—DMS Descriptor format

The DMSID field is set to 0 when the Request Type field is "Add" as defined in Table 9-229; otherwise, the DMSID field is set to the nonzero value assigned by the AP to identify the DMS traffic flow.

The DMS Length field is set to 1 + *n*, where *n* indicates the total length in octets of all of the TCLAS Elements, optional TCLAS Processing Element, optional TSPEC Element, and Optional Subelements fields contained in the DMS Descriptor field. The maximum value of the DMS Length field is 253.

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The Request Type field identifies the type of DMS request. The encoding of the Request Type field is shown in Table 9-229.

Table 9-229—DMS Request Type field

Description	Request Type field value
Add	0
Remove	1
Change	2
Reserved	3–255

When the Request Type field contains "Add," the TCLAS Elements field contains one or more TCLAS elements to specify group addressed frames as defined in 9.4.2.30. When a GCR Request subelement is included in the DMS Descriptor and the Request Type field is equal to "Add," the TCLAS Elements field contains at least a TCLAS element with frame classifier type set to 0 (Ethernet parameters) to specify a destination group address as defined in 9.4.2.30. When the Request Type field contains any value other than "Add," the TCLAS Elements field contains zero TCLAS elements.

When the Request Type field contains "Add" and when there are two or more TCLAS elements present, the TCLAS Processing Element field contains one TCLAS Processing element to define how these TCLAS elements are to be processed, as defined in 9.4.2.32. Otherwise, the TCLAS Processing Element field contains zero TCLAS Processing elements.

When the Request Type field contains "Add" or "Change," the TSPEC Element field optionally contains one TSPEC element to specify the characteristics and QoS expectations of the corresponding traffic flow as defined in 9.4.2.29. When a GCR Request subelement is included in the DMS Descriptor and the Request Type field is equal to "Add" or "Change," the TSPEC Element field contains one TSPEC element. Otherwise, the TSPEC Element field contains zero TSPEC elements.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-230.

Table 9-230—Optional subelement IDs for DMS Descriptor

Subelement ID	Name	Extensible
0	Reserved	
1	GCR Request	Yes
2–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

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Each DMS Descriptor contains zero or one GCR Request subelements. If present and the Request Type field is equal to "Add" or "Change," the GCR Request subelement indicates a request by a STA to respectively add or change the GCR service for a group addressed stream identified by the TCLAS element or by the DMSID in the DMS Descriptor. The format of the GCR Request subelement is shown in Figure 9-477.

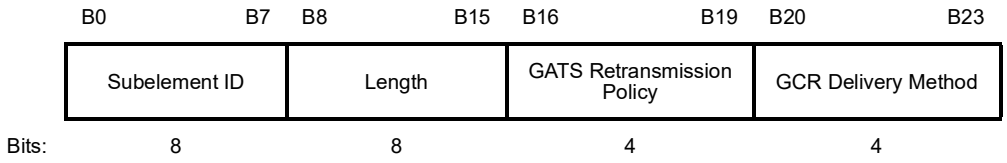

Figure 9-477—GCR Request subelement format

The Length field is defined in 9.4.3.

The GATS Retransmission Policy field is set to indicate the STA's preferred retransmission policy for the group address for which the GCR service is requested. The values are shown in Table 9-231.

Table 9-231—GATS Retransmission Policy field values

Value	GATS retransmission policy	Notes
0	No preference	
1	DMS	See 11.21.16.2.
2	GCR unsolicited retry	See 11.21.16.3.6.
3	GCR Block Ack	See 11.21.16.3.7.
4–15	Reserved	

The GCR Delivery Method field is set to indicate the STA's preferred delivery method for the group address for which the GCR service is requested. The values are shown in Table 9-232.

Table 9-232—GCR Delivery Method field values

Value	GCR delivery method	Notes
0	No preference	
1	Non-GCR-SP	See 11.21.16.3.1.
2	GCR-SP	See 11.21.16.3.8.
3–15	Reserved	

The DMS Request element is included in DMS Request frames, as described in 9.6.13.26, and Reassociation Request frames, as described in 9.3.3.7. The use of the DMS Request element and frames is described in 11.21.16.

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9.4.2.88 DMS Response element

The DMS Response element provides the status information about the requested group addressed frames. The format of the DMS Response element is shown in Figure 9-478.

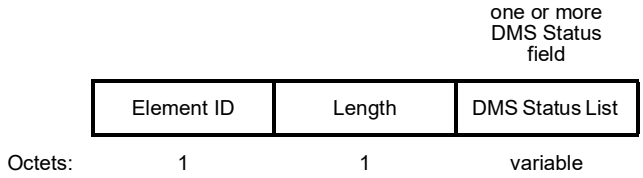

Figure 9-478—DMS Response element format

The Element ID and Length fields are defined in 9.4.2.1.

The DMS Status List field contains one or more DMS Status field. The format of the DMS Status field is defined in Figure 9-479.

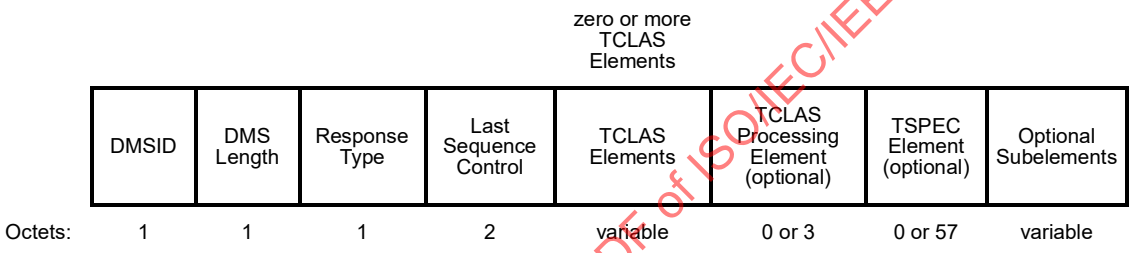

Figure 9-479—DMS Status field format

The DMSID is assigned by the AP and provides a unique identifier within the BSS for the DMS traffic flow identified by the TCLAS Elements, TCLAS Processing Element, and TSPEC Element fields. The uniqueness of the identifier is independent of the ordering of the TCLAS elements. In a mesh BSS, the DMSID is assigned by a mesh STA that responds to a GCR request and is unique among all existing DMSIDs used by the mesh STA for its current GCR agreements.

The DMS Length field is set to $3 + n$, where n indicates the total length in octets of all of the TCLAS Elements, optional TCLAS Processing Element, optional TSPEC Element, and Optional Subelements fields contained in the DMS Status field. When the Response Type field is equal to "Terminate," the DMS Length field is set to 3. The maximum value of the DMS Length field is 253.

The Response Type field indicates the response type returned by the AP responding to the non-AP STA's request or by a mesh STA responding to its peer mesh STA's request or indicates the DMS status is an advertisement of an existing GCR service, as indicated in Table 9-233.

Table 9-233—Response Type field values

Field value	Description	Notes
0	Accept	STA accepts the DMS or GCR request
1	Denied	STA rejects the DMS or GCR request
2	Terminate	STA terminates DMS previously accepted DMS or GCR request
3	GCR Advertise	STA advertises a group addressed stream subject to an existing GCR agreement.
4–255	Reserved	

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When the Last Sequence Control field is not supported the Last Sequence Control field is set to 65 535. When the Last Sequence Control field is supported and the Response Type field does not contain "Terminate" or "GCR Advertise," the Last Sequence Control field is reserved.

When the Response Type field is "Terminate" and the Last Sequence Control field is supported, Bit 0 to Bit 3 of the Last Sequence Control field is 0, and Bit 4 to Bit 15 of the Last Sequence Control field contains the sequence number of the last group addressed frame that the AP delivered to the non-AP STA that is the recipient of the DMS Response frame. If the Response Type field is "Terminate" and the last frame received by the non-AP STA prior to DMS termination has not also been sent using a group addressed frame, the Last Sequence Control field is set to 65 534.

When the Response Type field contains "Accept" or "Denied" and a GCR Response subelement is not included in the DMS Status field, the TCLAS Elements field contains one or more TCLAS elements to specify group addressed frames as defined in 9.4.2.30. When the Response Type field is equal to "Accept," "Denied," or "GCR Advertise" and a GCR Response subelement is included in the DMS Status field, the TCLAS Elements field contains at least one TCLAS element with frame classifier type set to 0 (Ethernet parameters) to specify a destination group address as defined in 9.4.2.30. Otherwise, the TCLAS Elements field contains zero TCLAS elements.

When the Response Type field contains "Accept" or "Denied," the TCLAS Processing Element field optionally contains one TCLAS Processing element to define how these TCLAS elements are to be processed, as defined in 9.4.2.32. When the Response Type field contains "Terminate" or when there is only one TCLAS element, the TCLAS Processing Element field contains zero TCLAS Processing elements.

When the Response Type field contains "Accept" or "Denied," the TSPEC Element field optionally contains one TSPEC element to specify the characteristics and QoS expectations of the corresponding traffic flow as defined in 9.4.2.29. When a GCR Response subelement is included in the DMS Status field and the Response Type field is equal to "Accept," "Denied," or "GCR Advertise," the TSPEC Element field contains one TSPEC element. Otherwise, the TSPEC Element field contains zero TSPEC elements.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-234.

Table 9-234—Optional subelement IDs for DMS Status

Subelement ID	Name	Extensible
0	Reserved	
1	GCR Response	Subelements
2–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The GCR Response subelement contains one of the following:

— A response by an AP to a GCR request by a non-AP STA for GCR service for a group address
— A response by a mesh STA to a GCR request by a peer mesh STA for GCR service for a group address
— An unsolicited advertisement for the parameters of a group addressed stream subject to the GCR service

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The format of the GCR Response subelement is shown in Figure 9-476.

	Subelement ID	Length	GATS Retransmission Policy	GCR Delivery Method	GCR Concealment Address	Schedule Element
Octets:	1	1	0 or 1	0 or 1	0 or 6	0 or 14

Figure 9-480—GCR Response subelement format

The GATS Retransmission Policy, GCR Delivery Method, and GCR Concealment Address fields are present when the Response Type field is not equal to "Denied"; otherwise, they are omitted. The Schedule Element field is optionally present when the Response Type field is not equal to "Denied."

The GATS Retransmission Policy field is set to indicate the current GCR retransmission policy for the group address for which the GCR service is requested. The values are shown in Table 9-231.

The GCR Delivery method field is set to indicate the current GCR Delivery method for the group address for which the GCR service is requested. The values are shown in Table 9-232.

The GCR Concealment Address field, when present, indicates the GCR concealment address, as described in 11.21.16.3.5.

The Schedule Element field is present if the GCR delivery method is equal to GCR-SP. It indicates the current SP schedule for the group addressed stream (see 9.4.2.33).

The DMS Response element is included in DMS Response frames, as described in 9.6.13.27, and Reassociation Response frames, as described in 9.3.3.8. The use of the DMS Response element and frames is described in 11.21.16.

9.4.2.89 Destination URI element

The Destination URI element contains URI and ESS Detection Interval values from the requesting STA that the responding STA can be used to deliver Event or Diagnostic Report frames. The format of the Destination URI element is shown in Figure 9-481.

	Element ID	Length	ESS Detection Interval	URI
Octets:	1	1	1	1–253

Figure 9-481—Destination URI element format

The Element ID and Length fields are defined in 9.4.2.1.

The ESS Detection Interval field is defined in 9.4.2.70.2 and its use for Event and Diagnostic requests is described in 11.21.2 and 11.21.3.

The URI field specifies the destination URI for Event and Diagnostic reports using the format defined in IETF RFC 3986. The URI field value is limited to 253 octets.

The Destination URI element is included as the last element in an Event or Diagnostic Request frame.

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The Destination URI element is included in Event Request frames, as described in 9.6.13.2, or Diagnostic Request frames, as described in 9.6.13.4.

Use of the Destination URI element in an Event Request frame is described in 11.21.2.1. Use of the Destination URI element in a Diagnostic Request frame is described in 11.21.3.1.

9.4.2.90 U-APSD Coexistence element

The U-APSD coexistence element provides the duration of requested transmission during a U-APSD service period. The format of the U-APSD Coexistence element is shown in Figure 9-482.

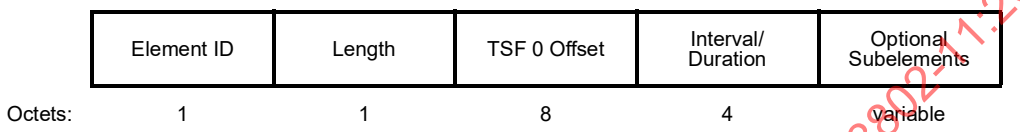

Figure 9-482—U-APSD Coexistence element format

The Element ID and Length fields are defined in 9.4.2.1.

The TSF 0 Offset field is set to the number of microseconds since TSF time 0 when the non-AP STA knew the start of interference. The AP uses the TSF 0 Offset field together with the Interval/Duration field to enqueue frames for transmission to the non-AP STA using the procedures as described in 11.2.3.5.2.

Setting the TSF 0 Offset field to 0 indicates the non-AP STA requests the AP transmit frames to the non-AP STA using the procedure described in 11.2.3.5.2 for the case where TSF 0 Offset is equal to 0.

The Interval/Duration field is defined as follows:

— When the TSF 0 Offset is 0, the Interval/Duration field is the number of microseconds during the U-APSD service period when the AP transmits frames to the non-AP STA as described in 11.2.3.5.2.

— When the TSF 0 Offset is nonzero, the Interval/Duration field is the number of microseconds between the start of consecutive interference bursts.

The Interval/Duration field value of 0 is reserved.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-235.

Table 9-235—Optional subelement IDs for U-APSD coexistence

Subelement ID	Name	Extensible
0–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

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9.4.2.91 Interworking element

The Interworking element contains information about the interworking service capabilities of a STA as shown in Figure 9-483.

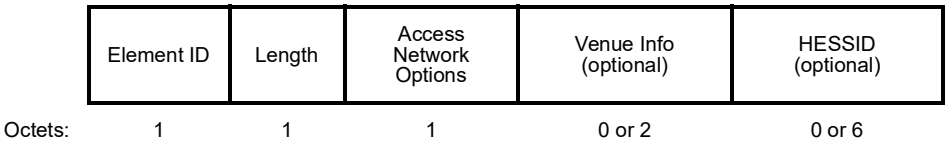

Figure 9-483—Interworking element format

The Element ID and Length fields are defined in 9.4.2.1.

The format of Access Network Options field is shown in Figure 9-484.

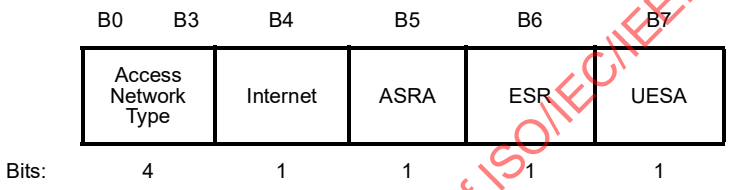

Figure 9-484—Access Network Options field format

A non-AP STA sets Internet, ASRA, ESR, and UESA fields to 0 when including the Interworking element in the Probe Request frame. A non-AP STA sets the Internet, ASRA and ESR bits to 0 when including the Interworking element in (Re)Association Request frames. A mesh STA sets the Internet bit to 0 when including the Interworking element in Mesh Peering Open frames. In (Re)Association Request frames, a non-AP STA sets the UESA bit according to the procedures in 11.3.5. The access network types are shown in Table 9-236. The Access Network Type field is set by the AP or the mesh STA to advertise its access network type to non-AP STAs. A non-AP STA uses this field to indicate the desired access network type in an active scan. See R.2 for the usage of fields contained within the Interworking element.

Table 9-236—Access network type

Access network type	Meaning	Description
0	Private network	Nonauthorized users are not permitted on this network. Examples of this access network type are home networks and enterprise networks, which might employ user accounts. Private networks do not necessarily employ encryption.
1	Private network with guest access	Private network but guest accounts are available. Example of this access network type is enterprise network offering access to guest users.
2	Chargeable public network	The network is accessible to anyone, however, access to the network requires payment. Further information on types of charges might be available through other methods (e.g., IEEE Std 802.21-2017, http/https redirect, or DNS redirection). Examples of this access network type is a hotspot in a coffee shop offering internet access on a subscription basis or a hotel offering in-room internet access service for a fee.

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Table 9-236—Access network type *(continued)*

Access network type	Meaning	Description
3	Free public network	The network is accessible to anyone and no charges apply for the network use. An example of this access network type is an airport hotspot or municipal network providing free service.
4	Personal device network	A network of personal devices. An example of this type of network is a camera attaching to a printer, thereby forming a network for the purpose of printing pictures.
5	Emergency services only network	A network dedicated and limited to accessing emergency services.
6 to 13	Reserved	Reserved
14	Test or experimental	The network is used for test or experimental purposes only.
15	Wildcard	Wildcard access network type

Bit 4 is the Internet field. The AP or mesh STA sets this field to 1 if the network provides connectivity to the Internet; otherwise it is set to 0 indicating that it is unspecified whether the network provides connectivity to the Internet.

Bit 5 is the Additional Step Required for Access (ASRA) field. It is set to 1 by the AP to indicate that the network requires a further step for access. For more information, refer to Network Authentication Type Information in 9.4.5.6. A mesh STA uses the ASRA field as an emergency indicator. If a mesh STA requires emergency services, the ASRA field is set to 1; otherwise it is set to 0. See 11.22.6.

Bit 6 is the ESR (emergency services reachable) field. It is set to 1 by the AP or mesh STA to indicate that emergency services are reachable through the AP or mesh STA; otherwise it is set to 0 indicating that it is unable to reach the emergency services. See 11.22.6.

Bit 7 is the UESA (unauthenticated emergency service accessible) field. When set to 0, this field indicates that no unauthenticated emergency services are reachable through this AP or mesh STA. When set to 1, this field indicates that higher layer unauthenticated emergency services are reachable through this AP or mesh STA. A STA uses the Interworking element with the UESA bit set to 1 to gain unauthenticated access to a BSS to access emergency services. A mesh STA uses the Interworking element with the UESA bit set to 1 to gain unauthenticated access to another mesh STA to access emergency services. See 11.3.5.

The Venue Info field is defined in 9.4.1.34.

The HESSID field, which is the identifier for a homogeneous ESS, specifies the value of HESSID; see 11.22.2. A STA may use this field to indicate the target HESSID in an active scan per 11.1.4. The HESSID field for an AP is set to dot11HESSID. This optional field is not used by mesh STAs.

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9.4.2.92 Advertisement Protocol element

The Advertisement Protocol element contains information that identifies a particular advertisement protocol and its corresponding Advertisement Control. The Advertisement Protocol element format is shown in Figure 9-485.

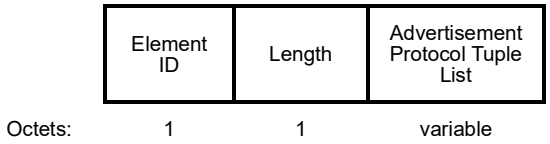

Figure 9-485—Advertisement Protocol element format

The Element ID and Length fields are defined in 9.4.2.1.

The Advertisement Protocol Tuple List field contains one or more Advertisement Protocol Tuple fields.

The format of an Advertisement Protocol Tuple field is shown in Figure 9-486.

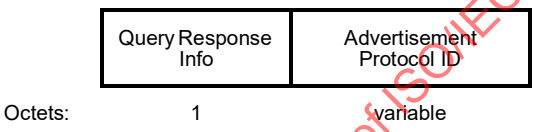

Figure 9-486—Advertisement Protocol Tuple field format

The format of Query Response Info field is shown in Figure 9-487.

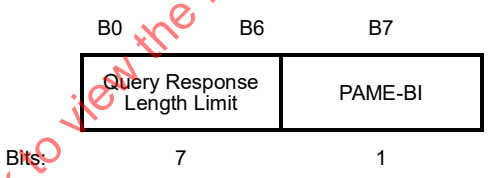

Figure 9-487—Query Response Info field format

The Query Response Info field is defined as follows:

— The Query Response Length Limit field indicates the maximum number of octets a STA will transmit in the Query Response field contained within one or more GAS Comeback Response frames. If the Query Response Length Limit field is larger than the maximum MMPDU size, the Query Response will span multiple MMPDUs. The Query Response Length Limit field is encoded as an integer number of 256 octet units. The value of 0 is reserved. The Query Response Length Limit field is set to 0x7F to indicate the maximum limit enforced is determined by the maximum allowable number of fragments in the GAS Query Response Fragment ID (see 9.4.1.33). The Query Response Length Limit field is reserved in a transmission from the requesting STA to the responding STA.

— Bit 7, the Preassociation Message Exchange BSSID Independent (PAME-BI) bit, is used by an AP to indicate whether the Advertisement Server, which is the non-AP STA's peer for this advertisement protocol, returns a Query Response that is independent of the BSSID used for the GAS frame exchange. This bit is set to 1 to indicate the Query Response is independent of the BSSID; it is set to 0 to indicate that the Query Response may be dependent on the BSSID. See 11.22.3.2 for further information. Bit 7 is reserved for non-AP STAs.

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The Advertisement Protocol ID field is a variable length field. When this field contains a vendor-specific advertisement protocol ID, then this field will be structured per the Vendor Specific element defined in 9.4.2.25, where the Element ID of the Vendor Specific element of 9.4.2.25 is the first octet of the field and contains the vendor-specific value for advertisement protocol ID defined in Table 9-237; otherwise its length is 1 octet and its value is one of the values in Table 9-237. When one or more vendor-specific tuples are included in the Advertisement Protocol element, their total length needs to be constrained such that the total length of all of the Advertisement Protocol Tuple fields (both vendor specific and otherwise) is less than or equal to 255 octets.

— The ANQP supports information retrieval from an Advertisement Server. ANQP is a protocol used by a requesting STA to query another STA (i.e., the receiving STA might respond to queries with or without proxying the query to a server in an external network). See 11.22.3.3 for information on ANQP procedures.

— The MIS Information Service is a service defined in IEEE Std 802.21-2017 to support information retrieval from an information repository.

— The MIS Command and Event Services capability discovery is a mechanism defined in IEEE Std 802.21-2017 to support discovering capabilities of command service and event service entities in a STA or an external network.

— The EAS allows a network to disseminate emergency alert notifications from an external network to non-AP STAs. EAS uses the message format as defined in OASIS EDXL (see OASIS Standard EDXL-DE).

— The RLQP supports information retrieval from a RLSS. RLQP is a protocol used by a requesting STA to query another STA (i.e., the receiving STA can respond to queries with and without proxying the query to a server in an external network). 11.22 for information on RLQP procedures.

— The Advertisement protocol ID value 221 is reserved for vendor specific advertisement protocols. When the Advertisement Protocol ID field is equal to 221, the format of the Advertisement Protocol ID subfield follows the format of the Vendor Specific element in 9.4.2.25.

Table 9-237—Advertisement protocol ID definitions

Name	Value
Access network query protocol (ANQP)	0
MIS Information Service	1
MIS Command and Event Services Capability Discovery	2
Emergency Alert System (EAS)	3
Registered location query protocol (RLQP)	4
Reserved	5–220
Vendor Specific	221
Reserved	222–255

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9.4.2.93 Expedited Bandwidth Request element

The Expedited Bandwidth Request element is transmitted from a non-AP STA to an AP in an ADDTS Request frame containing a TSPEC element and provides usage information for the bandwidth request. The Expedited Bandwidth Request element format is shown in Figure 9-488.

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	Element ID	Length	Precedence Level
Octets:	1	1	1

Figure 9-488—Expedited Bandwidth Request element format

The Element ID and Length fields are defined in 9.4.2.1.

The Precedence Level field is provided in Table 9-238.

Table 9-238—Precedence Level field description

Precedence level value	Description
0–15	Reserved
16	Emergency call, defined in NENA 08-002 [B57]
17	First responder (public)
18	First responder (private)
19	MLPP Level A
20	MLPP Level B
21	MLPP Level 0
22	MLPP Level 1
23	MLPP Level 2
24	MLPP Level 3
25	MLPP Level 4
26–255	Reserved

The precedence levels are derived from the 3rd Generation Partnership Project (3GPP) document 3GPP TS 22.067 [B2].

The first responders (public) in Table 9-238 are government agencies or entities acting on behalf of the government, and the first responders (private) are private entities, such as individuals or companies.

9.4.2.94 QoS Map element

The QoS Map element is transmitted from an AP to a non-AP STA in a (Re)Association Response frame or a QoS Map Configure frame and provides the mapping of higher layer quality-of-service constructs to User Priorities defined by transmission of Data frames in this standard. This element maps the higher layer priority from the DSCP field used with the Internet Protocol to User Priority as defined by this standard. The QoS Map element is shown in Figure 9-489.

	Element ID	Length	DSCP Exception List	UP 0 DSCP Range	UP 1 DSCP Range	UP 2 DSCP Range	...	UP 7 DSCP Range
Octets:	1	1	$n \times 2$	2	2	2		2

Figure 9-489—QoS Map element format

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The Element ID and Length fields are defined in 9.4.2.1.

The DSCP Exception List field contains zero or more (*n*) DSCP Exception fields. The maximum value of *n* is 21. The format of each DSCP Exception field is shown in Figure 9-490.

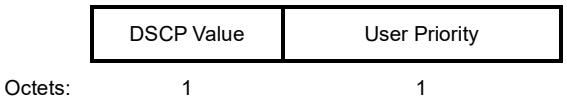

Figure 9-490—DSCP Exception format

The DSCP value in the DSCP Exception field is in the range 0 to 63, or 255; the User Priority value is in the range 0 to 7.

— When a non-AP STA begins transmission of a Data frame containing the Internet Protocol, it matches the DSCP field in the IP header to the corresponding DSCP value contained in this element. The non-AP STA first attempts to match the DSCP value to a DSCP exception field and uses the UP from the corresponding UP in the same DSCP exception field if successful; if no match is found then the non-AP STA attempts to match the DSCP field to a UP n DSCP Range field, and uses the n as the UP if successful; and otherwise uses a UP of 0.

— Each DSCP Exception field has a unique DSCP Value.

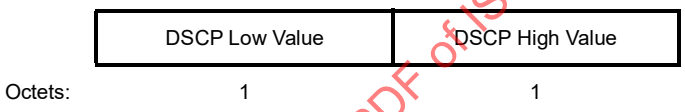

Figure 9-491—DSCP Range description

The QoS Map element has a DSCP Range field corresponding to each of the 8 user priorities. The format of the range field is shown in Figure 9-491. The DSCP Range value is between 0 and 63, or 255.

— The DSCP range for each user priority is nonoverlapping.

— The DSCP High Value is greater than or equal to the DSCP Low Value.

— If the DSCP Range high value and low value are both equal to 255, then the corresponding UP is not used.

9.4.2.95 Roaming Consortium element

The Roaming Consortium element contains information identifying the roaming consortium and/or SSP whose security credentials can be used to authenticate with the AP transmitting this element; see 11.22.8. The element's format is shown in Figure 9-492.

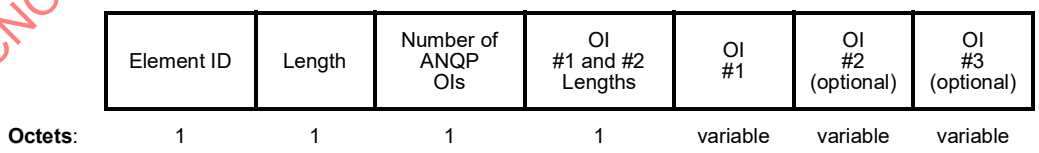

Figure 9-492—Roaming Consortium element format

The Element ID and Length fields are defined in 9.4.2.1.

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The format of the Number of ANQP OIs field is an unsigned integer whose value is the number of additional roaming consortium organization identifiers (OIs) obtainable via ANQP. The Number of ANQP OIs field is set to 0 to indicate that no additional OIs are returned in response to an ANQP request for the Roaming Consortium list. The Number of ANQP OIs field is set to 255 to indicate that 255 or more additional OIs are obtainable via ANQP.

The OI #1 and #2 Lengths field format is shown in Figure 9-493.

— The OI #1 Length subfield is set to the length in octets of the OI #1 field.
— The OI #2 Length subfield is set to the length in octets of the OI #2 field. If the OI #2 field is not present, the OI #2 Length subfield is set to 0.

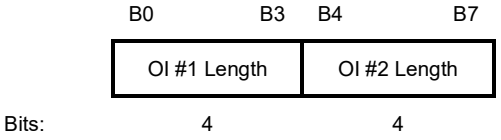

Figure 9-493—OI #1 and #2 Lengths field format

NOTE—When there are three OIs, the OI #3 Length is calculated by subtracting sum of 2 plus the value of the OI #1 Length subfield plus the value of the OI #2 Length subfield from the value of the Length field.

The OI field is defined in 9.4.1.31. Each OI identifies a roaming consortium (group of SSPs with inter-SSP roaming agreement) or a single SSP. The OI(s) in this table are equal to the first 3 OIs in the dot11RoamingConsortiumTable. If fewer than 3 values are defined in the dot11RoamingConsortiumTable, then only as many OIs as defined in the table are populated in this element. The values of the OIs in this element are equal to the values of the first OIs, up to 3, from the table.

9.4.2.96 Emergency Alert Identifier element

The Emergency Alert Identifier element provides a hash to identify instances of the active EAS messages that are currently available from the network. The hash allows the non-AP STA to assess whether an EAS message advertised by an AP has been previously received and therefore whether it is necessary to download from the network. The format of the Emergency Alert Identifier element is shown in Figure 9-494.

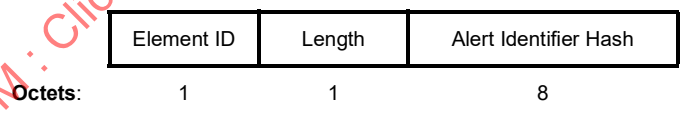

Figure 9-494—Emergency Alert Identifier element format

The Element ID and Length fields are defined in 9.4.2.1.

The Alert Identifier Hash (AIH) contains a unique value used to indicate an instance of an EAS message. This field is set to the hash produced by the HMAC-SHA-1-64 hash algorithm operating on the EAS message.

AIH =HMAC-SHA-1-64(“ES_ALERT”, Emergency_Alert_Message)

where

“ES_ALERT” is an ASCII string.
Emergency_Alert_Message is the EAS message itself.

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9.4.2.97 Mesh Configuration element

9.4.2.97.1 General

The Mesh Configuration element shown in Figure 9-495 is used to advertise mesh services. It is contained in Beacon frames and Probe Response frames transmitted by mesh STAs and is also contained in Mesh Peering Open and Mesh Peering Confirm frames.

	Element ID	Length	Active Path Selection Protocol Identifier	Active Path Selection Metric Identifier	Congestion Control Mode Identifier	Synchronization Method Identifier	Authentication Protocol Identifier	Mesh Formation Info	Mesh Capability
Octets	1	1	1	1	1	1	1	1	1

Figure 9-495—Mesh Configuration element format

The Element ID and Length fields are defined in 9.4.2.1.

The remainder of the fields are described in the following subclauses.

9.4.2.97.2 Active Path Selection Protocol Identifier

The Active Path Selection Protocol Identifier field indicates the path selection protocol that is currently activated in the MBSS. Table 9-239 provides path selection protocol identifier values defined by this standard.

Table 9-239—Active Path Selection Protocol Identifier field values

Value	Meaning
0	Reserved
1	Hybrid wireless mesh protocol (default path selection protocol) defined in 14.10 (default path selection protocol)
2–254	Reserved
255	Vendor specific (The active path selection protocol is specified in a Vendor Specific element)

When the Active Path Selection Protocol Identifier field is 255, the active path selection protocol is specified by a Vendor Specific element that is present in the frame. The content of the Vendor Specific element is beyond the scope of this standard. (See 9.4.2.25.)

9.4.2.97.3 Active Path Selection Metric Identifier

The Active Path Selection Metric Identifier field indicates the path metric that is currently used by the active path selection protocol in the MBSS. Table 9-240 provides the path selection metric identifier values defined by this standard.

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Table 9-240—Active Path Selection Metric Identifier field values

Value	Meaning
0	Reserved
1	Airtime link metric defined in 14.9.2 (default path selection metric)
2	High PHY rate airtime link metric defined in 14.9.2
3–254	Reserved
255	Vendor specific (The active metric is specified in a Vendor Specific element)

When the Active Path Selection Metric Identifier field is 255, the active path metric is specified by a Vendor Specific element that is present in the frame. The content of the Vendor Specific element is beyond the scope of this standard. (See 9.4.2.25.)

9.4.2.97.4 Congestion Control Mode Identifier

The Congestion Control Mode Identifier field indicates the congestion control protocol that is currently activated in the MBSS. Table 9-241 provides the congestion control mode identifier values defined by this standard.

Table 9-241—Congestion Control Mode Identifier field values

Value	Meaning
0	Congestion control is not activated (default congestion control mode)
1	Congestion control signaling protocol defined in 14.12.2
2–254	Reserved
255	Vendor specific (The active congestion control protocol is specified in a Vendor Specific element)

The Congestion Mode Identifier field set to 0 indicates the mesh STA has no active congestion control protocol and is set as the default value for the congestion control mode identifier in the MBSS.

When the Congestion Control Mode Identifier field is 255, the active congestion control protocol is specified by a Vendor Specific element that is present in the frame. The content of the Vendor Specific element is beyond the scope of this standard. (See 9.4.2.25.)

9.4.2.97.5 Synchronization Method Identifier

The Synchronization Method Identifier field indicates the synchronization method that is currently activated in the MBSS. Table 9-242 provides the synchronization method identifier values defined by this standard.

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Table 9-242—Synchronization Method Identifier field values

Value	Meaning
0	Reserved
1	Neighbor offset synchronization method defined in 14.13.2.2 (default synchronization method)
2–254	Reserved
255	Vendor specific (The active synchronization method is specified in a Vendor Specific element)

The neighbor offset synchronization method is defined as the default synchronization method among mesh STAs. The details of the neighbor offset synchronization method are described in 14.13.2.2.

When the Synchronization Method Identifier field is 255, the active synchronization method is specified by a Vendor Specific element that is present in the frame. The content of the Vendor Specific element is beyond the scope of this standard. (See 9.4.2.25.)

9.4.2.97.6 Authentication Protocol Identifier

The Authentication Protocol Identifier field indicates the type of authentication protocol that is currently used to secure the MBSS. Table 9-243 provides the authentication protocol identifier values defined by this standard.

Table 9-243—Authentication Protocol Identifier field values

Value	Meaning
0	No authentication method is required to establish mesh peerings within the MBSS
1	SAE defined in 12.4
2	IEEE 802.1X authentication
3–254	Reserved
255	Vendor specific (The active authentication protocol is specified in a Vendor Specific element)

When the Authentication Protocol Identifier field is 255, the active authentication protocol is specified by a Vendor Specific element that is present in the frame. The content of the Vendor Specific element is beyond the scope of this standard. (See 9.4.2.25.)

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9.4.2.97.7 Mesh Formation Info

The format of the Mesh Formation Info field is shown in Figure 9-496.

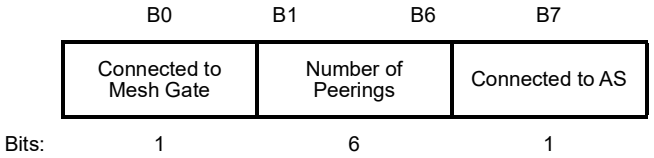

Figure 9-496—Mesh Formation Info field format

The Connected to Mesh Gate subfield is set to 1, if the mesh STA has a mesh path to a mesh gate that announces its presence using GANN elements, RANN elements, or PREQ elements, and set to 0 otherwise.

The Number of Peerings subfield contains an unsigned integer that indicates the number of mesh peerings currently maintained by the mesh STA or 63, whichever is smaller.

The Connected to AS subfield is set to 1 if the Authentication Protocol Identifier field in the Mesh Configuration element is equal to 2 (indicating IEEE 802.1X authentication) and the mesh STA has an active connection to an AS.

NOTE—When an AS is collocated with an IEEE 802.1X Authenticator an active connection is implicitly true.

9.4.2.97.8 Mesh Capability

The Mesh Capability field comprises a set of values indicating whether a mesh STA is a possible candidate for mesh peering establishment. The details of the Mesh Capability field are shown in Figure 9-497.

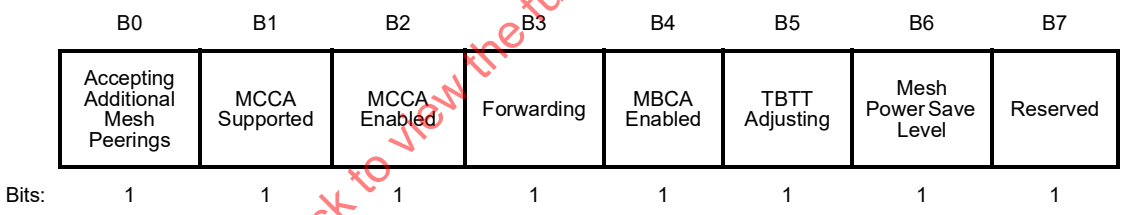

Figure 9-497—Mesh Capability field format

The Accepting Additional Mesh Peerings subfield is set to 1 if the mesh STA is willing to establish additional mesh peerings with other mesh STAs and set to 0 otherwise (i.e., the Accepting Additional Mesh Peerings subfield is set in accordance with dot11MeshAcceptingAdditionalPeerings). When the Mesh Configuration element is included in the Mesh Peering Open frame and in the Mesh Peering Confirm frame, the Accepting Additional Mesh Peerings subfield is set to 1.

The MCCA Supported subfield is set to 1 if the mesh STA implements MCCA and set to 0 otherwise (i.e., the MCCA Supported subfield is set in accordance with dot11MCCAImplemented).

The MCCA Enabled subfield is set to 1 if the mesh STA is using the MCCA and set to 0 otherwise (i.e., the MCCA Enabled subfield is set in accordance with dot11MCCAActivated).

The Forwarding subfield is set to 1 if the mesh STA forwards MSDUs and set to 0 otherwise (i.e., the Forwarding subfield is set in accordance with dot11MeshForwarding).

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The MBCA Enabled subfield is set to 1 if the mesh STA is using MBCA and is set to 0 otherwise (i.e., the MBCA Enabled subfield is set in accordance with dot11MBCAActivated). (See 14.13.4.)

The TBTT Adjusting subfield is set to 1 while the TBTT adjustment procedure is ongoing and is set to 0 otherwise. (See 14.13.4.4.3.)

The Mesh Power Save Level subfield is set to 1 if at least one of the peer-specific mesh power management modes is deep sleep mode and set to 0 otherwise. The Mesh Power Save Level subfield is reserved when the Power Management subfield in the Frame Control field is set to 0. See 9.2.4.5.11.

9.4.2.98 Mesh ID element

The Mesh ID element is used to advertise the identification of an MBSS and is described in 14.2.2. The format of the Mesh ID element is shown in Figure 9-498. The Mesh ID element is transmitted in Mesh Peering Open frames, Mesh Peering Confirm frames, Mesh Peering Close frames, Beacon frames, and Probe Request and Response frames.

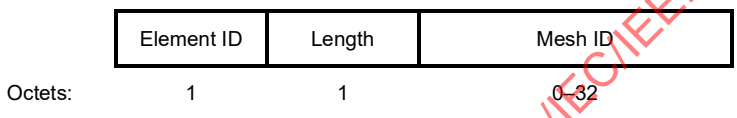

Figure 9-498—Mesh ID element format

The Element ID and Length fields are defined in 9.4.2.1.

A Mesh ID field of length 0 indicates the wildcard Mesh ID, which is used within Probe Request frame.

Detailed usage of the Mesh ID element is described in 14.2.2.

9.4.2.99 Mesh Link Metric Report element

The Mesh Link Metric Report element is transmitted by a mesh STA to a neighbor peer mesh STA to indicate the quality of the link between the transmitting mesh STA and the neighbor peer mesh STA. The format of the Mesh Link Metric Report element is shown in Figure 9-499.

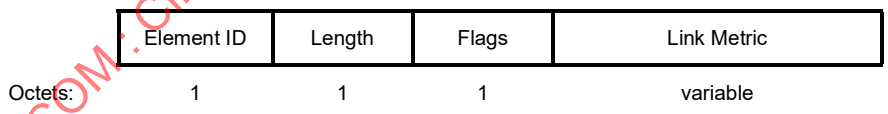

Figure 9-499—Mesh Link Metric Report element format

The Element ID and Length fields are defined in 9.4.2.1.

The format of the Flags field is shown in Figure 9-500.

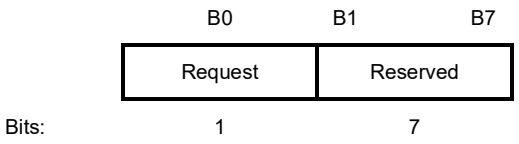

Figure 9-500—Flags field format

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The Flags field is set as follows:

— Bit 0: Request subfield (0 = not a request, 1 = link metric report request). A Request subfield equal to 1 indicates that the recipient of Mesh Link Metric Report element is requested to send a link metric report to the transmitter of the Mesh Link Metric Report element.

— Bit 1–7: Reserved.

The Link Metric field indicates the link metric associated with the mesh link between the peer mesh STA transmitting the Mesh Link Metric Report and the neighbor mesh STA receiving the Mesh Link Metric report. The length and the data type of the Link Metric field are determined by the active path selection metric identifier (see 9.4.2.97.3). The length and the data type for the airtime link metric are given in Table 14-5 in 14.9.2. The length and the data type for the airtime link metric and the high PHY rate airtime link metric are given in Table 14-5 in 14.9.2.

9.4.2.100 Congestion Notification element

The Congestion Notification element is used to indicate the congestion status of the mesh STA per mesh destination and AC, and the duration for which the STA expects the congestion to last. The format of the Congestion Notification element is shown in Figure 9-501. The Congestion Notification element is included in Congestion Control Notification frames, as described in 9.6.16.5.

	Element ID	Length	Destination Mesh STA Address	Congestion Notification Duration (AC_BK)	Congestion Notification Duration (AC_BE)	Congestion Notification Duration (AC_VI)	Congestion Notification Duration (AC_VO)
Octets:	1	1	6	2	2	2	2

Figure 9-501—Congestion Notification element format

The Element ID and Length fields are defined in 9.4.2.1.

The Destination Mesh STA Address field is represented as a 48-bit MAC address and is set to the address of the mesh destination for which the intra-mesh congestion control is applied. It is set to the broadcast address if the intra-mesh congestion control is applied to all destinations.

The element contains four Congestion Notification Duration fields for the four EDCA access categories to indicate the estimated congestion duration per AC at the mesh STA transmitting the congestion notification. The congestion notification duration values are encoded as unsigned integers in units of 100 μs.

9.4.2.101 Mesh Peering Management element

The Mesh Peering Management element is used to manage a mesh peering with a neighbor mesh STA. The format of the Mesh Peering Management element is shown in Figure 9-502.

	Element ID	Length	Mesh Peering Protocol Identifier	Local Link ID	Peer Link ID (optional)	Reason Code (optional)	Chosen PMK (optional)
Octets:	1	1	2	2	0 or 2	0 or 2	0 or 16

Figure 9-502—Mesh Peering Management element format

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The Element ID and Length fields are defined in 9.4.2.1.

The Mesh Peering Protocol Identifier field indicates the type of mesh peering protocol that is currently used to establish mesh peerings. Table 9-244 provides the mesh peering protocol identifier values defined by this standard.

Table 9-244—Mesh Peering Protocol Identifier field values

Value	Meaning
0	Mesh peering management protocol
1	Authenticated mesh peering exchange protocol
2–254	Reserved
255	Vendor specific (The active mesh peering protocol is specified in a Vendor Specific element)
256–65 535	Reserved

When the Mesh Peering Protocol Identifier field is 255, the active mesh peering protocol is specified by a Vendor Specific element that is present in the frame. The content of the Vendor Specific element is beyond the scope of this standard. (See 9.4.2.25.)

The Local Link ID field is the unsigned integer value generated by the local mesh STA to identify the mesh peering instance.

The conditional components of the Mesh Peering Management element are present depending on the Action field of the frame in which the Mesh Peering Management element is conveyed.

The Peer Link ID field is the unsigned integer value generated by the peer mesh STA to identify the mesh peering instance. This field is not present for the Mesh Peering Open frame, is present for the Mesh Peering Confirm frame, and is optionally present for the Mesh Peering Close frame. The presence or absence of the Peer Link ID in a Mesh Peering Close is inferred by the Length field.

The Reason Code field enumerates reasons for sending a Mesh Peering Close. It is present for the Mesh Peering Close frame and is not present for Mesh Peering Open or Mesh Peering Confirm frames. The reason code is defined in 9.4.1.7.

The Chosen PMK field is present when dot11MeshSecurityActivated is true and a PMK is shared between the transmitter and receiver of the frame containing the element. It contains the PMKID that identifies the PMK used to protect the mesh peering Management frame.

Detailed usage of the Mesh Peering Management element is described in 14.3.6, 14.3.7, 14.3.8, and 14.5.5.

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9.4.2.102 Mesh Channel Switch Parameters element

The Mesh Channel Switch Parameters element is used together with Channel Switch Announcement element and Extended Channel Switch Announcement element by a mesh STA to advertise to other mesh STAs when it is changing to a new operating channel and/or operating class. The format of the Mesh Channel Switch Parameters element is shown in Figure 9-503.

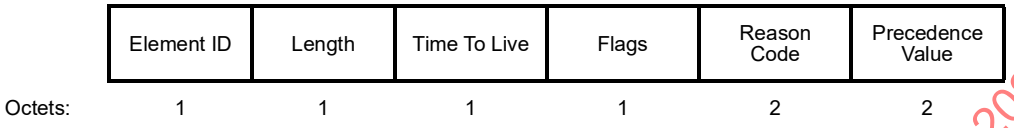

Figure 9-503—Mesh Channel Switch Parameters element format

The Element ID and Length fields are defined in 9.4.2.1.

The Time To Live field is coded as an unsigned integer and indicates the remaining number of hops allowed for this element.

The Flags field indicates the attribute of this channel switch attempt. The format of the Flags field is shown in Figure 9-504.

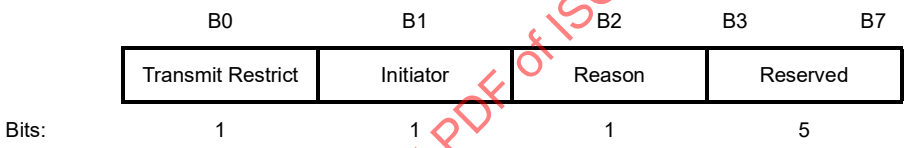

Figure 9-504—Flags field format

The Transmit Restrict subfield is set to 1 when the mesh STA asks neighboring peer mesh STAs not to transmit further frames except frames containing Mesh Channel Switch Parameters element on the current channel until the scheduled channel switch. The Transmit Restrict subfield is set to 0 otherwise.

The Initiator subfield is set to 1 when the mesh STA initiates this channel switch attempt. The Initiator subfield is set to 0 when this channel switch attempt is initiated by another mesh STA and propagated by the current mesh STA.

The Reason subfield indicates the validity of the Reason Code field. It is set to 1 if the Reason Code field is valid and is set to 0 otherwise. When the Reason subfield is 0, the content of the Reason Code field is reserved.

The Reason Code field specifies the reason for the mesh channel switch. The Reason Code is defined in 9.4.1.7. The content of the Reason Code field is valid only when Reason subfield of Flags field is set to 1 and is reserved otherwise.

The Precedence Value field is coded as unsigned integer and is set to a random value drawn from a uniform distribution in the range 0 to 65 535 determined by the initiator of this channel switch attempt.

The Mesh Channel Switch Parameters element is included in Channel Switch Announcement frames, as described in 9.6.2.6, and Extended Channel Switch Announcement frames, as described in 9.6.7.7. During MBSS channel switching, the Mesh Channel Switch Parameters element is included in Beacon frames, as described in 9.3.3.2, and Probe Response frames, as described in 9.3.3.10, until the scheduled channel switch.

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9.4.2.103 Mesh Awake Window element

The Mesh Awake Window element is present in DTIM Beacon frames and is optionally present in Beacon and Probe Response frames. The format of the Mesh Awake Window element is shown in Figure 9-505.

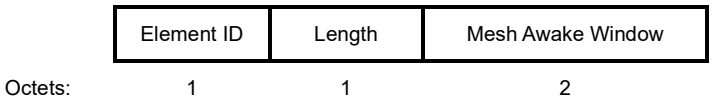

Figure 9-505—Mesh Awake Window element format

The Element ID and Length fields are defined in 9.4.2.1.

The Mesh Awake Window field contains an unsigned integer that indicates the duration of the mesh awake window in TUs.

9.4.2.104 Beacon Timing element

The Beacon Timing element is used to advertise the beacon timing information of neighbor STAs (mesh STAs, IBSS APs, or IBSS STAs). The format of the Beacon Timing element is shown in Figure 9-506.

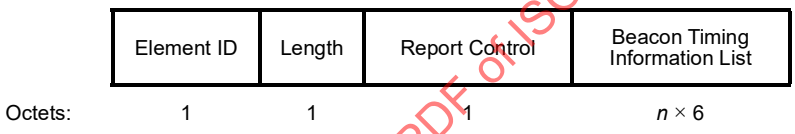

Figure 9-506—Beacon Timing element format

The Element ID and Length fields are defined in 9.4.2.1.

The Report Control field is used to signal information about the beacon timing information tuple contained in the Beacon Timing element. The structure of the Report Control field is defined in Figure 9-507.

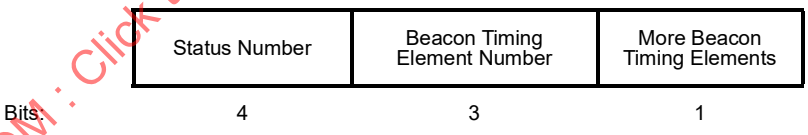

Figure 9-507—Report Control field format

The Status Number subfield is set to the status number of the beacon timing information set. The status number is managed as described in 14.13.4.2.4.

The Beacon Timing Element Number subfield is an unsigned integer that indicates the index of the beacon timing information tuple contained in this Beacon Timing element. The Beacon Timing Element Number is set to 0 in the Beacon Timing element for the first or only tuple of the beacon timing information and is incremented by one for each successive tuple of the beacon timing information. The beacon timing information tuples are managed as described in 14.13.4.2.5.

The More Beacon Timing Element subfield is set to 1 if a successive tuple of beacon timing information exists, and set to 0 otherwise.

The Beacon Timing Information List field contains one or more (n) Beacon Timing Information fields.

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Each Beacon Timing Information field contains the beacon timing information of a neighbor STA. When the mesh STA reports multiple beacon timing information, multiple Beacon Timing Information fields are included in the Beacon Timing element. The structure of the Beacon Timing Information field is defined in Figure 9-508.

Figure 9-508—Beacon Timing Information field format

The Neighbor STA ID subfield is an unsigned integer that indicates the identification of the neighbor STA corresponding to this beacon timing information. When a mesh peering is established with this neighbor STA, the MSB of this field is set to 0, and the rest of this field is set to the last 7 digits (7 LSBs) of the AID value assigned to this neighbor mesh STA. When a mesh peering is not established with this neighbor STA, the MSB of this field is set to 1, and the rest of this field is set to MAC_ADDR[42:47] of the 48-bit MAC address of this neighbor STA.

NOTE—Since the Neighbor STA ID subfield is provided in abbreviated form, it is possible that the same Neighbor STA ID value appears in multiple Beacon Timing Information fields.

The Neighbor TBTT subfield is an unsigned integer that indicates a TBTT of the corresponding neighbor STA, measured in the local TSF timer of the mesh STA. The value is indicated in multiples of 32 μs. When the active synchronization method is the neighbor offset synchronization method, the TBTT is calculated as described in 14.13.4.2.2. The B5 to the B28 (taking the B0 as the LSB) of the calculated TBTT are contained in this subfield.

The Neighbor Beacon Interval subfield is an unsigned integer that indicates the beacon interval being used by the corresponding neighbor STA. The unit of the Neighbor Beacon Interval subfield is TU.

Detailed usage of the Beacon Timing element is described in 14.13.4.2.

9.4.2.105 MCCAOP Setup Request element

9.4.2.105.1 General

The MCCAOP Setup Request element is used to make an MCCAOP reservation. This element is transmitted in individually addressed MCCA Setup Request frames or in group addressed MCCA Setup Request frames. The mesh STA transmitting the MCCA Setup Request element is the MCCAOP owner of the MCCAOPs that will be scheduled with this reservation setup request. The receivers of the MCCAOP Setup Request frame are the MCCAOP responders. The format of the element is shown in Figure 9-509.

Figure 9-509—MCCAOP Setup Request element format

The Element ID and Length fields are defined in 9.4.2.1.

The MCCAOP Reservation ID field is an unsigned integer that represents the ID for the MCCAOP reservation. It is determined by the MCCAOP owner. When used in combination with the MAC address of the MCCAOP owner, the MCCAOP Reservation ID uniquely identifies the MCCAOP reservation. If this

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MCCAOP Setup Request element is for an individually addressed transmission, the MCCAOP Reservation ID is between 0 and 127 and the MCCAOP Setup Request element is transmitted in an individually addressed frame to the intended responder. If this MCCAOP Setup Request element is for a group addressed transmission, the MCCAOP Reservation ID is between 128 and 254 and the MCCAOP Setup Request element is transmitted in a group addressed frame. The value 255 is not used to identify a single MCCAOP reservation.

The MCCAOP Reservation field is described in 9.4.2.105.2.

9.4.2.105.2 MCCAOP Reservation field

The MCCAOP Reservation field is a 5-octet field specifying a schedule for frame transmissions called *MCCAOPs*. The MCCAOP Reservation field consists of three subfields and its format is shown in Figure 9-510.

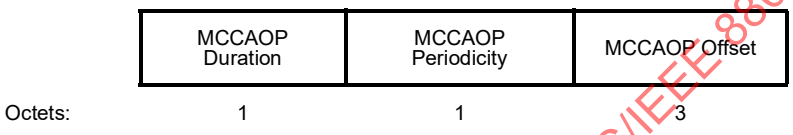

Figure 9-510—MCCAOP Reservation field format

The MCCAOP Duration subfield contains an unsigned integer. It specifies the duration of the MCCAOPs in multiples of 32 μs.

The MCCAOP Periodicity subfield contains a positive integer. It specifies the number of MCCAOPs scheduled in each DTIM interval.

The MCCAOP Offset subfield is 3 octets in length and contains an unsigned integer. It specifies the beginning of the first MCCAOP in each DTIM interval. The value is specified in multiples of 32 μs. The sum of MCCAOP Offset plus MCCAOP Duration is constrained to be smaller than the duration of the DTIM interval divided by MCCAOP Periodicity.

9.4.2.106 MCCAOP Setup Reply element

The MCCAOP Setup Reply element is used to reply to an MCCAOP Setup Request. This element is transmitted in individually addressed MCCA Setup Reply frames. The mesh STA transmitting the MCCA Setup Reply element is the MCCAOP responder of the MCCAOPs scheduled in this reservation setup. The receiver of the MCCAOP Setup Reply is the MCCAOP owner. The format of the element is shown in Figure 9-511.

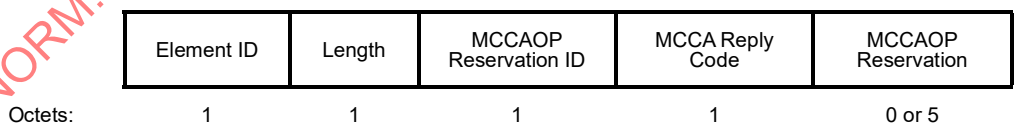

Figure 9-511—MCCAOP Setup Reply element format

The Element ID and Length fields are defined in 9.4.2.1.

The MCCAOP Reservation ID field is an unsigned integer that represents the ID for the requested series of MCCAOPs. It is determined by the MCCAOP owner and copied from the MCCAOP Setup Request element. When used in combination with the MAC address of the MCCAOP owner, the MCCAOP Reservation ID uniquely identifies the MCCAOP reservation.

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The MCCA Reply Code field is a 1-octet field that contains the reply code used in an MCCAOP Setup Reply element. The reply codes are defined in Table 9-245.

Table 9-245—MCCA Reply Code field values

MCCA reply code	Meaning
0	Accept
1	Reject: MCCAOP reservation conflict
2	Reject: MAF limit exceeded
3	Reject: MCCA track limit (dot11MCCATrackStatesActive) exceeded
4–255	Reserved

The MCCAOP Reservation field includes an alternative to the MCCAOP reservation specified in the MCCAOP Setup Request frame. Its format is described in 9.4.2.105.2. When the MCCA Reply Code is 1, the MCCAOP Reservation field might be present. When the MCCA Reply Code is set to other values, the MCCAOP Reservation field is not present.

9.4.2.107 MCCAOP Advertisement Overview element

The MCCAOP Advertisement Overview element is used by a mesh STA to advertise its MCCA Information and information about its MCCAOP Advertisement elements, representing its MCCAOP advertisement set, to its neighbors. This element is transmitted in MCCA Advertisement frames and optionally present in Beacon frames. The format of the MCCAOP Advertisement Overview element is shown in Figure 9-512.

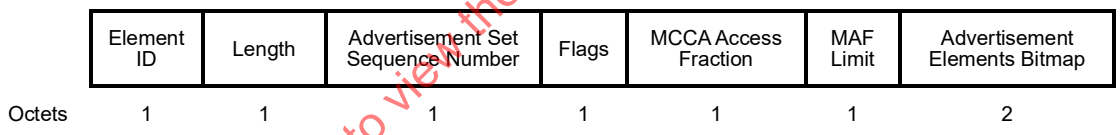

Figure 9-512—MCCAOP Advertisement Overview element format

The Element ID and Length fields are defined in 9.4.2.1.

The Advertisement Set Sequence Number field is coded as an unsigned integer. It is set to the advertisement set sequence number of the current MCCAOP advertisement set. The Advertisement Set Sequence Number, together with the MAC address of the transmitter of the MCCAOP Advertisement Overview element, identifies an MCCAOP advertisement set and provides an identifier and a chronological order of different MCCAOP advertisement sets of the same mesh STA.

The format of the Flags field is shown in Figure 9-513.

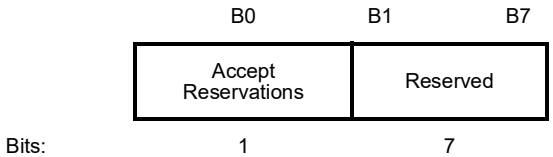

Figure 9-513—Flags field format

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The Flags field is set as follows:

— Bit 0: Accept Reservations subfield. The Accept Reservations subfield is set to 1 if the mesh STA accepts additional reservations. It is set to 0 otherwise.

— Bit 1–7: Reserved

The MCCA Access Fraction field is an unsigned integer. The MCCA Access Fraction field is set to the current value of the MCCA access fraction at the mesh STA rounded down to the nearest multiple of (1/255) of the DTIM interval length.

The MAF Limit field is an unsigned integer. The MAF Limit field is set to the maximum MCCA access fraction allowed at the mesh STA rounded down to the nearest multiple of (1/255) of the DTIM interval length.

The Advertisement Elements Bitmap field indicates the MCCAOP Advertisement elements that are part of this MCCAOP advertisement set. The Advertisement Elements Bitmap field is a bitmap. Bit i in this bitmap equals 1 if the MCCAOP Advertisement element with MCCAOP Advertisement Element Index equal to i is part of this MCCAOP advertisement set, and it equals 0 otherwise.

9.4.2.108 MCCAOP Advertisement element

9.4.2.108.1 General

The MCCAOP Advertisement element is used by a mesh STA to advertise MCCAOP reservations to its neighbors. This element is transmitted in MCCA Advertisement frames and optionally present in Beacon frames. The format of the element is shown in Figure 9-514.

	Element ID	Length	Advertisement Set Sequence Number	MCCAOP Advertisement Element Information	TX-RX Periods Report	Broadcast Periods Report	Interference Periods Report
Octets:	1	1	1	1	variable	variable	variable

Figure 9-514—MCCAOP Advertisement element format

The Element ID and Length fields are defined in 9.4.2.1.

The Advertisement Set Sequence Number field is coded as an unsigned integer. It is set to the advertisement set sequence number of the current MCCAOP advertisement set. The Advertisement Set Sequence Number, together with the MAC address of the transmitter of the MCCAOP Advertisement element, identifies an MCCAOP advertisement set and provides an identifier and a chronological order of different MCCAOP advertisement sets of the same mesh STA.

The MCCAOP Advertisement Element Information field is described in 9.4.2.108.2.

The TX-RX Periods Report field is a variable length field that contains an MCCAOP Reservation Report field, as described in 9.4.2.108.3. This field is present when the TX-RX Report Present subfield of the MCCAOP Advertisement Element Information field is equal to 1; it is not present otherwise. The TX-RX Periods Report field is described in 10.24.3.7.2.

The Broadcast Periods Report field is a variable length field that contains an MCCAOP Reservation Report field, as described in 9.4.2.108.3. This field is present when the Broadcast Report Present subfield of the MCCAOP Advertisement Element Information field is equal to 1; it is not present otherwise. The Broadcast Periods Report field is described in 10.24.3.7.2.

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The Interference Periods Report field is a variable length field that contains an MCCAOP Reservation Report field, as described in 9.4.2.108.3. This field is present when the Interference Report Present subfield of the MCCAOP Advertisement Element Information field is equal to 1; it is not present otherwise. The Interference Periods Report field is described in 10.24.3.7.2.

9.4.2.108.2 MCCAOP Advertisement Element Information field

The MCCA Information field is 1 octet in length and provides information on the MCCAOP reservations. The field consists of four subfields and its format is shown in Figure 9-515.

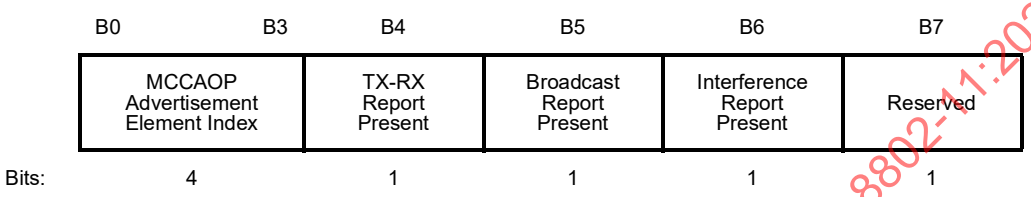

Figure 9-515—MCCAOP Advertisement Element Information field format

The MCCAOP Advertisement Element Index subfield is an unsigned integer. It identifies the MCCAOP Advertisement element.

The TX-RX Report Present subfield is set to 1 if the TX-RX Periods Report field is present in the MCCAOP Advertisement element and set to 0 if no TX-RX Periods Report field is present.

The Broadcast Report Present subfield is set to 1 if the Broadcast Periods Report field is present in the MCCAOP Advertisement element and set to 0 if no Broadcast Periods Report field is present.

The Interference Report Present subfield is set to 1 if the Interference Periods Report field is present in the MCCAOP Advertisement element and set to 0 if no Interference Periods Report field is present.

9.4.2.108.3 MCCAOP Reservation Report field

The MCCAOP Reservation Report field is of variable length and is used to report a number of MCCAOP reservations. The field consists of a variable number of subfields and its format is shown in Figure 9-516.

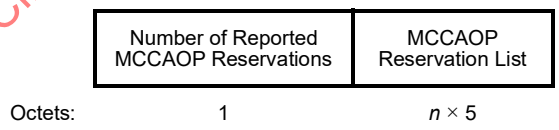

Figure 9-516—MCCAOP Reservation Report field format

The Number of Reported MCCAOP Reservations field is an unsigned integer that indicates the number, *n*, of MCCAOP Reservation fields reported in the MCCAOP Reservation List field.

The MCCAOP Reservation List field contains one or more (*n*) MCCAOP Reservation fields.

The MCCAOP Reservation fields specify the MCCAOP reservations reported. The format of each MCCAOP Reservation field is shown in Figure 9-510 in 9.4.2.105.2.

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9.4.2.109 MCCAOP Teardown element

The MCCAOP Teardown element is used to announce the teardown of an MCCAOP reservation. The MCCAOP Teardown element is transmitted in individually addressed MCCA Teardown frames or in group addressed MCCA Teardown frames. Its format is shown in Figure 9-517.

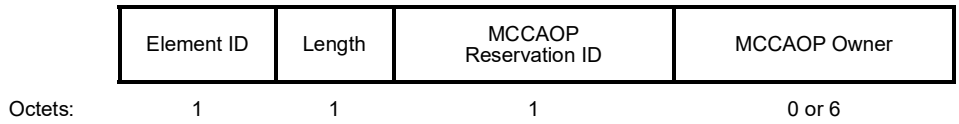

Figure 9-517—MCCAOP Teardown element format

The Element ID and Length fields are defined in 9.4.2.1.

An MCCAOP Teardown element is transmitted by either the MCCAOP owner or the MCCAOP responder of an MCCAOP reservation to tear down the MCCAOP reservation.

The MCCAOP Reservation ID field is an unsigned integer that represents the ID for the MCCAOP reservation.

The MCCAOP Owner field, if present, indicates the 48-bit MAC address of the MCCAOP owner. This field is included if the element is transmitted by the MCCAOP responder; it is not included otherwise.

9.4.2.110 GANN element

The GANN (gate announcement) element is used for announcing the presence of a mesh gate in the MBSS. The GANN element is transmitted in a Gate Announcement frame (see 9.6.16.4). The format of the GANN element is shown in Figure 9-518.

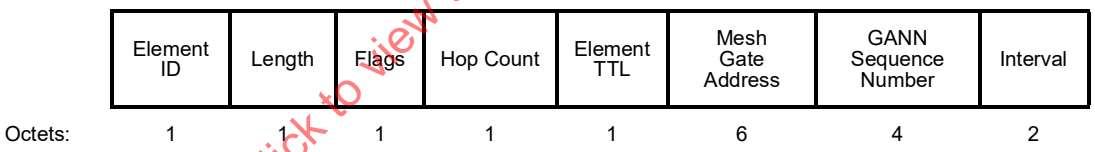

Figure 9-518—GANN element format

The Element ID and Length fields are defined in 9.4.2.1.

The Flags field is reserved.

The Hop Count field is coded as an unsigned integer and indicates the number of hops from the originating mesh gate to the mesh STA transmitting this element.

The Element TTL field is coded as an unsigned integer and indicates the remaining number of hops allowed for this element.

The Mesh Gate Address field is represented as a 48-bit MAC address and is set to the MAC address of the mesh gate.

The GANN Sequence Number field is coded as an unsigned integer and is set to a GANN Sequence Number specific for the originating mesh gate.

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The Interval field is coded as an unsigned integer and is set to the number of seconds between the periodic transmissions of Gate Announcements by the mesh gate.

Detailed usage of the GANN element is described in 14.11.2.

9.4.2.111 RANN element

The RANN (root announcement) element is used for announcing the presence of a mesh STA configured as root mesh STA with dot11MeshHWMProotMode set to rann (4). RANN elements are sent out periodically by such a root mesh STA. The RANN element is transmitted in an HWMP Mesh Path Selection frame (see 9.6.16.3). The format of the RANN element is shown in Figure 9-519.

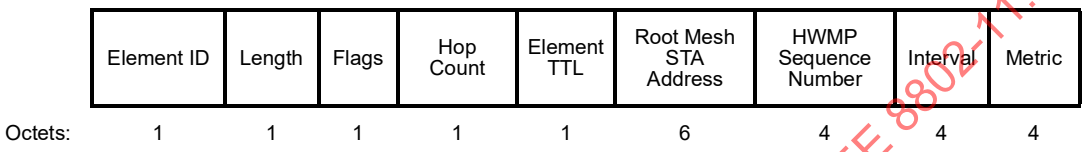

Figure 9-519—RANN element format

The Element ID and Length fields are defined in 9.4.2.1.

The format of the Flags field is shown in Figure 9-520.

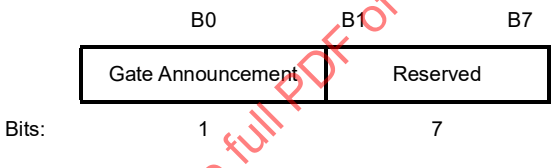

Figure 9-520—Flags field format

The Flags field is set as follows:

— Bit 0: Gate Announcement subfield (0 = gate announcement protocol not activated, 1 = gate announcement protocol activated). A Gate Announcement subfield equal to 1 indicates that the Root Mesh STA Address is a mesh gate with dot11MeshGateAnnouncements equal to true.

— Bit 1–7: Reserved.

The Hop Count field is coded as an unsigned integer and indicates the number of hops from the originating root mesh STA to the mesh STA transmitting this element.

The Element TTL field is coded as an unsigned integer and indicates the remaining number of hops allowed for this element.

The Root Mesh STA Address field is represented as a 48-bit MAC address and is set to the MAC address of the root mesh STA.

The HWMP Sequence Number field is coded as an unsigned integer and is set to the HWMP sequence number (SN) specific to the root mesh STA.

The Interval field is coded as an unsigned integer and is set to the number of TUs between the periodic transmissions of Root Announcements.

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The Metric field is set to the cumulative metric from the originating root mesh STA to the mesh STA transmitting the announcement.

Detailed usage of the RANN element is described in 14.10.12.

9.4.2.112 PREQ element

The PREQ (path request) element is used for discovering a path to one or more target mesh STAs, maintaining a path (optional), building a proactive (reverse) path selection tree to the root mesh STA, and confirming a path to a target mesh STA (optional). The PREQ element is transmitted in an HWMP Mesh Path Selection frame (see 9.6.16.3). The format of the PREQ element is shown in Figure 9-521.

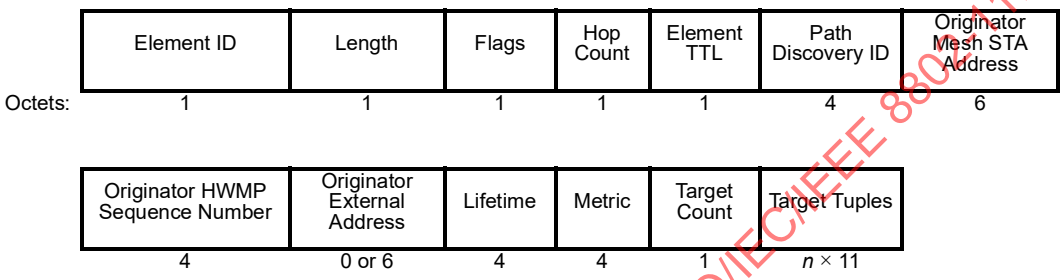

Figure 9-521—PREQ element format

The Element ID and Length fields are defined in 9.4.2.1.

The format of the Flags field is shown in Figure 9-522.

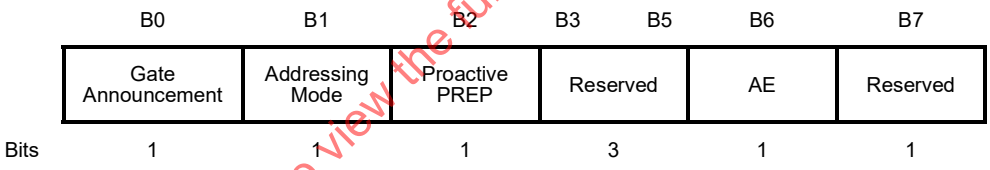

Figure 9-522—Flags field format

The Flags field is set as follows:

— Bit 0: Gate Announcement subfield (0 = gate announcement protocol not activated, 1 = gate announcement protocol activated). A Gate Announcement subfield equal to 1 indicates that the originator mesh STA address is a mesh gate with dot11MeshGateAnnouncements equal to true.

— Bit 1: Addressing Mode subfield (0 = group addressed, 1 = individually addressed). When the Addressing Mode subfield is 0, the PREQ element is sent in an HWMP Mesh Path Selection frame that is group addressed to all neighbor peer mesh STAs. When the Addressing Mode subfield is 1, the PREQ element is sent in an HWMP Mesh Path Selection frame that is individually addressed to a neighbor peer mesh STA. Detailed addressing information is provided in 14.10.7.

— Bit 2: Proactive PREP subfield (0 = off, 1 = on). The Proactive PREP subfield is of relevance only if the Target Address is the broadcast address (all 1s). If equal to 1, every recipient of a PREQ element with Target Address equal to the broadcast address replies with a PREP element. If equal to 0, a recipient replies only under certain conditions (see 14.10.4.2) and does not reply otherwise.

— Bit 3–5: Reserved.

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— Bit 6: AE (Address Extension) subfield (1= external address present, 0 = otherwise). An AE subfield equal to 1 indicates that the field Originator External Address is present, and that the originator mesh STA is a proxy for this external address.
— Bit 7: Reserved.

The Hop Count field is coded as an unsigned integer and is set to the number of hops from the originator to the mesh STA transmitting this element.

The Element TTL field is coded as an unsigned integer and indicates the remaining number of hops allowed for this element.

The Path Discovery ID field is coded as an unsigned integer and is set to some unique ID for this PathDiscovery.

The Originator Mesh STA Address field is represented as a 48-bit MAC address and is set to the originator MAC address.

The Originator HWMP Sequence Number field is coded as an unsigned integer and is set to the HWMP SN specific to the originator.

The Originator External Address field is the MAC address of an external STA proxied by the originator. This field is present only if the AE subfield in the Flags field is set to 1 and is represented as a 48-bit MAC address.

The Lifetime field is coded as an unsigned integer and is set to the time for which mesh STAs receiving the PREQ element consider the forwarding information to be valid. The lifetime is measured in TUs.

The Metric field is set to the cumulative metric from the originator to the mesh STA transmitting the PREQ element.

The Target Count field is an unsigned integer and gives the number of targets (n) contained in this PREQ element. The maximum value of n is 20.

The Target Tuples field contains one or more Target Tuple fields. The format of a Target Tuple field is shown in Figure 9-523.

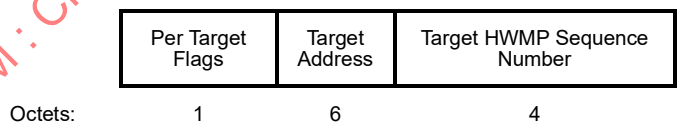

Figure 9-523—Target Tuple field format

The format of the Per Target Flags field is shown in Figure 9-524.

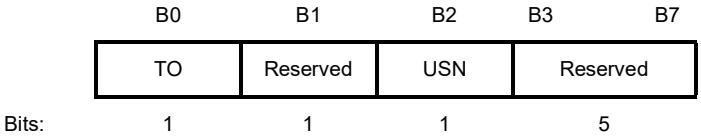

Figure 9-524—Per Target Flags field format

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The Per Target Flags field is set as follows:

— Bit 0: TO (Target Only) subfield: The TO subfield defines the mesh STA to respond with a PREP element to the PREQ element containing an individual target address. If TO = 1, only the target mesh STA responds. If TO = 0, intermediate mesh STAs with active forwarding information to the target mesh STA also respond. See 14.10.10.3.

— Bit 1: Reserved.

— Bit 2: USN (Unknown Target HWMP Sequence Number) subfield: The USN subfield indicates whether the Target HWMP Sequence Number field of the corresponding target is interpreted as HWMP SN (USN = 0) or not (USN = 1), the latter meaning that a target HWMP SN is unknown at the originator mesh STA.

— Bit 3–7: Reserved.

The Target Address field is represented as a 48-bit MAC address.

The Target HWMP Sequence Number field is coded as an unsigned integer and is the latest known HWMP SN received in the past by the originator mesh STA for any path toward the target. If such a target HWMP SN is not known, the USN subfield is set to 1 and Target HWMP Sequence Number field is reserved.

Detailed usage of the PREQ element is described in 14.10.9.

9.4.2.113 PREP element

The PREP (path reply) element is used to establish a forward path to a target and to confirm that a target is reachable. The PREP element is issued in response to a PREQ element. The PREP element is transmitted in an HWMP Mesh Path Selection frame (see 9.6.16.3). The format of the PREP element is shown in Figure 9-525.

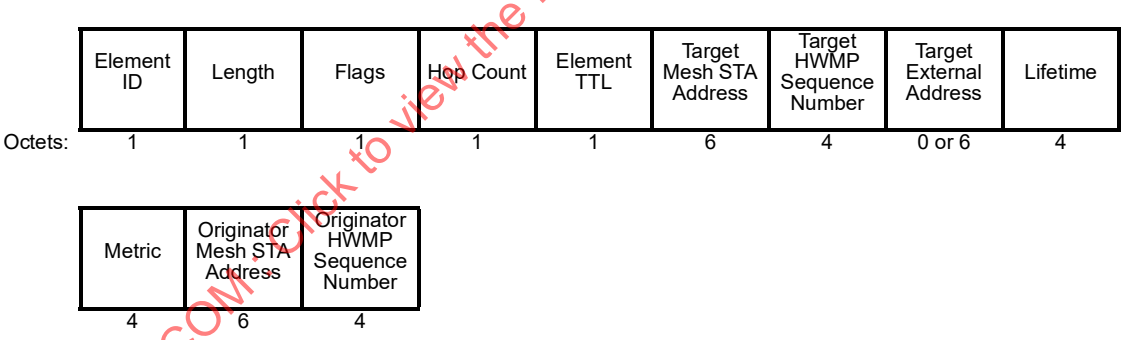

Figure 9-525—PREP element format

The Element ID and Length fields are defined in 9.4.2.1.

The format of the Flags field is shown in Figure 9-526.

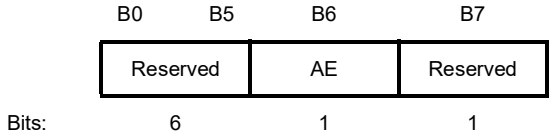

Figure 9-526—Flags field format

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The Flags field is set as follows:

— Bit 0–5: Reserved.

— Bit 6: AE (Address Extension) subfield (1 = external address present, 0 = otherwise). An AE subfield equal to 1 indicates that the field Target External Address is present, and that the target mesh STA is a proxy for this external address.

— Bit 7: Reserved.

The Hop Count field is coded as an unsigned integer and is set to the number of hops from the path target to the mesh STA transmitting this element.

The Element TTL field is coded as an unsigned integer and indicates the remaining number of hops allowed for this element.

The Target Mesh STA Address is the MAC address of the target mesh STA or target proxy mesh gate and is represented as a 48-bit MAC address.

The Target HWMP Sequence Number field is coded as an unsigned integer and is set to the HWMP SN of the target mesh STA (if the AE subfield in the Flags field is equal to 0) or target proxy mesh gate (if the AE subfield in the Flags field is equal to 1).

The Target External Address field is set to the external address on behalf of which the PREP element is sent. This field is present only if Bit 6 (AE subfield) in Flags field equals 1, and is represented as a 48-bit MAC address.

The Lifetime field is coded as an unsigned integer and is set to the time for which mesh STAs receiving the PREP element consider the forwarding information to be valid. The lifetime is measured in TUs.

The Metric field indicates the cumulative metric from the path target to the mesh STA transmitting this element.

The Originator Mesh STA Address field is represented as a 48-bit MAC address and is set to the MAC address of the originator, which is contained in the PREQ element.

The Originator HWMP Sequence Number field is coded as an unsigned integer and is set to the HWMP SN of the originator mesh STA contained in the PREQ element.

The detailed usage of the PREP element is described in 14.10.10.

9.4.2.114 PERR element

The PERR (path error) element is used for announcing an unreachable destination. The PERR element is transmitted in an HWMP Mesh Path Selection frame (see 9.6.16.3). The format of the PERR element is shown in Figure 9-527.

	Element ID	Length	Element TTL	Number of Destinations	Destination Tuples
Octets:	1	1	1	1	variable

Figure 9-527—PERR element format

The Element ID and Length fields are defined in 9.4.2.1.

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The Element TTL field is an unsigned integer that indicates the remaining number of hops allowed for this element.

The Number of Destinations field is an unsigned integer and indicates the number of announced destinations in PERR, *n*. The maximum value of *n* is 19.

The Destination Tuples field contains one or more Destination Tuple fields. The format of a Destination Tuple field is shown in Figure 9-528.

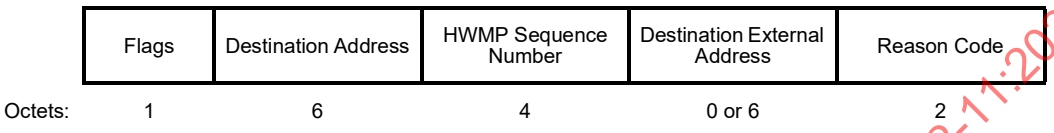

Figure 9-528—Destination Tuples field format

The format of the Flags field is shown in Figure 9-529.

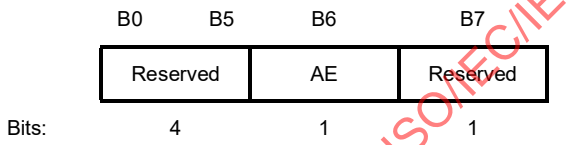

Figure 9-529—Flags field format

The Flags field is set as follows:

— Bit 0–5: Reserved.
— Bit 6: AE (Address Extension) subfield (1 = destination external address is present, 0 = otherwise).
— Bit 7: Reserved.

The Destination Address field is represented as a 48-bit MAC address and indicates the detected unreachable destination MAC address.

The HWMP Sequence Number field is coded as an unsigned integer and indicates the HWMP SN for the invalidated destination, if applicable. Otherwise, the HWMP Sequence Number field is reserved depending on the reason code.

The Destination External Address field is set to the external address, on behalf of which the PERR is sent. This field is present only if Bit 6 (AE subfield) in the Flags field equals 1 and is represented as a 48-bit MAC address.

The Reason Code field specifies the reason for sending a PERR element. The Reason Code is defined in 9.4.1.7.

The detailed usage of the PERR element is described in 14.10.11.

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9.4.2.115 PXU element

The PXU (proxy update) element is used to inform the destination mesh STA of the proxy information at the originator mesh STA. The PXU element is transmitted in a Proxy Update frame (see 9.6.17.2). The format of the PXU element is shown in Figure 9-530.

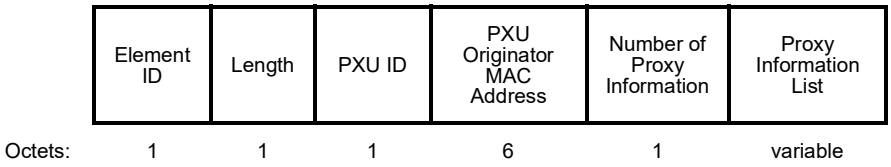

Figure 9-530—PXU element format

The Element ID and Length fields are defined in 9.4.2.1.

The PXU ID field is an unsigned integer and is set to the sequence number of the PXU. The source mesh STA sets the PXU ID field in the PXU element to a value from a single modulo 256 counter that is incremented by 1 for each new PXU element.

The PXU Originator MAC Address field is represented as a 48-bit MAC address and is the MAC address of the mesh STA that originates this PXU element.

The Number of Proxy Information field is set to the number *n* of Proxy Information fields in the Proxy Information List field and that are reported to the destination mesh STA. The maximum value of *n* is 22.

The Proxy Information List field contains one or more (*n*) Proxy Information fields.

A Proxy Information field contains a single proxy information (see 14.11.4.2). The length of the Proxy Information field depends on the settings of the subfields in the Flags subfield and is 11, 15, 17, or 21 octets.

The format of the Proxy Information field is defined in Figure 9-531.

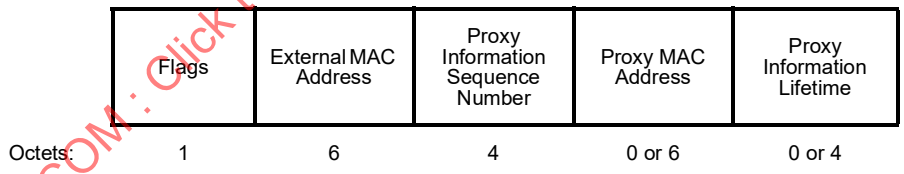

Figure 9-531—Proxy Information field format

The format of the Flags subfield is shown in Figure 9-532.

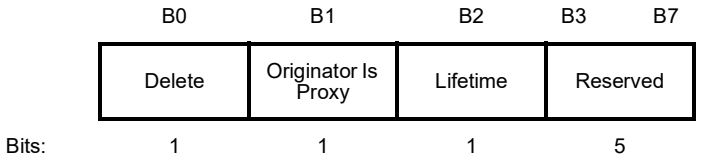

Figure 9-532—Flags subfield format

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The Flags subfield is set as follows:

- Bit 0: The Delete subfield indicates whether this proxy information is to be deleted. It is set to 1 if the proxy information is to be deleted, and set to 0 otherwise.
- Bit 1: The Originator Is Proxy subfield indicates that the originator mesh STA of the PXU element is the proxy mesh gate of this proxy information when set to 1. In this case, there is no Proxy MAC Address subfield present in this Proxy Information field. When the Originator Is Proxy subfield is 0, the Proxy MAC Address subfield is present in this Proxy Information field.
- Bit 2: The Lifetime subfield indicates that the Proxy Information Lifetime subfield is present in this Proxy Information field when set to 1.
- Bit 3–7: Reserved.

The External MAC Address subfield is represented as a 48-bit MAC address and is the MAC address of the external STA proxied by the proxy mesh gate.

The Proxy Information Sequence Number field is coded as an unsigned integer and is set to the sequence number of the proxy information. The sequence number of the proxy information defines a chronological order of the proxy information for the external STA at this proxy mesh gate.

The Proxy MAC Address subfield is represented as a 48-bit MAC address and is set to the MAC address of proxy mesh gate. It is present if the Originator Is Proxy subfield of the Flags subfield is 0; it is not present otherwise.

The Proxy Information Lifetime subfield is coded as an unsigned integer and is set to the time for which the mesh STA receiving this PXU considers this proxy information to be valid. The proxy information lifetime is measured in TUs. It is present if the Lifetime subfield of the Flags subfield is 1; it is not present otherwise.

9.4.2.116 PXUC element

The PXUC (proxy update confirmation) element is used to confirm the previously received PXU. The PXUC element is transmitted in a Proxy Update Confirmation frame (see 9.6.17.3). The format of PXUC element is shown in Figure 9-533.

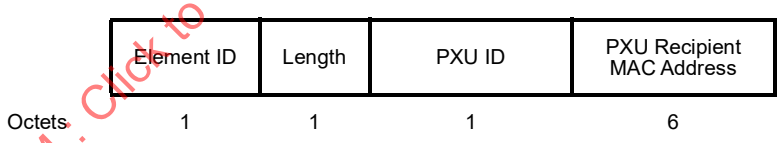

Figure 9-533—PXUC element format

The Element ID and Length fields are defined in 9.4.2.1.

The PXU ID field is coded as an unsigned integer and is the PXU ID of the received PXU that is being confirmed.

The PXU Recipient MAC Address is represented as a 48-bit MAC address and is set to the MAC address of the recipient of the PXU, i.e., the originator of the PXUC element.

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9.4.2.117 Authenticated Mesh Peering Exchange element

The Authenticated Mesh Peering Exchange element includes information needed to perform the authentication sequence during an authenticated mesh peering exchange. This element is shown in Figure 9-534.

	Element ID	Length	Selected Pairwise Cipher Suite	Local Nonce	Peer Nonce	Key Replay Counter (optional)	GTKdata (optional)	IGTKdata (optional)
Octets	1	1	4	32	32	8	variable	variable

Figure 9-534—Authenticated Mesh Peering Exchange element format

The Element ID and Length fields are defined in 9.4.2.1.

The Selected Pairwise Cipher Suite field contains a pairwise cipher suite selector, as defined in 9.4.2.24.2, indicating a cipher suite to be used to secure the link.

The Local Nonce field contains a nonce value chosen by the mesh STA that is transmitting the element. It is encoded following the conventions from 9.2.2.

The Peer Nonce field contains a nonce value that was chosen by the peer mesh STA or candidate peer mesh STA to which the element is being sent. It is encoded following the conventions from 9.2.2.

The Key Replay Counter field is optional. It is used only for the Mesh Group Key Inform frame (see 14.6.3) and the Mesh Group Key Acknowledge frame (see 14.6.4). It is represented as an unsigned integer.

The GTKdata field is optional. When present, it contains the bit string of {GTK || Key RSC || GTKExpirationTime} as the GTK data material. When present, the GTKdata field is protected by the exchange in which it is contained (see 14.5). The Key RSC denotes the last TSC or PN sent using the GTK and is specified in Table 12-8 of 12.7.2. GTKExpirationTime denotes the key lifetime of the GTK in seconds and the format is specified in Figure 12-40 of 12.7.2.

The IGTKdata field is present when dot11RSNAProtectedManagementFramesActivated equals true. When present, it contains the Key ID, IPN and IGTK used with BIP for management frame protection. The format of the IGTKdata field is specified in Figure 12-42 of 12.7.2.

Detailed usage of the Authenticated Mesh Peering Exchange element is described in 14.5.5 and in 14.6.

9.4.2.118 MIC element

The MIC element provides message integrity to mesh peering Management frames. The format of the MIC element is shown in Figure 9-535.

	Element ID	Length	MIC
Octets:	1	1	16

Figure 9-535—MIC element format

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The Element ID and Length fields are defined in 9.4.2.1.

The MIC field contains a message integrity code calculated over the mesh peering Management frame (as specified in 14.5) and the mesh group key handshake frame (as specified in 14.6).

9.4.2.119 Quality-of-Service Management Frame Policy element

The Quality-of-Service Management Frame (QMF) Policy element defines a QMF access category mapping (QACM) of Management frames and is used to advertise and exchange QMF policy between STAs. The use of the QMF Policy element is given in 11.24. See Figure 9-536.

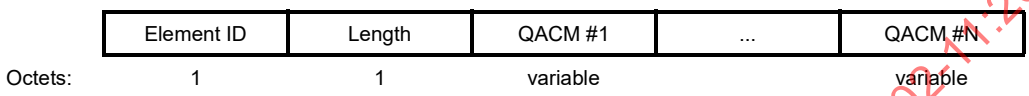

Figure 9-536—QMF Policy element format

The Element ID and Length fields are defined in 9.4.2.1.

The QACM field specifies a group of Management frames and their associated access categories. See Figure 9-537 and see 11.24.3.

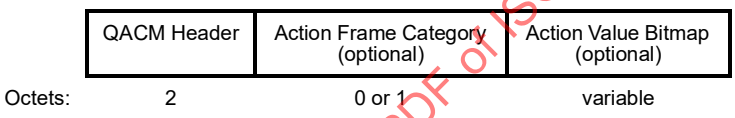

Figure 9-537—QACM field format

The format of the QACM Header subfield of the QACM field is defined in Figure 9-538.

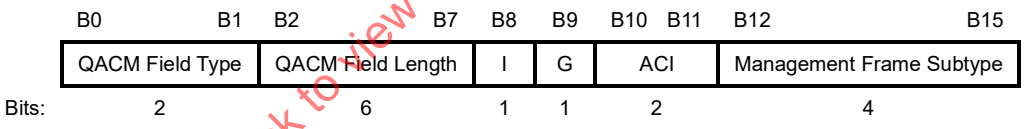

Figure 9-538—QACM Header subfield format

The QACM Field Type subfield defines the structure of the QACM field. Its value is 0. Values 1, 2, and 3 are reserved.

The QACM Field Length subfield defines the length in octets of the QACM field excluding the QACM Header subfield.

When the QACM applies to individually addressed Management frames, the Individually Addressed (I) subfield is set to 1. Otherwise, it is 0.

When the QACM applies to group addressed Management frames, the Group Addressed (G) subfield is set to 1. Otherwise, it is 0.

The combination of I = 0 and G = 0 is not allowed.

Each Management frame that is listed in the QACM Header subfield is transmitted using the access category identified by the accompanying ACI subfield.

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The Management Frame Subtype subfield indicates the subtype of Management frames that are sent using the access category indicated in the ACI subfield. The valid values for this subfield are the subtypes in Table 9-1 that correspond to Management frames.

The Action Frame Category subfield indicates the category of the Action frame, as defined in 9.4.1.1, of Action frames that are sent using the access category indicated in the ACI subfield. The Action Frame Category subfield is included only when the Management Frame Subtype subfield indicates Action or Action No Ack subtype as specified in 11.24.3.

The Action Value Bitmap subfield is included when the QACM Policy is specified for a subset of Action frame types in a Action Frame Category. The Action Value Bitmap subfield is of variable length and indicates the action values, as defined in 9.6, for the corresponding Action frame category that are sent using the access category indicated in the ACI subfield. The Action Value Bitmap subfield is included only when the Management Frame Subtype subfield indicates Action or Action No Ack subtype and the QACM Field Length subfield is greater than or equal to 2. Each bit in the Action Value Bitmap subfield is mapped to the corresponding action value. The Action Value Bitmap subfield is zero padded to complete any incomplete octet. When included, the size in octets of the Action Value Bitmap field is found by subtracting 1 from the value of the QACM Field Length subfield.

9.4.2.120 Intra-Access Category Priority element

The Intra-Access Category Priority element provides information from a non-AP STA to an AP on the relative priorities of streams within an AC, as described in 10.2.3.2 and 11.25.2. This element is optionally present in ADDTS Request, QoS Map Configure, or SCS Request frames. The Intra-Access Category Priority element is defined in Figure 9-539.

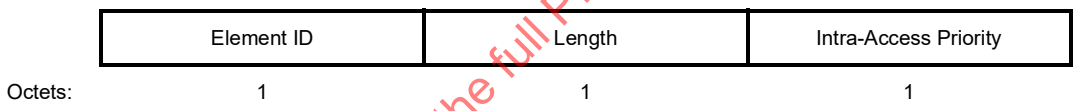

Figure 9-539—Intra-Access Category Priority element format

The Element ID and Length fields are defined in 9.4.2.1.

The Intra-Access Priority field is defined in Figure 9-540.

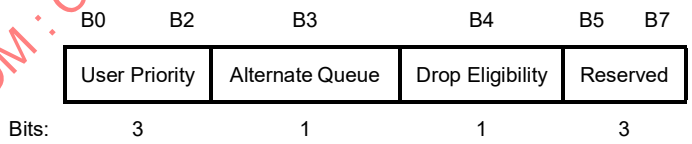

Figure 9-540—Intra-Access Priority field format

The User Priority subfield indicates the UP of MSDUs or A-MSDUs of the stream to which this Intra-Access Category Priority element relates.

The Alternate Queue subfield indicates the intended primary or alternate EDCA queue that is used for this stream. When dot11AlternateEDCAActivated is false, this subfield is reserved. When the Alternate Queue subfield is equal to 0, the primary EDCA queue for this AC is used. When the Alternate Queue subfield is equal to 1, the Alternate EDCA queue for this AC (see 10.2.3.2) is used.

The Drop Eligibility subfield is used to indicate the suitability of this TS to be discarded if there are insufficient resources. If there are insufficient resources, a STA should discard the MSDUs or A-MSDUs of

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a TS with a Drop Eligibility subfield equal to 1, in preference to MSDUs or A-MSDUs of a TS whose Drop Eligibility subfield is equal to 0. See 11.24.2. The mechanisms for determining whether the resources are insufficient or when to discard MSDUs or A-MSDUs are beyond the scope of this standard.

9.4.2.121 SCS Descriptor element

The SCS Descriptor element defines information about the stream that is being classified using the procedures defined in 11.25.2. The format of the SCS Descriptor element is shown in Figure 9-541.

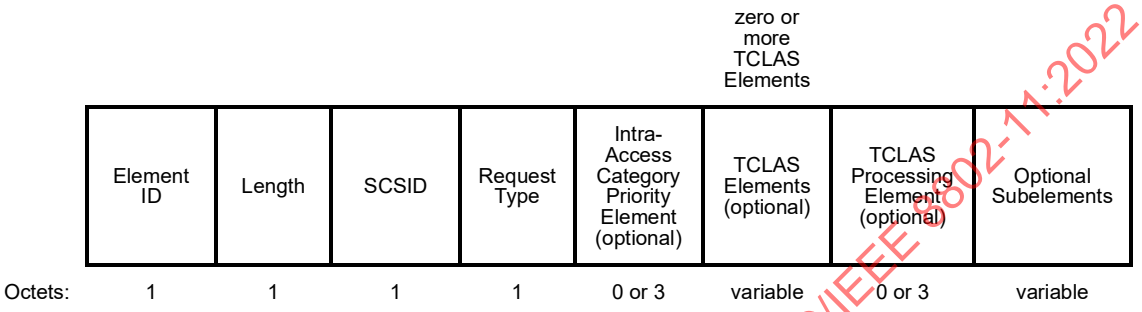

Figure 9-541—SCS Descriptor element format

The Element ID and Length fields are defined in 9.4.2.1.

The SCSID field is set to a nonzero value chosen by the non-AP STA identifying the SCS stream specified in this SCS Descriptor element.

The Request Type field is set to a number to identify the type of SCS request. The Request Types are shown in Table 9-246.

Table 9-246—SCS Request Type definitions

Name	Value
Add	0
Remove	1
Change	2
Reserved	3–255

The Intra-Access Category Priority Element field is present when Request Type field is equal to “Add” or “Change” and is defined in 9.4.2.120.

The TCLAS Elements field contains zero or more TCLAS elements to specify how incoming MSDUs are classified as part of this SCS stream, as defined in 9.4.2.30. One or more TCLAS elements are present when Request Type field is equal to “Add” or “Change,” and no TCLAS elements are present when Request Type field is equal to “Remove.”

The TCLAS Processing Element field is present when more than one TCLAS element is present in the TCLAS Elements field and contains a TCLAS Processing element that defines how the multiple TCLAS elements are to be processed, as defined in 9.4.2.32.

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The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Optional Subelement ID field values for the defined subelements are shown in Table 9-247.

Table 9-247—Optional subelement IDs for SCS Descriptor element

Subelement ID	Name	Extensible
0–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The SCS Descriptor element is included in SCS Request frames, as described in 9.6.18.2. The use of the SCS Descriptor element and SCS Request frames is described in 11.25.2.

9.4.2.122 QLoad Report element

9.4.2.122.1 QLoad Report element format

The QLoad Report element contains the set of parameters necessary to support OBSS management. The format of the QLoad Report element is shown in Figure 9-542.

	Element ID	Length	Potential Traffic Self	Allocated Traffic Self	Allocated Traffic Shared	EDCA Access Factor	HCCA Peak	HCCA Access Factor	Overlap	Sharing Policy	Optional Subelements
Octets:	1	1	5	5	5	1	2	1	1	1	variable

Figure 9-542—QLoad Report element format

The Element ID and Length fields are defined in 9.4.2.1.

Potential Traffic Self, Allocated Traffic Self, and Allocated Traffic Shared fields use the QLoad field format as described in 9.4.2.122.2.

The Potential Traffic Self field represents the peak composite QoS traffic for this BSS if all of the potential admission control and HCCA TSPECs from the non-AP STAs are active. The methods for gathering the total potential TSPEC information are described in 11.26.2.

The Allocated Traffic Self field represents the composite QoS traffic for this BSS based upon all of the admission control and HCCA TSPECs admitted within the same BSS, as described in 11.26.2.

The Allocated Traffic Shared field represents the sum of the Allocated Traffic Self field values that have been received or obtained from other APs whose beacons have been detected or obtained within the last 100 beacon periods, plus the Allocated Traffic Self field value of the AP itself. Computation of the values represented in the Allocated Traffic Shared field is described in 11.26.2.

As described in 11.26.2, the EDCA Access Factor field value is the sum of the Potential Traffic Self field values that have been received or obtained from other APs, plus the Potential Traffic Self field value of the AP itself, minus the sum of the HCCA Peak field values that have been received or obtained from

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overlapping APs, minus the HCCA Peak field value of the AP itself. The EDCA Access Factor is expressed as a fraction rounded down to a multiple of 1/64. When the EDCA Access Factor is greater than 254/64, the EDCA Access Factor field is set to 255.

The HCCA Peak field is the total peak HCCA TXOP requirement, over a period of 1 s, for the AP and BSS, for all of the HCCA TSPECs that are included in the QLoad. HCCA Peak is expressed in multiples of 32 µs over a period of 1 s. The HCCA Peak field is reserved if HCCA is not supported.

NOTE—Because the HCCA peak is calculated over 1 s periods, its value might be an underestimate of the instantaneous peak of interactive variable bit rate (VBR) flows.

The HCCA Access Factor field value is the sum of the HCCA Peak field values in the QLoad Report elements that have been received from the APs of OBSSs, plus the HCCA Peak field value of the AP itself, as described in 11.26.2. It is expressed as a fraction rounded down to a multiple of 1/64. When the HCCA Access Factor is greater than 254/64, the HCCA Access Factor field is set to 255.

The Overlap field indicates the number of other APs that are sharing the same channel and whose beacons have been detected or obtained within the last 100 beacon periods by the AP issuing this beacon.

The Sharing Policy field contains the currently active sharing policy. The values for the Sharing Policy field are described in Table 9-248.

Table 9-248—Sharing Policy definitions

Sharing Policy field value	Current sharing policy
0	Not specified
1	Static
2	Dynamic
3–220	Reserved
221	Vendor Specific
222–255	Reserved

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-249.

Table 9-249—Optional subelement IDs for QLoad Report element

Subelement ID	Name	Extensible
0–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

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9.4.2.122.2 QLoad field format

The QLoad field format is shown in Figure 9-543.

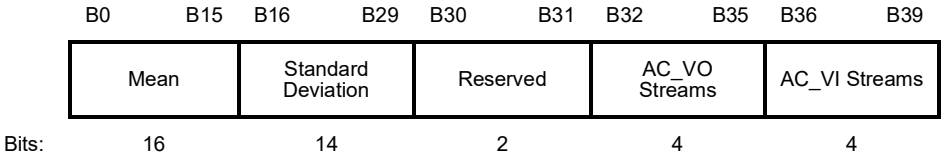

Figure 9-543—QLoad field format

The Mean subfield represents the amount of time admitted, or the amount of time scheduled traffic requires to access the medium, in units of 32 μs per second. In the case of EDCA admission control, this value is the sum of the admitted medium times, and for HCCA it is the total TXOP time required per second (see T.2.2). If the mean medium time is larger than 2 097 088 μs (65 534 × 32), the Mean subfield is set to 0xFFFE. The Mean subfield is set to 0xFFFF to indicate that the mean medium time is unknown.

The Standard Deviation subfield indicates the standard deviation from the mean medium time, in units of 32 μs per second. If the standard deviation is larger than 8128 μs (254 × 32), the Standard Deviation subfield is set to 0x3FFE. The Standard Deviation subfield is set to 0x3FFF to indicate that the standard deviation from the mean is unknown.

The AC_VO Streams subfield indicates the number of TSs using explicit admission control for AC_VO in the QoS traffic load report. Bidirectional streams are counted as two streams. If the number of admitted AC_VO streams is larger than 14, the AC_VO Streams subfield is set to 0xE. The AC_VO Streams subfield is set to 0xF to indicate that the number of TSs using explicit admission control for AC_VO is unknown.

The AC_VI Streams subfield indicates the number of TSs using explicit admission control for AC_VI in the QoS traffic load report. Bidirectional streams are counted as two streams. If the number of TSs using explicit admission control for AC_VO is larger than 14, the AC_VI Streams subfield is set to 0xE. The AC_VI Streams subfield is set to 0xF to indicate that the number of TSs using explicit admission control for AC_VI is unknown.

See 11.26.2 and Annex T.

9.4.2.123 HCCA TXOP Update Count element

The HCCA TXOP Update Count element is used by an AP to advertise its change in TXOP schedule. The format is shown in Figure 9-544.

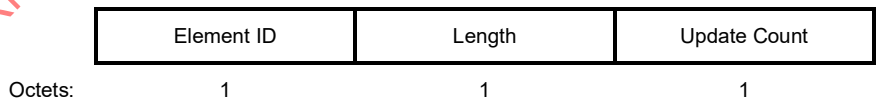

Figure 9-544—HCCA TXOP Update Count element format

The Element ID and Length fields are defined in 9.4.2.1.

The Update Count field is described in 11.26.3 and is used to indicate that a change has occurred in the number of active HCCA or HEMM TSs.

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9.4.2.124 Higher Layer Stream ID element

The Higher Layer Stream ID element identifies a stream from a higher layer protocol. This element is used to bind messages that are exchanged in order to complete a procedure, e.g., messages exchanged in an AP-initiated TS setup procedure. See 11.4.4.3. The format is shown in Figure 9-545.

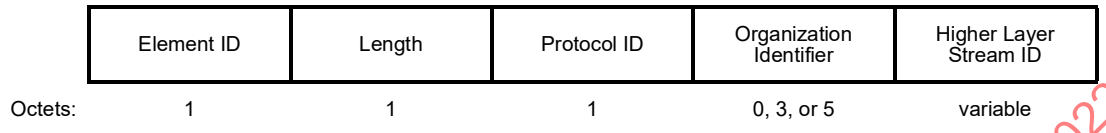

Figure 9-545—Higher Layer Stream ID element format

The Element ID and Length fields are defined in 9.4.2.1.

The Protocol ID field identifies the higher layer protocol to which the stream belongs. The values defined for the Protocol ID field are described in Table 9-250.

Table 9-250—Protocol ID definitions

Protocol ID	Protocol	Description
0	Reserved	
1	IEEE 802.1Q SRP	Protocol is IEEE 802.1Q SRP, and the corresponding Stream ID is 8 octets long.
2–220	Reserved	
221	Vendor Specific	Corresponding Organization Identifier field is included in the element.
222–255	Reserved	

The Organization Identifier field is present when the Protocol ID field is equal to 221 and contains a organization identifier assigned by IEEE. The identifier is specified in 9.4.1.31. The order of the Organization Identifier field is described in 9.2.2.

The Higher Layer Stream ID field is an octet string and is defined by the higher layer protocol specified in the Protocol ID field.

9.4.2.125 GCR Group Address element

The GCR Group Address element defines information about group addressed frames to be transmitted using the GCR service. The format of the GCR Group Address element is shown in Figure 9-546.

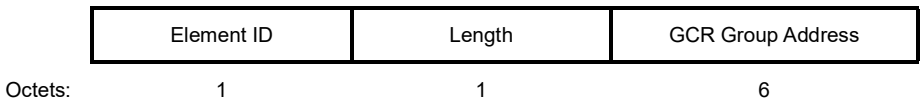

Figure 9-546—GCR Group Address element format

The Element ID and Length fields are defined in 9.4.2.1.

GCR Group Address field is the MAC address of the GCR group.

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9.4.2.126 DMG BSS Parameter Change element

The DMG BSS Parameter Change element is defined in Figure 9-547.

	Element ID	Length	Change Type Bitmap	TBTT Offset	BI Duration
Octets:	1	1	1	4	2

Figure 9-547—DMG BSS Parameter Change element format

The Element ID and Length fields are defined in 9.4.2.1.

The Change Type Bitmap field indicates the type of the parameter change to the BSS. This field is defined in Figure 9-548.

	B0	B1	B2 ... B7
	Move	Size	Reserved
Bits:	1	1	6

Figure 9-548—Change Type Bitmap field format

If the Move subfield is set to 1, it indicates a change in the TBTT of the BSS. The TBTT is not changed if the Move field is set to 0. If the Size subfield is set to 1, it indicates a change in the beacon interval duration. The beacon interval duration is not changed if the Size subfield is set to 0.

The TBTT Offset field contains a value expressed in microseconds. In any DMG BSS Parameter Change element included in the DMG Beacon and/or Announce frame, the TBTT Offset field represents the lower order 4 octets of the AP or PCP TSF timer of the first changed TBTT.

The BI Duration field value indicates the beacon interval, expressed in TUs, following the indicated DMG BSS parameter change. The BI Duration field is reserved if the Size bit of the Change Type Bitmap field is set to 0.

9.4.2.127 DMG Capabilities element

9.4.2.127.1 General

The DMG Capabilities element contains a STA identifier and several fields that are used to advertise the support of optional DMG capabilities of a DMG STA. The element is present in Association Request, Association Response, Reassociation Request, Reassociation Response, Probe Request and Probe Response frames and can be present in DMG Beacon, Information Request, and Information Response frames. The DMG Capabilities element is formatted as defined in Figure 9-549.

	Element ID	Length	STA Address	AID	DMG STA Capability Information	DMG AP Or PCP Capability Information	DMG STA Beam Tracking Time Limit	Extended SC MCS Capabilities	Maximum Number Of Basic A-MSDU Subframes In A-MSDU	Maximum Number Of Short A-MSDU Subframes In A-MSDU
Octets:	1	1	6	1	8	2	2	1	1	1

Figure 9-549—DMG Capabilities element format

The Element ID and Length fields are defined in 9.4.2.1.

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The STA Address field contains the MAC address of the STA.

The AID field contains the AID assigned to the STA by the AP or PCP. The AID field is reserved in Association Request, Reassociation Request and Probe Request frames and when used in an IBSS.

9.4.2.127.2 DMG STA Capability Information field

The DMG STA Capability Information field, shown in Figure 9-550, represents the transmitting STA capabilities irrespective of the role of the STA.

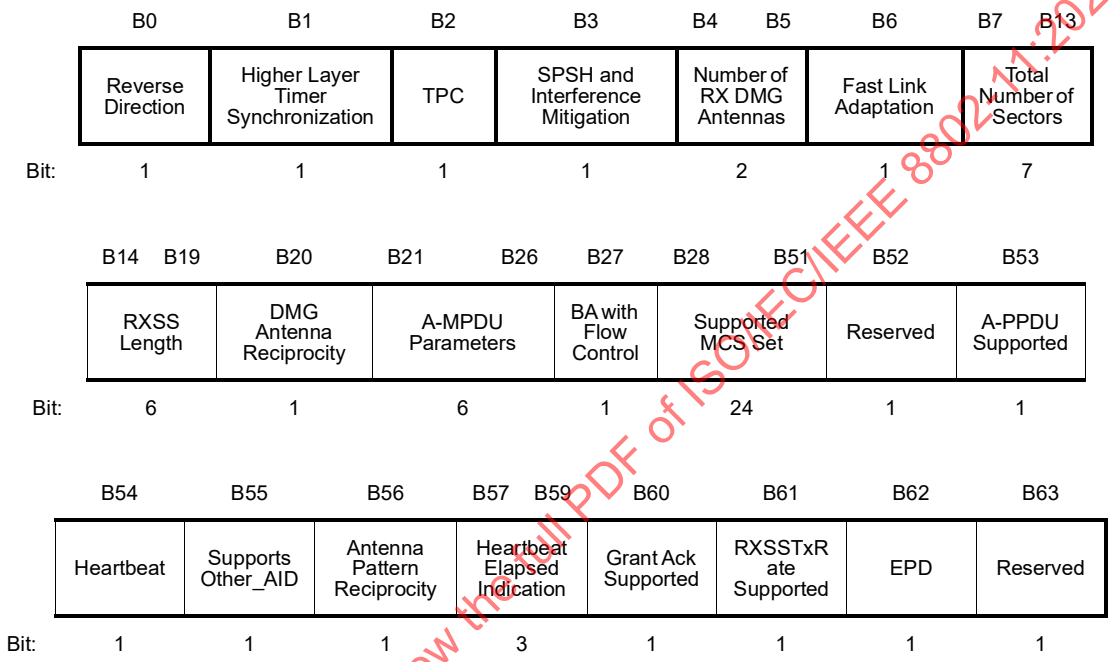

Figure 9-550—DMG STA Capability Information field format

The Reverse Direction subfield is set to 1 if the STA supports RD as defined in 10.29 and is set to 0 otherwise.

The Higher Layer Timer Synchronization subfield is set to 1 if the STA supports Higher Layer Timer Synchronization as defined in 11.6 and is set to 0 otherwise.

The TPC subfield is set to 1 if the STA supports the TPC as defined in 11.7 and is set to 0 otherwise.

The SPSH (spatial sharing) and Interference Mitigation subfield is set to 1 if the STA is capable of performing the function of SPSH and Interference Mitigation and if dot11RadioMeasurementActivated is true and is set to 0 otherwise (see 11.30).

The Number of RX DMG Antennas subfield indicates the total number of receive DMG antennas of the STA minus 1.

The Fast Link Adaptation subfield is set to 1 to indicate that the STA supports the fast link adaptation procedure described in 10.43.3. Otherwise, it is set to 0.

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The Total Number of Sectors subfield indicates the total number of transmit sectors the STA uses in a transmit sector sweep combined over all DMG antennas, including any LBIFS required for DMG antenna switching (see 10.42), minus 1.

The value represented by the RXSS Length subfield specifies the total number of receive sectors combined over all receive DMG antennas of the STA, including any LBIFS required for DMG antenna switching (see 10.42). This subfield is set to (RXSS Length+1)×2, which ranges from 2 to 128.

The DMG Antenna Reciprocity subfield is set to 1 to indicate that the best transmit DMG antenna of the STA is the same as the best receive DMG antenna of the STA and vice versa. Otherwise, this subfield is set to 0.

The A-MPDU Parameters subfield is shown in Figure 9-551.

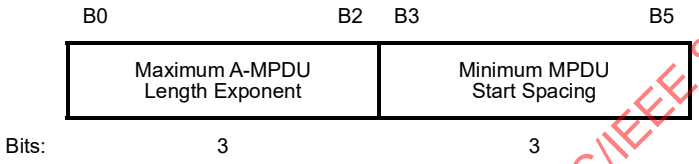

Figure 9-551—A-MPDU parameters subfield format

The subfields of the A-MPDU Parameters subfield are defined in Table 9-251.

Table 9-251—Subfields of the A-MPDU Parameters subfield

Subfield	Definition	Encoding
Maximum A-MPDU Length Exponent	Indicates the maximum length of A-MPDU that the STA can receive.	This subfield is an integer in the range 0 to 5. The length defined by this subfield is equal to $2^{(13 + \text{Maximum A-MPDU Length Exponent})} - 1$ octets.
Minimum MPDU Start Spacing	Determines the minimum time between the start of adjacent MPDUs within an A-MPDU that the STA can receive, measured at the PHY SAP.	Set to 0 for no restriction Set to 1 for 16 ns Set to 2 for 32 ns Set to 3 for 64 ns Set to 4 for 128 ns Set to 5 for 256 ns Set to 6 for 512 ns Set to 7 for 1024 ns

The BA with Flow Control subfield is set to 1 if the STA supports BA with flow control as defined in 10.42.9 and is set to 0 otherwise.

The Supported MCS Set subfield indicates the MCSs a STA supports. An MCS is identified by an MCS index, which is represented by an integer in the range 0 to 12, or an integer in the range 25 to 31 or by one of the values 9.1, 12.1, 12.2, 12.3, 12.4, 12.5 and 12.6. The interpretation of the MCS index (i.e., the mapping from MCS to data rate) is PHY dependent. For the DMG PHY, see Clause 20. The structure of the Supported MCS Set subfield is defined in Figure 9-552.

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	B0 B4	B5 B9	B10 B14	B15 B19	B20	B21	B22	B23
	Maximum SC Rx MCS	Reserved	Maximum SC Tx MCS	Reserved	Low-Power SC Mode Supported	Code Rate 13/16	π/2-8-PSK Capable	Reserved
Bits:	5	5	5	5	1	1	1	1

Figure 9-552—Supported MCS Set subfield format

The Maximum SC Rx MCS subfield contains the value of the maximum MCS index the STA supports for reception of single-carrier frames. Values 0-3 of this subfield are reserved. Possible values for this subfield are shown in Table 20-15. This subfield does not indicate support for MCSs 9.1, 12.1, 12.2, 12.3, 12.4, 12.5, and 12.6. Support for these MCSs is indicated using the Extended SC MCS Capabilities field; see 9.4.2.127.5.

The Maximum SC Tx MCS subfield contains the value of the maximum MCS index the STA supports for transmission of single-carrier frames. Values 0-3 of this subfield are reserved. Possible values for this subfield are shown in Table 20-15. This subfield does not indicate support for MCSs 9.1, 12.1, 12.2, 12.3, 12.4, 12.5, and 12.6. Support for these MCSs is indicated using the Extended SC MCS Capabilities field; see 9.4.2.127.5.

The Low-Power SC Mode Supported subfield is set to 1 to indicate that the STA supports the DMG low-power SC mode (20.6). Otherwise, it is set to 0. If the STA supports the low-power SC mode, it supports all low-power SC mode MCSs indicated in Table 20-21.

The Code Rate 13/16 subfield specifies whether the STA supports rate 13/16. It is set to 1 to indicate that the STA supports rate 13/16 and is set to 0 otherwise. If this subfield is 0, MCS with 13/16 code rate specified in Table 20-15 is not supported regardless of the value in Maximum SC Tx/Rx MCS subfields.

The π/2-8-PSK Capable subfield specifies whether the STA supports the use of π/2-8-PSK for MCS 10 and MCS 11. It is set to 1 to indicate the STA supports π/2-8-PSK for both transmission and reception and is set to 0 otherwise.

The A-PPDU Supported subfield is set to 1 to indicate that the STA supports A-PPDU aggregation as described in 10.14. Otherwise, it is set to 0.

The Supports Other_AID subfield is set to 1 to indicate that the STA sets its AWV configuration according to the Other_AID subfield in the BRP Request field during the BRP procedure as described in 10.42.6.4.4 and 20.9.2.2.6, if the value of the Other_AID subfield is different from zero. Otherwise, this subfield is set to 0.

The Heartbeat subfield is set to 1 to indicate that the STA expects to receive a frame from the AP or PCP during the ATI (10.39.3) and expects to receive a frame with the DMG Control modulation from a source DMG STA at the beginning of an SP (10.39.6.2) or TXOP (10.23.2). Otherwise, it is set to 0.

The Antenna Pattern Reciprocity subfield is set to 1 to indicate that the transmit antenna pattern associated with an AWV is the same as the receive antenna pattern for the same AWV. Otherwise, this subfield is set to 0.

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The Heartbeat Elapsed Indication subfield is used to calculate the value of the Heartbeat Elapsed Time. The Heartbeat Elapsed Time is computed according to the following equation:

$$T_{HE} = \begin{cases} 0, & F_{HE} = 0 \\ \frac{2^{F_{HE}}}{4}, & F_{HE} > 0 \end{cases}$$

where

T_{HE} is the Heartbeat Elapsed Time (in milliseconds)
F_{HE} is the value of the Heartbeat Elapsed Indication subfield

The Grant Ack Supported subfield is set to 1 to indicate that the STA is capable of responding to a Grant frame with a Grant Ack frame. Otherwise, this subfield is set to 0.

The RXSSTxRate Supported subfield is set to 1 to indicate that the STA can perform an RXSS with SSW frames transmitted at MCS 1 of the DMG SC modulation class. Otherwise, it is set to 0.

A DMG STA sets the EPD subfield in the DMG STA Capability Information field to 1 when dot11EPDImplemented is true and sets it to 0 otherwise.

9.4.2.127.3 DMG AP Or PCP Capability Information field

The DMG AP Or PCP Capability Information field, shown in Figure 9-553, represents the capabilities when the transmitting STA performs in the role of AP or PCP and that are in addition to the capabilities in the DMG STA Capability Information field.

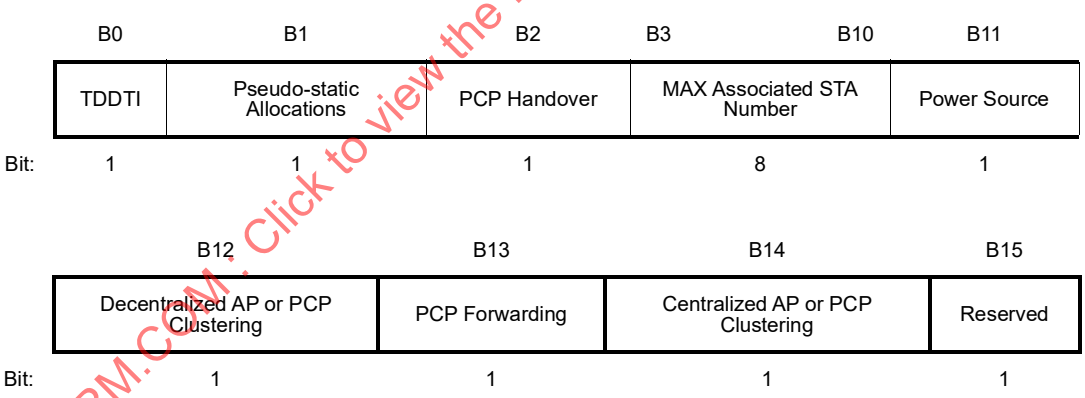

Figure 9-553—DMG AP Or PCP Capability Information field format

The TDDTI (time division data transfer interval) subfield is set to 1 if the STA, while operating as an AP or PCP, is capable of providing channel access as defined in 10.39.6 and 11.4 and is set to 0 otherwise.

The Pseudo-static Allocations subfield is set to 1 if the STA, while operating as an AP or PCP, is capable of providing pseudo-static allocations as defined in 10.39.6.4 and is set to 0 otherwise. The Pseudo-static Allocations subfield is set to 1 only if the TDDTI subfield in the DMG AP Or PCP Capability Information field is set to 1. The Pseudo-static Allocations subfield is reserved if the TDDTI subfield in the DMG AP Or PCP Capability Information field is set to 0.

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The PCP Handover subfield is set to 1 if the STA, while operating as a PCP, is capable of performing a PCP Handover as defined in 11.27.2 and is set to 0 if the STA does not support PCP Handover.

The MAX Associated STA Number subfield indicates the maximum number of STAs that the STA can perform association with if operating as an AP or PCP. This subfield includes the STAs, if any, that are co-located with the AP or PCP.

The Power Source subfield is set to 0 if the STA is battery powered and is set to 1 otherwise.

The Decentralized AP or PCP Clustering subfield is set to 1 if the STA, when operating as an AP or PCP, is capable of performing decentralized AP or PCP clustering and is set to 0 otherwise.

The PCP Forwarding subfield is set to 1 if the STA, while operating as a PCP, is capable of forwarding frames it receives from a non-PCP STA and destined to another non-PCP STA in the PBSS. This subfield is set to 0 otherwise.

The Centralized AP or PCP Clustering subfield is set to 1 if the STA, when operating as an AP or PCP, is capable of performing centralized AP or PCP clustering and is set to 0 otherwise. An AP or PCP that is incapable of performing centralized AP or PCP clustering is subject to requirements as described in 10.40.2.2.

9.4.2.127.4 DMG STA Beam Tracking Time Limit field

The DMG STA Beam Tracking Time Limit field contains the value of dot11BeamTrackingTimeLimit. This field indicates the maximum time between a request for beam tracking feedback and the feedback response, such that the response will be considered valid. This use of this field is discussed in 10.42.7.

9.4.2.127.5 Extended SC MCS Capabilities field

The Extended SC MCS Capabilities field (see Figure 9-554) advertises the support of the STA for MCSs 9.1, 12.1, 12.2, 12.3, 12.4, 12.5, and 12.6.

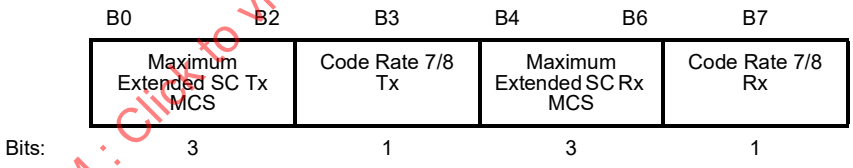

Figure 9-554—Extended SC MCS Capabilities field format

The Maximum Extended SC Tx MCS subfield indicates the maximum transmit extended SC MCS supported by the STA. The values in the subfield are ordered as shown in Table 9-252.

A STA that indicates support for transmission of an extended SC MCS by setting the value in the Maximum Extended SC Tx MCS subfield to *k* supports the subset of MCSs {9.1, 12.1, 12.2, 12.3, 12.4, 12.5 12.6} that have a data rate lower than or equal to the data rate of the MCS indicated by *k*. A STA that indicates support for MCSs with a data rate higher than the data rate of MCS 9.1 in the Maximum Extended SC Tx MCS subfield sets the Maximum SC Tx MCS subfield of the Supported MCS Set subfield to 12.

A STA that indicates support for transmission of an extended SC MCS by setting the value in the Maximum Extended SC Tx MCS subfield to *k* supports all extended SC MCSs with values lower than or equal to *k*.

The Maximum Extended SC Rx MCS subfield indicates the maximum receive extended SC MCS supported by the STA. The values in the subfield are ordered as shown in Table 9-252.

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Table 9-252—Mapping of Extended SC MCS to Maximum Supported Rx/Tx MCS subfield values

Extended MCS name	Value in Maximum Extended SC Rx/Tx MCS subfield
None	0
MCS 9.1	1
MCS 12.1	2
MCS 12.2	3
MCS 12.3	4
MCS 12.4	5
MCS 12.5	6
MCS 12.6	7

A STA indicates support for transmission of code rate 7/8 by setting the Code Rate 7/8 Tx subfield to 1. If a STA indicates that it does not support code rate 7/8, then the STA does not support MCS 9.1 or 12.2 even if the value in the Maximum Extended SC Tx MCS subfield is greater than 1 or 3 respectively. A STA that indicates support for MCSs with a data rate higher than the data rate of MCS 9.1 in the Maximum Extended SC Rx MCS subfield sets the Maximum SC Rx MCS subfield of the Supported MCS Set subfield to 12.

A STA that indicates support for reception of an extended SC MCS by setting the Maximum Extended SC Rx MCS subfield to *k* supports the subset of MCSs {9.1, 12.1, 12.2, 12.3, 12.4, 12.5 12.6} that have a data rate lower than or equal to the data rate of the MCS indicated by *k*.

A STA indicates support for reception of code rate 7/8 by setting the Code Rate 7/8 Rx subfield to 1. If a STA indicates that it does not support code rate 7/8, the STA does not support MCS 9.1 or 12.2 even if the value in the Maximum Extended SC Rx MCS field is greater than 1 or 3 respectively.

9.4.2.127.6 Maximum number of A-MSDU subframes in an A-MSDU

The Maximum Number Of Basic A-MSDU Subframes In A-MSDU subfield is defined in Table 9-253 and indicates the maximum number of Basic A-MSDU subframes in an A-MSDU that the DMG STA is able to receive from another DMG STA.

Table 9-253—Maximum Number Of Basic A-MSDU Subframes In A-MSDU subfield

Value	Meaning
0	No limit on the maximum number of Basic A-MSDU subframes supported
1	A maximum of 4 Basic A-MSDU subframes are supported
2	A maximum of 8 Basic A-MSDU subframes are supported
3	A maximum of 16 Basic A-MSDU subframes are supported
4	A maximum of 32 Basic A-MSDU subframes are supported

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Table 9-253—Maximum Number Of Basic A-MSDU Subframes In A-MSDU subfield *(continued)*

Value	Meaning
5	A maximum of 64 Basic A-MSDU subframes are supported
6	A maximum of 128 Basic A-MSDU subframes are supported
7	A maximum of 256 Basic A-MSDU subframes are supported
8–255	Reserved

The Maximum Number Of Short A-MSDU Subframes In A-MSDU subfield is defined in Table 9-254 and indicates the maximum number of Short A-MSDU subfields in an A-MSDU that the DMG STA is able to receive from another DMG STA.

Table 9-254—Maximum Number Of Short A-MSDU Subframes In A-MSDU subfield

Value	Meaning
0	No limit on the maximum number of Short A-MSDU subframes supported
1	A maximum of 32 Short A-MSDU subframes are supported
2	A maximum of 64 Short A-MSDU subframes are supported
3	A maximum of 128 Short A-MSDU subframes are supported
4	A maximum of 256 Short A-MSDU subframes are supported
5	A maximum of 512 Short A-MSDU subframes are supported
6	A maximum of 1024 Short A-MSDU subframes are supported
7–255	Reserved

9.4.2.128 DMG Operation element

The operational parameters of a BSS provided by the AP or PCP are determined by the DMG Operation element defined in Figure 9-555.

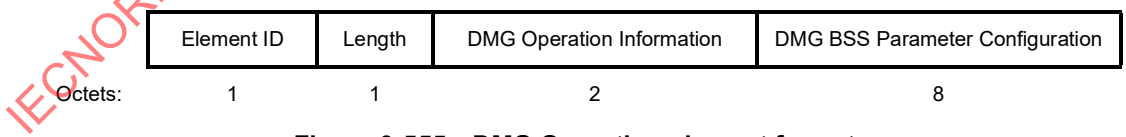

Figure 9-555—DMG Operation element format

The Element ID and Length fields are defined in 9.4.2.1.

The DMG Operation Information field is shown in Figure 9-556.

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Figure 9-556—DMG Operation Information field format

The TDDTI subfield is set to 1 if the AP or PCP provides time division channel access as defined in 10.39.6 and is set to 0 otherwise.

The Pseudo-static allocations subfield is set to 1 if the AP or PCP provides pseudo-static allocations as defined in 10.39.6.4 and is set to 0 otherwise. The Pseudo-static allocations subfield is set to 1 only if the TDDTI subfield in the DMG Operation Information field is 1. The Pseudo-static allocations subfield is reserved if the TDDTI subfield in the DMG Operation Information field is 0.

The PCP Handover subfield is set to 1 if the PCP provides PCP Handover as defined in 11.27.2 and is set to 0 if the PCP does not provide PCP Handover.

The DMG BSS Parameter Configuration field is defined in Figure 9-557.

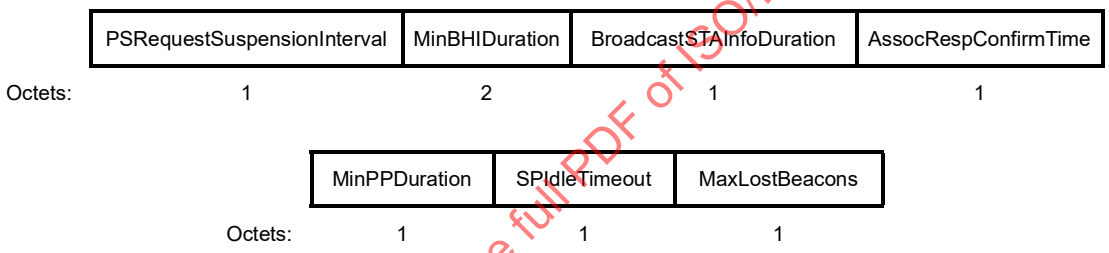

Figure 9-557—DMG BSS Parameter Configuration field format

The PSRequestSuspensionInterval subfield indicates the power save suspension interval and is specified in number of beacon intervals.

The MinBHIDuration subfield indicates the minimum duration of the BHI, which can include the BTI, A-BFT, and ATI and is specified in microseconds.

The BroadcastSTAInfoDuration subfield indicates the amount of time that the AP or PCP expects to take to transmit information about associated STAs and is specified in number of beacon intervals.

The AssocRespConfirmTime subfield indicates the amount of time that the AP or PCP expects to take to respond to association requests and is specified in units of 50 milliseconds. A non-PCP and non-AP STA that receives a DMG Operation element can use the value of this field to set dot11AssociationResponseTimeOut.

The MinPPDuration subfield indicates the minimum duration of the PP and GP as part of the dynamic allocation of service period mechanism and is specified in microseconds.

The SPIdleTimeout subfield indicates time during which a STA expects to receive a frame from its peer STA and is specified in microseconds.

The MaxLostBeacons subfield contains the value of dot11MaxLostBeacons.

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9.4.2.129 DMG Beam Refinement element

The DMG Beam Refinement element is defined as shown in Figure 9-558.

Figure 9-558—DMG Beam Refinement element format

The Element ID and Length fields are defined in 9.4.2.1.

An Initiator field set to 1 indicates that the sender is the beam refinement initiator. Otherwise, this field is set to 0.

A TX-train-response field set to 1 indicates that this element is the response to a TX training request. Otherwise, this field is set to 0.

A RX-train-response field set to 1 indicates that the element serves as an acknowledgment for a RX training request. Otherwise, this field is set to 0.

A TX-TRN-OK field set to 1 confirms a previous training request received by a STA. Otherwise, this field is set to 0.

A TXSS-FBCK-REQ field set to 1 indicates a request for transmit sector sweep feedback.

The BS-FBCK field indicates the index of the TRN-T subfield that was received with the best quality in the last received BRP-TX PPDU, where the first TRN-T subfield in the PPDU is defined as having an index equal to 1. If the last received PPDU was not a BRP-TX PPDU, this field is set to 0. The determination of best quality is implementation dependent.

The BS-FBCK DMG Antenna ID field specifies the DMG antenna ID corresponding to the sector indicated by the BF-FBCK field.

The FBCK-REQ field is defined in Figure 9-559 and is described in Table 9-255.

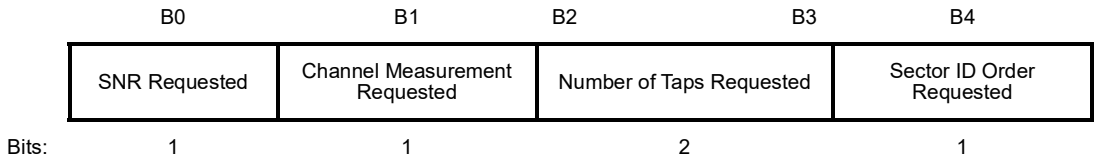

Figure 9-559—FBCK-REQ field format

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Table 9-255—FBCK-REQ field description

Subfield	Meaning
SNR Requested	If set to 1, the SNR subfield is requested as part of the returned Channel Measurement element(s). Otherwise, set to 0.
Channel Measurement Requested	If set to 1, the Channel Measurement subfield is requested as part of the returned Channel Measurement element(s). Otherwise, set to 0.
Number of Taps Requested	Number of taps in each channel measurement: 0 x 0 – 1 tap 0 x 1 – 5 taps 0 x 2 – 15 taps 0 x 3 – 63 taps
Sector ID Order Requested	If set to 1, the Sector ID Order subfield is requested as part of the returned Channel Measurement element(s). Otherwise, set to 0.

The FBCK-TYPE field is defined in Figure 9-560 and is described in Table 9-256. When both N_{meas} and N_{beam} in this field are equal to 0, the Channel Measurement Feedback element is not present.

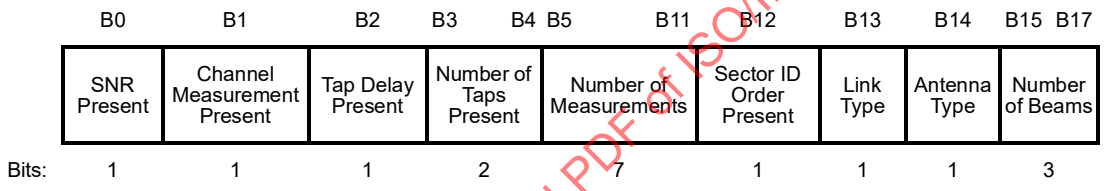

Figure 9-560—FBCK-TYPE field format

Table 9-256—FBCK-TYPE field description

Subfield	Meaning
SNR Present	Set to 1 to indicate that the SNR subfield is present as part of the channel measurement feedback. Set to 0 otherwise.
Channel Measurement Present	Set to 1 to indicate that the Channel Measurement subfield is present as part of the channel measurement feedback. Set to 0 otherwise.
Tap Delay Present	Set to 1 to indicate that the Tap Delay subfield is present as part of the channel measurement feedback. Set to 0 otherwise.
Number of Taps Present	Number of taps in each channel measurement: 0 x 0 – 1 tap 0 x 1 – 5 taps 0 x 2 – 15 taps 0 x 3 – 63 taps
Number of Measurements	Number of measurements in the SNR subfield and the Channel Measurement subfield. It is equal to the number of TRN-T subfields in the BRP-TX frame on which the measurement is based, or the number of received sectors if TXSS result is reported by setting the TXSS-FBCK-REQ subfield to 1.
Sector ID Order Present	Set to 1 to indicate that the Sector ID Order subfield is present as part of the channel measurement feedback. Set to 0 otherwise.

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Table 9-256—FBCK-TYPE field description *(continued)*

Subfield	Meaning
Link Type	Set to 0 for the initiator link and to 1 for the responder link
Antenna Type	Set to 0 for the transmitter antenna and to 1 for the receiver antenna
Number of Beams	Indicates the number of beams in the Sector ID Order subfield for the MIDC subphase

A MID Extension field set to 1 indicates the intention to continue transmitting BRP-RX frames during the MID subphases. Otherwise, this field is set to 0.

A Capability Request field set to 1 indicates that the transmitter of the frame requests the intended receiver to respond with a BRP frame that includes the BRP Request field. Otherwise, this field is set to 0.

9.4.2.130 DMG Wakeup Schedule element

The DMG Wakeup Schedule element is defined in Figure 9-561.

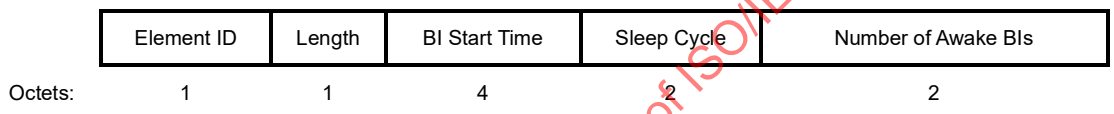

Figure 9-561—DMG Wakeup Schedule element format

The Element ID and Length fields are defined in 9.4.2.1.

The DMG Wakeup Schedule element is used to communicate the wakeup schedule (WS) of DMG STAs.

The BI Start Time field indicates the lower order 4 octets of the TSF timer at the start of the first A-BI in the WS defined by the DMG Wakeup Schedule element. A transmitted BI Start Time field points to a TBTT not more than 2^{31} μs minus aDMGDWSValidPeriod before, and not more than (2^{31} – 1) μs after the TBTT of the beacon interval during which the BI Start Time field is transmitted.

NOTE—The delay between the moment a STA receives a DMG Wakeup Schedule element over the air and the moment the STA interprets the value of the BI Start Time field in the element can be large, to the extent that the beacon interval during which the BI Start Time filed is interpreted is different from the beacon interval during which the DMG Wakeup Schedule element is received. Excluding an interval from the range of BI Start Time field values at transmission enables the receiving STA to be able to correctly interpret any received value for the BI Start Time field of the DMG Wakeup Schedule element belonging to a STA in PS mode without having to remember the beacon interval during which the DMG Wakeup Schedule element was received, as long as the beginning of the beacon interval at the time of interpretation has not advanced more than aDMGDWSValidPeriod relative to the beginning of the beacon interval at the time of reception.

The Sleep Cycle field indicates the sleep cycle duration in beacon intervals, i.e., the sum of A-BIs and D-BIs that make up the sleep cycle.

The Number of Awake BIs field indicates the number of A-BIs at the beginning of each sleep cycle. A Number of Awake BIs field set to 0 indicates that all beacon intervals in the WS are D-BIs.

9.4.2.131 Extended Schedule element

The Extended Schedule element is defined in Figure 9-562. Because the length parameter supports only 255 octets of information in an element, the AP or PCP can split the Allocation fields into more than

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one Extended Schedule element entry in the same DMG Beacon or Announce frame. Despite this splitting, the set of Extended Schedule element entries conveyed within a DMG Beacon and Announce frame is considered to be a single schedule for the beacon interval, and in this standard referred to simply as Extended Schedule element unless otherwise noted. The Allocation fields are ordered by increasing allocation start time with allocations beginning at the same time arbitrarily ordered.

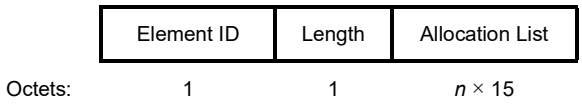

Figure 9-562—Extended Schedule element format

The Element ID and Length fields are defined in 9.4.2.1.

The Allocation List field contains one or more (*n*) Allocation fields. The Allocation fields are ordered by increasing allocation start time with allocations beginning at the same time arbitrarily ordered.

An Allocation field is formatted as shown in Figure 9-563.

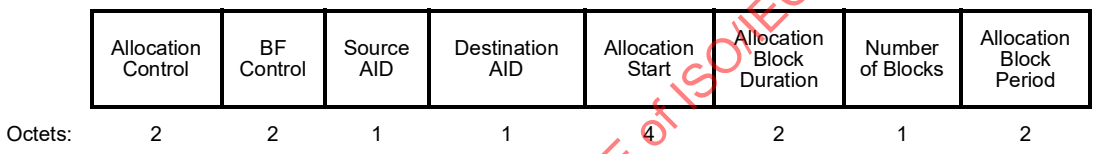

Figure 9-563—Allocation field format

The Allocation Control subfield is defined in Figure 9-564 for a DMG STA and in Figure 9-565 for a CDMG STA.

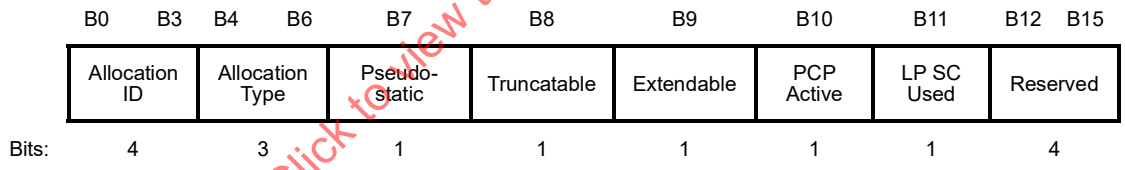

Figure 9-564—Allocation Control subfield format (DMG)

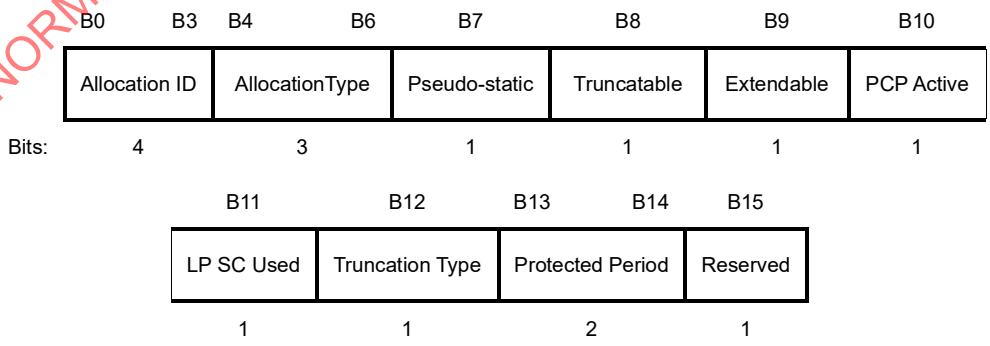

Figure 9-565—Allocation Control subfield format (CDMG)

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The Allocation ID subfield, when set to a nonzero value, identifies an airtime allocation from Source AID to Destination AID. Except for CBAP allocations with broadcast Source AID and broadcast Destination AID, the tuple (Source AID, Destination AID, Allocation ID) uniquely identifies the allocation. For CBAP allocations with broadcast Source AID and broadcast Destination AID, the Allocation ID subfield is set to 0.

The AllocationType subfield defines the channel access mechanism during the allocation, with possible values listed in Table 9-257.

Table 9-257—AllocationType subfield values

Bit 4	Bit 5	Bit 6	Meaning
0	0	0	SP allocation
1	0	0	CBAP allocation
0	1	0	SP allocation on a 1.08 GHz channel
1	1	0	CBAP allocation on a 1.08 GHz channel
All other combinations			Reserved

The Pseudo-static subfield is set to 1 to indicate that this allocation is pseudo-static (10.39.6.4) and set to 0 otherwise.

For an SP allocation, the Truncatable subfield is set to 1 to indicate that the source DMG STA and destination DMG STA can request SP truncation and set to 0 otherwise. For a CBAP allocation, the Truncatable subfield is reserved.

For an SP allocation, the Truncatable subfield is set to 1 to indicate that the source CDMG STA and destination CDMG STA can request SP truncation, and the SP truncation type is determined by the Truncation Type subfield. Otherwise, it is set to 0, and the Truncation Type subfield is reserved. For a CBAP allocation, the Truncatable subfield is reserved

For an SP allocation, the Extendable subfield is set to 1 to indicate that the source DMG STA and destination DMG STA can request SP extension and set to 0 otherwise. For a CBAP allocation, the Extendable subfield is reserved.

For a PCP in active mode (see 11.2.7), or when applied to a CBAP or SP in a PCP A-BI, a PCP Active subfield set to 1 indicates that the PCP is available to transmit or receive during the CBAP or SP, and a PCP Active subfield set to 0 indicates the PCP is unavailable to transmit or receive. For a DMG PCP, the PCP Active subfield is set to 1 at least in the following cases:

— The PCP transmitting the subfield is the source or destination of the CBAP or SP
— At least one of the Truncatable or Extendable subfields is set to 1
— The subfield is transmitted by an AP

For a CDMG PCP, the PCP Active subfield is set to 1 at least in the following cases:

— The PCP transmitting the field is the source or destination of the CBAP or SP
— The Truncatable subfield is equal to 1, and the Truncation Type subfield is equal to 0
— The Extendable subfield is equal to 1
— The subfield is transmitted by an AP

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The PCP Active subfield is ignored when it applies to a CBAP or SP that resides in a PCP D- BI.

The BF Control subfield is defined in 9.5.5.

The Source AID subfield is set to the AID of the STA that initiates channel access during the SP or CBAP allocation or, in the case of a CBAP allocation, can also be set to the broadcast AID if all STAs are allowed to transmit during the CBAP allocation.

The Destination AID subfield is set to the AID of the STA that the source STA targets during the allocation, or to the broadcast AID if the source STA targets more than one STA during the allocation. If both Source AID and Destination AID subfields for an SP allocation are set to the broadcast AID, then during the SP a non-AP and non-PCP STA does not transmit unless it receives a Poll or Grant frame from the AP or PCP.

The Allocation Start subfield contains the lower 4 octets of the TSF at the time the SP or CBAP starts. The Allocation Start subfield can be specified at a future beacon interval when the pseudo-static subfield is set to 1.

The Allocation Block Duration subfield indicates the duration, in microseconds, of a time block for which the SP or CBAP allocation is made and cannot cross beacon interval boundaries. Possible values range from 1 to 32 767 for an SP allocation and 1 to 65 535 for a CBAP allocation.

The Number of Blocks subfield contains the number of time blocks making up the allocation.

The Allocation Block Period subfield contains the time, in microseconds, between the start of two consecutive time blocks belonging to the same allocation. The Allocation Block Period subfield is reserved when the Number of Blocks subfield is set to 1.

The LP SC Used subfield is set to 1 to indicate that the low-power SC mode described in 20.6 is used in this SP. Otherwise, it is set to 0.

If the Truncatable subfield is equal to 0, the Truncation Type subfield is reserved. Otherwise, a CDMG AP or a CDMG PCP sets the Truncation Type subfield to 0 to indicate that the CDMG STA is to return the time left in the SP to the CDMG AP or PCP, and it sets the Truncation Type subfield to 1 to indicate that the CDMG STA allocates any portion of its SP as a CBAP.

For CDMG STAs, the Protected Period subfield is used to indicate whether the source and destination STAs of the allocated SP are required to establish a protected period and on which channels the protected period is established. The Protected Period subfield is set to 0 to indicate the source and destination STAs of the SP are allowed to create a protected period, and the STA determines whether to establish a protected period. The Protected Period subfield is set to a nonzero value to indicate the source and destination STAs of the SP are required to create a protected period on the indicated channel(s). The values of the Protected Period subfield for a CDMG STA operating on a 2.16 GHz channel or a 1.08 GHz are listed in Table 9-258 and Table 9-259, respectively. For a CBAP allocation, the Protected Period subfield is reserved.

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Table 9-258—Protected Period subfield value for a CDMG STA operating on a 2.16 GHz channel

Value	Meaning
0	The STA determines whether to establish a protected period.
1	The current channel needs a protected period.
2	Both the current 2.16 GHz channel and the low frequency channel 35 or channel 37 need a protected period.
3	Both the current 2.16 GHz channel and the high frequency channel 36 or channel 38 need a protected period.

Table 9-259—Protected Period subfield value for a CDMG STA operating on a 1.08 GHz channel

Value	Meaning
0	The STA determines whether to establish a protected period.
1	The current channel needs a protected period.
2	The current 1.08 GHz channel and the overlapping 2.16 GHz channel need a protected period.
3	Reserved.

9.4.2.132 STA Availability element

The STA Availability element is used by a non-AP and non-PCP STA to inform an AP or PCP about the STA availability during the subsequent CBAPs (10.39.5) and to indicate participation in the dynamic allocation of service periods (10.39.7). The AP or PCP uses the STA Availability element to inform the non-AP and non-PCP STAs of other STAs availability during subsequent CBAPs and participation of other STAs in the Dynamic allocation of service periods.

The format of the STA Availability element is defined in Figure 9-566.

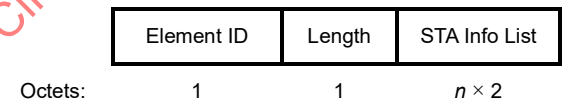

Figure 9-566—STA Availability element format

The Element ID and Length fields are defined in 9.4.2.1.

The STA Info List field contains one or more (*n*) STA Info fields.

The format of the STA Info field is shown in Figure 9-567.

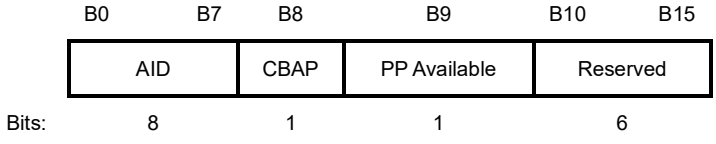

Figure 9-567—STA Info field format

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The AID subfield contains the AID of the STA for which availability is indicated.

The CBAP subfield is set to 1 to indicate that the STA is available to receive transmissions during CBAPs and set to 0 otherwise.

The PP Available subfield is set to 1 to indicate that the STA is available during PPs (10.39.7) and is set to 0 otherwise.

9.4.2.133 DMG TSPEC element

The DMG TSPEC element is present in the ADDTS Request frame sent by a non-AP and non-PCP DMG STA and contains the set of parameters needed to create or modify an airtime allocation. The DMG TSPEC element is also present in the ADDTS Response frame sent by a DMG AP or PCP and reflects the parameters, possibly modified, by which the allocation was created. The format of the DMG TSPEC element is shown in Figure 9-568.

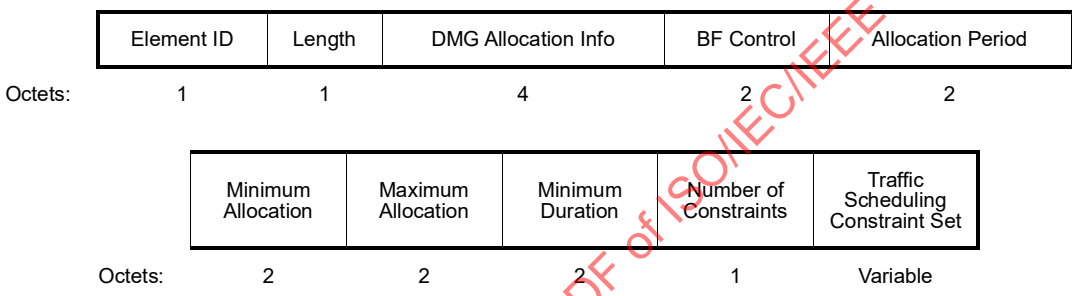

Figure 9-568—DMG TSPEC element format

The Element ID and Length fields are defined in 9.4.2.1.

The DMG Allocation Info field is formatted as shown in Figure 9-569.

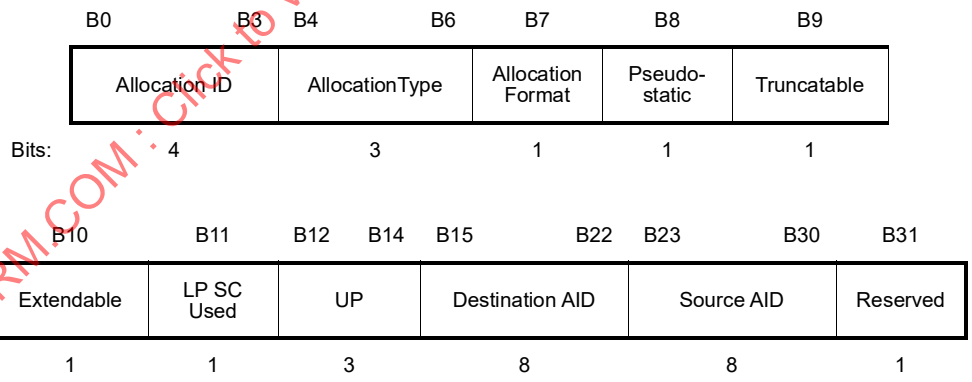

Figure 9-569—DMG Allocation Info field format

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The Allocation ID subfield identifies an allocation if set to a nonzero value and is used as follows:

— The STA that transmits an ADDTS Request frame containing the DMG TSPEC element sets the Allocation ID subfield to a nonzero value to create a new allocation or modify an existing allocation.

— The STA that transmits an ADDTS Response frame containing the DMG TSPEC element sets the Allocation ID subfield to a nonzero value to identify a created or modified allocation or sets it to 0 if creating or modifying the allocation failed.

The AllocationType subfield defines the channel access mechanism used during the allocation, with values listed in Table 9-257.

The Allocation Format field values are listed in Table 9-260.

Table 9-260—Allocation Format subfield values

Allocation Format subfield value	Description
1	Isochronous allocation format
0	Asynchronous allocation format

The Pseudo-static subfield is set to 1 for a pseudo-static allocation and set to 0 otherwise.

For an SP allocation, the Truncatable subfield is set to 1 if the STA expects to truncate the SP, as described in 10.39.8. If the STA does not expect to truncate the SP, the Truncatable subfield is set to 0. The subfield is reserved for CBAP allocations.

For an SP allocation, the Extendable subfield is set to 1 if the STA expects to extend the SP, as described in 10.39.9. If the STA does not expect to extend the SP, the Extendable subfield is set to 0. The subfield is reserved for CBAP allocations.

The LP SC Used subfield is defined in 9.4.2.131.

The UP subfield indicates the lowest priority UP to be used for possible transport of MSDUs belonging to TCs with the same source and destination of the allocation.

The Destination AID subfield contains the AID of a STA that the requesting STA targets during the allocation.

The Source AID subfield contains the AID of the STA that initiates channel access during the allocation.

The BF Control subfield is defined in 9.5.5.

The Allocation Period is specified as a fraction or multiple of the beacon interval as defined in Table 9-261.

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Table 9-261—Allocation Period field values

B0–B14	B15	Meaning
0	0	Reserved
0	1	Not periodic or periodicity unknown
1–32 767	0	The allocation period is a multiple of the beacon interval, i.e., allocation period = *n* x *bi* where *n* is the value represented by B0–B14 and *bi* is the beacon interval.
1–32 767	1	The allocation period is a fraction of the beacon interval, i.e., allocation period = *bi*/*n* where *n* is the value represented by B0–B14 and *bi* is the beacon interval.

For isochronous allocation format requests the Allocation Period, Minimum Allocation and Maximum Allocation fields are set as follows:

— The Allocation Period field indicates the period over which the allocation repeats.
— The Minimum Allocation field is set to the minimum acceptable allocation in microseconds in each allocation period.
— The Maximum Allocation field is set to the requested allocation in microseconds in each allocation period.

For asynchronous allocation format requests the Maximum Allocation field is reserved, and the Allocation Period and Minimum Allocation fields are set as follows:

— The Allocation Period field indicates the period over which the minimum allocation applies. The Allocation Period is an integer multiple of the beacon interval.
— The Minimum Allocation field specifies the minimum allocation in microseconds that the STA expects within the allocation period.

The Minimum Duration field specifies the minimum acceptable duration in microseconds. Possible values range from 1 to 32 767 for an SP allocation and 1 to 65 535 for a CBAP allocation. This field is set to 0 to indicate no minimum specified.

The Number of Constraints field indicates the number of Constraint subfields contained in the element. The field ranges from 0 to 15. Other values are reserved.

The Traffic Scheduling Constraint Set field contains one or more Constraint subfields (see Figure 9-570).

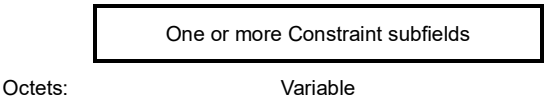

Figure 9-570—Traffic Scheduling Constraint Set field format

The Constraint subfield is defined as shown in Figure 9-571.

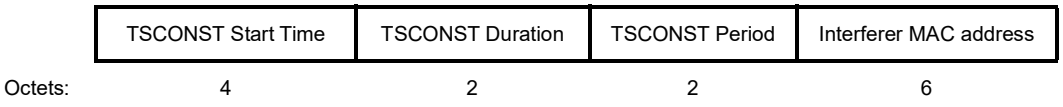

Figure 9-571—Constraint subfield format

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The TSCONST Start Time subfield contains the lower 4 octets of the TSF at the time the scheduling constraint starts.

The TSCONST Duration subfield indicates the time, in microseconds, for which the scheduling constraint is specified.

The TSCONST Period subfield is specified as a fraction or multiple of the beacon interval as defined in Table 9-262. This subfield is used to indicate a periodic scheduling constraint by specifying the temporal gap between two consecutive scheduling constraints.

Table 9-262—TSCONST Period values

B0–B14	B15	Meaning
0	0	Reserved
0	1	Not periodic or periodicity unknown
1–32 767	0	The TSCONST period is a multiple of the beacon interval, i.e., TSCONST period = *n* x *bi* where *n* is the value represented by B0–B14 and *bi* is the beacon interval..
1–32 767	1	The TSCONST period is a fraction of the beacon interval, i.e., TSCONST period = *bi*/*n* where *n* is the value represented by B0–B14 and *bi* is the beacon interval..

The Interferer MAC Address subfield is set to the TA field within a frame received during the interval of time indicated by this Constraint subfield. If the value is unknown, the Interferer MAC Address subfield is set to the broadcast address.

9.4.2.134 CMMG TSPEC element

The definition of the CMMG TSPEC element is similar with the definition of the DMG TSPEC element except for the specific change defined by Figure 9-572 and Figure 9-573.

The Constraint subfield is defined in Figure 9-572 for CMMG STAs.

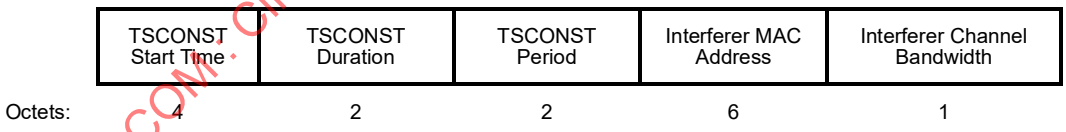

Figure 9-572—Constraint subfield format for CMMG STAs

The Interference Channel Bandwidth subfield is defined in Figure 9-573.

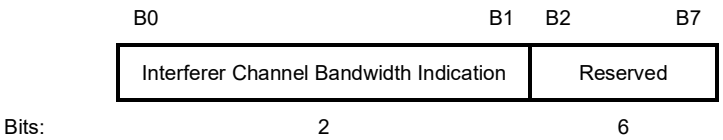

Figure 9-573—Interferer Channel Bandwidth subfield format

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The Interferer Channel Bandwidth Indication subfield is present only when the operating channel bandwidth of the CMMG STA is 1080 MHz. The Interferer Channel Bandwidth Indication subfield indicates the part of the operating channel with interference during the time interval indicated by the TSCONST subfields. If the Interferer Channel Bandwidth Indication subfield is 0, interference occurred in the upper 540 MHz of the 1080 MHz operating channel. If the Interferer Channel Bandwidth Indication subfield is 1, interference occurred in the lower 540 MHz of the 1080 MHz operating channel. If the Interferer Channel Bandwidth Indication subfield is 2, interference occurred in over the total operating channel. A value of 3 for the Interferer Channel Bandwidth Indication subfield is reserved.

9.4.2.135 Next DMG ATI element

The Next DMG ATI element indicates the earliest start time for the next ATI in a subsequent beacon interval. See Figure 9-574.

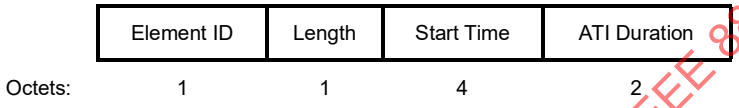

Figure 9-574—Next DMG ATI element format

The Element ID and Length fields are defined in 9.4.2.1.

The Start Time field contains the low order 4 octets of the TSF for the earliest time at which the next ATI in a subsequent beacon interval starts.

The ATI Duration field contains the duration, in microseconds, of the next ATI in a subsequent beacon interval.

9.4.2.136 Channel Measurement Feedback element

The Channel Measurement Feedback element is used to carry the channel measurement feedback in response to a request in the DMG Beam Refinement element of a BRP frame. It may contain data that the STA has measured on the TRN-T subfields of the BRP PPDU that contained the BRP frame, or a list of sectors identified during a sector sweep or during beam combination (10.42.6.3). The format and size of the Channel Measurement Feedback element are defined by the parameter values specified in the accompanying DMG Beam Refinement element.

The Channel Measurement Feedback element, as shown in Table 9-263, is composed of 4 subfields: the SNR subfield, the Channel Measurement subfield, the Tap Delay subfield, and the Sector ID Order subfield.

The Element ID and Length fields are defined in 9.4.2.1.

The number of channel/SNR measurements reported, N_{meas}, is equal to the number of TRN-T subfields that were appended to the PPDU on which the measurements were performed. If the measurement reports the result of an SLS or of an MID, it is equal to the number of frames received during the sector sweep, or the number of PPDUs used during the MID subphase.

The SNR subfield levels are unsigned integers referenced to a level of –8 dB. Each step is 0.25 dB. SNR values less than or equal to –8 dB are represented as 0. SNR values greater than or equal to 55.75 dB are represented as 0xFF.

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Table 9-263—Channel Measurement Feedback element format

Field	Size		Meaning
Element ID	8 bits		
Length	8 bits		
SNR	SNR_1	8 bits	SNR as measured in the first TRN-T subfield or at the first sector from which SSW frame is received.
	SNR_2	8 bits	SNR as measured in the second TRN-T subfield or at the second sector from which SSW frame is received.
	…		
	$SNR_{N_{meas}}$	8 bits	SNR as measured in the N_{meas} TRN-T subfield or at sector N_{meas} from which SSW frame is received.
Channel Measurement	Channel Measurement 1	N_{taps}×16 bits	Channel measurement for the first TRN-T subfield
	Channel Measurement 2	N_{taps}×16 bits	Channel measurement for the second TRN-T subfield
	…		
	Channel Measurement N_{meas}	N_{taps}×16 bits	Channel measurement for the N_{meas} TRN-T subfield
Tap Delay	Relative Delay Tap #1	8 bits	The delay of Tap #1 in units of T_c relative to the path with the shortest delay detected.
	Relative Delay Tap #2	8 bits	The delay of Tap #2 in units of T_c relative to the path with the shortest delay detected.
	…		
	Relative Delay Tap #N_{taps}	8 bits	The delay of Tap #N_{taps} in units of T_c relative to the path with the shortest delay detected.
Sector ID Order	Sector ID_1	6 bits	Sector ID for SNR_1 being obtained, or sector ID of the first detected beam.
	DMG Antenna ID_1	2 bits	DMG Antenna ID corresponding to sector ID_1.
	Sector ID_2	6 bits	Sector ID for SNR_2 being obtained, or sector ID of the second detected beam.
	DMG Antenna ID_2	2 bits	DMG Antenna ID corresponding to sector ID_2.
	…		
	Sector ID_{Nmeas} or sector ID_{Nbeam}	6 bits	Sector ID for SNR_{Nmeas} being obtained, or sector ID of the detected beam N_{beam}.
	DMG Antenna ID_{Nmeas} or DMG Antenna ID_{Nbeam}	2 bits	DMG Antenna ID corresponding to sector ID_{Nmeas} or sector ID_{Nbeam}

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The format of each channel measurement is specified in Table 9-264.

Table 9-264—Channel measurement

Field	Size	Meaning
Relative I Component Tap #1	8 bits	The in-phase component of impulse response for Tap #1, relative to the amplitude of the strongest tap measured.
Relative Q Component Tap #1	8 bits	The quadrature component of impulse response for Tap #1, relative to the amplitude of the strongest tap measured.
Relative I Component Tap #2	8 bits	The in-phase component of impulse response for Tap #2, relative to the amplitude of the strongest tap measured.
Relative Q Component Tap #2	8 bits	The quadrature component of impulse response for Tap #2, relative to the amplitude of the strongest tap measured.
…		
Relative I Component Tap #N_{taps}	8 bits	The in-phase component of impulse response for Tap #N_{taps}, relative to the amplitude of the strongest tap measured.
Relative Q Component Tap #N_{taps}	8 bits	The quadrature component of impulse response for Tap #N_{taps}, relative to the amplitude of the strongest tap measured.

Each channel measurement contains N_{taps} channel impulse taps. The channel impulse response reported for all N_{meas} measurements correspond to a common set of relative tap delays. If the Tap Delay subfield is not present, then the N_{taps} channel taps is interpreted as consecutive time samples, separated by T_c. Selection of which taps are sent is implementation dependent. The delay values in the Tap Delay subfield, when present, correspond to the strongest taps and are unsigned integers, in increments of T_c, starting from 0. Each channel tap is reported as an in-phase and quadrature component pair, with each component value represented as a 2s complement number between –128 and 127. Unless all in-phase and quadrature component values are reported as zero, they are scaled such that the two most significant bits for at least one of the component values equal 01 or 10 (binary). The same scale applies to all measurements over all TRN subfields.

The Sector ID Order subfield indicates the TX sector IDs corresponding to the SNRs in the SNR subfield when the SNR Present subfield is set to 1 and Sector ID Order Present subfield is set to 1, in response to a BRP PPDU with the SNR Requested subfield set to 1. The Sector ID Order subfield indicates the TX sector IDs ranked in the decreasing order of link quality, as measured on a preceding sector sweep, MID, or BC phase, determined in an implementation dependent manner, when the SNR Present subfield is set to 0 and the Sector ID Order Present subfield is set to 1 in response to setting the SNR Requested subfield to 0 and the Sector ID Order Requested subfield to 1. The FBCK-REQ field and the FBCK TYPE field in the DMG Beam Refinement element are used by the transmitter and receiver to, respectively, request for and indicate the sector IDs and their order.

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9.4.2.137 Awake Window element

The Awake Window element is defined as shown in Figure 9-575.

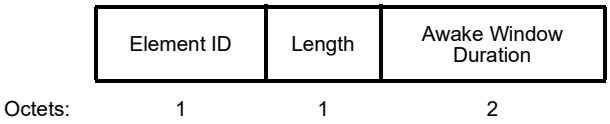

Figure 9-575—Awake Window element format

The Element ID and Length fields are defined in 9.4.2.1.

The Awake Window Duration field contains the duration of the Awake Window in microseconds.

9.4.2.138 Multi-band element

The Multi-band element indicates that the STA transmitting this element (the transmitting STA) is within a multi-band device capable of operating in a frequency band or operating class or channel other than the one in which this element is transmitted. In addition, if used as part of a fast session transfer, this element indicates that the transmitting STA is able to accomplish a fast session transfer from the current channel to a channel using another STA in the same device, in the other or same band. The format of the Multi-band element is shown in Figure 9-576.

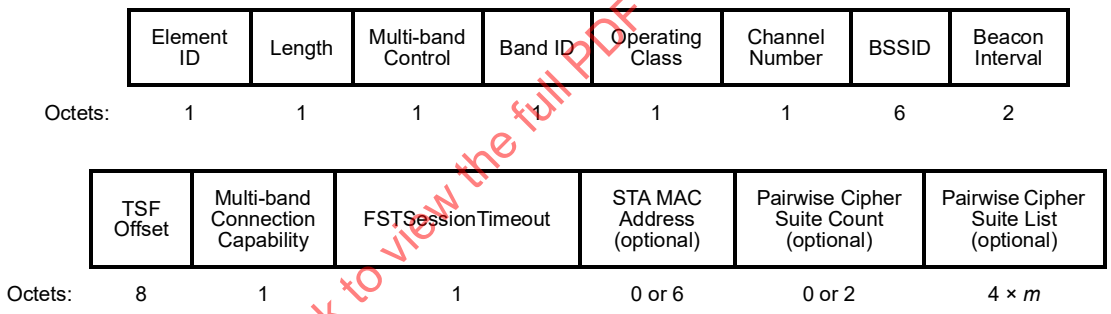

Figure 9-576—Multi-band element format

The Element ID and Length fields are defined in 9.4.2.1.

The format of the Multi-band Control field is shown in Figure 9-577.

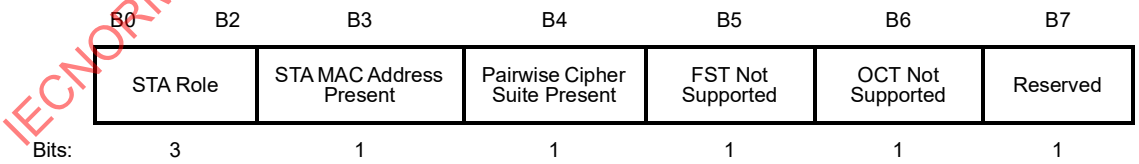

Figure 9-577—Multi-band Control field format

The STA Role subfield specifies the role the transmitting STA plays on the channel of the operating class indicated in this element. The possible values of the STA Role subfield are indicated in Table 9-265.

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Table 9-265—STA Role subfield values

STA role	Value
AP	0
TDLS STA	1
IBSS STA	2
PCP	3
Non-PCP and Non-AP STA	4
Reserved	5–7

NOTE—A STA can perform in more than one role in a channel, and the STA Role subfield identifies the role that is most relevant for the STA for that channel.

The STA MAC Address Present subfield indicates whether the STA MAC Address subfield is present in the Multi-band element. If the present subfield is set to 1, the STA MAC Address subfield is present. If the STA MAC Address Present subfield is set to 0, the STA MAC Address subfield is not present.

The Pairwise Cipher Suite Present subfield indicates whether the Pairwise Cipher Suite Count field and the Pairwise Cipher Suite List field are present in the Multi-band element. If the Pairwise Cipher Suite Present subfield is set to 1, the Pairwise Cipher Suite Count field and the Pairwise Cipher Suite List field are present. If the Pairwise Cipher Suite Present subfield is set to 0, the Pairwise Cipher Suite Count field and the Pairwise Cipher Suite List field are not present.

The FST Not Supported subfield is set to 1 to indicate that FST protocol (see 11.31.3) is not supported. The FST protocol is supported otherwise.

The OCT Not Supported subfield is set to 1 to indicate that OCT (see 11.31.5) is not supported. OCT is supported otherwise.

The Band ID field provides the identification of the frequency band related to the Operating Class and Channel Number fields. The Band ID field is defined in 9.4.1.45.

The Operating Class field indicates the channel set for which the Multi-band element applies. The Operating Class and Channel Number fields together specify the channel frequency and spacing for which the Multi-band element applies. Valid values of the Operating Class field are shown in Annex E. This field is set to 0 to indicate all operating classes within the frequency band specified by the Band ID field.

The Channel Number field is set to the number of the channel the transmitting STA is operating on or intends to operate on. This field is set to 0 to indicate all channels within the frequency band specified by the Band ID field.

The BSSID field specifies the BSSID of the BSS operating on the channel and frequency band indicated by the Channel Number and Band ID fields. When used as part of the on-channel tunneling operation (see 11.31.5), this field can contain the wildcard BSSID.

The Beacon Interval field specifies the size of the beacon interval for the BSS operating on the channel and frequency band indicated by the Channel Number and Band ID fields. This field is set to 0 if no BSS is in operation in the indicated channel and frequency band.

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If the transmitting STA is a member of a PBSS or infrastructure BSS on both the channel indicated in this element and the channel on which the element is transmitted, then the TSF Offset field contains the time offset of the TSF of the PBSS or infrastructure BSS of which the transmitting STA is member on the channel indicated in this element relative to the TSF of the PBSS or infrastructure BSS corresponding to the BSSID indicated in the Address 3 field of the MPDU in which this element is transmitted. The TSF Offset field is specified as a 2s complement integer in microsecond units. If the transmitting STA is not a member of an infrastructure BSS or PBSS on both the channel indicated in this element and the channel on which the element is transmitted, then the TSF Offset field contains the value 0.

The Multi-band Connection Capability field is defined in Figure 9-578. The Multi-band Connection Capability field indicates the connection capabilities supported by the STA on the channel and band indicated in this element.

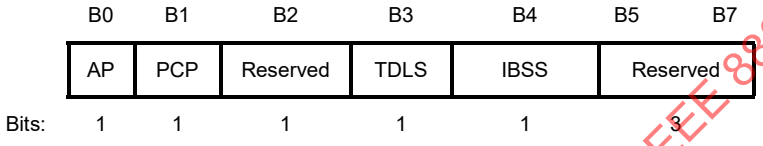

Figure 9-578—Multi-band Connection Capability field format

The AP subfield specifies whether the STA can function as an AP on the channel and band indicated in the element. It is set to 1 when the STA is capable to function as an AP, and it is set to 0 otherwise.

The PCP subfield specifies whether the STA can function as a PCP on the channel and band indicated in the element. It is set to 1 when the STA is capable to function as a PCP, and it is set to 0 otherwise.

The TDLS subfield is set to 1 to indicate that the STA can perform a TDLS on the channel and band indicated in the element. Otherwise, it is set to 0.

The IBSS subfield is set to 1 to indicate that the STA is able to support IBSS on the channel and band indicated in the element. Otherwise, it is set to 0.

The FSTSessionTimeout field is used in the FST Setup Request frame to indicate the timeout value for FST session setup protocol as defined in 11.31.1. The FSTSessionTimeout field contains the duration, in TUs, after which the FST setup is terminated. The FSTSessionTimeout field is reserved if the FST Not Supported subfield is 1.

The STA MAC Address field contains the MAC address that the transmitting STA uses while operating on the channel indicated in this element. The STA MAC Address field is not present in this element if the STA MAC Address Present field is set to 0.

The Pairwise Cipher Suite Count field and the Pairwise Cipher Suite List field are defined in 9.4.2.24. These fields are not present in this element if the Pairwise Cipher Suite Present subfield is set to 0.

9.4.2.139 ADDBA Extension element

The ADDBA Extension element is shown in Figure 9-579.

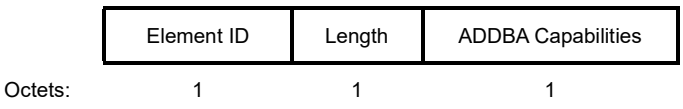

Figure 9-579—ADDBA Extension element format

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The Element ID and Length fields are defined in 9.4.2.1.

The ADDBA Capabilities field is shown in Figure 9-580.

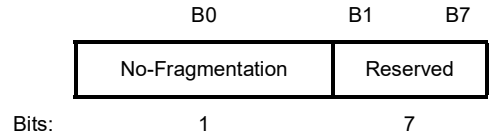

Figure 9-580—ADDBA Capabilities field format

The ADDBA Extension element can be included in the ADDBA Request and Response frames.

The No-Fragmentation subfield determines whether a fragmented MSDU can be carried in the MPDU sent under the block ack agreement. When this subfield set to 1 in the ADDBA Request frame, it indicates that the originator is not fragmenting sent MSDUs. When this subfield set to 1 in the ADDBA Response frame, it indicates that the recipient is not capable of receiving fragmented MSDUs.

9.4.2.140 Next PCP List element

The Next PCP List element contains one or more AID of NextPCP *i* fields as shown in Figure 9-581.

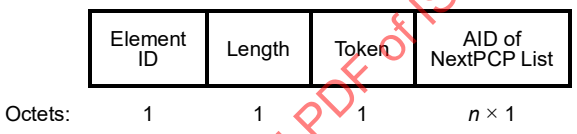

Figure 9-581—Next PCP List element format

The Element ID and Length fields are defined in 9.4.2.1.

The Token field is set to 0 when the PBSS is initialized and incremented each time the sequence of AID of NextPCP *i* fields is updated.

The AID of NextPCP List field contains one or more (*n*) AID of NextPCP fields.

Each AID of NextPCP field contains the AID value of a STA. The AID values are listed in the order described in 11.27.2.

9.4.2.141 PCP Handover element

The PCP Handover element is used to indicate the STA becoming the new PCP following an explicit or implicit handover procedure. The PCP Handover element is defined in Figure 9-582.

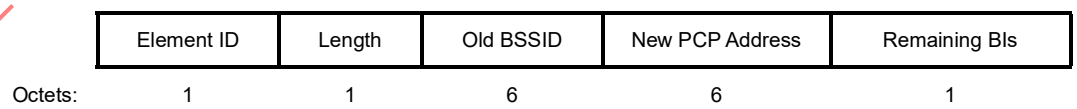

Figure 9-582—PCP Handover element format

The Element ID and Length fields are defined in 9.4.2.1.

The Old BSSID field contains the BSSID of the PBSS from which control is being handed over.

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The New PCP Address field indicates the MAC address of the new PCP following a handover.

The Remaining BIs field indicates the number of beacon intervals, from the beacon interval in which this element is transmitted, remaining until the handover takes effect.

9.4.2.142 DMG Link Margin element

9.4.2.142.1 General

The format of the DMG Link Margin element is shown in Figure 9-583. The DMG Link Margin element is included in a Link Measurement Report frame.

	Element ID	Length	Activity	MCS	Link Margin	SNR	Reference Timestamp
Octets:	1	1	1	1	1	1	4

Figure 9-583—DMG Link Margin element format

The Element ID and Length fields are defined in 9.4.2.1.

The Activity field is set to a preferred action that the STA sending this element recommends that the peer STA indicated in the RA field of the Link Measurement Report frame execute. The method by which the sending STA determines a suitable action for the peer STA is implementation specific. The Activity field is defined in 9.4.2.142.2.

The MCS field is set to an integer representation of the MCS that the STA sending this element recommends that the peer STA indicated in the RA field of the Link Measurement Report frame use to transmit frames to this STA. The reference PER for selection of the MCS is 10^{-2} for an MPDU length of 4096 octets. The method by which the sending STA determines a suitable MCS for the peer STA is implementation specific. Values 0–12 and values 25–31 indicate MCS 0 to MCS 12 and MCS 25 to MCS 31, respectively. Values 133, 134, 135, 136, 137, 138, and 140 indicate MCSs 12.1, 9.1, 12.3, 12.4, 12.5, 12.2, and 12.6, respectively.

The Link Margin field contains the measured link margin of Data frames received from the peer STA indicated in the RA field of the Link Measurement Report frame and is coded as a 2s complement signed integer in units of decibels. This field is set to –128 to indicate that no link margin is provided. The method used to measure the link margin is beyond the scope of this standard.

The SNR field indicates the SNR measured during the reception of a PPDU. Values are from –13 dB to 50.75 dB in 0.25 dB steps.

The Reference Timestamp field contains the lower 4 octets of the TSF timer value sampled at the instant that the MAC received the PHY-CCA.indication(IDLE) primitive that corresponds to the end of the reception of the PPDU that was used to generate the feedback information contained in the Link Measurement Report frame.

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9.4.2.142.2 Activity field

The Activity field values are defined in Table 9-266.

Table 9-266—Activity field values

Preferred Action value	Meaning
0	No change preferred
1	Change(d) MCS
2	Decrease(d) transmit power
3	Increase(d) transmit power
4	Fast session transfer (FST)
5	Power conserve mode
6	Perform SLS
7–255	Reserved

9.4.2.143 DMG Link Adaptation Acknowledgment element

The format of the DMG Link Adaptation Acknowledgment element is shown in Figure 9-584. The DMG Link Adaptation Acknowledgment element is carried in the Optional Subelements field of the Link Measurement Report frame.

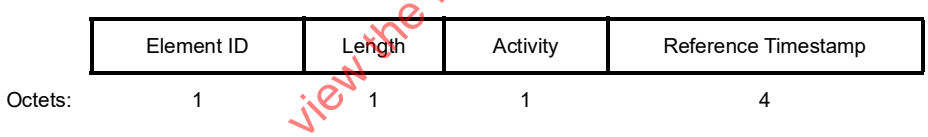

Figure 9-584—DMG Link Adaptation Acknowledgment element format

The Element ID and Length fields are defined in 9.4.2.1.

The Activity field is set to the action that the STA sending this element has executed following the reception of the recommended activity in a Link Measurement Report frame. The method by which the sending STA determines the action is described in 10.42.9 and the Activity field is defined in 9.4.2.142.2.

The Reference Timestamp field contains the lower 4 octets of the TSF timer value sampled at the instant that the MAC received the PHY-CCA.indication(IDLE) primitive that corresponds to the end of the reception of the PPDU that was used to generate the feedback information contained in the Link Measurement Report frame.

9.4.2.144 Switching Stream element

The Switching Stream element indicates the streams that the transmitting STA requests to be switched to a new frequency band or operating class or channel. The format of the Stream Switching element is shown in Figure 9-585.

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	Element ID	Length	Old Band ID	New Band ID	Non-QoS Data Frames	Number of Streams Switching	Switching Parameters
Octets:	1	1	1	1	1	1	2 × Number of Streams Switching

Figure 9-585—Switching Stream element format

The Element ID and Length fields are defined in 9.4.2.1.

The Old Band ID field specifies the frequency band to which the information carried in this element is related. This field is defined in 9.4.1.45.

The New Band ID field specifies the frequency band to which the information contained in the Stream ID In New Band subfield of this element is related. This field is defined in 9.4.1.45.

The Non-QoS Data Frames field specifies whether non-QoS Data frames can be transmitted in the frequency band indicated in the New Band ID field. If the Non-QoS Data Frames field is equal to 0, non-QoS Data frames cannot be transmitted in the frequency band indicated in the New Band ID field. If the Non-QoS Data Frames field is equal to 1, non-QoS Data frames can be transmitted in the frequency band indicated in the New Band ID field.

The Number of Streams Switching field specifies the number of streams to be switched.

The format of Switching Parameters field is shown in Figure 9-586.

	B0 B3	B4	B5 B8	B9	B10	B11	B12 B15
	Stream ID In Old Band		Stream ID In New Band		Stream ID In New Band Valid	LLT Type	Reserved
	TID	Direction	TID	Direction			
Bits:	4	1	4	1	1	1	4

Figure 9-586—Switching Parameters field format

The Stream ID In Old Band and Stream ID In New Band subfields are comprised of the TID and Direction subfields. The subfields within the Stream ID In New Band subfield are reserved if the Stream ID In New Band Valid subfield is set to 0.

The TID subfield specifies the stream in the corresponding band.

The Direction subfield specifies whether the STA transmitting this element is the source or destination of the corresponding TID. It is set to 0 to indicate that the STA transmitting this element is the source of the TID, and it is set to 1 otherwise.

The Stream ID In New Band Valid subfield is set to 1 if the information contained in the Stream ID In New Band subfield is valid, that is, the TID specified within the Stream ID In New Band subfield has been established in the band identified in the New Band ID field. The Stream ID In New Band Valid subfield is set to 0 otherwise.

The LLT Type subfield is set to 1 to indicate that the streambased Link Loss Countdown is used for the stream identified by the Stream ID In Old Band subfield. The LLT Type subfield is set to 0 to indicate that the STA-based Link Loss Countdown is used for the stream identified by the Stream ID In Old Band subfield. This subfield is reserved when the LLT field within the FST Setup Request or FST Setup Response frame containing this element is set to 0.

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9.4.2.145 Session Transition element

The Session Transition element is defined in Figure 9-587.

	Element ID	Length	FSTS ID	Session Control	New Band			Old Band		
					Band ID	Setup	Operation	Band ID	Setup	Operation
Octets:	1	1	4	1	1	1	1	1	1	1

Figure 9-587—Session Transition element format

The Element ID and Length fields are defined in 9.4.2.1.

The FSTS ID (fast session transfer session identifier) field contains the identification of the FST session established between a pair of STAs as allocated by the initiator (11.31).

The Session Control field is defined in Figure 9-588.

	B0	B3	B4	B5	B7
	Session Type		Switch Intent	Reserved	
Bit:	4		1	3	

Figure 9-588—Session Control field format

The Session Type subfield is defined as shown in Table 9-267 and indicates the type of connection/session that is intended to be set up in the new band for this FST session.

Table 9-267—Session Type subfield values

Value	Session type
0	Infrastructure BSS
1	IBSS
2	Reserved
3	TDLS
4	PBSS
5–255	Reserved

When the Session Type subfield is set to IBSS and the STA Role subfield within the Multi-band element is set to IBSS STA, the BSSID field within the Multi-band element contains the BSSID. This indicates that the transmitting STA is not associated with an AP on the band and channel indicated in the Multi-band element.

The Switch Intent subfield is set to 1 to indicate that the FST initiator that transmitted the FST Setup Request frame intends to switch to the band/channel indicated within the Band ID subfield of the FST Setup Request frame and in the Multi-band element, even if the fast session transfer does not succeed. Otherwise, this subfield is set to 0. This subfield is reserved when transmitted within an FST Setup Response frame.

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The New Band and Old Band subfields are used for the signaling described in 11.31.1. Both the New Band and Old Band subfields contain a Band ID subfield, a Setup subfield, and an Operation subfield.

The Band ID subfield is defined in 9.4.1.45. If a Multi-band element is present in the frame containing this Session Transition element, the Band ID subfield refers to the Operating Class and Channel Number fields within the Multi-band element provided both of these fields are nonzero.

The Setup subfield is set to 1 to indicate that the STA transmitting this element has an FST session established with the STA that the frame containing this element is addressed and in the band indicated within the Band ID subfield. Otherwise, it is set to 0. Other values are reserved.

The Operation subfield is set to 1 to indicate that the STA is operating in the band indicated within the Band ID subfield. Otherwise, it is set to 0. Other values are reserved.

9.4.2.146 Cluster Report element

The format of the Cluster Report element is shown in Figure 9-589. The Cluster Report element is included Action frames, such as Announce and Information Response frames, transmitted to the AP or PCP of the BSS. Because the Length field supports only 255 octets of information in an element, the STA can split the content of the Extended Schedule Element field, as described in 9.4.2.131, in different Cluster Report elements.

	Element ID	Length	Cluster Report Control	Reported BSSID	Reference Timestamp	Clustering Control
Octets:	1	1	1	0 or 6	0 or 4	0 or 8

	ECAPC Policy Element	Extended Schedule Element	Number of Constraints	Traffic Scheduling Constraint Set
Octets:	0, 13 or 17	0 or 17 – *n*	1	Variable

Figure 9-589—Cluster Report element format

The value of *n* in Figure 9-589 is given by the following equation:

$$n = 255 - (2 + S_{RB} + S_{RT} + S_{CC} + S_{EPE} + S_{TSCONST})$$

where

S_{RB} is the size of the Reported BSSID field in octets
S_{RT} is the size of the Reference Timestamp field in octets
S_{CC} is the size of the Clustering Control field in octets
S_{EPE} is the size of the ECAPC Policy Element field in octets
$S_{TSCONST}$ is the size of the Traffic Scheduling Constraint Set field in octets

The Element ID and Length fields are defined in 9.4.2.1.

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The Cluster Report Control field is defined in Figure 9-590.

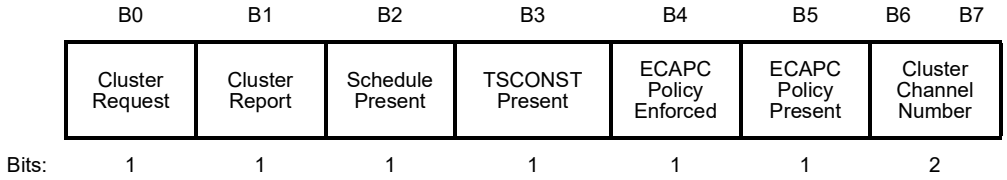

Figure 9-590—Cluster Report Control field format

The Cluster Request subfield is set to 1 to indicate that the STA is requesting the AP or PCP to start AP or PCP clustering (10.40). Otherwise, it is set to 0.

The Cluster Report subfield is set to 1 to indicate that this element contains a cluster report. If this subfield is set to 1, the Reported BSSID, Reference Timestamp and Clustering Control fields are present in this element. Otherwise, if the Cluster Report subfield is set to 0, none of the Reported BSSID, Reference Timestamp, Clustering Control, Extended Schedule Element, and Traffic Scheduling Constraint Set fields is present in this element.

The Schedule Present subfield is valid only if the Cluster Report subfield is set to 1; otherwise, it is reserved. The Schedule present subfield is set to 1 to indicate that the Extended Schedule Element field is present in this element. Otherwise, the Extended Schedule Element field is not present in this element.

The TSCONST Present subfield is valid only if the Cluster Report subfield is set to 1; otherwise, it is reserved. The TSCONST Present subfield is set to 1 to indicate that the Number of Constraints field and the Traffic Scheduling Constraint Set field are present in this element. Otherwise, these fields are not present in this element.

The ECAPC Policy Enforced subfield is valid only if the Cluster Report subfield is set to 1; otherwise, it is reserved. The ECAPC Policy Enforced subfield is defined in 9.3.4.2 and contains the ECAPC Policy Enforced subfield received in the DMG Beacon frame that generated this report.

The Cluster Channel Number subfield is set to 0 to indicate that the operating channel of the reported cluster is the common 2.16 GHz channel; it is set to 1 to indicate that the operating channel of the reported AP or PCP cluster is the low frequency 1.08 GHz channel 35 or 37 (see Annex E); it is set to 2 to indicate the operating channel of the reported AP or PCP cluster is the high frequency 1.08 GHz channel 36 or 38; and the value 3 is reserved.

The ECAPC Policy Present subfield is valid only if the Cluster Report subfield is set to 1; otherwise, it is reserved. The ECAPC Policy Present subfield is set to 1 to indicate that the ECAPC Policy Present Element field is present in this element. Otherwise, the ECAPC Policy Present Element field is not present in this element.

The Reported BSSID field contains the BSSID field of the DMG Beacon frame that triggered this report.

The Reference Timestamp field contains the lower 4 octets of the TSF timer value sampled at the instant that the STA's MAC received a DMG Beacon frame that triggered this report.

The Clustering Control field is defined in 9.3.4.2 and contains the Clustering Control received in the DMG Beacon frame that triggered this report.

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The ECAPC Policy Element field is defined in 9.4.2.150 and contains the ECAPC Policy element obtained from the AP or PCP that sent the DMG Beacon frame that generated this report (see 10.40.4).

The Extended Schedule Element field is defined in 9.4.2.131 and contains a single Extended Schedule element received in the DMG Beacon frame that generated this report. If an Extended Schedule element is not present in the received DMG Beacon, this field is set to all 0s.

The Number of Constraints field indicates the number of Constraint subfields contained in the Traffic Scheduling Constraint Set field. This field ranges from 0 to 15. Other values are reserved.

The Traffic Scheduling Constraint Set field contains one or more Constraint subfields as defined in 9.4.2.133 and specifies periods of time with respect to the TBTT of the beacon interval of the BSS the STA participates where the STA experiences poor channel conditions, such as due to interference.

9.4.2.147 Relay Capabilities element

A STA that intends to participate in relay operation (11.34) advertises its capabilities through the Relay Capabilities element. The Relay Capabilities element is defined in Figure 9-591.

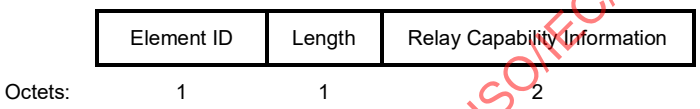

Figure 9-591—Relay Capabilities element format

The Element ID and Length fields are defined in 9.4.2.1.

The Relay Capability Information field is defined in Figure 9-592.

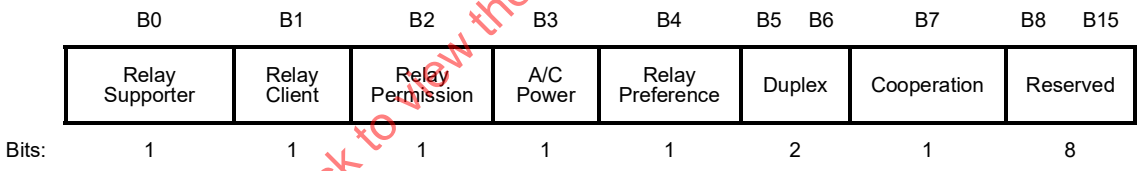

Figure 9-592—Relay Capability Information field format

The Relay Supporter subfield indicates whether the STA is capable of relaying by transmitting and receiving frames between a pair of other STAs. A STA capable of relaying is called a *relay* STA. This subfield is set to 1 if the STA supports relaying; otherwise, it is set to 0.

The Relay Client subfield indicates whether the STA is capable of using frame-relaying through a relay STA. It is set to 1 if the STA supports transmission and reception of frames through a relay STA; otherwise, it set to 0.

The Relay Permission subfield indicates whether the AP or PCP allows relay operation (11.34) to be used within the AP's or PCP's BSS. It is set to 0 if relay operation is not allowed in the BSS; otherwise, it is set to 1. This subfield is reserved when transmitted by a non-AP and non-PCP STA.

The A/C Power subfield indicates whether the STA is power constrained or not. It is set to 1 if the STA is not power constrained, i.e., supplied by external power, including PoE, wall plug, etc.; otherwise, it is set to 0.

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The Relay Preference subfield indicates whether the STA prefers to become RDS rather than REDS. It is set to 1 if a STA prefers to be RDS; otherwise, it is set to 0.

The Duplex subfield indicates whether the STA is capable of full-duplex/amplify-and-forward (FD-AF) or half-duplex/decode-and-forward (HD-DF). It is set to 1 if the STA is not capable of HD-DF but is capable of only FD-AF. It is set to 2 if the STA is capable of HD-DF but is not capable of FD-AF. It is set to 3 if the STA is capable of both HD-DF and FD-AF. The value 0 is reserved.

The Cooperation subfield indicates whether a STA is capable of supporting link cooperation. It is set to 1 if the STA supports both link cooperation and link switching. It is set to 0 otherwise.

9.4.2.148 Relay Transfer Parameter Set element

A source REDS that intends to transfer frames via an RDS advertises the parameters for the relay operation with the transmission of a Relay Transfer Parameter Set element (11.34). The Relay Transfer Parameter Set element is defined in Figure 9-593.

	Element ID	Length	Relay Transfer Parameter
Octets:	1	1	8

Figure 9-593—Relay Transfer Parameter Set element format

The Element ID and Length fields are defined in 9.4.2.1.

The Relay Transfer Parameter field is defined in Figure 9-594.

	B0	B1	B2	B3 B7	B8 B15	B16 B23	B24 B39	B40 B55	B56 B63
	Duplex-Mode	Cooperation-Mode	Tx-Mode	Reserved	Link Change Interval	Data Sensing Time	First Period	Second Period	Reserved
Bits:	1	1	1	5	8	8	16	16	8

Figure 9-594—Relay Transfer Parameter field format

The Duplex-Mode subfield indicates that the source REDS set the duplex mode of the RDS involved in RLS. The Duplex-Mode subfield value is set to 0 if the RDS operates in HD-DF mode. It is set to 1 if the RDS operates in FD-AF mode.

The Cooperation-Mode subfield indicates whether the source REDS sets the link cooperation of the RDS involved in RLS. This subfield is valid only when the RDS is capable of link cooperation and Duplex-Mode subfield is set to 0. Otherwise, this subfield is reserved. The Cooperation-Mode subfield value is set to 0 if the RDS operates in link switching. It is set to 1 if the RDS operates in link cooperation.

The Tx-Mode subfield indicates that the source REDS sets the transmission mode of the RDS involved in RLS. This subfield is valid only when the RDS is capable of link switching and the Duplex-Mode subfield is set to 1. Otherwise, this subfield is reserved. The Tx-Mode subfield value is set to 0 if a group of three STAs involved in the RLS operates in Normal mode and is set to 1 if the group operates in Alternation mode.

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The Link Change Interval subfield indicates when the link of frame transmission between source REDS and destination REDS is changed. From the start position of one reserved continuous SP, every time instant of link change interval can have an opportunity to change the link. Within one link change interval, only one link is used for frame transfer. The unit of this subfield is microseconds. This subfield is used only when the group involved in the RLS operates in link switching.

The Data Sensing Time subfield indicates the defer time offset from the time instant of the next link change interval when the link switching occurs. By default, it is set to SIFS plus SBIFS. This subfield is used only when the STAs involved in the RLS operate in link switching with Tx-Mode that is 0.

The First Period subfield indicates the period of the source REDS-RDS link in which the source REDS and RDS exchange frames. This subfield is used only when HD-DF RDS operates in link switching.

The Second Period subfield indicates the period of the RDS-destination REDS link in which the RDS and destination REDS exchange frames and the following period of the RDS-source REDS link in which the RDS informs the source REDS of finishing one frame transfer. This subfield is used only when HD-DF RDS operates in link switching.

9.4.2.149 Quiet Period Request element

The Quiet Period Request element defines a periodic sequence of quiet intervals that the requester AP requests the responder AP to schedule. The format of the Quiet Period Request element is shown in Figure 9-595.

	Element ID	Length	Request Token	Quiet Period Offset	Quiet Period	Quiet Duration	Repetition Count	Target BSSID
Octets:	1	1	2	2	4	2	1	6

Figure 9-595—Quiet Period Request element format

The Element ID and Length fields are defined in 9.4.2.1.

The Request Token field is set to a nonzero value chosen by the requester AP.

The Quiet Period Offset field is set to the offset of the start of the first quiet interval from the QAB Request frame that contains this element, expressed in TUs. The reference time is the start of the preamble of the PPDU that contains this element.

The Quiet Period field is set to the spacing between the start of two consecutive quiet intervals, expressed in TUs.

The Quiet Duration field is set to duration of the quiet time, expressed in TUs.

The Repetition Count field is set to the number of requested quiet intervals.

NOTE—The periodic sequence of quiet intervals ends after the start of preamble of the PPDU containing the QAB IE + Quiet Period Offset + (Repetition Count-1)×Quiet Period + Quiet Duration (in TUs).

The Target BSSID field is set to the responder AP's MAC address.

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9.4.2.150 Quiet Period Response element

The Quiet Period Response element defines the feedback information from the AP that received the Quiet Period Request element. The format of the Quiet Period Response element is shown in Figure 9-596.

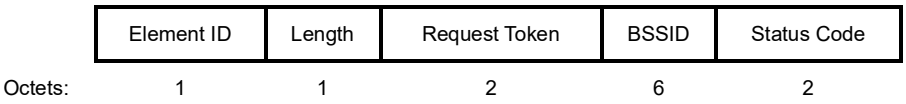

Figure 9-596—Quiet Period Response element format

The Element ID and Length fields are defined in 9.4.2.1.

The Request Token field is set to the value of the Request Token field of the corresponding received Quiet Period Request element.

The BSSID field is set to the value of the Target BSSID field of the corresponding received Quiet Period Request element.

The Status Code field is defined in 9.4.1.9.

9.4.2.151 BeamLink Maintenance element

The format of the BeamLink Maintenance element is shown in Figure 9-597. The BeamLink Maintenance element is included in Action frames, such as Probe, Announce and the Information Request and Response frames, transmitted between a non-AP and non-PCP DMG STA and a DMG AP or PCP. The element is included in the Probe and Information Request and Response frames transmitted between non-AP and non-PCP DMG STAs.

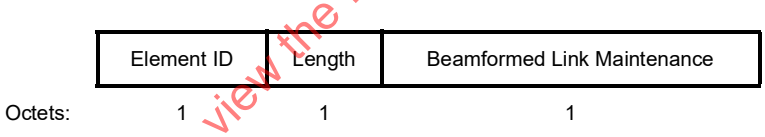

Figure 9-597—BeamLink Maintenance element format

The Element ID and Length fields are defined in 9.4.2.1.

The Beamformed Link Maintenance field is defined in 9.5.6.

9.4.2.152 Multiple MAC Sublayers (MMS) element

The format of Multiple MAC Sublayers (MMS) element is shown in Figure 9-598. The MMS element is included in Action frames, such as Probe Request, Association Request, Information Request, Announce, and Information Response frames, transmitted to the peer STA and the AP or PCP of the BSS.

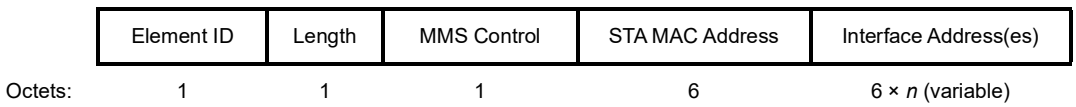

Figure 9-598—MMS element format

The Element ID and Length fields are defined in 9.4.2.1.

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The MMS Control field is defined in Figure 9-599.

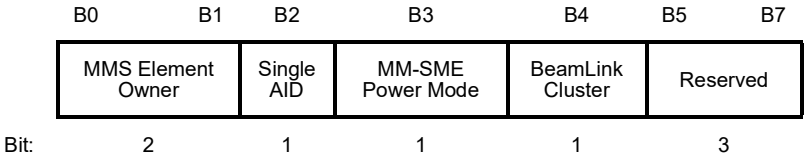

Figure 9-599—MMS Control field format

The MMS Element Owner subfield is encoded as shown in Table 9-268. If the MMS Element Owner field is set to No Owner, then the Interface address(es) field in the MMS element is reserved.

Table 9-268—MMS Element Owner subfield definition

MMS Element Owner subfield value		Meaning
B0	B1	
0	0	No Owner
1	0	Non-AP and Non-PCP MMS element
0	1	PCP MMS element
1	1	AP MMS element

The Single AID subfield is 1 bit in length and is encoded as defined in Table 9-269.

Table 9-269—Single AID subfield definition

MMS element sent from	MMS element sent to	MMS Element Owner		Single AID	Meaning
		B0	B1	B3	
Non-AP and non-PCP STA	AP or PCP	1	0	1	Request to allocate single AID for MAC addresses included in the MMS element
Non-AP and non-PCP STA	AP or PCP	1	0	0	Do not allocate single AID for MAC addresses included in the MMS element
AP or PCP	Non-PCP, non-AP STA	1	0	1	Single AID is allocated for all MAC addresses in the MMS element
AP or PCP	Non-PCP, non-AP STA	1	0	0	Single AID is not allocated for all MAC addresses in the MMS element
Non-AP and non-PCP STA	Non-PCP, non-AP STA	1	0	1	Single AID is allocated for all MAC addresses in the MMS element

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Table 9-269—Single AID subfield definition *(continued)*

MMS element sent from	MMS element sent to	MMS Element Owner		Single AID	Meaning
		B0	B1	B3	
Non-AP and non-PCP STA	Non-PCP, non-AP STA	1	0	0	Single AID is not allocated for all MAC addresses in the MMS element
AP or PCP	Non-PCP, non-AP STA	0	1	1	Single AID is allocated for all MAC addresses in the non-AP and non-PCP STA MMS element
AP or PCP	Non-PCP, non-AP STA	0	1	0	Single AID is not allocated for all MAC addresses in the non-AP and non-PCP STA MMS element

The MM-SME Power Mode subfield is 1 bit in length and is set to 1 to indicate that when a STA advertised in the MMS element sent by the STA coordinated by an MM-SME moves from the awake to the doze state, then all other STAs advertised in the MMS element sent by the STA move to the doze state. The STA coordinated by the MM-SME moves to the awake state only when all STAs advertised in the MMS element move to the awake state. The MM-SME Power Mode subfield is set to 0 to indicate that when a STA advertised in the MMS element sent by the STA moves from the doze to the awake state, then all other STAs advertised in the MMS element sent by the STA coordinated by the MM-SME move to the awake state. The STA coordinated by the MM-SME moves to the doze state only when all STAs advertised in the MMS element move to the doze state.

The BeamLink Cluster subfield is 1 bit in length and is set to 1 if the DMG STA intends to maintain the same beamformed link for all of the links within the MMSL cluster. Otherwise, this subfield is set to 0.

The STA MAC Address field contains the MAC address of the STA.

When present in the element, the Interface Address(es) field contains one or more MAC addresses that can be used to identify the STAs in addition to the STA MAC address, coordinated by the same MM-SME (see 11.32).

9.4.2.153 U-PID element

The format of the Upper Layer Protocol Identification (U-PID) element is shown in Figure 9-600.

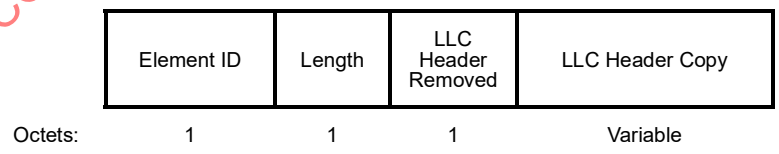

Figure 9-600—U-PID element format

The Element ID and Length fields are defined in 9.4.2.1.

The LLC Header Removed field is set to 1 to indicate that MSDUs do not contain the LLC (Logical Link Control) header over the WM. It is set to 0 otherwise.

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The content and corresponding size of the LLC Header Copy field are specified in Table 9-270.

Table 9-270—LLC Header Copy field size

LLC Header Copy field contents	LLC Header Copy field size (octets)
LLC header with 8-bit control field without SNAP	3
LLC header with 8-bit control field with SNAP	8
LLC header with 16-bit control field without SNAP	4
LLC header with 16-bit content field with SNAP	9

NOTE—The structure of the LLC header is defined in IEEE Std 802.2-1998. The structure of the LLC with SNAP extension is defined in IEEE Std 802.2-1998.

9.4.2.154 ECAPC Policy element

The format of the ECAPC Policy element is shown in Figure 9-601.

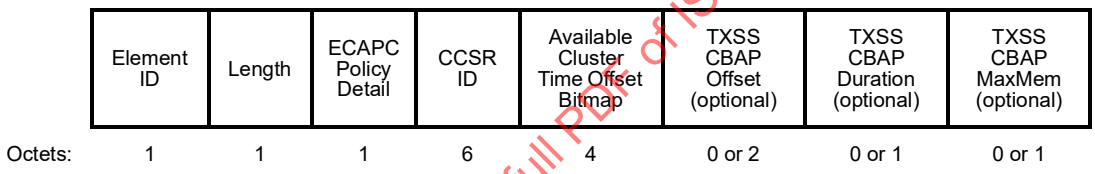

Figure 9-601—ECAPC Policy element format

The Element ID and Length fields are defined in 9.4.2.1.

The ECAPC Policy Detail field is defined in Figure 9-602.

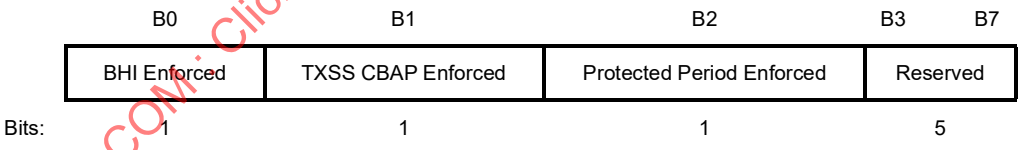

Figure 9-602—ECAPC Policy Detail field format

The BHI Enforced subfield set to 1 indicates that an AP or PCP in a centralized AP or PCP cluster completes the BHI for the current beacon interval before TBTT + (8×Beacon SP duration), as described in 10.40.3.4. The BHI Enforced subfield set to 0 indicates that an AP or PCP within a cluster does not have to complete the BHI for the current beacon interval before TBTT + (8×Beacon SP duration).

The TXSS CBAP Enforced subfield set to 1 indicates that a STA in a centralized AP or PCP cluster performs each of its TXSSs in the DTI within one or more TXSS CBAPs, as described in 10.40.3.4. The TXSS CBAP Enforced subfield set to 0 indicates that a STA within a centralized AP or PCP cluster does not have to perform each of its TXSSs in the DTI within one or more TXSS CBAPs.

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The Protected Period Enforced subfield indicates that every scheduled SP in the BSS is a DMG protected period as specified in 10.39.6.6. The Protected Period Enforced subfield set to 0 indicates that a scheduled SP in the BSS does not have to be a DMG protected period.

The CCSR ID field is set to the MAC address of the CCSR within the ECAPC that the AP or PCP belongs to. The AP or PCP is the transmitter of the frame containing the ECAPC Policy element except when the ECAPC Policy element is transmitted in a Cluster Report element, where the AP or PCP is the transmitter that triggered the Cluster report.

The Available Time Cluster Offset Bitmap field is a bitmap where the bit n–1, n = 1 to 32, indicates the availability of the n^{th} Beacon SP. Values of n = 1 and greater than ClusterMaxMem are reserved (i.e., bit 0 and bits ClusterMaxMem+1 to 31). Bit n–1 set to 0 indicates that $ClusterTimeOffset_{n-1}$ is determined to be already in use by a neighboring AP or PCP, excluding the recipient if sent within an individually addressed frame, in the ECAPC. Bit n–1 set to 1 indicates that $ClusterTimeOffset_{n-1}$ is not determined to be already in use by a neighboring AP or PCP, excluding the recipient if sent within an individually addressed frame, in the ECAPC.

If TXSS CBAP Enforced field is set to 0, then the TXSS CBAP Offset field, the TXSS CBAP Duration field, and the TXSS CBAP MaxMem field are not present in the element; otherwise, they are present in the element.

The TXSS CBAP Offset field is the delay of the first TXSS CBAP in a beacon interval from the TBTT, in units of 8 μs.

The TXSS CBAP Duration field indicates the duration of each TXSS CBAP, in units of 8 μs.

The TXSS CBAP MaxMem field is the number of TXSS CBAPs per beacon interval.

9.4.2.155 Cluster Time Offset element

The format of the Cluster Time Offset element is shown in Figure 9-603.

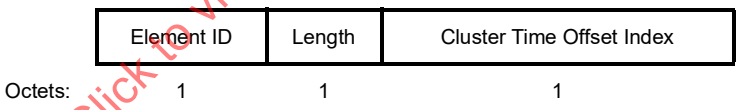

Figure 9-603—Cluster Time Offset element format

The Element ID and Length fields are defined in 9.4.2.1.

The Cluster Time Offset Index field is set to n–1 for a member AP or member PCP of a centralized AP or PCP cluster that adopted the n^{th} Beacon SP (see 10.40). Values equal to 0 and greater than ClusterMaxMem are reserved.

9.4.2.156 Antenna Sector ID Pattern element

The format of the Antenna Sector ID Pattern element is shown in Figure 9-604.

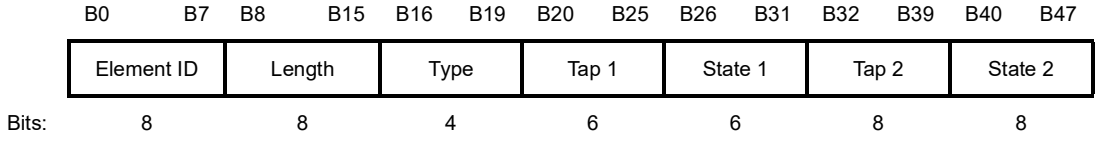

Figure 9-604—Antenna Sector ID Pattern element format

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The Element ID and Length fields are defined in 9.4.2.1.

The Type field is set to 0 for Random Sequence Generator. Values 1 to 3 are reserved.

The Tap 1 field indicates the taps for Sequence Generator 1.

The State 1 field indicates the state for Sequence Generator 1.

The Tap 2 field indicates the taps for Sequence Generator 2.

The State 2 field indicates the state for Sequence Generator 2.

Sequence Generator 1 is shown in Figure 9-605 and is defined as follows:

— Generate the sector IDs for subsequent DMG Beacons by advancing the Sequence Generator 1, which is initialized using the values of the Tap 1 and State 1 fields contained in the Antenna Sector ID Pattern element received from the AP or PCP.

— Advance the Sequence Generator 1 by one shift for each anticipated DMG Beacon frame transmission thereafter.

— After advancing the Sequence Generator 1, if the next state equals the initial state for the second time, overwrite the state with an all-zero state. The next state following the state following all zero-state uses the first 6 bits of the state of Sequence Generator 2 as the initial state.

— If the STA's total number of transmit sectors is not equal to the period of the Sequence Generator 1, ignore state(s) greater than or equal total number of transmit sectors and continue advancing Sequence Generator 1 until the state is less than the total number of transmit sectors.

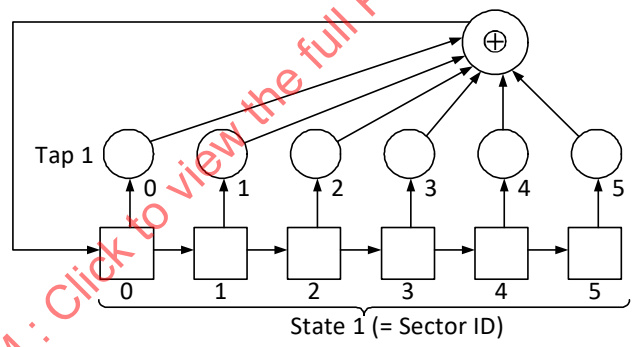

Figure 9-605—Sequence Generator 1

NOTE 1—The taps are selected from the set of sequences with maximal length property.

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Sequence Generator 2 is shown in Figure 9-606 and is defined as follows:

— Sequence Generator 2 is initiated with the value of the Tap 2 and State 2 fields contained in the Antenna Sector ID Pattern element received from the AP or PCP.

— Sequence Generator 2 is advanced by one shift when a new initial state is needed from Sequence Generator 1.

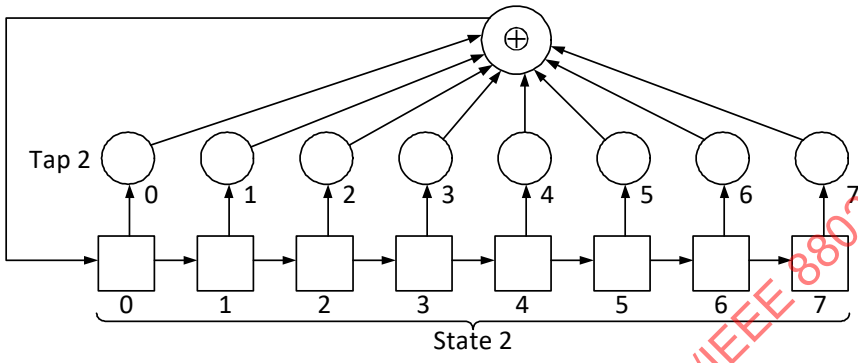

Figure 9-606—Sequence Generator 2

NOTE 2—The taps are selected from the set of the sequences with maximal length property.

9.4.2.157 VHT Capabilities element

9.4.2.157.1 VHT Capabilities element structure

A VHT STA declares that it is a VHT STA by transmitting the VHT Capabilities element.

The VHT Capabilities element contains a number of fields that are used to advertise the VHT capabilities of a VHT STA. The VHT Capabilities element is defined in Figure 9-607.

Element ID	Length	VHT Capabilities Info	Supported VHT-MCS and NSS Set
Octets: 1	1	4	8

Figure 9-607—VHT Capabilities element format

The Element ID and Length fields are defined in 9.4.2.1.

9.4.2.157.2 VHT Capabilities Information field

The structure of the VHT Capabilities Information field is defined in Figure 9-608.

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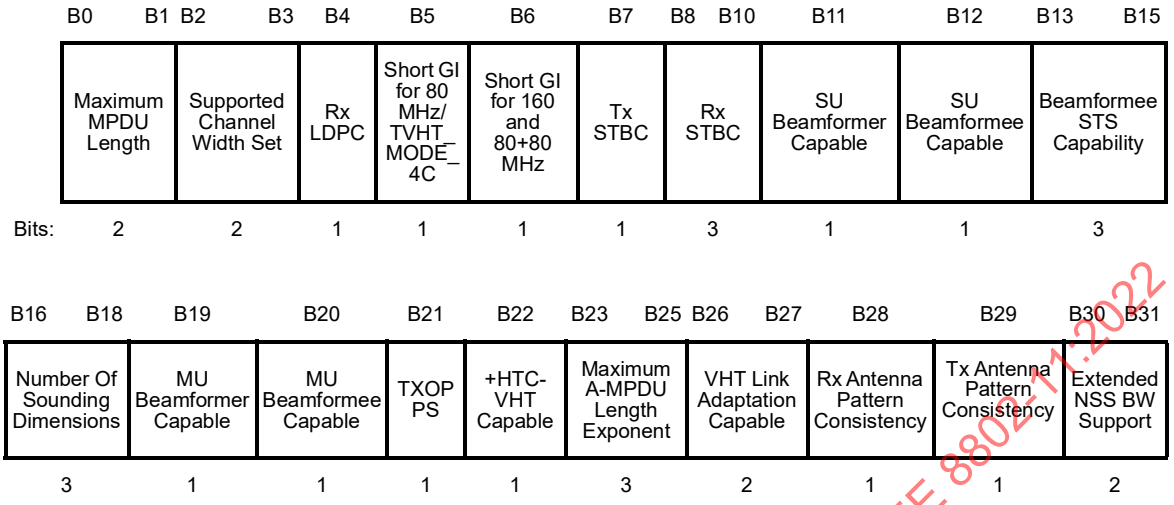

Figure 9-608—VHT Capabilities Information field format

The subfields of the VHT Capabilities Information field are defined in Table 9-271.

Table 9-271—Subfields of the VHT Capabilities Information field

Subfield	Definition	Encoding
Maximum MPDU Length	Indicates the maximum MPDU length that the STA is capable of receiving (see 10.11).	Set to 0 for 3895 octets. Set to 1 for 7991 octets. Set to 2 for 11 454 octets. The value 3 is reserved.
Supported Channel Width Set	Together with the Extended NSS BW Support subfield and Supported VHT-MCS and NSS Set field, indicates the channel widths and maximum NSS values per width supported by the STA. See 11.38.	In a non-TVHT STA, see Table 9-272. When the Channel Width subfield of the VHT Operation element is 2 or 3 (deprecated), the channel center frequency is defined in Table 11-24. In a TVHT STA, the field is structured into subfields as defined in Figure 9-609. In a TVHT STA, set the TVHT_MODE_2C Support subfield to 1 if it supports TVHT_MODE_2C; otherwise set the subfield to 0. In a TVHT STA, set the TVHT_MODE_2N Support subfield to 1 if it supports TVHT_MODE_2N; otherwise set the subfield to 0.
Rx LDPC	Indicates support for receiving LDPC encoded PPDUs.	Set to 0 if not supported. Set to 1 if supported.
Short GI for 80 MHz/ TVHT_MODE_4C	In a non-TVHT STA, indicates short GI support for the reception of PPDUs transmitted with the TXVECTOR parameter FORMAT equal to VHT and CH_BANDWIDTH equal to CBW80. In a TVHT STA, indicates support for TVHT_MODE_4C.	In a non-TVHT STA, set to 1 if Short GI for 80 MHz is supported. In a TVHT STA, set to 1 if TVHT_MODE_4C is supported. Otherwise set to 0.

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Table 9-271—Subfields of the VHT Capabilities Information field *(continued)*

Subfield	Definition	Encoding
Short GI for 160 and 80+80 MHz	Indicates short GI support for the reception of PPDUs transmitted with TXVECTOR parameters FORMAT equal to VHT and CH_BANDWIDTH equal to CBW160 or CBW80+80.	Set to 0 if not supported. Set to 1 if supported. In a TVHT STA, set to 1 if it supports TVHT_MODE_4N.
Tx STBC	Indicates support for the transmission of at least 2×1 STBC.	Set to 0 if not supported. Set to 1 if supported.
Rx STBC	Indicates support for the reception of PPDUs using STBC.	Set to 0 for no support. Set to 1 for support of one spatial stream. Set to 2 for support of one and two spatial streams. Set to 3 for support of one, two, and three spatial streams. Set to 4 for support of one, two, three, and four spatial streams. The values 5, 6, 7 are reserved. See NOTE 3.
SU Beamformer Capable	Indicates support for operation as an SU beamformer (see 10.36.5).	Set to 0 if not supported. Set to 1 if supported.
SU Beamformee Capable	Indicates support for operation as an SU beamformee (see 10.36.5).	Set to 0 if not supported. Set to 1 if supported.
Beamformee STS Capability	Indicates the maximum number of space-time streams that the STA can receive in a VHT NDP and the maximum value of *Nr* that the STA transmits in a VHT Compressed Beamforming frame.	If the SU Beamformee Capable field is set to 1, set to maximum number of space-time streams that the STA can receive in a VHT NDP minus 1. Otherwise, reserved.
Number of Sounding Dimensions	Beamformer's capability indicating the maximum value of the TXVECTOR parameter NUM_STS for a VHT NDP.	If the SU Beamformer Capable field is set to 1, set to the maximum supported value of the TXVECTOR parameter NUM_STS minus 1. Otherwise, reserved.
MU Beamformer Capable	Indicates support for operation as an MU beamformer (see 10.36.5).	Set to 0 if not supported or if SU Beamformer Capable is set to 0 or if sent by a non-AP STA. Set to 1 if supported and SU Beamformer Capable is set to 1.
MU Beamformee Capable	Indicates support for operation as an MU beamformee (see 10.36.5).	Set to 0 if not supported or if SU Beamformee Capable is set to 0 or if sent by an AP. Set to 1 if supported, SU Beamformee Capable is set to 1 and not sent by an AP.
TXOP PS	Indicates whether the AP supports TXOP power save mode or whether the non-AP STA has enabled TXOP power save mode.	Set to 0 if the AP does not support TXOP power save mode. Set to 1 if the AP supports TXOP power save mode. Set to 0 if the non-AP STA does not enable TXOP power save mode. Set to 1 if the non-AP STA enables TXOP power save mode.

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Table 9-271—Subfields of the VHT Capabilities Information field *(continued)*

Subfield	Definition	Encoding
+HTC-VHT Capable	Indicates whether the STA supports receiving a VHT variant HT Control field.	Set to 0 if not supported. Set to 1 if supported.
Maximum A-MPDU Length Exponent	Indicates the maximum length of an A-MPDU pre-EOF padding that the STA can receive.	The length defined by this field is equal to $2^{(13 + \text{Maximum A-MPDU Length Exponent})} - 1$ octets.
VHT Link Adaptation Capable	Indicates whether the STA supports link adaptation using VHT variant HT Control field.	If +HTC-VHT Capable is 1: Set to 0 (No Feedback) if the STA does not provide VHT MFB. Set to 2 (Unsolicited) if the STA provides only unsolicited VHT MFB. Set to 3 (Both) if the STA can provide VHT MFB in response to VHT MRQ and if the STA provides unsolicited VHT MFB. The value 1 is reserved. Reserved if +HTC-VHT Capable is 0.
Rx Antenna Pattern Consistency	Indicates the possibility of a receive antenna pattern change.	Set to 0 if the receive antenna pattern might change during the lifetime of the current association. Set to 1 if the receive antenna pattern does not change during the lifetime of the current association. See 11.38.6.
Tx Antenna Pattern Consistency	Indicates the possibility of a transmit antenna pattern change.	Set to 0 if the transmit antenna pattern might change during the lifetime of the current association. Set to 1 if the transmit antenna pattern does not change during the lifetime of the current association. See 11.38.6.
Extended NSS BW Support	Together with the Supported Channel Width Set subfield and Supported VHT-MCS and NSS Set field, indicates the channel widths and maximum NSS values per width supported by the STA (for non-TVHT VHT STAs). See 11.38.	In a non-TVHT STA, see Table 9-272. In a TVHT STA, the field is reserved. In a STA with dot11VHTExtendedNSSBWCapable equal to false or not present, this field is set to 0.

NOTE 1—An AP that sets MU Beamformer Capable to 1 can transmit a VHT MU PPDU with only one nonzero TXVECTOR parameter NUM_STS[p], for $0 \le p \le 3$. However, a STA that sets MU Beamformee Capable to 0 is not required to be able to demodulate a VHT MU PPDU with only one nonzero RXVECTOR parameter NUM_STS[p], for $0 \le p \le 3$.

NOTE 2—The Maximum MPDU Length subfield of the VHT Capabilities Information field imposes a constraint on the allowed value in the Maximum MPDU Length subfield of the HT Capabilities element carried in the same frame (see 10.11).

NOTE 3—Subject to any extended NSS BW support constraint.

In the context of Table 9-272:

— 1/2× or 3/4× Max VHT NSS support can be less than 1, indicating no support.
— A supported multiple of Max VHT NSS applies to both transmit and receive.
— 2× Max VHT NSS support can be used for 20 MHz or 40 MHz HT PPDUs.
— Any other combination than the ones listed in this table is reserved.

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Table 9-272—Setting of the Supported Channel Width Set subfield and Extended NSS BW Support subfield at a STA transmitting the VHT Capabilities Information field

Transmitted VHT Capabilities Information field		NSS support of STA transmitting the VHT Capabilities Information field as a function of the VHT PPDU (×Max VHT NSS) (see requirements R1 and R2)					Location of 160 MHz channel center frequency if BSS bandwidth is 160 MHz	Location of secondary 80 MHz channel center frequency if BSS bandwidth is 80+80 MHz
Supported Channel Width Set	Extended NSS BW Support	20 MHz	40 MHz	80 MHz	160 MHz	80+80 MHz		
0	0	1	1	1				
0	1	1	1	1	1/2		CCFS2	
0	2	1	1	1	1/2	1/2	CCFS2	CCFS2
0	3	1	1	1	3/4	3/4	CCFS2	CCFS2
1	0	1	1	1	1		CCFS1	
1	1	1	1	1	1	1/2	CCFS1	CCFS2
1	2	1	1	1	1	3/4	CCFS1	CCFS2
1	3	2	2	2	2	1	CCFS1	CCFS1
2	0	1	1	1	1	1	CCFS1	CCFS1
2	3	2	2	2	1	1	CCFS1	CCFS1

R1: NSS support is rounded down to the nearest integer.
R2: The maximum NSS supported is 8.

NOTE 1—Max VHT NSS is defined per MCS in 9.4.2.157.3.

NOTE 2—CCFS1 refers to the Channel Center Frequency Segment 1 field of the most recently transmitted VHT Operation element.

NOTE 3—CCFS2 refers to the Channel Center Frequency Segment 2 field of the most recently transmitted HT Operation element.

NOTE 4—CCFS1 is nonzero when the current BSS bandwidth is 160 MHz or 80+80 MHz and the NSS support is at least Max VHT NSS. CCFS2 is zero in this case.See NOTE 7.

NOTE 5—CCFS2 is nonzero when the current BSS bandwidth is 160 MHz or 80+80 MHz and the NSS support is less than Max VHT NSS. CCFS1 is zero in this case. See NOTE 7.

NOTE 6—At most one of CCFS1 and CCFS2 is nonzero when the current BSS bandwidth is 160 MHz or 80+80 MHz. See NOTE 7.

NOTE 7—See Table 11-24.

NOTE 8—A receiving STA in which dot11VHTExtendedNSSBWCapable is false will ignore the Extended NSS BW Support subfield and effectively evaluate this table only at the entries where Extended NSS BW Support is 0.

NOTE 9—See also 11.38.

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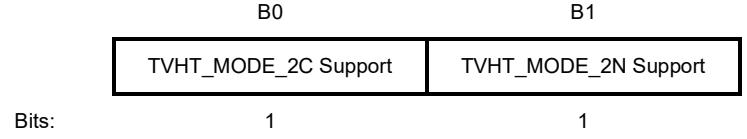

Figure 9-609—Supported Channel Width Set field format (TVHT)

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Support for short GI for the reception of PPDUs with the TXVECTOR parameter CH_BANDWIDTH equal to CBW20 or CBW40 is indicated in the HT Capabilities Info field of the HT Capabilities element.

9.4.2.157.3 Supported VHT-MCS and NSS Set field

The Supported VHT-MCS and NSS Set field is used to convey the combinations of VHT-MCSs and spatial streams that a STA supports for reception and the combinations that it supports for transmission. The structure of the field is shown in Figure 9-610.

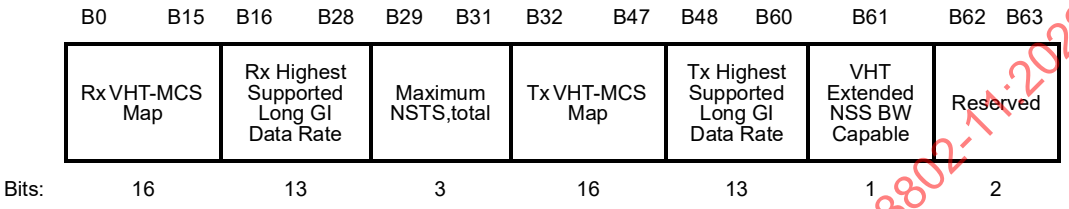

Figure 9-610—Supported VHT-MCS and NSS Set field format

The Supported VHT-MCS and NSS Set field's subfields are defined in Table 9-273.

Table 9-273—Supported VHT-MCS and NSS Set subfields

Subfield	Definition	Encoding
Rx VHT-MCS Map	If transmitted by a STA in which dot11VHTExtendedNSSBWCapable is not true, it indicates the maximum value of the RXVECTOR parameter MCS of a PPDU that can be received at all channel widths supported by this STA for each number of spatial streams. If transmitted by a STA in which dot11VHTExtendedNSSBWCapable is true, this field combined with the Extended NSS BW Support subfield and the 160/80+80 BW subfield of the Operating Mode field determines the maximum value of the RXVECTOR parameter MCS of a PPDU as described in 9.4.2.157.2 and 9.4.1.53.	The format and encoding of this subfield are defined in Figure 9-611 and the associated description.
Rx Highest Supported Long GI Data Rate	Indicates the highest long GI VHT PPDU data rate that the STA is able to receive.	The largest integer value less than or equal to the highest long GI VHT PPDU data rate in Mb/s the STA is able to receive (see 10.6.13.1). The value 0 indicates that this subfield does not specify the highest long GI VHT PPDU data rate that the STA is able to receive.

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Table 9-273—Supported VHT-MCS and NSS Set subfields *(continued)*

Subfield	Definition	Encoding
Maximum NSTS,total	Indicates the maximum value for $N_{STS,total}$ that can be sent to the STA in a VHT MU PPDU.	If MU beamformee capable and different from 0, indicates the maximum value for $N_{STS,total}$ minus 1 that can be sent to the STA in a VHT MU PPDU. NOTE—This value is greater than or equal to the value in the Beamformee STS Capability subfield of the VHT Capabilities Information field. If MU Beamformee capable and equal to 0, indicates that the maximum value for $N_{STS,total}$ is equal to the value in the Beamformee STS Capability subfield of the VHT Capabilities Information field. Otherwise reserved.
Tx VHT-MCS Map	If transmitted by a STA in which dot11VHTExtendedNSSBWCapable is not true, indicates the maximum value of the TXVECTOR parameter MCS of a PPDU that can be transmitted at all channel widths supported by this STA for each number of spatial streams. If transmitted by a STA in which dot11VHTExtendedNSSBWCapable is true, this field combined with the Extended NSS BW Support subfield and the 160/80+80 BW subfield of an Operating Mode field determines the maximum value of the TXVECTOR parameter MCS of a PPDU as described in 9.4.2.157.2 and 9.4.1.53.	The format and encoding of this subfield are defined in Figure 9-611 and the associated description.
Tx Highest Supported Long GI Data Rate	Indicates the highest long GI VHT PPDU data rate at which the STA is able to transmit.	The largest integer value less than or equal to the highest long GI VHT PPDU data rate in Mb/s that the STA is able to transmit (see 10.6.13.2). The value 0 indicates that this subfield does not specify the highest long GI VHT PPDU data rate that the STA is able to transmit.
VHT Extended NSS BW Capable	Indicates whether the STA is capable of interpreting the Extended NSS BW Support subfield of the VHT Capabilities Information field.	If dot11VHTExtendedNSSBWCapable is true, then this field is set to 1 to indicate that the STA is capable of interpreting the Extended NSS BW Support subfield of the VHT Capabilities Information field. Set to 0 otherwise.

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The Rx VHT-MCS Map subfield and the Tx VHT-MCS Map subfield have the structure shown in Figure 9-611.

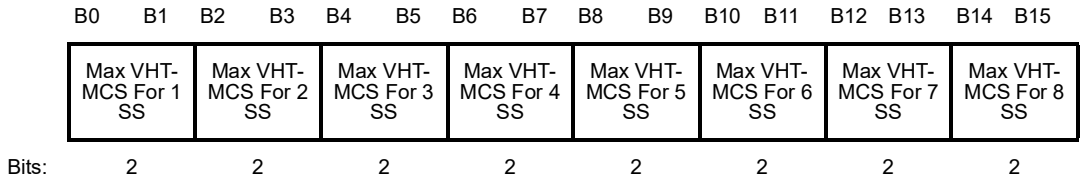

Figure 9-611—Rx VHT-MCS Map and Tx VHT-MCS Map subfields and Basic VHT-MCS And NSS Set field format

The Max VHT-MCS For *n* SS subfield (where *n* = 1, ..., 8) is encoded as follows:

— 0 indicates support for VHT-MCS 0-7 for *n* spatial streams
— 1 indicates support for VHT-MCS 0-8 for *n* spatial streams
— 2 indicates support for VHT-MCS 0-9 for *n* spatial streams
— 3 indicates that *n* spatial streams is not supported

The Max VHT NSS for a given MCS is equal to the smaller of the following:

— The maximum value of *n* for which the Max VHT-MCS for *n* SS has a value that indicates support for that VHT-MCS (0, 1 or 2 for VHT-MCS 0-7, 1 or 2 for VHT-MCS 8, 2 for VHT-MCS 9).
— The maximum supported NSS as indicated by the Rx NSS field of the Operating Mode Notification frame if the RX NSS Type is 0.

NOTE—A VHT-MCS indicated as supported in the VHT-MCS Map fields for a particular number of spatial streams might not be valid at all bandwidths (see 21.5), might be limited by the declaration of Tx Highest Supported Long GI Data Rates and Rx Highest Supported Long GI Data Rates, and might be affected by 10.6.13.3 and the Extended NSS BW Support field of the VHT Capabilities Information field in 9.4.2.157.2 and the 160/80+80 BW subfield of the Operating Mode field in 9.4.1.53.

9.4.2.158 VHT Operation element

The operation of VHT STAs in the BSS is controlled by the HT Operation element and the VHT Operation element. The format of the VHT Operation element is defined in Figure 9-612.

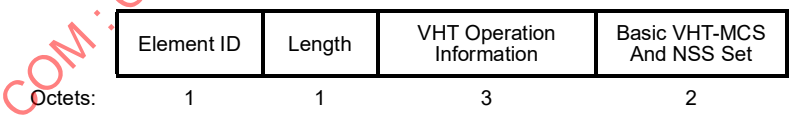

Figure 9-612—VHT Operation element format

The Element ID and Length fields are defined in 9.4.2.1.

The structure of the VHT Operation Information field is defined in Figure 9-613.

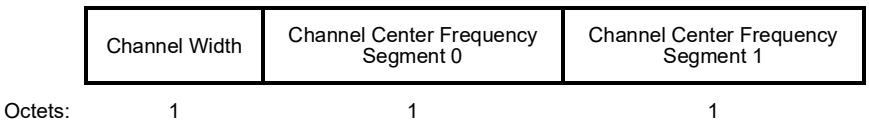

Figure 9-613—VHT Operation Information field format

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The VHT STA gets the primary channel information from the HT Operation element. The subfields of the VHT Operation Information field are defined in Table 9-274.

The Basic VHT-MCS And NSS Set field indicates the VHT-MCSs for each number of spatial streams in VHT PPDUs that are supported by all VHT STAs in the BSS (including IBSS and MBSS). The Basic VHT-MCS And NSS Set field is a bitmap of size 16 bits; each 2 bits indicates the supported VHT-MCS set for N_{SS} from 1 to 8. The Basic VHT-MCS And NSS Set field is defined in Figure 9-611.

Table 9-274—VHT Operation Information subfields

Subfield	Definition	Encoding
Channel Width	This field, together with the HT Operation element STA Channel Width field, defines the BSS bandwidth (see 11.38.1).	Set to 0 for 20 MHz or 40 MHz BSS bandwidth. Set to 1 for 80 MHz, 160 MHz or 80+80 MHz BSS bandwidth. Set to 2 for 160 MHz BSS bandwidth (deprecated). Set to 3 for noncontiguous 80+80 MHz BSS bandwidth (deprecated). Values in the range 4 to 255 are reserved.
Channel Center Frequency Segment 0	Defines a channel center frequency for a 20, 40, 80, 160, or 80+80 MHz VHT BSS. See 21.3.14.	For 20, 40, or 80 MHz BSS bandwidth, indicates the channel center frequency index for the 20, 40, or 80 MHz channel on which the VHT BSS operates. For 160 MHz BSS bandwidth and the Channel Width subfield equal to 1, indicates the channel center frequency index of the 80 MHz channel segment that contains the primary channel. For 160 MHz BSS bandwidth and the Channel Width subfield equal to 2, indicates the channel center frequency index of the 160 MHz channel on which the VHT BSS operates. For 80+80 MHz BSS bandwidth and the Channel Width subfield equal to 1 or 3, indicates the channel center frequency index for the primary 80 MHz channel of the VHT BSS. Reserved otherwise.
Channel Center Frequency Segment 1	Defines a channel center frequency for a 160 or 80+80 MHz VHT BSS. See 21.3.14.	For a 20, 40, or 80 MHz BSS bandwidth, this subfield is set to 0. For a 160 MHz BSS bandwidth and the Channel Width subfield equal to 1, indicates the channel center frequency index of the 160 MHz channel on which the VHT BSS operates. For a 160 MHz BSS bandwidth and the Channel Width subfield equal to 2, this field is set to 0. For an 80+80 MHz BSS bandwidth and the Channel Width subfield equal to 1 or 3, indicates the channel center frequency index of the secondary 80 MHz channel of the VHT BSS. See Table 9-275. Reserved otherwise.

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Table 9-275—BSS bandwidth when the VHT Operation Information field Channel Width subfield is 1

Channel Center Frequency Segment 1 subfield value	BSS bandwidth
CCFS1 = 0	80 MHz or less
CCFS1 > 0 and | CCFS1 – CCFS0 | = 8 (40 MHz apart)	160 MHz (CCFS0: center frequency of the 80 MHz channel segment that contains the primary channel) (CCFS1: center frequency of the 160 MHz channel)
CCFS1 > 0 and | CCFS1 – CCFS0 | > 16 (> 80 MHz apart)	80+80 MHz (CCFS0: center frequency of the primary 80 MHz channel) (CCFS1: center frequency of the secondary 80 MHz channel)
CCFS1 > 0 and | CCFS1 – CCFS0 | < 8 (< 40 MHz apart)	Reserved
CCFS1 > 0 and 8 < | CCFS1 – CCFS0 | ≤ 16 (> 40 MHz and ≤ 80 MHz apart)	Reserved
NOTE 1—CCFS0 represents the Channel Center Frequency Segment 0 subfield. NOTE 2—CCFS1 represents the Channel Center Frequency Segment 1 subfield.	

9.4.2.159 Extended BSS Load element

The Extended BSS Load element reported by the AP contains information on MIMO spatial stream underutilization and bandwidth utilization. The element format is defined in Figure 9-614. A STA receiving the element might use the information it conveys in an implementation-specific AP selection algorithm.

	Element ID	Length	MU-MIMO Capable STA Count	Spatial Stream Underutilization	Observable Secondary 20 MHz Utilization	Observable Secondary 40 MHz Utilization	Observable Secondary 80 MHz Utilization
Octets:	1	1	2	1	1	1	1

Figure 9-614—Extended BSS Load element format

The Element ID and Length fields are defined in 9.4.2.1.

The MU-MIMO Capable STA Count field indicates the total number of STAs currently associated with this BSS that have a 1 in the MU Beamformee Capable field of their VHT Capabilities element.

The Spatial Stream Underutilization field is defined as the percentage of time, linearly scaled with 255 representing 100%, that the AP has underutilized spatial domain resources for given busy time of the medium. The spatial stream underutilization is calculated only for the primary channel. This percentage is computed using the formula,

$$\text{Spatial Stream Underutilization} = \left\lfloor \frac{N_{\text{max_SS}} \times T_{\text{busy}} - T_{\text{utilized}}}{N_{\text{max_SS}} \times T_{\text{busy}}} \times 255 \right\rfloor$$

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where

N_{max_SS} is the maximum number of spatial streams supported by the AP

T_{busy} is the number of microseconds during which CCA indicated the channel was busy during the measurement duration. The resolution of the CCA busy measurement is in microseconds

$T_{utilized}$ is $\sum_{i=1}^{N} N_{SS,i} T_i$, where T_i is the time interval, in units of microseconds, during which the primary 20 MHz channel is busy due to the transmission of one or more spatial streams by the AP to MU beamformee capable STAs; $N_{SS,i}$ is the number of spatial streams transmitted during the time interval T_i; and N is the number of busy events that occurred during the total measurement time, which is less than or equal to dot11ChannelUtilizationBeaconIntervals consecutive beacon intervals

If T_{busy} is 0, the Spatial Stream Underutilization field is reserved.

The measurement of the observable loading on each of the secondary 20 MHz channel, secondary 40 MHz channel, and secondary 80 MHz channel in conjunction with the measurement on the primary 20 MHz channel provides a STA with the loading on the 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz channels.

The Observable Secondary 20 MHz Utilization, Observable Secondary 40 MHz Utilization, and Observable Secondary 80 MHz Utilization fields are defined using Equation (9-3).

$$\text{Observable Secondary } W1 \text{ Utilization} = \left\lfloor \frac{T_{busy,W1}}{\text{dot11ChannelUtilizationBeaconIntervals} \times \text{dot11BeaconPeriod} \times 1024} \times 255 \right\rfloor \quad (9\text{-}3)$$

where

dot11ChannelUtilizationBeaconIntervals represents the number of consecutive beacon intervals during which the secondary channel busy time is measured

$T_{busy,W1}$ is computed as the sum of the times from PHY-CCA.indication(BUSY,{W2}) to the next issue of a PHY-CCA.indication primitive and that overlap the measurement interval, for W1 = 20, 40, or 80, and where W2 equals secondary, secondary40, or secondary80 for W1 = 20, 40, or 80, respectively

If the AP indicates a channel width of 20 MHz, 40 MHz, or 80 MHz in the STA Channel Width field in the HT Operation element and in the Channel Width field in the VHT Operation element, then the Observable Secondary 80 MHz Utilization field is reserved. If the AP indicates a channel width of 20 MHz or 40 MHz in the STA Channel Width field in the HT Operation element, then the Observable Secondary 40 MHz Utilization field is reserved. If the AP indicates a channel width of 20 MHz in the STA Channel Width field in the HT Operation element, then the Observable Secondary 20 MHz Utilization field is reserved.

9.4.2.160 Wide Bandwidth Channel Switch element

The Wide Bandwidth Channel Switch element is included in Channel Switch Announcement frames, as described in 9.6.2.6, Extended Channel Switch Announcement frames, as described in 9.6.7.7, and TDLS Channel Switch Request frames, as described in 9.6.12.7. The format of the Wide Bandwidth Channel Switch element is shown in Figure 9-615.

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Element ID	Length	New Channel Width	New Channel Center Frequency Segment 0	New Channel Center Frequency Segment 1
Octets: 1	1	1	1	1

Figure 9-615—Wide Bandwidth Channel Switch element format

The Element ID and Length fields are defined in 9.4.2.1.

If the New Operating Class field in the frame that contains this element does not indicate an S1G band, the subfields New Channel Width, New Channel Center Frequency Segment 0, and New Channel Center Frequency Segment 1 have the same definition, respectively, as Channel Width, Channel Center Frequency Segment 0, and Channel Center Frequency Segment 1 in the VHT Operation Information field, described in Table 9-274. Otherwise, the subfields New Channel Width and New Channel Center Frequency Segment 0 have the same definition, respectively, as the Channel Width and the Channel Center Frequency in the S1G Operation Information field, described in Table 9-311. The New Channel Center Frequency Segment 1 subfield is reserved.

9.4.2.161 Transmit Power Envelope element

The Transmit Power Envelope element conveys the local maximum transmit power for various transmission bandwidths. The format of the Transmit Power Envelope element is shown in Figure 9-616.

	Element ID	Length	Transmit Power Information	Local Maximum Transmit Power For 20 MHz	Local Maximum Transmit Power For 40 MHz	Local Maximum Transmit Power For 80 MHz	Local Maximum Transmit Power For 160/80+80 MHz
Octets:	1	1	1	1	0 or 1	0 or 1	0 or 1

Figure 9-616—Transmit Power Envelope element format

The Element ID and Length fields are defined in 9.4.2.1.

The format of the Transmit Power Information field is defined in Figure 9-617.

	B0 B2	B3 B5	B6 B7
	Local Maximum Transmit Power Count	Local Maximum Transmit Power Unit Interpretation	Reserved
Bits:	3	3	2

Figure 9-617—Transmit Power Information field format

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The Local Maximum Transmit Power Count subfield indicates the number of Local Maximum Transmit Power For *X* MHz fields (where *X* = 20, 40, 80, or 160/80+80) minus 1 in the Transmit Power Envelope element, as shown in Table 9-276.

Table 9-276—Meaning of Local Maximum Transmit Power Count subfield

Value	Field(s) present
0	Local Maximum Transmit Power For 20 MHz.
1	Local Maximum Transmit Power For 20 MHz and Local Maximum Transmit Power For 40 MHz.
2	Local Maximum Transmit Power For 20 MHz, Local Maximum Transmit Power For 40 MHz, and Local Maximum Transmit Power For 80 MHz.
3	Local Maximum Transmit Power For 20 MHz, Local Maximum Transmit Power For 40 MHz, Local Maximum Transmit Power For 80 MHz, and Local Maximum Transmit Power For 160/80+80 MHz. For TVHT STAs, reserved.
4–7	Reserved

The Local Maximum Transmit Power Unit Interpretation subfield provides additional interpretation for the units of the Local Maximum Transmit Power For *X* MHz fields (where *X* = 20, 40, 80, or 160/80+80) and is defined in Table 9-277. Allowed values are further constrained as defined in Annex E.

Table 9-277—Definition of Local Maximum Transmit Power Unit Interpretation subfield

Value	Unit interpretation of the Local Maximum Transmit Power For *X* MHz fields
0	EIRP
1–7	Reserved
NOTE—This table is expected to be updated only if regulatory domains mandate the use of transmit power control with limits that cannot be converted into an EIRP value per transmission bandwidth.	

Local Maximum Transmit Power For *X* MHz fields (where *X* = 20, 40, 80, or 160/80+80) define the local maximum transmit power limit of *X* MHz PPDUs. Each Local Maximum Transmit Power For *X* MHz field is encoded as an 8-bit 2s complement signed integer in the range –64 dBm to 63 dBm with a 0.5 dB step. Setting this field to 63.5 dBm indicates 63.5 dBm or higher (i.e., no local maximum transmit power constraint).

In frames transmitted by a TVHT STA the Local Maximum Transmit Power for 20 MHz field indicates the Local Maximum Transmit Power for TVHT_W bandwidth; the Local Maximum Transmit Power for 40 MHz field indicates the Local Maximum Transmit Power for TVHT_2W or TVHT_W+W bandwidth; the Local Maximum Transmit Power for 80 MHz field indicates the Local Maximum Transmit Power for TVHT_4W or TVHT_2W+2W bandwidth; the Local Maximum Transmit Power for 160/80+80 MHz field is not included in the Transmit Power Envelope element.

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9.4.2.162 Channel Switch Wrapper element

The Channel Switch Wrapper element contains subelements that indicate characteristics of the BSS after a channel switch. The format of the Channel Switch Wrapper element is defined in Figure 9-618. Procedures related to the inclusion of subelements in the Channel Switch Wrapper element are defined in 11.38.4.

	Element ID	Length	New Country subelement (optional)	Wide Bandwidth Channel Switch subelement (optional)	New Transmit Power Envelope subelement (optional)
Octets:	1	1	variable	variable	variable

Figure 9-618—Channel Switch Wrapper element format

The Element ID and Length fields are defined in 9.4.2.1.

The New Country subelement is present when an AP or mesh STA performs extended channel switching to a new Country, new Operating Class Table, or a changed set of operating classes relative to the contents of the Country element sent in the Beacon; otherwise, this subelement is not present. The format of the New Country subelement is defined to be the same as the format of the Country element (see 9.4.2.8), except that no Subband Triplet fields are present in the New Country subelement. The Country String field in the New Country subelement indicates the Country and Operating Class Table of the BSS after extended channel switching, and Operating Triplet fields within the New Country subelement indicate the operating classes of the BSS after extended channel switching (see 11.38.1).

The Wide Bandwidth Channel Switch subelement is present under the following conditions:

— Channel switching to a BSS bandwidth of 40 MHz or wider
— Extended channel switching to a BSS bandwidth of 80 MHz or wider

The Wide Bandwidth Channel Switch subelement is optionally present if extended channel switching to a BSS bandwidth of 40 MHz. The Wide Bandwidth Channel Switch subelement is not present if channel switching to a 20 MHz BSS bandwidth.

The format of the Wide Bandwidth Channel Switch subelement is the same as the Wide Bandwidth Channel Switch element (see 9.4.2.160) except for the following:

— A value 0 in the New Channel Width field signifies only a 40 MHz BSS bandwidth.
— When switching to a 40 MHz BSS bandwidth, the New Channel Center Frequency Segment 0 field indicates the channel center frequency index for the 40 MHz channel after the channel switch.

If present, the Wide Bandwidth Channel Switch subelement indicates the BSS bandwidth after channel switching (see 11.38.1). For example, when switching to a 40 MHz BSS bandwidth on channel indices 36 and 40, the New Channel Width field is set to 0, and the New Channel Center Frequency Segment 0 field is set to 38.

Each New Transmit Power Envelope subelement that is present is defined to have the same format as the Transmit Power Envelope element (see 9.4.2.161) and includes a distinct value of the Local Maximum Transmit Power Unit Interpretation subfield. Each New Transmit Power Envelope subelement indicates the local maximum transmit powers for the BSS for the indicated bandwidths with an indicated unit interpretation after channel switching (see 11.38.1).

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If transmitted by a TVHT STA, the Wide Bandwidth Channel Switch subelement is present when the STA is switching channels to a BSS bandwidth of TVHT_2W or TVHT_W+W bandwidth or wider; if switching to a TVHT_W bandwidth BSS bandwidth then this subelement is not present.

9.4.2.163 AID element

The AID element includes the AID assigned by an AP during association that represents the 16-bit ID of a STA. The format of the AID element is shown in Figure 9-619.

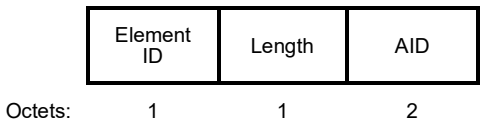

Figure 9-619—AID element format

The Element ID and Length fields are defined in 9.4.2.1.

The AID field is defined in 9.4.1.8.

9.4.2.164 Quiet Channel element

The Quiet Channel element is used to indicate that the secondary 80 MHz channel of a VHT BSS is to be quieted during a quiet interval, and, in an infrastructure BSS, to indicate if the primary 80 MHz channel of a VHT BSS can be used during the quiet interval. A quiet interval is established using either a Quiet element (see 9.4.2.22) or, in an infrastructure BSS, the Quiet Channel element if its AP Quiet Mode field is equal to 1.

The Quiet Channel element is optionally present in Beacon frames, as described in 9.3.3.2, and Probe Response frames, as described in 9.3.3.10. The use of Quiet Channel elements is described in 11.8.3.

The format of the Quiet Channel element is shown in Figure 9-620.

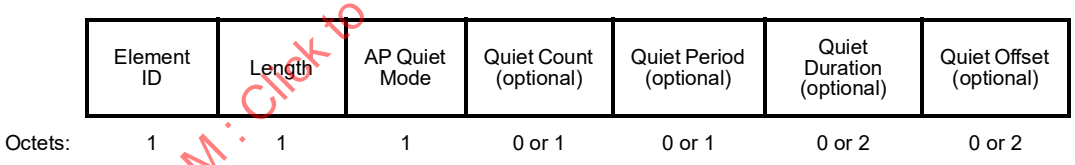

Figure 9-620—Quiet Channel element format

The Element ID and Length fields are defined in 9.4.2.1.

The AP Quiet Mode field specifies STA behavior in an infrastructure BSS during the quiet intervals. When communications to the AP are allowed within the primary 80 MHz channel, then the AP Quiet Mode field is set to 1. Otherwise, the AP Quiet Mode field is set to 0.

If the AP Quiet Mode field is 1, then the Quiet Count field, Quiet Period field, Quiet Duration field, and Quiet Offset field are present in the Quiet Channel element; otherwise, these fields are not present in the Quiet Channel element.

The Quiet Count field, Quiet Period field, Quiet Duration field, and Quiet Offset field have the same definition as described in 9.4.2.22.

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9.4.2.165 Operating Mode Notification element

The Operating Mode Notification element is used to notify STAs that the transmitting STA is changing one or more of its operating channel width, the maximum number of spatial streams it can receive, and its LDPC receive preference. The format of the Operating Mode Notification element is defined in Figure 9-621.

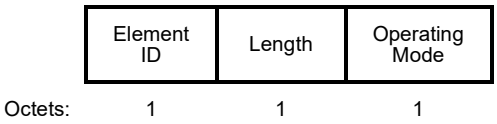

Figure 9-621—Operating Mode Notification element format

The Element ID and Length fields are defined in 9.4.2.1.

The Operating Mode field is defined in 9.4.1.53.

9.4.2.166 UPSIM element

The UPSIM element is defined as shown in Figure 9-622.

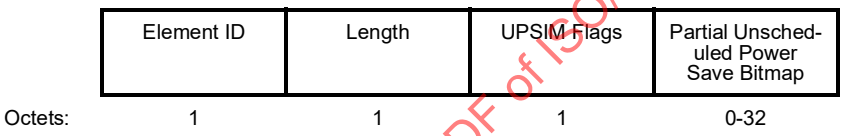

Figure 9-622—UPSIM element format

The Element ID and Length fields are defined in 9.4.2.1.

The Length field for this element is constrained as described below.

The UPSIM Flags field is defined in Figure 9-623.

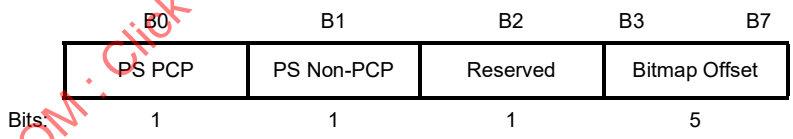

Figure 9-623—UPSIM Flags field format

The PS PCP field is set to 1 if the PCP is in unscheduled PS mode at the time of UPSIM element transmission and is set to 0 otherwise. The PS PCP field is set to 0 in infrastructure BSS. The PS Non-PCP field is set to 1 if all non-AP and non-PCP STAs are in unscheduled PS mode at the time of UPSIM element transmission and is set to 0 otherwise. The Bitmap Offset field defines the octet offset into a virtual bitmap maintained by the AP or PCP, as described below.

The AP or PCP maintains an unscheduled power save indication virtual bitmap that is 256 bits in length and is organized into 32 octets such that bit number N ($0 \le N \le 255$) in the bitmap corresponds to bit number (N mod 8) in octet number $\lfloor N / 8 \rfloor$, where the low order bit of each octet is bit number 0, and the high order bit is bit number 7. Bit N in the bitmap is set to 1 if there is an associated DMG STA with AID equal to N and the STA is in unscheduled PS mode and is set to 0 if there is no associated DMG STA with AID equal to N or the STA is not in unscheduled PS mode. Bit 0 is set to 0 in the infrastructure BSS. Bit 255 is set to 0.

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The Partial Unscheduled Power Save Bitmap field is not present when bits numbered 1 to 254 of the unscheduled power save indication virtual bitmap all have the same value at the time of UPSIM element transmission. In this case, the Length field is set to 1 and the Bitmap Offset field is set to 0.

When there are two bits in the unscheduled power save indication virtual bitmap with numbers between 1 and 254 and different values, the Partial Unscheduled Power Save Bitmap field consists of octets numbered $N1$ to $N2$ of the unscheduled power save indication virtual bitmap, where $N1$ is the largest integer such that bits numbered 1 to ($N1$× 8) - 1 in the unscheduled power save indication virtual bitmap are all 0, and $N2$ is the smallest number such that bits numbered ($N2$ + 1) × 8 to 255 in the unscheduled power save indication virtual bitmap are all 0. In this case, the Length field is set to ($N2$ - $N1$) + 2 and the Bitmap Offset subfield is set to $N1$.

NOTE—The Partial Unscheduled Power Save Bitmap field does not need to include bit 0 of the unscheduled power save indication virtual bitmap even if that bit is set.

9.4.2.167 Fine Timing Measurement Parameters element

The Fine Timing Measurement Parameters element contains a number of subfields that are used to advertise the requested or allocated FTM configuration from one STA to another. The Fine Timing Measurement Parameters element is included in the initial Fine Timing Measurement Request frame, as described in 9.6.7.32, and the initial Fine Timing Measurement frame, as described in 9.6.7.33. The use of the Fine Timing Measurement Parameters element is described in 11.21.6.

The format of the Fine Timing Measurement Parameters element is shown in 9-624.

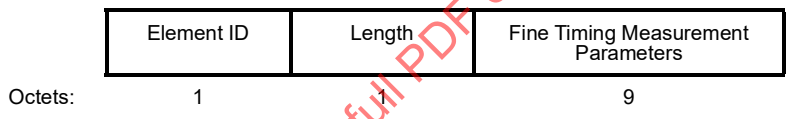

Figure 9-624—Fine Timing Measurement Parameters element format

The Element ID and Length fields are defined in 9.4.2.1.

The format of the Fine Timing Measurement Parameters field is shown in 9-625.

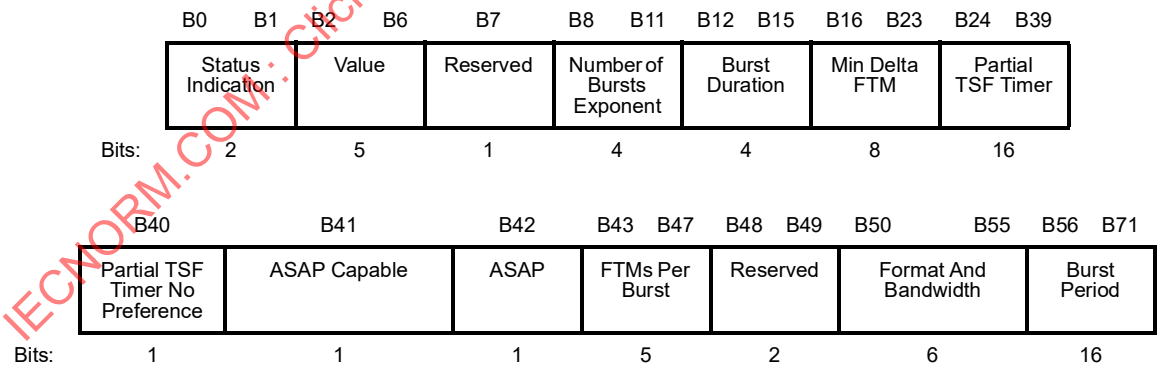

Figure 9-625—Fine Timing Measurement Parameters field format

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The Status Indication subfield indicates the responding STA's response to the initial Fine Timing Measurement Request frame. The encoding of the Status Indication subfield is shown in Table 9-278.

Table 9-278—Status Indication subfield values

Value	Description
0	Reserved
1	Successful (some requested parameters might have been overridden). Measurement exchanges are about to begin.
2	Request incapable. Do not send same request again. FTM session ends.
3	Request failed. Do not send new request for Value seconds. FTM session ends.

The Status Indication subfield and Value subfield are reserved in the initial Fine Timing Measurement Request frame. When the Status Indication subfield is set to 3 by the responding STA, the Value subfield contains a duration in units of seconds; otherwise the Value subfield is reserved.

The Number of Bursts Exponent subfield indicates how many burst instances, defined in 11.21.6.4, are requested for the FTM session if included in an initial Fine Timing Measurement Request frame, or allocated for the FTM session if included in an initial Fine Timing Measurement frame respectively, where the number of burst instances is $2^{\text{Number of Bursts Exponent}}$. The value 15 in an initial Fine Timing Measurement Request frame indicates no preference by the initiating STA and is valid (indicating 2^{15} burst instances) when set by the responding STA.

The Burst Duration subfield indicates the duration of a burst instance. The value 15 in the initial Fine Timing Measurement Request indicates no preference by the initiating STA and is not used by the responding STA. Table 9-279 shows the encoding of this subfield.

Table 9-279—Burst Duration subfield encoding

Value	Represents
0-1	Reserved
2	250 μs
3	500 μs
4	1 ms
5	2 ms
6	4 ms
7	8 ms
8	16 ms
9	32 ms
10	64 ms
11	128 ms
12–14	Reserved
15	No preference

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The Min Delta FTM subfield indicates the minimum time between consecutive Fine Timing Measurement frames. It is measured from the start of a Fine Timing Measurement frame to the start of following Fine Timing Measurement frame, in units of 100 μs. The value 0 indicates no preference by the initiating STA and is not used by the responding STA.

The value in the Partial TSF Timer subfield is the partial value of the responding STA's TSF at the start of the first burst instance. The Partial TSF Timer subfield value is derived as follows, so as to have units of TUs: from the 64 TSF timer bits at the start of the first burst instance of an FTM session, remove the most significant 38 bits and the least significant 10 bits.

The initiating STA indicates a preferred time for the start of the first burst instance by setting the Partial TSF Timer No Preference subfield to 0 and by setting the Partial TSF Timer subfield to indicate the preferred start of the first burst instance, in the Fine Timing Measurement Request frame. Otherwise the Partial TSF Timer No Preference subfield is set to 1 and the Partial TSF Timer subfield is reserved. The Partial TSF Timer No Preference subfield is reserved when the Fine Timing Measurement Parameters element is included in an initial Fine Timing Measurement frame.

The value of the Partial TSF Timer subfield in an initial Fine Timing Measurement frame is the partial value of the responding STA's TSF timer at the start of the first burst instance of an FTM session.

NOTE 1—1024 TUs out of the full range of the Partial TSF Timer subfield are not used in order to allow the recipient to resolve ambiguity arising from 1) imperfect synchronization between the initiating and responding STAs, and 2) retries of the initial Fine Timing Measurement Request frame or retransmissions of the initial Fine Timing Measurement frame.

The ASAP Capable subfield indicates that the responding STA is capable of capturing timestamps associated with an initial Fine Timing Measurement frame and its acknowledgment and sending them in the following Fine Timing Measurement frame. This subfield is reserved in the initial Fine Timing Measurement Request frame.

The ASAP subfield indicates the initiating STA's request to start the first burst instance of the FTM session with the initial Fine Timing Measurement frame and capture timestamps corresponding to the transmission of the initial Fine Timing Measurement frame and the receipt of its acknowledgment. The responding STA sets the ASAP subfield to 1 to indicate the STA's intent to send a Fine Timing Measurement frame as soon as possible and capture timestamps corresponding to the transmission of the initial Fine Timing Measurement frame and the receipt of its acknowledgment.

When the ASAP subfield is set to 0 and the Partial TSF Timer No Preference subfield is set to 0 by an initiating STA, the initiating STA requests the start of the first burst instance specified by the Partial TSF Timer subfield in the initial Fine Timing Measurement Request frame. When the ASAP subfield is set to 1 and the Partial TSF Timer No Preference subfield is set to 0 by an initiating STA, the Partial TSF Timer subfield in the Fine Timing Measurement Request frame indicates the requested start of the first burst instance if the ASAP subfield is set to 0 in the corresponding initial Fine Timing Measurement frame. The Partial TSF Timer subfield in both these frames is set to a value between 0 and 62/64 of 65 535 TUs.

Figure 9-626 describes how the value of the Partial TSF Timer subfield is determined based on the ASAP subfield and the Partial TSF Timer No Preference subfield at an initiating STA and on the ASAP subfield at the responding STA.

The ASAP subfield is also used by the responding STA to signal whether that request has been honored or not. When the ASAP subfield is set to 0 by the responding STA, the Partial TSF Timer subfield in the initial Fine Timing Measurement frame indicates the start time of the first burst instance and the earliest time the Fine Timing Measurement Request frame (see 11.21.6.4) should be sent by the initiating STA. The Partial TSF Timer subfield in both these frames is set to a value between 0 and 62/64 of 65 535 TUs.

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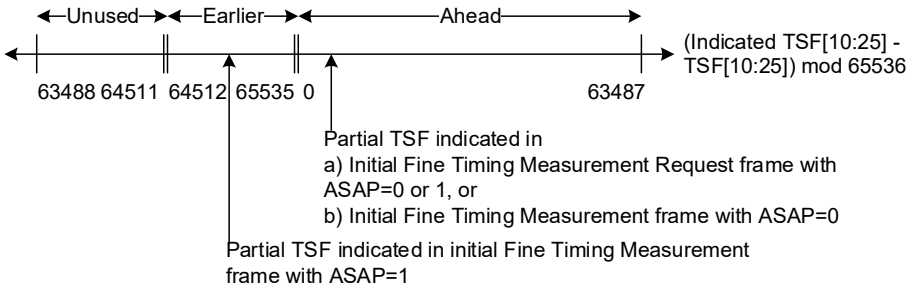

Figure 9-626—Calculation of the value of the Partial TSF Timer subfield

When the ASAP subfield is set to 1 by the responding STA, the Partial TSF Timer subfield in the initial Fine Timing Measurement frame indicates the start time of the first burst instance and the earliest time the initial Fine Timing Measurement frame will be sent. The value in the Partial TSF Timer subfield in this case is set to a value less than 1/64 of 65 536 TUs (≥1024 TUs) from the responding STA's TSF timer.

The FTMs Per Burst subfield indicates how many successfully transmitted Fine Timing Measurement frames are requested per burst instance by the initial Fine Timing Measurement Request frame, or allocated by the initial Fine Timing Measurement frame, respectively. The value 0 indicates no preference by the initiating STA and is not used by the responding STA.

The Format And Bandwidth subfield indicates the requested or allocated PPDU format and bandwidth that can be used by Fine Timing Measurement frames in an FTM session and is shown in Table 9-280. The value 0 indicates no preference by the initiating STA in the associated state and is not used by the responding STA.The value 0 is not used by the initiating STA in the unassociated state.

Table 9-280—Format And Bandwidth subfield

Field value	Format	Bandwidth (MHz)
0	No preference	No preference
1–3	Reserved	Reserved
4	Non-HT	5
5	Reserved	Reserved
6	Non-HT	10
7	Reserved	Reserved
8	Non-HT, excluding Clause 15 and Clause 16	20
9	HT mixed	20
10	VHT	20
11	HT mixed	40
12	VHT	40
13	VHT	80
14	VHT	80+80
15	VHT (two separate RF LOs)	160

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Table 9-280—Format And Bandwidth subfield *(continued)*

Field value	Format	Bandwidth (MHz)
16	VHT (single RF LO)	160
17–30	Reserved	Reserved
31	DMG	2160
32–63	Reserved	Reserved

NOTE 2—See 21.3.17.3 regarding the usage of two separate RF LOs.

The Burst Period subfield indicates the interval between two consecutive burst instances, in units of 100 ms. The value 0 indicates no preference by the initiating STA. This subfield is reserved when the Number of Bursts Exponent subfield is set to 0.

9.4.2.168 Device Location element

A Device Location element includes the location configuration information (LCI), which contains latitude, longitude, and altitude information. The Device Location element format is shown in Figure 9-627.

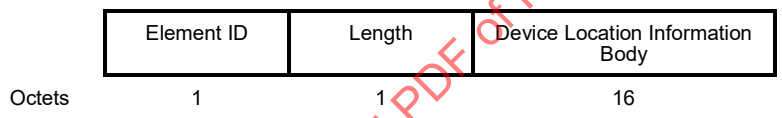

Figure 9-627—Device Location element format

The Element ID and Length fields are defined in 9.4.2.1.

The format of the Device Location Information Body field is defined in 9.4.1.56.

9.4.2.169 White Space Map element

The White Space Map element includes available radio frequency information obtained from a GDB. The format of the WSM Information field is determined by the WSM Type field. The format of the White Space Map Announcement element is shown in Figure 9-628.

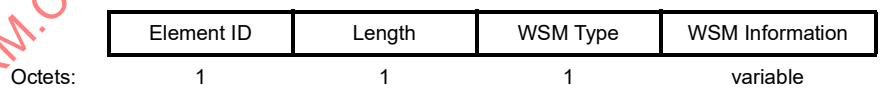

Figure 9-628—WSM element format

The Element ID and Length fields are defined in 9.4.2.1.

The format and values of WSM Type and WSM Information fields are defined in 9.4.1.57.

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9.4.2.170 Reduced Neighbor Report element

9.4.2.170.1 General

The Reduced Neighbor Report element contains channel and other information related to neighbor APs. The format of the Reduced Neighbor Report element is shown in Figure 9-629.

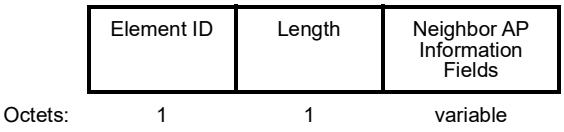

Figure 9-629—Reduced Neighbor Report element format

The Element ID and Length fields are defined in 9.4.2.1.

The Neighbor AP Information Fields field contains one or more of the Neighbor AP Information field described in 9.4.2.170.2.

9.4.2.170.2 Neighbor AP Information field

The Neighbor AP Information field specifies TBTT and other information related to a group of neighbor APs on one channel. See Figure 9-630.

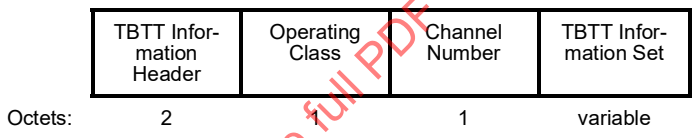

Figure 9-630—Neighbor AP Information field format

The format of TBTT Information Header subfield is defined in Figure 9-631.

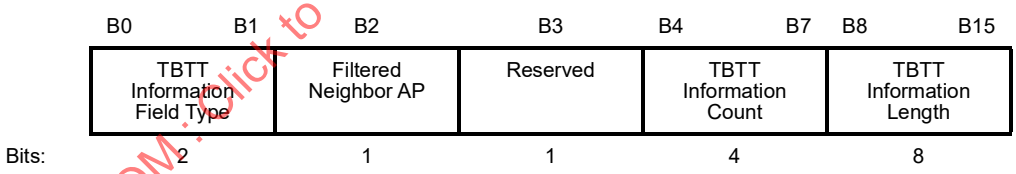

Figure 9-631—TBTT Information Header subfield format

The TBTT Information Field Type subfield identifies, together with the TBTT Information Length subfield, the format of the TBTT Information field. It is set to 0.. Values 1, 2, and 3 are reserved.

The Filtered Neighbor AP subfield is reserved except when the Reduced Neighbor Report element is carried in a Probe Response frame transmitted by a TVHT AP.

In a Probe Response frame transmitted by a TVHT AP, the Filtered Neighbor AP subfield is set to 1 if the specific SSID corresponding to every BSS of the APs in this Neighbor AP Information field matches the SSID in the corresponding Probe Request frame; otherwise it is set to 0.

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The TBTT Information Count subfield contains the number of TBTT Information fields included in the TBTT Information Set field of the Neighbor AP Information field, minus one.

The TBTT Information Length subfield indicates the length of each TBTT Information field included in the TBTT Information Set field of the Neighbor AP Information field. When the TBTT Information Field Type subfield is set to 0, the TBTT Information Length subfield

— Contains the length in octets of each TBTT Information field that is included in the TBTT Information Set field of the Neighbor AP Information field.
— Is set to 1, 5, 7, or 11; other values are reserved.
— Indicates the TBTT Information field contents as shown in Table 9-281.

A TVHT AP sets the TBTT Information Length subfield to 1.

The TBTT Information Length subfield is interpreted as shown in Table 9-281.

Table 9-281—TBTT Information field contents

TBTT Information Length subfield value	TBTT Information field contents
1	The Neighbor AP TBTT Offset subfield
5	The Neighbor AP TBTT Offset subfield and the Short SSID subfield
7	The Neighbor AP TBTT Offset subfield and the BSSID subfield
11	The Neighbor AP TBTT Offset subfield, the BSSID subfield and the Short SSID subfield
0, 2–4, 6, 8–10, 12–255	Reserved

The Operating Class field indicates a channel starting frequency that, together with the Channel Number field, indicates the primary channel of the BSSs of the APs in this Neighbor AP Information field.

NOTE—The Operating Class field and Channel Number tuple indicate the primary channel in order to assist with passive scanning.

The Channel Number field indicates the last known primary channel of the APs in this Neighbor AP Information field. Channel Number is defined within an Operating Class as shown in Table E-4.

The TBTT Information Set field contains one or more TBTT Information fields. The TBTT Information field is defined in Figure 9-632.

	Neighbor AP TBTT Offset	BSSID (optional)	Short SSID (optional)
Octets:	1	0 or 6	0 or 4

Figure 9-632—TBTT Information field format

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The Neighbor AP TBTT Offset subfield indicates the offset in TUs, rounded down to nearest TU, to the next TBTT of an AP's BSS from the immediately prior TBTT of the AP that transmits this element. The value 254 indicates an offset of 254 TUs or higher. The value 255 indicates an unknown offset value.

The BSSID field is defined in 9.2.4.3.4.

The Short SSID subfield is calculated as given in 9.4.2.170.3.

9.4.2.170.3 Calculating the short SSID

A short SSID is a 32-bit value calculated over an SSID. The SSID is referred to as the calculation fields.

The value of the Short SSID field is calculated using the following standard generator polynomial of degree 32:

$$G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$$

The value of the Short SSID field is the 1s complement of the sum (modulo 2) of the following:

a) The remainder of $x^k \times (x^{31} + x^{30} + x^{29} + \ldots + x^2 + x + 1)$ divided (modulo 2) by $G(x)$, where k is the number of bits in the calculation fields, and

b) The remainder after multiplication of the contents (treated as a polynomial) of the calculation fields by x^{32} and then division by $G(x)$.

The Short SSID field is transmitted commencing with the coefficient of the highest-order term.

9.4.2.171 TVHT Operation element

The operation of TVHT STAs in the BSS is controlled by the TVHT Operation element. The format of the TVHT Operation element is defined in Figure 9-633.

	Element ID	Length	TVHT Operation Information	Basic VHT-MCS And NSS Set
Octets:	1	1	4	2

Figure 9-633—TVHT Operation element format

The Element ID and Length fields are defined in 9.4.2.1.

The structure of the TVHT Operation Information field is defined in Figure 9-634.

	Primary Channel Number	Channel Width	Channel Center Frequency Segment 0	Channel Center Frequency Segment 1
Octets:	1	1	1	1

Figure 9-634—TVHT Operation Information field format

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The subfields of the TVHT Operation Information field are defined in Table 9-282.

Table 9-282—TVHT Operation Information subfields

Field	Definition	Encoding
Primary Channel Number	Indicates the channel number of the primary channel (see 11.41).	Channel number of the primary channel.
Channel Width	This field defines the BSS bandwidth (see 11.41).	Set to 0 for TVHT_W BSS bandwidth. Set to 1 for TVHT_2W BSS bandwidth. Set to 2 for TVHT_W+W BSS bandwidth. Set to 3 for TVHT_4W BSS bandwidth. Set to 4 for noncontiguous TVHT_2W+2W BSS bandwidth. Values in the range 5 to 255 are reserved.
Channel Center Frequency Segment 0	Defines the channel center frequency for a TVHT_W, TVHT_2W, and TVHT_4W TVHT BSS and the segment 0 channel center frequency for a TVHT_W+W and TVHT_2W+2W TVHT BSS. See 22.3.14.	For TVHT_W or TVHT_2W or TVHT_4W BSS bandwidth, indicates the center frequency of the lowest TV channel index for the TVHT_W or TVHT_2W or TVHT_4W channel on which the TVHT BSS operates. For TVHT_W+W or TVHT_2W+2W BSS bandwidth, indicates the lowest TV channel index for the TVHT_W or TVHT_2W channel of frequency segment 0 on which the TVHT BSS operates. Reserved otherwise.
Channel Center Frequency Segment 1	Defines the segment 1 channel center frequency for a TVHT_W+W and TVHT_2W+2W TVHT BSS. See 22.3.14.	For TVHT_W+W or TVHT_2W+2W BSS bandwidth, indicates the lowest TV channel index in the segment for the TVHT_W or TVHT_2W channel of frequency segment 1 on which the TVHT BSS operates. Reserved otherwise.

The Basic VHT-MCS And NSS Set field indicates the MCSs for each spatial stream in VHT PPDU in TVWS bands that are supported by all TVHT STAs in the BSS (including IBSS). The Basic VHT-MCS And NSS Set field is a bitmap of size 16 bits; B8-B9, B10-B11, B12-B13, and B14-B15 are set to 3. For B0-B7, each 2 bits indicates the supported MCS set for N_{SS} from 1 to 4. The Basic VHT-MCS And NSS Set field is defined as B0-B7 of Rx VHT-MCS Map subfield in 9.4.2.157.3.

9.4.2.172 FTM Synchronization Information element

The format of the FTM Synchronization Information element is defined in Figure 9-635.

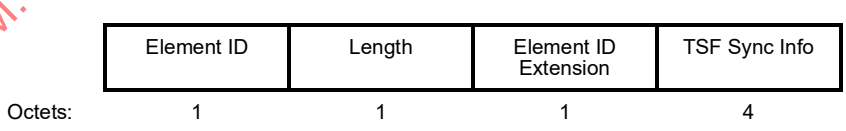

Figure 9-635—FTM Synchronization Information element format

The Element ID, Length and Element ID Extension fields are defined in 9.4.2.1.

The TSF Sync Info field is set to the 4 least significant octets of the TSF.

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9.4.2.173 Estimated Service Parameters Inbound element

The Estimated Service Parameters Inbound element is used by a STA to provide information to another STA that can then use the information as input to an algorithm to generate an estimate of inbound throughput between the two STAs.

The format of the Estimated Service Parameters Inbound element is shown in Figure 9-636.

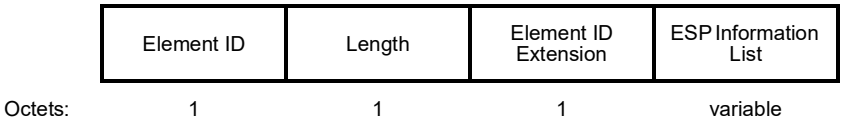

Figure 9-636—Estimated Service Parameters Inbound element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The ESP Information List field contains from 1 to 4 ESP Information fields, each corresponding to an access category for which estimated service parameters information is provided.

The format of the ESP Information field is shown in Figure 9-637.

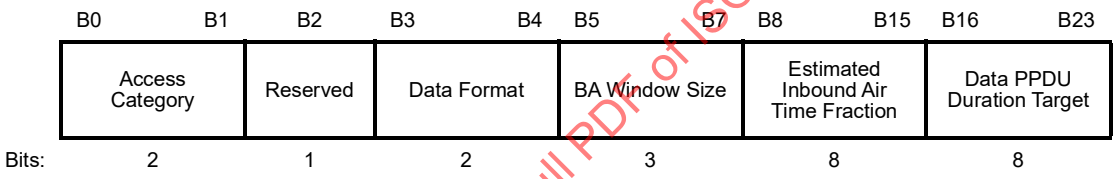

Figure 9-637—ESP Information field format

The Access Category subfield indicates the access category to which the remaining parameters of the ESP Information field apply. The encoding of the Access Category subfield is given in Table 9-283. When parameters for more than one access category are present in an Estimated Service Parameters Inbound element the ESP Information fields for the access categories appear in order of Access Category subfield value, with the ESP Information field with the lowest Access Category subfield value appearing first.

Table 9-283—Access Category subfield encoding

Value	Access Category
0	AC_BK
1	AC_BE
2	AC_VI
3	AC_VO

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The Data format subfield has the meaning indicated in Table 9-284.

Table 9-284—Data Format subfield encoding

Value	Description
0	No aggregation is expected to be performed for MSDUs or MPDUs with the Type subfield equal to Data for the corresponding AC
1	A-MSDU aggregation is expected to be performed for MSDUs for the corresponding AC, but A-MPDU aggregation is not expected to be performed for MPDUs with the Type subfield equal to Data for the corresponding AC
2	A-MPDU aggregation is expected to be performed for MPDUs with the Type subfield equal to Data for the corresponding AC, but A-MSDU aggregation is not expected to be performed for MSDUs for the corresponding AC
3	A-MSDU aggregation is expected to be performed for MSDUs for the corresponding AC, and A-MPDU aggregation is expected to be performed for MPDUs with the Type subfield equal to Data for the corresponding AC

The BA Window Size subfield is indicates the size of the Block Ack window that is expected for the corresponding access category as defined in Table 9-285. When the Block Ack window size expected to be used by the transmitter of the element does not match any of the values shown in the table, the transmitter uses the next lower value in the table.

Table 9-285—BA Window Size subfield encoding

Value	Expected block ack window size
0	Block Ack not expected to be used
1	2
2	4
3	6
4	8
5	16
6	32
7	64

The Estimated Inbound Air Time Fraction subfield contains an unsigned integer that represents the predicted percentage of time, linearly scaled with 255 representing 100% and 0 representing 0%, that a new STA joining the BSS can expect to be available for the transmission of PPDUs to that STA, including overhead, where such PPDUs contain MPDUs with the Type subfield equal to Data that belong to the access category indicated in the Access Category subfield of the corresponding ESP Information field and any other MPDUs in the PPDU are considered to be overhead.

The Data PPDU Duration Target field is an unsigned integer that indicates the expected target duration of PPDUs transmitted to the STA that contain MPDUs with the Type subfield equal to Data that belong to the access category indicated in the Access Category subfield of the corresponding ESP Information field for

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the corresponding access category in units of 50 μs. This value is determined using a method that is beyond the scope of this standard.

9.4.2.174 Future Channel Guidance element

The Future Channel Guidance element is used by an AP, IBSS STA, mesh STA, or PCP to guide STAs about the likely future channel if the sending STA changes channels of operation. The format of the Future Channel Guidance element is shown in Figure 9-638.

	Element ID	Length	Element ID Extension	New Channel Number	Secondary Channel Offset element	Mesh Channel Switch Parameters element	Wide Bandwidth Channel Switch element	New Transmit Power Envelope element
Octets:	1	1	1	4	0 or 3	0 or 6	0 or 5	variable

Figure 9-638—Future Channel Guidance element format

The Element ID, Length and Element ID Extension fields are defined in 9.4.2.1.

The New Channel Number field is set to the number of the channel to which the STA will be moving in the event of a channel switch (as defined in 17.3.8.4.3).

The Secondary Channel Offset element is defined in 9.4.2.19. This element is present when switching to a 40 MHz or wider channel. It is optionally present when switching to a 20 MHz channel (in which case the Secondary Channel Offset field is set to SCN). See 11.38.4.

The Mesh Channel Switch Parameters element is defined in 9.4.2.102. This element is present when a mesh STA performs MBSS channel switch. Otherwise, the Mesh Channel Switch Parameters element is not present.

The Wide Bandwidth Channel Switch element is defined in 9.4.2.160. This element is present when switching to a channel width wider than 40 MHz.

Each New Transmit Power Envelope element that is present is defined to have the same format as the Transmit Power Envelope element (see 9.4.2.161 and includes a distinct value of the Local Maximum Transmit Power Unit Interpretation subfield. If present, the New Transmit Power Envelope element indicates the local maximum transmit powers for the BSS for the BSS for the indicated bandwidths with an indicated unit interpretation after channel switching (see 11.38.1).

The Future Channel Guidance procedure is defined in 11.8.10.

9.4.2.175 Association Delay Info element

The Association Delay Info element is used to identify the minimum (re)association response timeout to the non-AP STA. The format of the Association Delay Info element is shown in Figure 9-639.

	Element ID	Length	Element ID Extension	Association Delay Info
Octets:	1	1	1	1

Figure 9-639—Association Delay Info element format

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The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Association Delay Info field contains an unsigned integer indicating the minimum association response delay in number of TUs.

9.4.2.176 CAG Number element

The Common Advertisement Group (CAG) is a group of elements that are defined by the same advertisement protocol and that do not change on a rapid basis within an AP. The CAG Number element provides one or more current version numbers of the CAG (CAG Version) associated with the AP, where each version number is associated with a specific advertisement protocol and server. The CAG Number element is optionally present in the Beacon or Probe Response frame to reduce GAS frame exchanges when dot11InterworkingServiceActivated is true. The CAG Number element is optionally present in the GAS Initial Request frame to indicate the CAG Version and the associated CAG Information Type cached by the non-AP STA when dot11SolicitedPADActivated is true.

The format of the CAG Number element is shown in Figure 9-640.

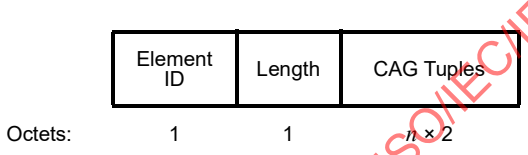

Figure 9-640—CAG Number element format

The Element ID and Length fields are defined in 9.4.2.1.

The CAG Tuples field contains one or more 2-octet CAG Tuple fields. The format of a CAG Tuple field is shown in Figure 9-641.

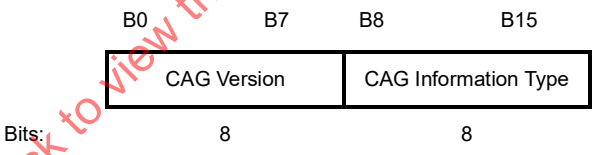

Figure 9-641—CAG Tuple field

The CAG Version subfield is an unsigned integer indicating the current version of the CAG of the associated advertisement protocol and server indicated by the CAG Information Type subfield in the same CAG Tuple field. The use of CAG Version is explained in 11.22.3.3.

The CAG Information Type subfield is indicates the type of information associated with the CAG Version in the same CAG Tuple field. The CAG Information Type is defined in Table 9-286.

Table 9-286—CAG Information Type definitions

Name	Value
Access network query protocol (ANQP)	0
MIS Information Service	1
MIS Command and Event Services Capability Discovery	2

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Table 9-286—CAG Information Type definitions *(continued)*

Name	Value
Emergency Alert System (EAS)	3
Registered location query protocol (RLQP)	4
Reserved	5–127
ANQP with Service Information Registry	128
Reserved	129–220
Vendor Specific	221
Reserved	222–255

9.4.2.177 FILS Request Parameters element(

The contents of the FILS Request Parameters element in Probe Request frame are used in determining whether to transmit a Probe Response frame as described in 11.1.4.3.4. The FILS Request Parameters element is defined in Figure 9-642.

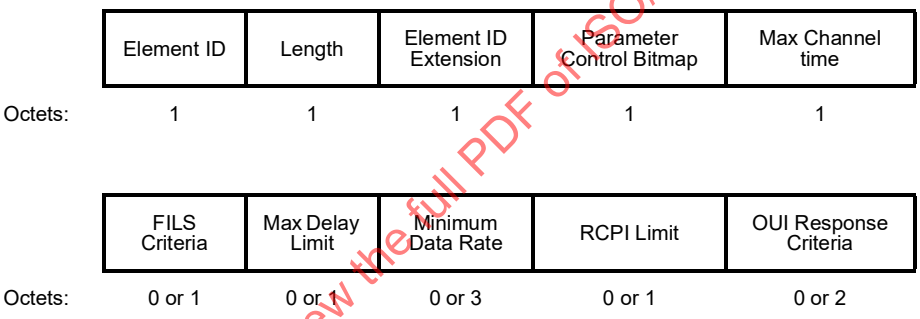

Figure 9-642—FILS Request Parameters element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Parameter Control Bitmap field is shown in Figure 9-643.

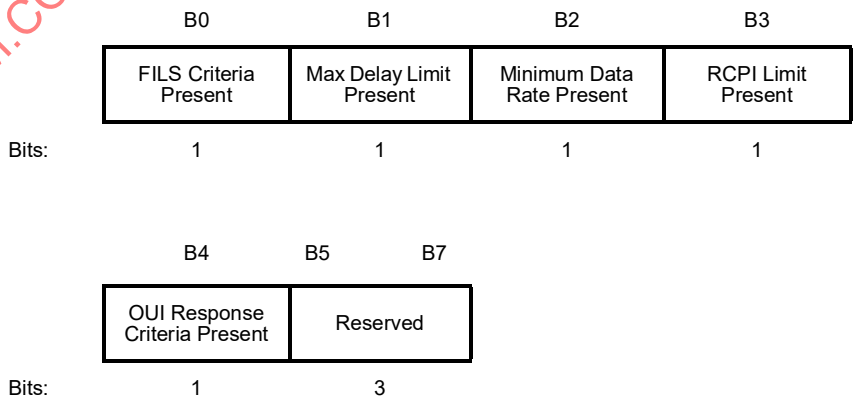

Figure 9-643—Parameter Control Bitmap field format

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Bits 0 to 4 of the Parameter Control Bitmap field correspond to the Parameter fields that are conditionally present in the element. A 1 in a bit indicates the corresponding parameter is present, and 0 indicates the corresponding parameter is not present.

The FILS Criteria field is shown in Figure 9-644.

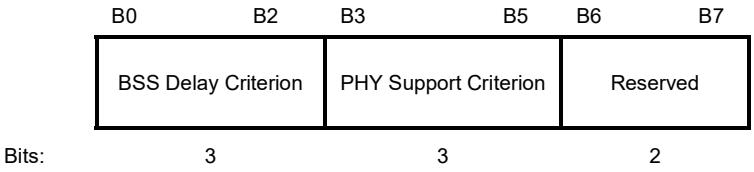

Figure 9-644—FILS Criteria field format

The BSS Delay Criterion subfield indicates the delay type that is applied in the decision to respond to the Probe Request frame as described in 11.1.4.3.4. The delay type is selected as indicated in Table 9-287.

Table 9-287—BSS Delay Criterion subfield

Value	Explanation
0	Delay criterion is not in use.
1	Access delay is indicated as Average Access Delay for Background (AC_BK) subfield of the BSS AC Access Delay element as described in 9.4.2.43.
2	Access delay is indicated as Average Access Delay for Best Effort (AC_BE) subfield of the BSS AC Access Delay element as described in 9.4.2.43.
3	Access delay is indicated as Average Access Delay for Video (AC_VI) subfield of the BSS AC Access Delay element as described in 9.4.2.43.
4	Access delay is indicated as Average Access Delay for Voice (AC_VO) subfield of the BSS AC Access Delay element as described in 9.4.2.43.
5	Access Delay is indicated as Average Access Delay as described in 9.4.2.43.
6, 7	Reserved

The PHY Support Criterion subfield indicates the required PHY type of the responding STA.

The indicated PHY type is used in the decision to respond to the Probe Request frame as described in 11.1.4.3.4. The meaning of the values for the PHY Support Criterion is shown in Table 9-288.

Table 9-288—PHY Support Criterion subfield

Value	Explanation
0	Indicates that PHY Support Criterion is not in use.
1	Indicates that a responding FILS STA is HT capable.
2	Indicates that a responding FILS STA is VHT capable.
3–7	Reserved

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The Max Delay Limit field (see 11.1.4.3.4) is an unsigned integer in units of 400 μs to indicate the maximum access delay as indicated by the BSS Delay Criterion subfield of the FILS Criteria of the FILS Request Parameters element. Value 0 is reserved. The use of the maximum access delay and the delay criterion are explained in 11.1.4.3.4. Max Delay Limit is not present if FILS Criteria is not present or BSS Delay Criterion is not in use.

The Minimum Data Rate field (see 11.1.4.3.4), if present, contains an unsigned integer in units of kilobits per second that specifies the lowest total data rate specified at the MAC SAP for transport of MSDUs or A-MSDUs that the STA is going to transmit. The minimum MAC SAP data rate does not include the MAC and PHY overheads incurred in transferring the MSDUs or A-MSDUs.

The RCPI Limit field is an unsigned integer in units of 1 dB. The use of the RCPI Limit field is explained in 11.1.4.3.4.

OUI Response Criteria field (see 11.1.4.3.9) is a bitmap whose bits correspond to the Vendor Specific elements of the Probe Request frame in order of presence. Bit 0 corresponds to the first Vendor Specific element, bit 1 corresponds to the second, etc. A bit value of 1 in the OUI Response Criteria field indicates that the receiver identifies the Organization Identifier field of the corresponding Vendor Specific element in order to respond to the request and otherwise is 0. If the number of the Vendor Specific elements of the Probe Request frame is less than the number of bits of the OUI Response Criteria field, the remaining bits of the OUI Response Criteria field are 0. If the number of bits in the OUI Response Criteria field is less than the number of Vendor Specific elements in the Probe Request frame, the corresponding bits not present in the OUI Response Criteria field are assumed to be 0.

The Max Channel Time field (see 11.1.4.3.9) contains the value of MaxChannelTime parameter of the MLME-SCAN.request primitive represented in units of TUs, as an unsigned integer. Setting the Max Channel Time field to 255 is used to indicate any duration of more than 254 TUs, or an unspecified or unknown duration.

9.4.2.178 FILS Key Confirmation element

The FILS Key Confirmation element is used to convey a cryptographic proof of authentication between a STA and an AP. The format of the FILS Key Confirmation element is shown in Figure 9-645.

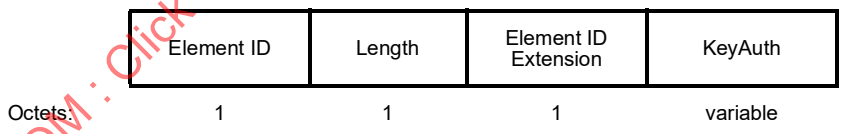

Figure 9-645—FILS Key Confirmation element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The KeyAuth field contains the cryptographic authentication information (see 12.11.2.6).

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9.4.2.179 FILS Session element

The FILS Session element is used to convey the (unique) identifier of an in-progress FILS authentication protocol session. The format of the FILS Session element is shown in Figure 9-646.

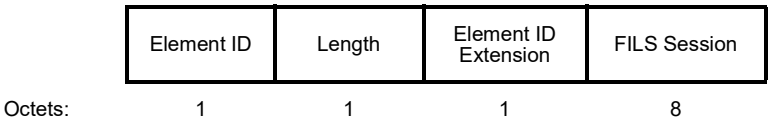

Figure 9-646—FILS Session element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The FILS Session field is chosen randomly by the non-AP STA.

9.4.2.180 FILS Public Key element

The FILS Public Key element is used to communicate the device's (certified) public key for use with the FILS authentication exchange. The format of the FILS Public Key element is shown in Figure 9-647.

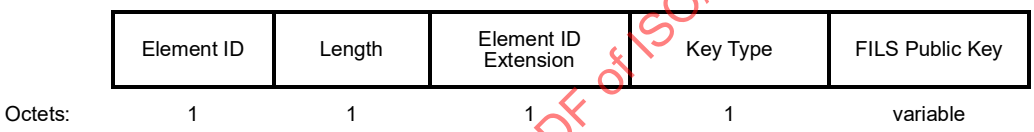

Figure 9-647—FILS Public Key element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Key Type field values are as follows:

0: Reserved.
1: FILS Public Key field contains an X.509v3 certificate encoded according to IETF RFC 5280.
2: FILS Public Key field contains an uncertified public key encoded according to IETF RFC 5480.
3: FILS Public Key field contains an uncertified public key encoded according to IETF RFC 3279.
4–255: Reserved.

9.4.2.181 AP Configuration Sequence Number (AP-CSN) element

An AP-CSN element indicates the change of system information within a BSS. The format of the AP-CSN element is shown in Figure 9-648.

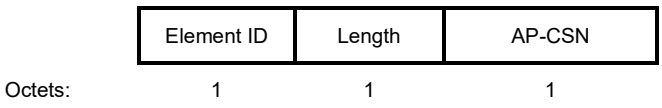

Figure 9-648—AP-CSN element format

The Element ID and Length fields are defined in 9.4.2.1.

The AP-CSN contains the version number of the BSS Configuration Parameter Set. This value increments when an update of the non-dynamic elements (all elements except dynamic elements indicated in 11.1.4.3.11) inside a Beacon frame has occurred, as described in 11.1.4.3.11.

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9.4.2.182 FILS Indication element

The FILS Indication element shown in Figure 9-649 contains information related to FILS authentication and higher layer setup capabilities of the AP.

	Element ID	Length	FILS Information	Cache Identifier	HESSID	Realm Identifier	Public Key Identifier
Octets:	1	1	2	0 or 2	0 or 6	variable	variable

Figure 9-649—FILS Indication element format

The Element ID and Length fields are defined in 9.4.2.1.

The FILS Information field provides information on the presence of the following optional fields in the FILS Indication element and the capability of the FILS authentication algorithms. The format of the FILS Information field is shown in Figure 9-650.

	B0 B2	B3 B5	B6	B7	B8	B9	B10	B11	B12 B15
	Number of Public Key Identifi-ers	Number of Realm Identifi-ers	FILS IP Address Configu-ration	Cache Identifier Included	HESSID Included	FILS Shared Key Authentic ation without PFS Sup-ported	FILS Shared Key Authentic ation with PFS Sup-ported	FILS Public Key Authenti cation Sup-ported	Reserved
Bits:	3	3	1	1	1	1	1	1	4

Figure 9-650—FILS Information field format

The Number of Public Key Identifiers subfield lists the number of Public Key Identifiers that are present in the Public Key Identifiers field in the FILS Indication element. When the Number of Public Key Identifiers subfield is 0, the Public Key Identifier field is not present in the FILS Indication element. Each Public Key Identifier is formatted per Figure 9-652. Up to seven Public Key Identifiers fields may be carried in a FILS Indication element.

The Number of Realm Identifiers subfield lists the number of realm identifiers that are present in the Realm Identifier field in the FILS Indication element. When the Number of Realm Identifiers subfield is 0, the Realm Identifier field is not present in the FILS Indication element. Each realm identifier is formatted per Figure 9-651. Up to seven Realm Identifiers fields may be carried in FILS Indication element.

An AP sets the FILS IP Address Configuration bit to 1 if the AP supports FILS IP address configuration and is set to 0 otherwise.

The Cache Identifier Included bit is set in the FILS Information field when PMKSA caching is supported. When the Cache Identifier Included bit is 1, a 2-octet Cache Identifier field is present in the FILS Indication element. When the Cache Identifier Included bit is 0 the Cache Identifier field is not present in the FILS Indication element. The content of the Cache Identifier field is an opaque octet string that identifies the scope in which PMKSAs are cached. The assignment of the cache identifier is outside the scope of the standard but its value must be unique per authenticator within an ESS. On the AP, dot11CacheIdentifier contains the value of the Cache Identifier.

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When the HESSID Included bit is 1, a 6-octet HESSID field is present in the FILS Indication element. When the HESSID Included bit is 0, the HESSID field is not present in the FILS Indication element. The HESSID field is set to the value of dot11HESSID.

An AP sets the FILS Shared Key authentication without PFS Supported bit to 1 if the AP supports FILS Shared Key authentication without PFS and sets it to 0 otherwise. An AP sets the FILS Shared Key authentication with PFS Supported bit to 1 if the AP supports FILS Shared Key authentication with PFS and sets it to 0 otherwise. An AP sets the FILS Public Key Authentication Supported bit to 1 if the AP supports FILS Public Key authentication and sets it to 0 otherwise.

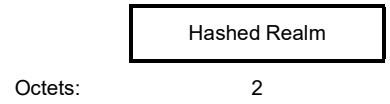

Figure 9-651—Realm Identifier field format

The Hashed Realm subfield of the Realm Identifier field entry is computed from the realm that is compliant with the preferred name syntax defined in IETF RFC 1035 (same as the domain name used in 9.4.5.15). The exact computation method for the hashed realm is given in 11.42.4.

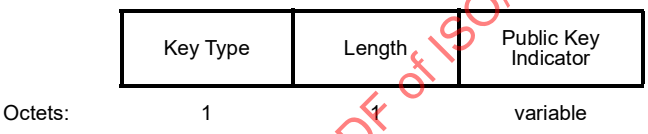

Figure 9-652—Public Key Identifier field format

The Key Type and Public Key Indicator subfields are described in Table 9-289. The Length subfield indicates the length in octets of the Public Key Indicator subfield.

Table 9-289—Key Type and Public Key Indicator subfields

Key Type subfield	Public Key Indicator subfield
0	Reserved
1	The Issuer, per IETF RFC 5280, of the AP's certificate
2	A SHA-256 hash of the AP's uncertified IETF RFC 5480 public key
3	A SHA-256 hash of the AP's uncertified IETF RFC 3279 public key
4–255	Reserved

9.4.2.183 FILS HLP Container element

The FILS HLP Container element contains higher layer protocol (HLP) packets transported during FILS association. If dot11FILSActivated is true, one or more FILS HLP Container elements may be included in a (Re)Association Request or Response frame. This element is used for higher layer protocol packet encapsulation (11.45.3.2). The format of the FILS HLP Container element is shown in Figure 9-653.

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	Element ID	Length	Element ID Extension	Destination MAC Address	Source MAC Address	HLP Packet
Octets:	1	1	1	6	6	variable

Figure 9-653—FILS HLP Container element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Destination MAC Address field and the Source MAC Address field are set as described in 11.45.3.2.

The HLP Packet field contains the HLP packet.

9.4.2.184 FILS IP Address Assignment element

9.4.2.184.1 General

The FILS IP Address Assignment element is used by a STA to request or to assign an IP address using FILS IP Address Configuration (11.45.3.3). If dot11FILSActivated is true, a FILS IP Address Assignment element may be sent in a (Re)Association Request/Response frame or a FILS Container frame. The format of the FILS IP Address Assignment element is shown in Figure 9-654.

	Element ID	Length	Element ID Extension	IP Address Data
Octets:	1	1	1	variable

Figure 9-654—FILS IP Address Assignment element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The IP Address Data field in (Re)Association Request and FILS Container frames from a non-AP STA to an AP is described in 9.4.2.184.2. The IP Address Data field in (Re)Association Response frame and FILS Container frames from an AP to a non-AP STA is described in 9.4.2.184.3.

9.4.2.184.2 IP Address Data field for request

The format of the IP Address Data field for request is shown in Figure 9-655.

	IP Address Request Control	Requested IPv4 Address (optional)	Requested IPv6 Address (optional)
Octets:	1	0 or 4	0 or 16

Figure 9-655—IP Address Data field format for request

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The format of the IP Address Request Control subfield is shown in Figure 9-656.

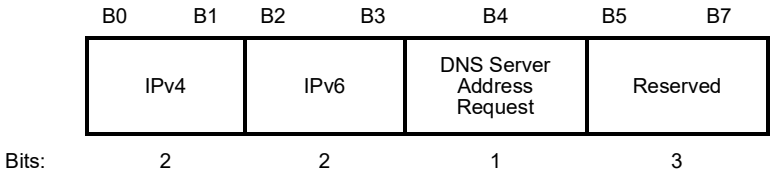

Figure 9-656—IP Address Request Control subfield format

The IPv4 subfields are set as shown in Table 9-290. The IPv6 subfields are set as shown in Table 9-291.

Table 9-290—IPv4 subfield settings

IPv4 subfield	Explanation
0	STA is not requesting an IPv4 address
1	Reserved
2	STA is requesting a new IPv4 address
3	STA is requesting the IPv4 address present in the element

Table 9-291—IPv6 subfield settings

IPv6 subfield	Explanation
0	STA is not requesting an IPv6 address
1	Reserved
2	STA is requesting a new IPv6 address
3	STA is requesting the IPv6 address present in the element

The DNS Server Address Request subfield is 1 if the STA is requesting DNS server(s) address(es). The type of DNS server requested corresponds to the type of the IP address requested. If both IPv4 and IPv6 are requested, then DNS server addresses for both types are also requested by setting this bit to 1.

The Requested IPv4 Address field (4 octets) carries the specific IPv4 address that the non-AP STA is requesting, when the IPv4 field indicates the STA is requesting a specific IPv4 address.

The Requested IPv6 Address field (16 octets) carries the specific IPv6 address that the non-AP STA is requesting, when the IPv6 field indicates the STA is requesting a specific IPv6 address.

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9.4.2.184.3 IP Address Data field for response

The format of the IP Address Data field for response is shown in Figure 9-657.

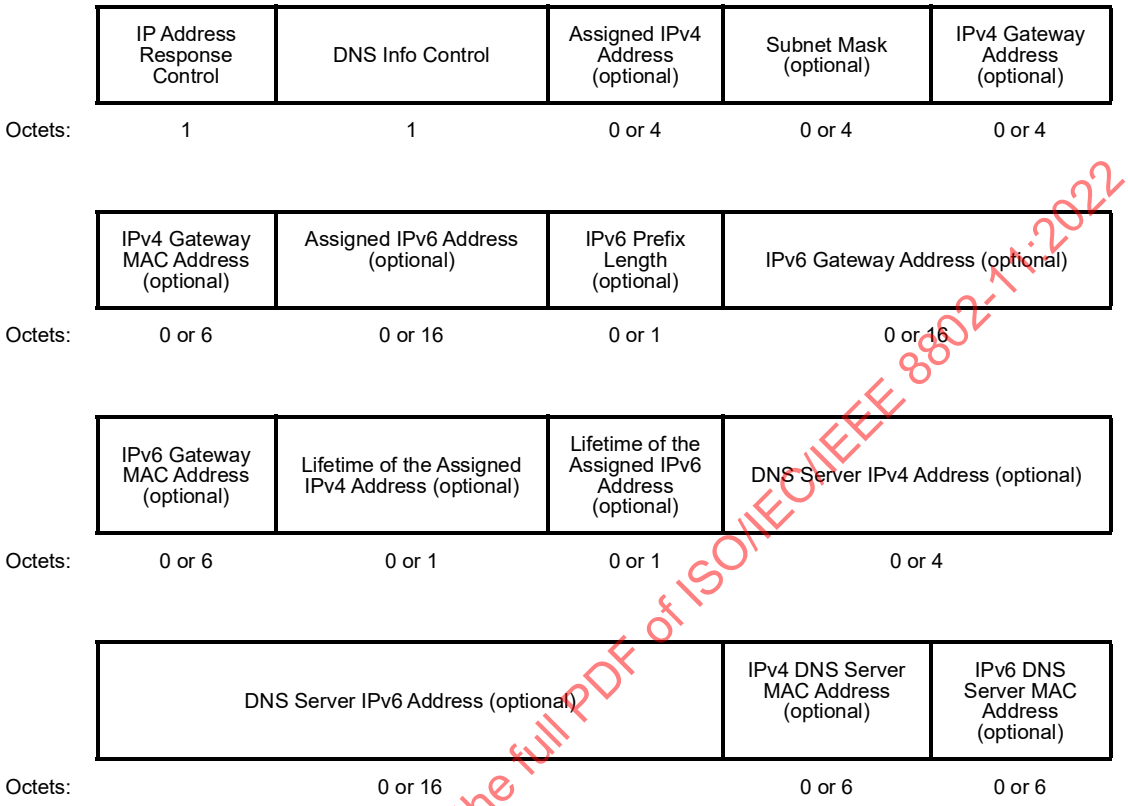

Figure 9-657—IP Address Data field format for response

NOTE—IPv4 addressing is described in IETF RFC 791. IP Subnet and Subnet Mask is described IETF RFC 917. IPv6 addressing, IPv6 prefix and prefix-length is described in IETF RFC 4291. A default gateway in computer networking is a device that is assumed to know how to forward packets on to other networks or the Internet. IPv4 Gateway Address is the IPv4 address of the default gateway when IPv4 is used. IPv6 Gateway Address is the IPv6 address of the default gateway when IPv6 is used. The IPv6 Gateway MAC address is the MAC address of the IPv6 default gateway.

Subfields of the IP Address Response Control field (8 bits) are interpreted dependent on the value of B0 (IP Address pending) as defined in Table 9-292 and Table 9-293.

Table 9-292—IP Address Response Control subfield with B0 = 0

Bit	Function of the subfield	Explanation
B0	IP address pending	Set to 0 if an IP address assignment is included in the frame. B1 to B6 are set as shown below in this table when B0 = 0.
B1	IPv4 assigned	Set to 1 if the Assigned IPv4 Address subfields are included in the element, and set to 0 otherwise.
B2	IPv4 gateway included	Set to 1 if IPv4 Gateway Address and IPv4 Gateway MAC Address subfields are included in the element and set to 0 otherwise. See NOTE.

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Table 9-292—IP Address Response Control subfield with B0 = 0 *(continued)*

Bit	Function of the subfield	Explanation
B3	IPv6 assigned	Set to 1 if Assigned IPv6 Address and IPv6 Prefix Length subfields are included in the element and set to 0 otherwise.
B4	IPv6 gateway included	Set(to 1 if IPv6 Gateway Address and IPv6 Gateway MAC Address subfields are included in the element and set to 0 otherwise. See NOTE.
B5	Lifetime of the assigned IPv4 address included	Set to 1 if Assigned IPv4 Address subfield is present and the Lifetime of the Assigned IPv4 Address is included in the element. If this bit is 0, and if Assigned IPv4 Address subfield is present, then the assigned IPv4 address is valid during the entire time of association with the AP.
B6	Lifetime of the assigned IPv6 address included	Set to 1 if Assigned IPv6 Address subfield is present and the Lifetime of the Assigned IPv6 Address is included in the element. If this bit is 0, and if Assigned IPv6 Address subfield is present, then the assigned IPv6 address is valid during the entire time of association with the AP.
B7	Reserved	

NOTE—A STA in a purely local network environment might be assigned an IP address without requiring a gateway address.

Table 9-293—IP Address Response Control subfield with B0 = 1

Bit	Function of the subfield	Explanation
B0	IP address pending	Set to 1 if an IP address is sent in a later transmission. An IP address is NOT present in the frame when set to 1. B1 to B6 are set as shown below in this table when B0 = 1.
B1–B6	IP address request timeout	IP address request timeout value is the maximum estimated time in the unit of seconds within which an IP address may be assigned and a DNS server address maybe provided to the requesting STA. The value of 0 is reserved.
B7	Reserved	

The format of the DNS Info Control subfield is shown in Figure 9-658 and the DNS Info Control subfield settings are shown in Table 9-294.

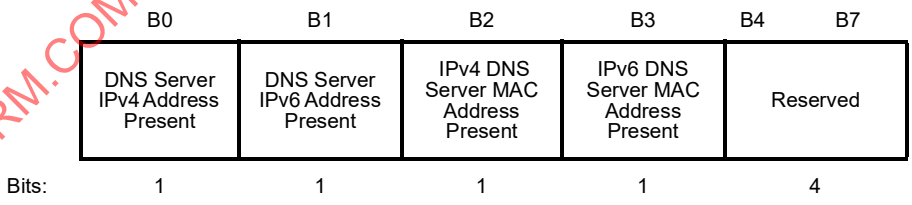

Figure 9-658—DNS Info Control subfield format

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Table 9-294—DNS Info Control subfield settings

Bit	Function of the subfield	Explanation
B0	DNS server IPv4 address included	Set to 1 if the DNS Server IPv4 Address subfield is present in the element and set to 0 otherwise. The value of the DNS Server IPv4 Address subfield is the IPv4 address of the DNS server if the DNS Server IPv4 address Present bit of the DNS Info Control subfield is 1.
B1	DNS server IPv6 address included	Set to 1 if the DNS Server IPv6 Address subfield is present in the element and set to 0 otherwise. The value of the DNS Server IPv6Address is the IPv6 address of the DNS server if the DNS Server IPv6 address Present bit of the DNS Info Control is 1.
B2	IPv4 DNS server MAC address included	Set to 1 if the MAC address to which IPv4 based DNS queries can be sent is present in the element and set to 0 otherwise. The value of the IPv4 DNS Server MAC Address subfield is the MAC address of the IPv4 DNS server if the IPv4 DNS Server MAC Address Present bit of the DNS Info Control subfield is 1.
B3	IPv6 DNS server MAC address included	Set to 1 if the MAC address to which IPv6 based DNS queries can be sent is present in the element and set to 0 otherwise. The value of the IPv6 DNS Server MAC Address subfield is the MAC address of the IPv6 DNS server if the IPv6 DNS Server MAC Address Present bit of the DNS Info Control subfield is 1.

9.4.2.185 Key Delivery element

The Key Delivery element contains the current Key RSC and one or more KDEs. This is used to communicate the Key RSC and one or more KDEs in a FILS authentication exchange. The format of the Key Delivery element is shown in Figure 9-659.

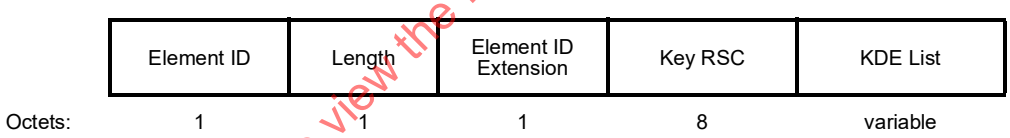

Figure 9-659—Key Delivery element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Key RSC field contains the current receive sequence counter (RSC) for the GTK being installed.

The KDE List field contains one or more KDEs encapsulated using the format shown in Figure 12-35.

9.4.2.186 DILS element

The DILS element includes the conditions for a STA to determine whether it is allowed to attempt fast initial link setup for the duration specified in the element. The DILS element is optionally present in the Beacon and Probe Response frames. The DILS element is defined in Figure 9-660.

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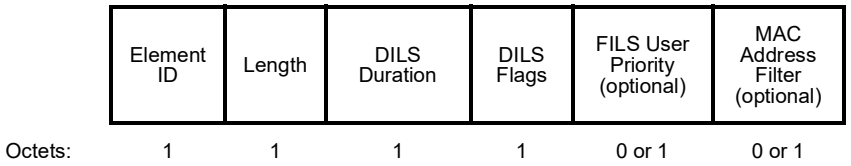

Figure 9-660—DILS element format

The Element ID and Length fields are defined in 9.4.2.1.

The DILS Duration field contains an unsigned integer that specifies the duration for the DILS restrictions (see 11.45.5.3), expressed in units of 10 ms, starting from the beginning of the frame transmission of the DILS element.

The DILS Flags field (see Figure 9-661) indicates the presence of optional fields following it.

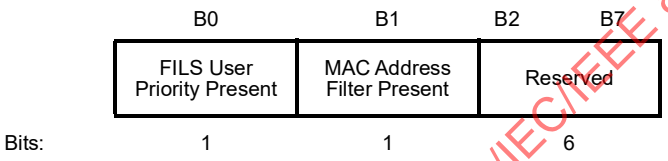

Figure 9-661—DILS Flags field format

Setting the FILS User Priority Present or MAC Address Filter Present subfields to 1 indicates that the corresponding field is present. At least one of the nonreserved bits in the DILS Flags field is set to 1.

The FILS User Priority field is defined in Figure 9-662.

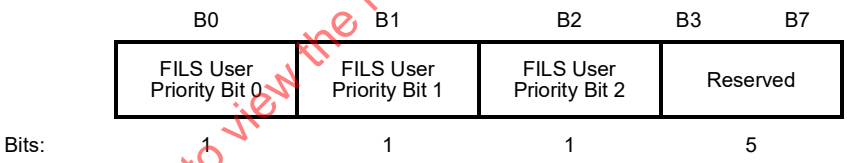

Figure 9-662—FILS User Priority field format

A value of 1 in the FILS User Priority Bit 0 subfield indicates FILS without additional delays for the STAs that have frames with User Priority 4–7 in their transmission queues, a value of 1 in the FILS User Priority Bit 1 subfield indicates high priority for the STAs that have frames with User Priority 0–3 in their transmission queues. A value of 1 in the FILS User Priority Bit 2 subfield indicates high priority for the STAs that have no frames in their transmission queues. See 11.45.5.2.

The MAC Address Filter field is defined in Figure 9-663.

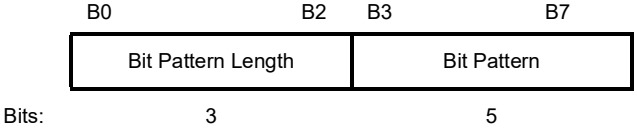

Figure 9-663—MAC Address Filter field format

The usage of the Bit Pattern Length subfield and Bit Pattern subfield is defined in Table 9-295. The Bit Pattern Length subfield specifies the number of bits and the position of the bits in the Bit Pattern subfield

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that are used for MAC address filtering. The Bit Pattern subfield specifies the MAC addresses of the STAs that are allowed to attempt fast initial link setup. The details of MAC address filtering are described in 11.45.5.3.

Table 9-295—MAC Address Filter field

Bit Pattern Length value B0 B1 B2	Bit Pattern				
	B3	B4	B5	B6	B7
1	Reserved	Reserved	Reserved	Reserved	Used for MAC address filtering
2	Reserved	Reserved	Reserved	Used for MAC address filtering	
3	Reserved	Reserved	Used for MAC address filtering		
4	Reserved	Used for MAC address filtering			
5	Used for MAC address filtering				
0	Reserved				
6–7	Reserved				

9.4.2.187 FILS Wrapped Data element

The FILS Wrapped Data element is used for the STA and AP to communicate data used by the FILS authentication algorithm. The format of the FILS Wrapped Data element is defined in Figure 9-664.

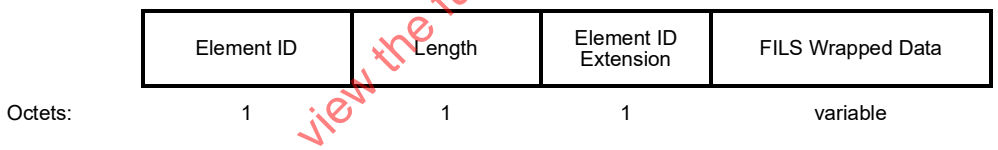

Figure 9-664—FILS Wrapped Data element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The FILS Wrapped Data field is the data used by the FILS authentication algorithm (see 12.11).

9.4.2.188 Fragment element

Elements are defined to have a common general format, per 9.4.2.1. The Length field of an Element is 1 octet, and thus limited to indicate 255 octets of payload in the Information field. However, since the Element ID Extension field is optional and included in the 1-octet Length count, the actual Information payload of an Element is limited to 254 octets if the Element ID Extension is present. If the information to be represented in an element is too large for this 255 or 254 octet limit, it is necessary to fragment the information as described in 10.28.11 and 10.28.12.

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The format of the Fragment element is shown in Figure 9-665.

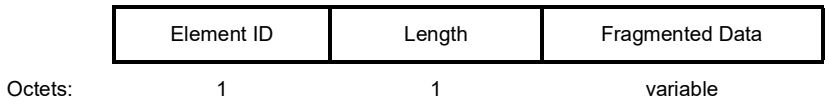

Figure 9-665—Fragment element format

The Element ID and Length fields are defined in 9.4.2.1.

The Fragmented Data field contains the data of the element that is fragmented as described in 10.28.11.

For the information being fragmented, each Fragment element contains 255 octets, except the final Fragment element that contains 1 to 255 octets.

9.4.2.189 FILS Nonce element

The FILS Nonce element is used for exchanging an additional source of randomness in the FILS authentication exchange. The format of the FILS Nonce element is shown in Figure 9-666.

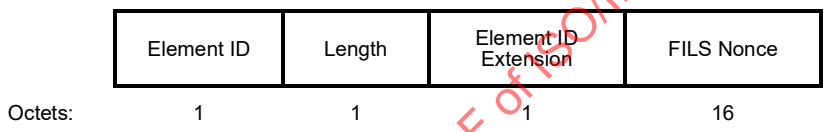

Figure 9-666—FILS Nonce element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The FILS Nonce field contains randomly generated data.

9.4.2.190 S1G Open-Loop Link Margin Index element

The S1G Open-Loop Link Margin Index element contains the link margin information. The S1G Open-Loop Link Margin Index element is optionally included in an S1G Beacon frame or a Probe Response frame without a corresponding request. The format of the S1G Open-Loop Link Margin Index element is shown in Figure 9-667.

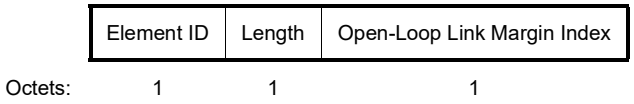

Figure 9-667—S1G Open-Loop Link Margin Index element format

The Element ID and Length fields are defined in 9.4.2.1.

The Open-Loop Link Margin Δ_{OPLM} is defined as the summation of transmit power P_{tx} and the receiver sensitivity $RX_{sensitivity}$

$$\Delta_{OPLM} = P_{tx1} + RX_{sensitivity}$$

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The transmit power P_{tx1} indicates the actual power used as measured at the antenna connector, in units of dBm, by a STA when transmitting the frame containing the S1G Open-Loop Link Margin Index element. The receiver sensitivity $RX_{sensitivity}$ is the minimum required receive power for reception of MCS 10 for 1 MHz channel.

The S1G Open-Loop Link Margin Δ_{OPLM} is calculated as (–128 + D × 0.5) dB, where D is called Open-Loop Link Margin Index. D is an unsigned integer value that is contained in S1G Open-Loop Link Margin Index field. For example, if the value D shown in S1G Open-Loop Link Margin Index field is 0, then it indicates the S1G Open-Loop Link Margin Δ_{OPLM} is –128 dB. If the value D shown in S1G Open-Loop Link Margin Index field is 255, then it indicates the S1G Open-Loop Link Margin Δ_{OPLM} is –0.5 dB.

The S1G Open-Loop Link Margin Index element can be used for open-loop link adaptation and open-loop transmit power control. When a STA receives the Open-loop link Margin index, it can calculate the S1G Open-Loop Link Margin Δ_{OPLM} by using (–128 + D × 0.5) dB. Then the SNR margin over the MCS 10 can be derived at the STA that receives the frame that contains S1G Open-Loop Link Margin Index based on its own transmit power P_{tx2} and the received RSSI measured for the PPDU containing the S1G Open-Loop Link Margin Index.

$$SNR_{Margin} = P_{tx2} - \Delta_{OPLM} + RSSI$$

9.4.2.191 RPS element

The RPS element contains one or more RAW Assignment subfields. Each RAW Assignment subfield contains parameters necessary to restrict medium access to one or multiple STAs within one RAW. The format of the RPS element is defined in Figure 9-668.

	Element ID	Length	RAW Assignments
Octets:	1	1	variable

Figure 9-668—RPS element format

The Element ID and Length fields are defined in 9.4.2.1.

The RAW Assignments field contains one or more RAW Assignment subfields.

The format of the RAW Assignment subfield is shown in Figure 9-669. The RAW Start Time, RAW Group, Channel Indication, and Periodic Operation Parameters subfields are conditionally present.

	RAW Control	RAW Slot Definition	RAW Start Time	RAW Group	Channel Indication	Periodic Operation Parameters
Octets:	1	2	0 or 1	0 or 3	0 or 2	0 or 3

Figure 9-669—RAW Assignment subfield format

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The format of the RAW Control subfield is shown in Figure 9-670.

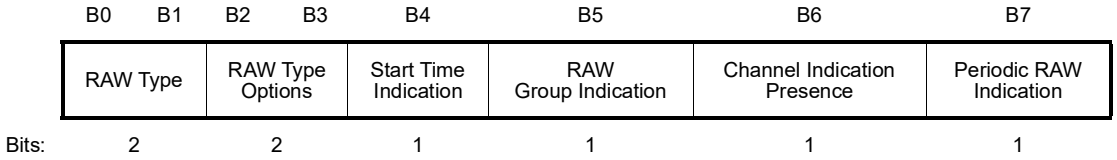

Figure 9-670—RAW Control subfield format

The value of the RAW Type field indicates the type of the RAW defined by the RAW assignment. The interpretation of the RAW Type subfields is shown in Table 9-296.

Table 9-296—Interpretation of RAW Type and RAW Type Options

RAW Type	Description	RAW Type Options subfield
0	Generic RAW	Bit 0 (Bit 2 of RAW Control subfield): Paged STA Bit 1 (Bit 3 of RAW Control subfield): RA frame
1	Sounding RAW	0: SST sounding RAW 1: SST report RAW 2: Sector sounding RAW 3: Sector report RAW
2	Simplex RAW	0: AP PM RAW 1: Non-TIM RAW 2: Omni RAW 3: Reserved
3	Triggering frame RAW	Reserved

The different types of RAWs are interpreted as follows:

— Generic RAW: used to provide restricted medium access only to a group of STAs.

— Sounding RAW: either used for SST sounding/SST report (SST RAW) or sector sounding/sector report (Sector RAW) as indicated by the RAW Type Options subfield as follows:

  — When the sounding RAW is used as an SST sounding RAW or a sector sounding RAW, non-AP STAs do not initiate a TXOP during the RAW but elect to listen to sector sounding (described in 10.53.5.2) or SST sounding (described in 10.52). Non-AP STAs are allowed to transmit response frames during the RAW.

  — When the sounding RAW is used as an SST report RAW or a sector report RAW, as a response to the preceding SST sounding RAW or sector sounding RAW, STAs in the RAW Group can transmit a report frame to the AP during the SST report RAW as described in 10.52, or transmit sector ID feedback frame to the AP during the sector report RAW as described in 10.53.5 regardless of their corresponding TIM bits.

— Simplex RAW: the Slot Definition Format Indication, Cross Slot Boundary, and Number of Slots subfields of the Slot Definition field are set to 1, and the RAW is either used for AP Power Management (as described in 11.2.3.18), for reserving channel time for S1G STAs in non-TIM mode, or for the omni RAW depending on the values of RAW Type Options subfield as follows:

  — When the RAW is used as the non-TIM RAW as indicated by the RAW Type Options subfield, the access is restricted to S1G STAs in non-TIM mode that have been previously scheduled within the RAW such as TWT STAs or doze awake cycle rescheduled STAs (as described

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in 10.48.2). The RAW Assignment subfield for non-TIM RAW also conditionally contains the RAW Start Time, Channel Indication, and Periodic Operation Parameters subfields.

- When the RAW is used as the AP PM RAW as indicated by the RAW Type Options subfield, the RAW Assignment subfield for AP PM RAW also conditionally contains the RAW Start Time and Periodic Operation Parameters subfields.
- When the RAW is used as the omni RAW as indicated by the RAW Type Options subfield of the RAW Assignment subfield for omni RAW, the access is not restricted for any specific STA and this duration can be used by non-AP STAs to communicate with the AP that has scheduled the omni RAW to send the Probe Request frame or Association Request frame. The RAW assignment subfield of the omni RAW also conditionally contains the RAW Start Time, and Periodic Operation Parameters subfields.

— Triggering Frame RAW: each paged STA belonging to the RAW group is allowed to send one specific trigger frame as described in 10.23.5.4 during its assigned RAW slot. The procedure of RAW slot assignment is described in 10.23.5.3.

The Start Time Indication subfield indicates whether the RAW Start Time subfield is present in the RAW Assignment subfield or not. If it is equal to 0, the RAW Start Time subfield is not present. If it is equal to 1, the RAW Start Time subfield is present. In the first RAW assignment, the Start Time Indication subfield equal to 0 indicates that the RAW starts immediately after the S1G Beacon, the Probe Response frame, or the PV1 Probe Response that includes the RPS element. For other RAW assignments, the Start Time Indication subfield equal to 0 indicates that the current RAW starts immediately after the end of the previous RAW.

The RAW Group Indication subfield indicates whether the RAW Group subfield is present in the RAW Assignment subfield and is interpreted as follows:

- When the RAW type is generic RAW, sounding RAW, or triggering frame RAW, the RAW Group Indication subfield indicates whether the RAW group defined in the current RAW assignment is the same RAW group as defined in the previous RAW assignment. When the RAW Group Indication subfield is equal to 0, the RAW group defined in the current RAW assignment is the same as the RAW group defined in the previous RAW assignment and the RAW Group subfield is not present in this RAW assignment. When the RAW Group Indication subfield is equal to 1, the RAW Group subfield is present in this RAW assignment. The RAW Group Indication subfield in the first RAW assignment is set to 0 to indicate the RAW group in the first RAW assignment is the same as the range of AIDs in all the TIM bitmaps in the S1G Beacon frame.
- When the RAW is a non-TIM RAW, the RAW Group Indication subfield is set to 0 and the RAW Group subfield is not present.
- When the RAW is an AP PM RAW, the RAW Group Indication subfield equal to 0 indicates that the RAW group does not include any of the non-AP STAs, and the RAW Group subfield is not present. When the RAW Group Indication subfield is equal to 1, the RAW Group subfield is present.

The Channel Indication Presence subfield indicates whether the Channel Indication subfield in the current RAW assignment is present or not. If it is equal to 0, the Channel Indication subfield is not present. If it is equal to 1, the Channel Indication subfield is present.

The Periodic RAW Indication subfield indicates whether the RAW is periodic. When the Periodic RAW Indication subfield is equal to 1, the RAW is a periodic restricted access window (PRAW), and the Periodic Operation Parameters subfield is present. When the Periodic RAW Indication subfield is equal to 0, the Periodic Operation Parameters subfield is not present.

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The definitions of RAW Type Options subfield are specified in Table 9-296. The RAW Type Options subfield is interpreted as follows:

— For generic RAW, Bit 0 of the RAW Type Options (Bit 2 of the RAW Control subfield) is Paged STA indication. When it is equal to 0, the RAW can be accessed by any STA (paged or unpaged) within the RAW group specified by the RAW Group subfield. When it is equal to 1, the RAW can only be accessed by paged STAs within the RAW group specified by the RAW Group subfield. Bit 1 of the RAW Type Options (Bit 3 of the RAW Control subfield) is RA Frame Indication. If it is equal to 1, the AP will transmit a Resource Allocation frame, as defined in 9.8.5.4, at the beginning of the RAW defined by the RAW Assignment subfield of the RPS element.

— For sounding RAW, the RAW Type Options subfield is treated as one subfield, the interpretation of which is defined in Table 9-296. For Simplex RAW, the RAW Type Options subfield is treated as one subfield, the interpretation of which is defined in Table 9-296.

— For Triggering Frame RAW, the RAW Type Options subfield is reserved.

The format of the RAW Slot Definition subfield is shown in Figure 9-671.

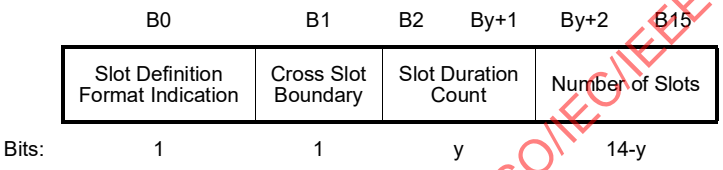

Figure 9-671—RAW Slot Definition subfield format

The Slot Definition Format Indication subfield indicates the number of bits used for the Slot Duration Count subfield, i.e., the value y in Figure 9-671 of the Slot Duration Count subfield. If it is set 0, the Slot Duration Count subfield is 8 bits (y=8). If it is equal to 1, the Slot Duration Count subfield is 11 bits (y=11). When the RAW Type is sounding RAW, the Slot Duration Count subfield is 8 bits in length (y=8).

The Cross Slot Boundary subfield indicates whether STAs are allowed to transmit after the assigned RAW slot boundary. If the bit is equal to 1, crossing a RAW slot boundary is allowed. If the bit is equal to 0, crossing a RAW slot boundary is not allowed for transmissions from STAs.

The Slot Duration Count subfield is an unsigned integer and it is used to calculate the duration of a RAW slot, or the RAW slot duration. The RAW slot duration, DSLOT, has time unit of microsecond and it is calculated as:

$$D_{\mathrm{SLOT}} = 500 + C_{\mathrm{SLOT}} \times 120$$

where

C_{SLOT} is the value of the Slot Duration Count subfield

The Number of Slots subfield is an unsigned integer and indicates the number of RAW slots (N_{RAW}) in the RAW.

The Slot Definition subfield is used to calculate the RAW duration. The RAW duration indicates the duration, in units of microsecond, of the restricted medium access assigned to a RAW. The RAW duration, D_{RAW}, indicated by the corresponding RAW assignment can be calculated as follows:

$$D_{\mathrm{RAW}} = D_{\mathrm{SLOT}} \times N_{\mathrm{RAW}}$$

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where

D_{SLOT} is the RAW slot duration, in microseconds

N_{RAW} is the value of the Number of Slots subfield

When the RAW Type is generic RAW or triggering frame RAW, the RAW Slot Definition subfield also provides the N_{RAW} and slot duration information for RAW slot assignment. The procedure of RAW slot assignment is described in 10.23.5.3.

The RAW Start Time subfield indicates the duration, in units of 2 TUs, from the end of the S1G Beacon, the Probe Response, or the PV1 Probe Response frame transmission that includes the RPS element to the start time of the RAW.

The format of the RAW Group subfield is shown in Figure 9-672.

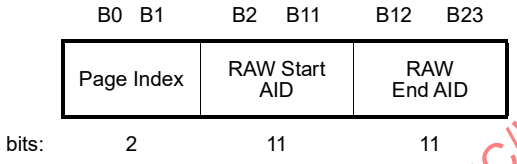

Figure 9-672—RAW Group subfield format

The RAW Group subfield indicates the STA AIDs that are allowed restricted access within the RAW period. The RAW Group subfield contains Page Index, RAW Start AID, and RAW End AID subfields according to the hierarchical addressing method of AIDs (see Figure 9-152). The Page Index subfield indicates the page index of the subset of AIDs.

The RAW Start AID field indicates the 11 LSBs of the AID of the STA with the lowest AID allocated in the RAW.

The RAW End AID field indicates the 11 LSBs of the AID of the STA with the highest AID allocated in the RAW.

The RAW Group field is set to all 0s to indicate that all STAs are allowed to access within the RAW.

The format of the Channel Indication subfield is shown in Figure 9-673. The Channel Activity Bitmap subfield shows the allowed operating channels for the STAs indicated in the RAW, as defined in 10.23.5.1. Each bit in the bitmap corresponds to one minimum width channel within the current BSS operating channels, with the least significant bit corresponding to the lowest numbered operating channel of the BSS. The Maximum Transmission Width, UL Activity, and DL Activity subfields are defined similarly as in 9.4.2.201.

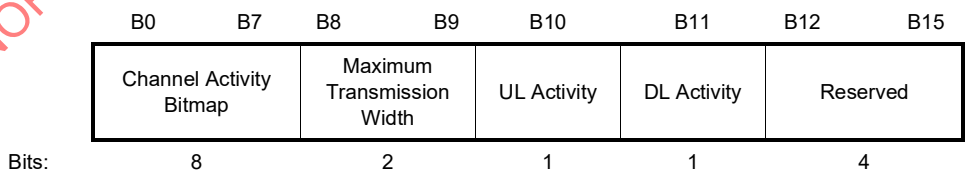

Figure 9-673—Channel Indication subfield format

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The Periodic Operation Parameters subfield comprises the PRAW Periodicity, PRAW Validity, and PRAW Start Offset subfields. The format of the Periodic Operation Parameters subfield is shown in Figure 9-674.

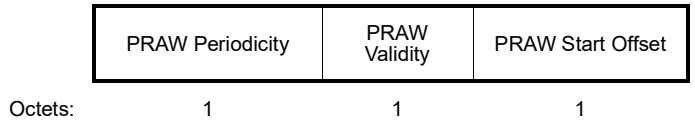

Figure 9-674—Periodic Operation Parameters subfield format

The PRAW Periodicity subfield indicates the period of current PRAW occurrence in the unit of beacon interval if dot11ShortBeaconInterval is false and in the unit of short beacon interval if dot11ShortBeaconInterval is true (see 11.1.3.10.2).

The PRAW Validity subfield indicates the number of periods that the PRAW repeats. A nonzero PRAW Validity subfield indicates the number of remaining PRAW occurrences, while a PRAW Validity subfield equal to 0 indicates that the PRAW validity is not determined.

The PRAW Start Offset subfield indicates the offset value from the end of the frame that carries the current RPS element to the S1G Beacon frame that the first window of the PRAW appears, in units of beacon interval or short beacon interval.

9.4.2.192 Page Slice element

The Page Slice element contains a subset of blocks from a single page, called a page slice. The STAs included in a page slice and indicated by the Page Slice element are served in the time intervals between Beacon frames within a page period, starting from the Beacon frame that carries the Page Slice element for the page (see 10.51). The frame format of the Page Slice element is defined in Figure 9-675.

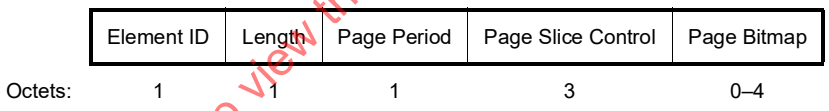

Figure 9-675—Page Slice element format

The Element ID and Length fields are defined in 9.4.2.1.

The Page Period field indicates the number of beacon intervals between successive beacons that carry the Page Slice element for the associated page.

The Page Slice Control field format is shown in Figure 9-676.

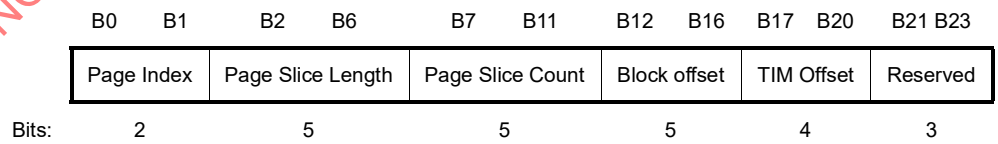

Figure 9-676—Page Slice Control field format

The Page Index subfield indicates the page whose slices are served during beacon intervals within a page period. Setting the Page Index subfield to 1 indicates the second page out of the four pages defined in the hierarchical AID addressing (see 9.4.2.5).

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The Page Slice Length subfield indicates the number of blocks included in each TIM for the associated page except for the last TIM. The Page Slice Length subfield is set to number of blocks in each page slice. The value 0 for the Page Slice Length subfield is reserved. For the last TIM, the size of the last page slice, PS_{last}, is computed as

$$PS_{last} = P_{length} - (PS_{count} - 1) \times PS_{length}$$

where

P_{length} is the length (in bits) of a page indicated in the Page Bitmap field and is calculated as $P_{length} = 8 \times PB_{length}$
PB_{length} is the length of the page (in octets) indicated in the Page Bitmap field
PS_{count} is the value indicated in the Page Slice Count subfield
PS_{length} is the value indicated in the Page Slice Length subfield

For example, with a Page Bitmap field of 2 octets, a value in the Page Slice Length subfield equal to 3, and a value in the Page Slice Count subfield equal to 5, the page slice consists of 4 (=16 – 3×4) blocks for the last TIM, i.e., a value greater than the value indicated in the Page Slice Length subfield. Again, for example, with a Page Bitmap field of 2 octets, a value in the Page Slice Length subfield equal to 6, and a value in the Page Slice Count subfield equal to 3, the page slice consists of 4 (=16 – 6×2) blocks for the last TIM, i.e., a value less than the value indicated in the Page Slice Length subfield.

The number of blocks assigned to all the TIMs, except the last TIM, within a DTIM interval, P_{rem}, is computed as

$$P_{rem} = P_{length} - PS_{last}$$

where

P_{length} is the length of a page indicated in the Page Bitmap field
PS_{last} is the size of the last page slice

For every TIM, a STA computes the location of its block within a page slice, SB_{STA}, using the following equation:

$$SB_{STA} = AID[6:10] - BO$$

where

AID is the association identifier of the STA
BO is the value indicated in the Block Offset subfield of the Page Slice element

If the SB_{STA} is greater than the P_{length} or less than zero, the STA is not included in the page slice for the Page Period, otherwise:

— If SB_{STA} is greater than P_{rem}, the page slice number for the STA indicated in the Page Slice Number field of the TIM element is equal to the value indicated in the Page Slice Count subfield of the Page Slice element
— Otherwise, the page slice number for the STA, PS_{number}, is computed as

$$PS_{number} = \lfloor SB_{STA} / PS_{length} \rfloor$$

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The Page Slice Count subfield indicates the number of TIMs scheduled in one page period, except when the value is equal to 0. This field indicates a maximum of 31 TIMs that include page slices in a page period. The Page Slice Count subfield is set to 0 to indicate signaling that depends on the Page Slice Length subfield:

— If the Page Slice Length subfield is greater than 1, a 0 in the Page Slice Count field indicates that the 32nd TIM that is scheduled during this DTIM interval can contain DL BU information for non-AP STAs that do not support page slicing and for non-AP STAs whose AID is within the 32nd block of this page and do support page slicing.

— If the Page Slice Length subfield is equal to 1, a 0 in the Page Slice Count subfield indicates that all non-AP STAs for which the AP has DL BU are included in the only TIM that is scheduled within the DTIM interval.

The Block Offset subfield indicates the offset of the block in the first page slice from the first block in the page assigned within the page period. Setting the Block Offset field to 16 indicates that the first page slice starts at block 16, i.e., STAs in the second half of the page are assigned within this page period.

The TIM Offset subfield indicates the offset, in number of beacon intervals, from the DTIM Beacon frame that carries the Page Slice element of a page to the beacon that carries the first page slice of the page indicated by the corresponding Page Slice element in the DTIM Beacon frame.

The Page Bitmap field indicates the presence of buffered data for each of the one or more blocks in a page slice or all the assigned page slices within a page period. A bit in the Page Bitmap field indicates information of buffered data for STAs in one block of a page slice corresponding to the location of the bit in the bitmap. The first block indicated in the Page Bitmap field is the block indicated in the Block Offset subfield. Based on the number of page slices assigned to the TIMs, this field is of variable length from 0 to 4 octets. For example, setting the Page Bitmap field to 129 indicates that there is buffered data for at least one STA in the first block and at least one STA in the last block. The bit sequence also indicates that only a page slice of 8 blocks is assigned within a page period. Further, the bit sequence indicates that there is no downlink buffered data for any STA in blocks 2 to 7. Hence these STAs can enter the doze state after receiving the group addressed BUs that are delivered by the AP following the DTIM Beacon frame as described in 11.2.3 and can avoid to wake up for the assigned TIM in the following TBTTs or TSBTTs within the DTIM interval to check for downlink buffered data.

9.4.2.193 AID Request element

The AID Request element contains information related to the characteristics of the device of the non-AP STA requesting an AID. The format of the AID Request element is shown in Figure 9-677.

	Element ID	Length	AID Request Mode	AID Request Interval (Optional)	Peer STA Address (Optional)	Service Characteristic (Optional)	Group Address (Optional)
Octets:	1	1	1	0 or 2	0 or 6	0 or 1	0 or 6

Figure 9-677—AID Request element format

The Element ID and Length fields are defined in 9.4.2.1.

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The format of AID Request Mode field is shown in Figure 9-678.

	B0	B1	B2	B3	B4	B5	B6	B7
	AID Request Interval Present	Peer STA Address Present	Service Characteristic Present	Non-TIM Mode Switch	TIM Mode Switch	Group Address Present	Reserved	
Bits:	1	1	1	1	1	1	2	

Figure 9-678—AID Request Mode field format

The AID Request Interval Present subfield of the AID Request Mode field is set to 1 if the AID Request Interval field is present in the AID Request element and set to 0 if no AID Request Interval field is present.

The Peer STA Address Present subfield of the AID Request Mode field is set to 1 if the Peer STA Address field is present in the AID Request element and set to 0 if no Peer STA Address field is present.

The Service Characteristic Present subfield of the AID Request Mode field is set to 1 if the Service Characteristic field is present in the AID Request element and set to 0 if no Service Characteristic field is present.

The Non-TIM Mode Switch subfield of the AID Request Mode field is set to 1 if the non-AP STA requests to switch from the TIM mode to non-TIM mode. Otherwise, it is set to 0.

The TIM Mode Switch subfield of the AID Request Mode field is set to 1 if the non-AP STA requests to switch from the non-TIM mode to TIM mode. Otherwise, it is set to 0.

The Group Address Present subfield of the AID Request Mode field is set to 1 if the Group Address field is present in the AID Request element and is set to 0 if no Group Address field is present.

The AID Request Interval field indicates to the AP:

— The listen interval, in units of beacon interval or short beacon interval as defined in 9.4.1.6, during which the S1G STA in TIM mode wakes to receive S1G Beacon frames when the Non-TIM Mode Switch field is equal to 0, TIM Mode Switch field is equal to 1, and the Group Address Present field is equal to 0.

— The listen interval, in units of beacon interval or short beacon interval as defined in 9.4.1.6, during which the S1G STA in non-TIM mode is required to transmit at least one PS-Poll or trigger frame to the AP when the Non-TIM Mode Switch field is equal to 1, TIM Mode Switch is equal to 0, and the Group Address Present field is equal to 0.

— The group listen interval, in units of beacon interval or short beacon interval (see 11.1.3.10.2), during which the non-AP STA wakes up to receive the S1G Beacon frames that signal the presence of group addressed BUs for the group MAC address contained in the Group Address field. In this case the Group Address Present field is equal to 1 and the TIM Mode Switch field and Non-TIM Mode Switch field are equal to any value.

The AID Request Interval field contains a Unified Scaling Factor subfield (see Table 9-48) and has a format as defined in Figure 9-89. The AID Request Interval field is calculated as the value of the Unscaled Interval subfield multiplied by the scaling factor that corresponds to the value indicated in the Unified Scaling Factor subfield.

The Peer STA Address field indicates the MAC address of the peer STA for STA-to-STA communication.

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The Service Characteristic field indicates the service characteristic provided by the non-AP STA so that the AP can assign a particular AID to the STA based on the service characteristic when the STA associates or requests AID switch. The format of the Service Characteristic field is shown in Figure 9-679.

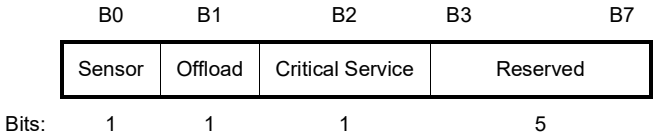

Figure 9-679—Service Characteristic field format

The Sensor subfield of the Service Characteristic field is set to 1 to indicate that the non-AP STA provides a sensor or a meter type services. Otherwise, it is set to 0. The Offload subfield of the Service Characteristic field is set to 1 to indicate that the non-AP STA provides a traffic offloading services. Otherwise, it is set to 0. The Critical Service subfield of the Service Characteristic field is set to 1 to indicate that it provides critical services such as health care, home, industrial, alarm monitoring or emergency services. Otherwise, it is set to 0.

The Group Address field indicates the group MAC address of the requesting STA. When the Group Address field is present in the AID Request element, the AID Request element is carried in an AID Switch Request frame to request a group AID.

9.4.2.194 AID Response element

The AID Response element defines information about the AID assignment. The format of AID Response element is shown in Figure 9-680.

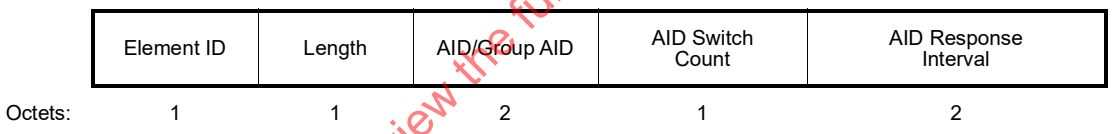

Figure 9-680—AID Response element format

The Element ID and Length fields are defined in 9.4.2.1.

The AID/Group AID field, which has the same format as the AID field described in 9.4.1.8, indicates:

— The AID that is assigned to the non-AP STA if the AID Response element is not sent as a response to an AID Switch Request frame that contained a Group Address field. If the AP does not change the AID of the STA, this field indicates the current AID assigned to the non-AP STA. If the AP changes the AID of the STA, this field indicates the changed AID assigned to the non-AP STA.

— The group AID that is assigned to a group MAC address if the AID Response element is sent as a response to an AID Switch Request frame that contained a Group Address field carrying the group MAC address.

The AID Switch Count field indicates a countdown value, in units of beacon interval or short beacon interval, that the AP sets for the non-AP STA to switch to the new AID or to activate the group AID. The countdown value is expressed in units of beacon interval if dot11ShortBeaconInterval is false and in units of short beacon interval if dot11ShortBeaconInterval is true (see 11.1.3.10.2). The AID Switch Count field indicates the duration after which the (group) listen interval starts and the counter that corresponds to the AID Switch Count field starts upon transmission of the AID Response element. The AID Switch Count field is set to 0 in an AID Response element that is carried in a (Re)Association Response frame.

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The AID Response Interval field indicates to the non-AP STA:

— The listen interval in units of beacon interval or short beacon interval as defined in 9.4.1.6, during which the S1G STA in TIM mode wakes to receive S1G Beacon frames. The S1G Beacon frames that the S1G STA in TIM mode wakes up to listen either include a TIM element that can include their new AID or include a Page Slice element that indicates the assignment of the new AID in the corresponding page slices.

— The listen interval in units of beacon interval or short beacon interval as defined in 9.4.1.6, during which the S1G STA in non-TIM mode is required to transmit at least one PS-Poll or trigger frame to the AP.

— The group listen interval, in units of beacon interval or short beacon interval (see 11.1.3.10.2), during which the non-AP STA is required to wake up for receiving the S1G Beacon frames that signal the presence of group addressed BUs for the group MAC address contained in the Group Address field of the eliciting AID Switch Request frame. The (group) listen interval will start from the first TBTT or TSBTT that follows the expiration of the AID switch counter obtained from the AID Switch Count field of this element.

The AID Response Interval field contains a Unified Scaling Factor subfield (see Table 9-48) and has a format as defined in Figure 9-89. The AID Response Interval field is calculated as the value of the Unscaled Interval subfield multiplied by the scaling factor that corresponds to the value indicated in the Unified Scaling Factor subfield.

9.4.2.195 S1G Sector Operation element

The S1G Sector Operation element includes the information necessary for a receiving STA to determine the type of sector operation, if it is allowed to transmit during a specified sector time interval and if it can perform sector training. The S1G Sector Operation element is optionally present in Probe Response, Beacon or Association Response frames.

The format of the S1G Sector Operation element is presented in Figure 9-681 and later in this subclause in Figure 9-682.

	B0 B7	B8 B15	B16	B17B22	B23	B24B26	B27 B30			
	Element ID	Length	Sectorization Type	Period	Omni	Sector ID	Number of Groups	Group IDs	Sector Duration	Pad
Bits:	8	8	1	6	1	3	4	variable	6	1, 3, 5, or 7

Figure 9-681—S1G Sector Operation element format (sectorization type is group sectorization)

The Element ID and Length fields are defined in 9.4.2.1.

The Sectorization Type field indicates the type of sectorization. When the Sectorization Type field is equal to 0, it indicates that the format of the S1G Sector Operation element is structured for group sectorization operation.

NOTE 1—The Sectorization Type field can be set to 0 only when the Sectorized Beam-Capable field setting is either 2 or 3.

The Period field specifies the time interval, in units of 10 ms, until the next transmission of frames in the sector identified by the Sector ID field.

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The Omni field indicates if the present transmission is sectorized or omnidirectional. When it is equal to 0, it indicates sectorized. When it is equal to 1, it indicates omnidirectional.

The Sector ID field identifies the ID of the active sector. It is reserved when Omni field is equal to 1.

The Number of Groups field indicates the number of Group ID subfields in the Group IDs field following this field.

Each Group ID subfield is 6 bits and identifies the group of STAs that are allowed to transmit during this sector interval.

The Sector Duration field indicates the duration of the current sector transmissions, in units of 10 ms.

The Pad field contains 1, 3, 5, or 7 bits of 0s to make the total number of bits in the S1G Sector Operation element equal to an integer number of octets.

The S1G Sector Operation element can be provided in Association Response frame when dot11S1GSectorizationActivated is true and it indicates the group ID allocated to that STA to be used during the sectorization purpose, the type of sectorization method, the value of the Period field, and the Sector Duration field if all the sector durations are equal. If the Sector Duration field is not equal for all sectors the Sector Duration field provided at the association time is 0. The values of the Sector ID and Omni fields are omitted by the STA in the Association Response frame. By default all the STAs that support group sectorization consider themselves in group ID 0 unless is specified otherwise via the Association Response frame. This way all the STAs can transmit at any time before their association. It is expected that during the association, STAs receive a nonzero group ID, which will restrict their activity to a particular sector interval or during omnidirectional time interval. An AP can allow some STAs to have the group zero even after association, for instance public safety STAs or some high priority sensors.

The S1G Sector Operation element in the Beacon frame provides:

- Information related to the type of sectorization operation;
- Indication if the Beacon frame is sectorized or not;
- The sector ID of the current sector;
- The group ID that identifies the group allowed transmitting during the current sector duration; and
- The duration of this sector.

A STA that receives a Beacon frame that includes an S1G Sector Operation element determines if the received Beacon frame is sectorized or omnidirectional. If the received Beacon frame is omnidirectional the STAs are allowed to transmit in all geographical sectors provided that their group ID is group zero or it is listed in S1G Sector Operation element. If the received Beacon frame is sectorized, the STAs with group zero from any sector are allowed to transmit and the STAs that receive the sectorized Beacon frame and have the group ID listed in the S1G Sector Operation element are allowed to transmit during the current sector duration. A Beacon frame that not carries an S1G Sector Operation element does not impose any sectorization restriction on the receiving STAs.

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When the sectorization type is TXOP-based sectorization operation, the element is presented in Figure 9-682.

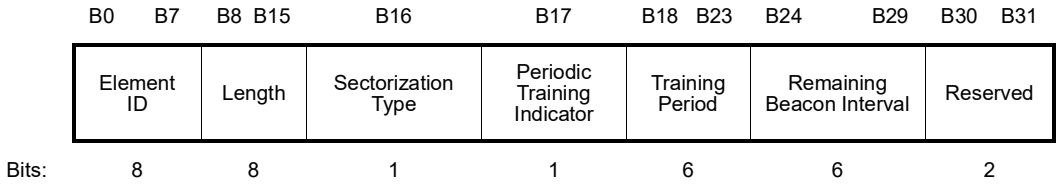

Figure 9-682—S1G Sector Operation element format (sectorization type is TXOP-based sectorization operation)

The Sectorization Type field is set to 1 to indicate that the format of the S1G Sector Operation element is structured for the TXOP-based sectorization operation.

NOTE 2—The Sectorization Type field can be set to 1 only when the Sectorized Beam-Capable field setting is 1 or 3.

The Periodic Training Indicator field is set to 1 to indicate periodic sector training is conducted by the AP and STAs can perform sector training. The Periodic Training Indicator field is set to 0 to indicate periodic sector training is not conducted by the AP.

The Training Period field is set to the number of beacon intervals in which the AP repeats the sector training.

The Remaining Beacon Interval field is set to the number of beacon intervals remaining before the next sector training commences. Setting the field to indicates the sector training is conducted in the current beacon interval.

9.4.2.196 S1G Beacon Compatibility element

The S1G Beacon Compatibility element carries the information that is shown in Figure 9-683.

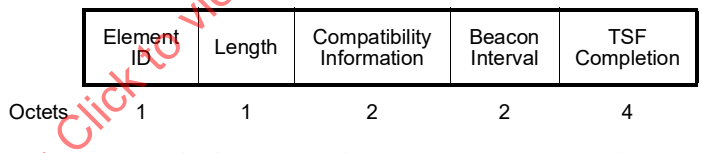

Figure 9-683—S1G Beacon Compatibility element format

The Element ID and Length fields are defined in 9.4.2.1.

The Compatibility Information field contains all the subfields defined in 9.4.1.4 except for the subfield located in B6 of the field, which is defined as the TSF Rollover Flag subfield. An S1G AP sets the TSF Rollover Flag subfield to the value of the most significant bit of the 4 least significant octets of the TSF timer at the time the TSF timer is read for the purpose of creating the element carrying the Compatibility Information field.

The Beacon Interval field in the element is defined in 9.4.1.3.

The TSF Completion field carries the 4 most significant octets of the TSF timer at the AP at the time of generation of the element carrying the TSF Completion field.

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9.4.2.197 Short Beacon Interval element(

The Short Beacon Interval element carries the short beacon interval and its format is shown in Figure 9-684.

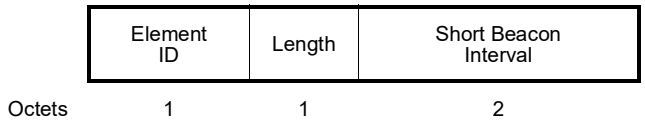

Figure 9-684—Short Beacon Interval element format

The Element ID and Length fields are defined in 9.4.2.1.

The Short Beacon Interval field represents the number of time units (TU)s between target short beacon transmission times (TSBTT)s.

9.4.2.198 Change Sequence element

The Change Sequence element indicates a change of system information within a BSS. The format of the Change Sequence element is shown in Figure 9-685.

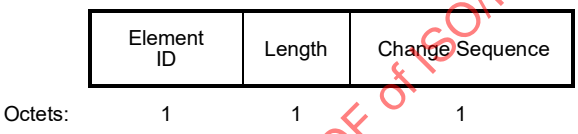

Figure 9-685—Change Sequence element format

The Element ID and Length fields are defined in 9.4.2.1.

The Change Sequence field is defined as an unsigned integer, initialized to 0, that increments when a critical update occurs to any of the elements inside an S1G Beacon frame; see 10.46.2.

9.4.2.199 TWT element

The TWT element is shown in Figure 9-686.

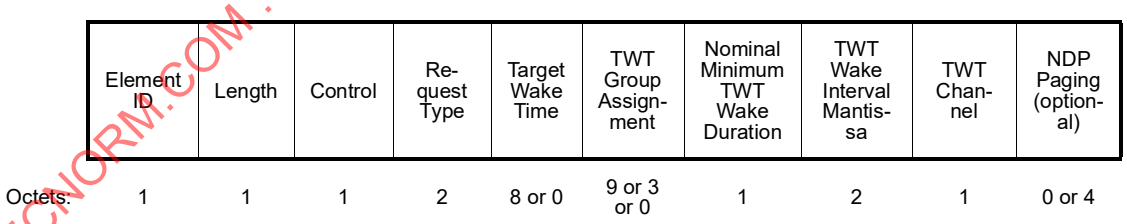

Figure 9-686—TWT element format

The Element ID and Length fields are defined in 9.4.2.1.

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The format of the Control field is shown in Figure 9-687.

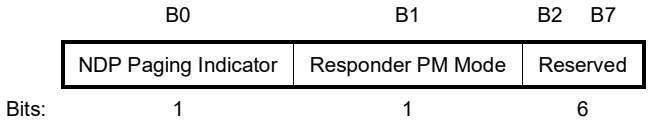

Figure 9-687—Control field format

The NDP Paging field is present if the NDP Paging Indicator subfield is equal to 1; otherwise, the NDP Paging field is not present.

The Responder PM Mode subfield indicates the power management mode as defined in 11.2.

The format of the Request Type field is shown in Figure 9-688.

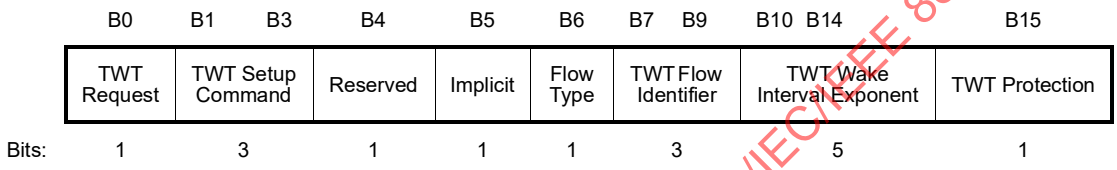

Figure 9-688—Request Type field format

A STA that transmits a TWT element with the TWT Request subfield equal to 1 is a TWT requesting STA. Otherwise, it is a TWT responding STA.

The TWT Setup Command subfield values indicate the type of TWT command, as shown in Table 9-297.

Table 9-297—TWT Setup Command field values

TWT Setup Command field value	Command name	Description when transmitted by a TWT requesting STA	Description when transmitted by a TWT responding STA
0	Request TWT	The Target Wake Time field of the TWT element contains 0s as the TWT responding STA specifies the target wake time value for this case, other TWT parameters are suggested by the TWT requesting STA in the TWT request (see NOTE).	N/A
1	Suggest TWT	TWT requesting STA includes a set of TWT parameters such that if the requested target wake time value and/or other TWT parameters cannot be accommodated, then the TWT setup might still be accepted.	N/A

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Table 9-297—TWT Setup Command field values *(continued)*

TWT Setup Command field value	Command name	Description when transmitted by a TWT requesting STA	Description when transmitted by a TWT responding STA
2	Demand TWT	TWT requesting STA includes a set of TWT parameters such that if the requested target wake time value and/ or other TWT parameters cannot be accommodated, then the TWT setup is not accepted.	N/A
3	TWT Grouping	N/A	TWT responding STA suggests TWT group parameters that are different from the suggested or demanded TWT parameters of the TWT requesting STA
4	Accept TWT	N/A	TWT responding STA accepts the TWT request with the TWT parameters (See NOTE) indicated in the TWT element transmitted by the responding STA
5	Alternate TWT	N/A	TWT responding STA suggests TWT parameters that are different from TWT requesting STA suggested or demanded TWT parameters
6	Dictate TWT	N/A	TWT responding STA demands TWT parameters that are different from TWT requesting STA TWT suggested or demanded parameters
7	Reject TWT	N/A	TWT responding STA rejects TWT setup

NOTE—TWT Parameters are TWT, Nominal Minimum TWT Wake Duration, TWT Wake Interval, and TWT Channel subfield values indicated in the element.

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When transmitted by a TWT requesting STA, the Implicit subfield is set to 1 to request an implicit TWT.

When transmitted by a TWT requesting STA, the Implicit subfield is set to 0 to request an explicit TWT.

The Flow Type subfield indicates the type of interaction between the TWT requesting STA and the TWT responding STA at a TWT. Setting the Flow Type subfield to 0 indicates an announced TWT in which the TWT requesting STA will send a PS-Poll or an APSD trigger frame (see 11.2.3.5) to signal its awake state to the TWT responding STA before a frame is sent from the TWT responding STA to the TWT requesting STA. Setting the Flow Type subfield to 1 indicates an unannounced TWT in which the TWT responding STA will send a frame to the TWT requesting STA at TWT without waiting to receive a PS-Poll or an APSD trigger frame from the TWT requesting STA.

The TWT Flow Identifier subfield contains a 3-bit value, which identifies the specific information for this TWT request uniquely from other requests made between the same TWT requesting STA and TWT responding STA pair.

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In a TWT element transmitted by a TWT requesting STA, the TWT wake interval is equal to the average time that the TWT requesting STA expects to elapse between successive TWT SPs. In a TWT element transmitted by a TWT responding STA, the TWT wake interval is equal to the average time that the TWT-responding STA expects to elapse between successive TWT SPs. The TWT Wake Interval Exponent subfield is set to the value of the exponent of the TWT wake interval value in microseconds, base 2. The TWT wake interval of the requesting STA is equal to (TWT Wake Interval Mantissa) × $2^{(\text{TWT Wake Interval Exponent})}$.

When transmitted by a TWT requesting STA, the Target Wake Time field contains a positive integer corresponding to a TSF time at which the STA requests to wake, or 0 when the TWT Setup Command subfield contains the value corresponding to the command "Request TWT". When a TWT responding STA with dot11TWTGroupingSupport equal to 0 transmits a TWT element to the TWT requesting STA, the TWT element contains a value in the Target Wake Time field corresponding to a TSF time at which the TWT responding STA requests the TWT requesting STA to wake and it does not contain the TWT Group Assignment field.

When a TWT responding STA with dot11TWTGroupingSupport equal to 1 transmits the TWT element to the TWT requesting STA from which it received a frame containing an S1G Capabilities element with the TWT Grouping Support subfield equal to 1, the TWT element does not contain the Target Wake Time field and it does contain the TWT Group Assignment field in order to indicate the TWT group of the requesting STA and the assigned TWT value. The presence of the TWT Group Assignment field is indicated by a TWT responding STA by using the TWT Grouping command in the TWT Setup Command subfield (see Table 9-297) within the TWT element.

The TWT Group Assignment field provides information to a requesting STA about the TWT group to which the STA is assigned. This field contains the TWT Group ID, Zero Offset of Group (optional), TWT Unit, and TWT Offset subfields. The TWT Group Assignment field and the corresponding subfields are depicted in Figure 9-689.

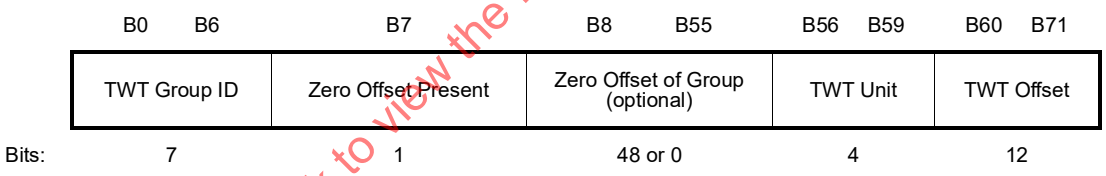

Figure 9-689—TWT Group Assignment field format

The TWT Group ID subfield is an unsigned integer and indicates the identifier of the TWT group to which the requesting STA is assigned. A TWT group is a group of STAs that have TWT values that lie within a specific interval of TSF values. The value zero in the TWT Group ID subfield is used to indicate the unique TWT group, which contains all STAs in the BSS.

The Zero Offset Present subfield indicates whether the following Zero Offset of Group subfield is included in the TWT Group Assignment field of the TWT element. Setting the Zero Offset Present subfield to 0 indicates that the Zero Offset of the Group subfield is not included in the TWT Group Assignment field.

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The Zero Offset of Group subfield indicates the initial TWT value for the TWT group identified by the TWT group ID. The Zero Offset of Group subfield is 6 octets and contains the initial TWT value for the TWT group with the given TWT group ID. When the Zero Offset of Group subfield is present, it contains the value of the 6 least significant octets of the TSF timer corresponding to the TWT group offset time. The Zero Offset of Group subfield is optionally present in the TWT Group Assignment field. If a STA transmits multiple TWT requests for multiple TWT flows, the next TWT Group Assignment field transmitted in a response to a TWT request can optionally exclude the Zero Offset of the Group subfield from an included TWT Group Assignment field provided that a previous response included a Zero Offset of the Group subfield. The receipt of a TWT response with a TWT Group Assignment field with no Zero Offset of the Group subfield implies that the Zero Offset of the Group subfield value for that TWT is the same as the Zero Offset of the Group subfield value for the most recently received Zero Offset of the Group subfield for the same TWT group ID from the TWT responding STA.

The TWT Unit subfield indicates the unit of increment of the TWT values within the TWT group identified by the TWT group ID. The TWT Unit subfield encoding is shown in Table 9-298.

Table 9-298—TWT Unit subfield encoding

TWT Unit subfield value	TWT Unit time value
0	32 μs
1	256 μs
2	1024 μs
3	8.192 ms
4	32.768 ms
5	262.144 ms
6	1.048576 s
7	8.388608 s
8	33.554432 s
9	268.435456 s
10	1073.741824 s
11	8589.934592 s
12–15	Reserved

The TWT Offset subfield indicates the position within the indicated group, of the STA corresponding to the RA of the frame containing the TWT element.

A non-AP STA uses the TWT Group ID, Zero Offset of Group, TWT Unit, and TWT Offset subfield values to compute its TWT value within the TWT group. A STA's TWT value is equal to the value of the Zero Offset of Group subfield plus TWT Offset subfield times the value of TWT Unit subfield.

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The Nominal Minimum TWT Wake Duration field indicates the minimum amount of time, in units of 256 μs, that the TWT requesting STA expects that it needs to be awake in order to complete the frame exchanges associated with the TWT flow identifier for the period of TWT wake interval, where TWT wake interval is the average time that the TWT requesting STA expects to elapse between successive TWT SPs.

The TWT Wake Interval Mantissa subfield is set to the value of the mantissa of the TWT wake interval value in microseconds, base 2.

When transmitted by a TWT requesting STA that is negotiating SST operation, the TWT Channel field contains a bitmap indicating the channel the STA requests to use as a temporary primary channel during a TWT SP. When transmitted by a TWT responding STA that is negotiating SST operation, the TWT Channel field contains a bitmap indicating which channel the TWT requesting STA is allowed to use as a temporary channel during the TWT SP. When transmitted by a STA that is not negotiating SST operation, the TWT Channel field is reserved.

Each bit in the bitmap corresponds to one minimum width channel for the band in which the TWT responding STA's associated BSS is currently operating, with the least significant bit corresponding to the lowest numbered channel of the operating channels of the BSS.The minimum width channel is equal to the SST Channel Unit field of the SST Operation element if such an element has been previously received or is equal to 1 MHz for a BSS with a BSS primary channel width of 1 MHz and 2 MHz for a BSS with a BSS primary channel width of 2 MHz if no such element has been previously received from the AP to which the SST STA is associated. Setting a position in the bitmap transmitted to 1 by a TWT requesting STA means that operation with that channel as the primary channel is requested during a TWT SP. Setting a position in the bitmap transmitted to 1 by a TWT responding STA means that operation with that channel as the primary channel is allowed during the TWT SP.

A TWT requesting STA sets the TWT Protection subfield to 1 to request the TWT responding STA to provide protection of the set of TWT SPs corresponding to the requested TWT flow identifier by allocating RAW(s) that restrict access to the medium during the TWT SP(s) for that(those) TWTs. A TWT requesting STA sets the TWT Protection subfield to 0 if TWT protection by RAW allocation is not requested for the corresponding TWT(s).

When transmitted by a TWT responding STA that is an AP, the TWT Protection subfield indicates whether the TWT SP(s) identified in the TWT element will be protected. A TWT responding STA sets the TWT Protection subfield to 1 to indicate that the TWT SP(s) corresponding to the TWT flow identifier(s) of the TWT element will be protected by allocating RAW(s) that restrict access to the medium during the TWT SP(s) for that(those) TWT(s). A TWT responding STA sets the TWT Protection subfield to 0 to indicate that the TWT SP(s) identified in the TWT element might not be protected from S1G STAs in TIM mode by allocating RAW(s).

The format of the NDP Paging field is defined in Figure 9-690.

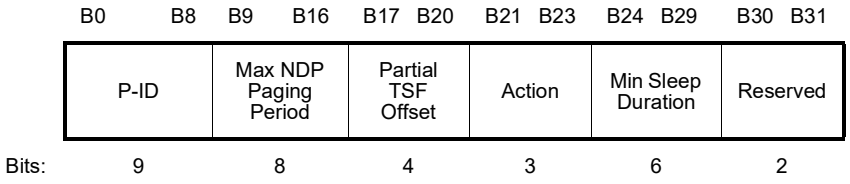

Figure 9-690—NDP Paging field format

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The P-ID field is the identifier of the paged STA, as described in 10.47.6.

The Max NDP Paging Period field indicates the maximum number of TWT wake intervals between two NDP Paging frames.

The Partial TSF Offset field includes timing indications, as described in 10.47.6.

Upon reception of an NDP Paging frame with matching P-ID field as defined in 10.47.6, the TWT STA that is an NDP Paging requester takes an action indicated by the Action field as described in Table 9-299.

Table 9-299—Action field

Action	Options
0	Send a PS-Poll or uplink trigger frame
1	Wake up at the time indicated by the Min Sleep Duration field
2	Wake up to receive the beacon
3	Wake up to receive the DTIM beacon
4	Wakeup at the time indicated by the sum of the Min Sleep Duration field and the ASD subfield in the APDI field of the NDP Paging frame
5–7	Reserved

The Min Sleep Duration field in the NDP Paging Request indicates in units of SIFS the minimum duration that STA will be in the doze state after receiving an NDP Paging frame with a matching P-ID.

9.4.2.200 S1G Capabilities element

9.4.2.200.1 S1G Capabilities element structure

An S1G STA declares that it is an S1G STA by transmitting the S1G Capabilities element.

The S1G Capabilities element contains a number of fields that are used to advertise S1G capabilities of an S1G STA. The S1G Capabilities element is defined in Figure 9-691.

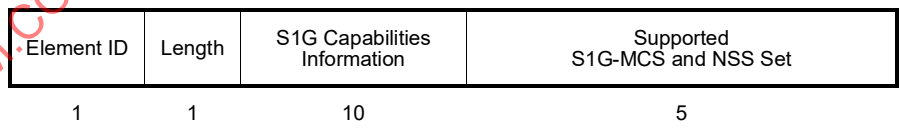

Figure 9-691—S1G Capabilities element format

The Element ID and Length fields are defined in 9.4.2.1.

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9.4.2.200.2 S1G Capabilities Information field

The structure of the S1G Capabilities Information field is defined in Figure 9-692.

	B0	B1	B2	B3	B4	B5	B6	B7
	S1G_LONG Support	Short GI for 1 MHz	Short GI for 2 MHz	Short GI for 4 MHz	Short GI for 8 MHz	Short GI for 16 MHz	Supported Channel Width	
Bits:	1	1	1	1	1	1	2	
	B8	B9	B10	B11	B12	B13		B15
	Rx LDPC	Tx STBC	Rx STBC	SU Beamformer Capable	SU Beamformee Capable	Beamformee STS Capability		
Bits:	1	1	1	1	1	3		
	B16		B18	B19	B20	B21	B22	B23
	Number Of Sounding Dimensions			MU Beamformer Capable	MU Beamformee Capable	+HTC-VHT Capable	Traveling Pilot Support	
Bits:	3			1	1	1	2	
	B24	B25	B26	B27	B28	B29		B31
	RD Responder	Reserved	Maximum MPDU Length	Maximum A-MPDU Length Exponent		Minimum MPDU Start Spacing		
Bits:	1	1	1	2		3		
	B32	B33	B34	B35	B36	B37	B38	B39
	Uplink Sync Capable	Dynamic AID	BAT Support	TIM ADE Support	Non-TIM Support	Group AID Support	STA Type Support	
Bits:	1	1	1	1	1	1	2	
	B40	B41	B42	B43	B44	B45	B46	B47
	Centralized Authentica-tion Control	Distributed Authentication Control	A-MSDU Supported	A-MPDU Supported	Asymmetric BA Supported	Flow Control Supported	Sectorized Beam-Capable	
Bits:	1	1	1	1	1	1	2	

Figure 9-692—S1G Capabilities Information field format

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	B48	B49	B50	B51	B52	B53	B54	B55
	OBSS Mitigation Support	Fragment BA Support	NDP PS-Poll Supported	RAW Operation Support	Page Slicing Support	TXOP Sharing Implicit Ack Support	VHT Link Adaptation Capable	
Bits:	1	1	1	1	1	1	2	

	B56	B57	B58	B59	B60	B61	B62	B63
	TACK Support as PS-Poll Response	Duplicate 1 MHz Support	MCS Negotiation Support	1 MHz Control Response Preamble Support	NDP Beamforming Report Poll Supported	Unsolicited Dynamic AID	Sector Training Operation Support	Temporary PS Mode Switch
Bits:	1	1	1	1	1	1	1	1

	B64	B65	B66	B68	B69	B70	B71
	TWT Grouping Support	BDT Capable	COLOR		TWT Requester Support	TWT Responder Support	PV1 Frame Support
Bits:	1	1	3			1	1

	B72	B73	B79
	Link Adaptation Without NDP CMAC PPDU Capable	Reserved	
Bits:	1	7	

Figure 9-692—S1G Capabilities Information field format *(continued)*

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The subfields of the S1G Capabilities Information field are defined in Table 9-300.

Table 9-300—Subfields of the S1G Capabilities Information field

Subfield	Definition	Encoding
S1G_LONG Support	Indicates support for the reception of S1G_LONG PPDUs. See 23.3.2.	Set to 0 if not supported. Set to 1 if supported.
Short GI for 1 MHz	Indicates short GI support for the reception of PPDUs transmitted with TXVECTOR parameters FORMAT equal to S1G and CH_BANDWIDTH equal to CBW1.	Set to 0 if not supported. Set to 1 if supported.
Short GI for 2 MHz	Indicates short GI support for the reception of PPDUs transmitted with TXVECTOR parameters FORMAT equal to S1G and CH_BANDWIDTH equal to CBW2.	Set to 0 if not supported. Set to 1 if supported.
Short GI for 4 MHz	Indicates short GI support for the reception of PPDUs transmitted with TXVECTOR parameters FORMAT equal to S1G and CH_BANDWIDTH equal to CBW4.	Set to 0 if not supported. Set to 1 if supported.
Short GI for 8 MHz	Indicates short GI support for the reception of PPDUs transmitted with TXVECTOR parameters FORMAT equal to S1G and CH_BANDWIDTH equal to CBW8.	Set to 0 if not supported. Set to 1 if supported.
Short GI for 16 MHz	Indicates short GI support for the reception of PPDUs transmitted with TXVECTOR parameters FORMAT equal to S1G and CH_BANDWIDTH equal to CBW16.	Set to 0 if not supported. Set to 1 if supported.
Supported Channel Width	Indicates the channel widths supported by the STA. See 10.46.	Set to 0 if the STA supports 1 MHz and 2 MHz operation. Set to 1 if the STA supports 1 MHz, 2 MHz, and 4 MHz operation. Set to 2 if the STA supports 1 MHz, 2 MHz, 4 MHz, and 8 MHz operation. Set to 3 if the STA supports 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz operation.
Rx LDPC	Indicates support for receiving LDPC encoded PPDUs.	Set to 0 if not supported. Set to 1 if supported.
Tx STBC	Indicates support for the transmission of at least 2×1 STBC.	Set to 0 if not supported. Set to 1 if supported.
Rx STBC	Indicates support for the reception of PPDUs using STBC.	Set to 0 if not supported. Set to 1 if supported.
SU Beamformer Capable	Indicates support for operation as an SU beamformer (see 10.36.5).	Set to 0 if not supported. Set to 1 if supported.
SU Beamformee Capable	Indicates support for operation as an SU beamformee (see 10.36.5).	Set to 0 if not supported. Set to 1 if supported.

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Table 9-300—Subfields of the S1G Capabilities Information field *(continued)*

Subfield	Definition	Encoding
Beamformee STS Capability	The maximum number of space-time streams that the STA can receive in an S1G NDP, the maximum value for $N_{STS,total}$ that can be sent to the STA in an S1G MU PPDU if the STA is MU beamformee capable and the maximum value of *Nr* that the STA transmits in a VHT Compressed Beamforming frame.	If SU beamformee capable, set to maximum number of space-time streams that the STA can receive in an S1G NDP minus 1. Otherwise reserved.
Number Of Sounding Dimensions	Beamformer's capability indicating the maximum value of the TXVECTOR parameter NUM_STS for an S1G NDP.	If SU beamformer capable, set to the maximum supported value of the TXVECTOR parameter NUM_STS minus 1. Otherwise reserved.
MU Beamformer Capable	Indicates support for operation as an MU beamformer (see 10.36.5).	Set to 0 if not supported or if SU Beamformer Capable is set to 0 or if sent by a non-AP STA. Set to 1 if supported and SU Beamformer Capable is equal to 1.
MU Beamformee Capable	Indicates support for operation as an MU beamformee (see 10.36.5).	Set to 0 if not supported or if SU Beamformee Capable is set to 0 or if sent by an AP. Set to 1 if supported and SU Beamformee Capable is equal to 1.
+HTC-VHT Capable	Indicates whether or not the STA supports receiving a VHT variant HT Control field.	Set to 0 if not supported. Set to 1 if supported.
Traveling Pilot Support	Indicates support for the reception of PPDUs with a traveling pilots. See 23.3.9.10.	Set to 1 if dot11S1GTravelingPilotOptionActivated is true, and reception of traveling pilot for one space-time stream is supported but reception of traveling pilot for two space-time streams with STBC is not supported. Set to 3 if dot11S1GTravelingPilotOptionActivated is true, and reception of traveling pilot for both one space-time stream and two space-time streams with STBC is supported. Set to 0 if dot11S1GTravelingPilotOptionActivated is false. Value 2 is reserved.
RD Responder	Indicates support for acting as a reverse direction responder, i.e., the STA can use an offered RDG to transmit data to an RD initiator using the reverse direction protocol described in 10.29.	Set to 0 if not supported. Set to 1 if supported.
Maximum MPDU Length	Indicates the maximum MPDU length (see 10.11).	Set to 0 for 3895 octets. Set to 1 for 7991 octets.
Maximum A-MPDU Length Exponent	Indicates the maximum length of A-MPDU that the STA can receive. EOF padding is not included in this limit.	The length defined by this field is equal to $2^{(13+\text{Maximum A-MPDU Length Exponent})} - 1$ octets.

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Table 9-300—Subfields of the S1G Capabilities Information field *(continued)*

Subfield	Definition	Encoding
Minimum MPDU Start Spacing	Determines the minimum time between the start of adjacent MPDUs within an A-MPDU that the STA can receive, measured at the PHY SAP. See 10.12.3.	Set to 0 for no restriction. Set to 1 for 1/4 μs. Set to 2 for 1/2 μs. Set to 3 for 1 μs. Set to 4 for 2 μs. Set to 5 for 4 μs. Set to 6 for 8 μs. Set to 7 for 16 μs.
Uplink Sync Capable	If sent by an AP, this subfield indicates support for sync frame transmission for uplink. If sent by a non-AP STA, this subfield indicates request for sync frame transmission for uplink. See 10.49.	If sent by an AP: Set to 0 if not supported. Set to 1 if supported. If sent by a non-AP STA: Set to 0 if not requested. Set to 1 if requested.
Dynamic AID	The STA sets the Dynamic AID field to 1 when dot11DynamicAIDActivated is true, and sets it to 0 otherwise. See 10.20.	Set to 1 if dot11DynamicAIDActivated is true. Set to 0 otherwise.
BAT Support	The BAT Support subfield indicates support for the use of the Block Acknowledgment TWT (BAT) frame in Block Agreements. When dot11BATImplemented is true, this field is set to 1 to indicate support for BAT frames as both originator and recipient.	Set to 1 if dot11BATImplemented is true. Set to 0 otherwise.
TIM ADE Support	This bit indicates support of the ADE mode of TIM bitmap encoding as described in 9.4.2.5.5.	Set to 1 if dot11TIMADEImplemented is true. Set to 0 otherwise.
Non-TIM Support	This bit indicates support of non-TIM mode.	In a non-AP STA: Set to 0: The non-AP STA does not support non-TIM mode; it needs TIM entry as in legacy PS mode. Set to 1: The non-AP STA supports non-TIM mode and does not need TIM entry when in non-TIM mode. In an AP: Set to 0: The AP does not support the STA's non-TIM mode. Set to 1: The AP supports the STA's non-TIM mode.
Group AID Support	This bit indicates support of group traffic delivery using a group AID as described in 10.55.	Set to 1 if dot11GroupAIDActivated is true. Set to 0 otherwise.

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Table 9-300—Subfields of the S1G Capabilities Information field *(continued)*

Subfield	Definition	Encoding
STA Type Support	If sent by an AP, this subfield indicates the STA types that are supported by the AP. If sent by a non-AP STA, this subfield indicates the STA type of the non-AP STA.	If sent by an AP: Set to 0 if the AP supports both sensor STAs and non-sensor STAs. Set to 1 if the AP supports only sensor STAs. Set to 2 if the AP supports only non-sensor STAs. 3 is reserved. If sent by a non-AP STA: Set to 1 if the STA is a sensor STA. Set to 2 if the STA is a non-sensor STA. 0 and 3 are reserved.
Centralized Authentication Control	This field indicates support of the centralized authentication control defined in 11.3.9.2.	Set to 1 if dot11S1GCentralizedAuthenticationControlActivated is true. Set to 0 otherwise.
Distributed Authentication Control	This field indicates support of the distributed authentication control defined in 11.3.9.3.	Set to 1 if dot11S1GDistributedAuthenticationControlActivated is true. Set to 0 otherwise.
A-MSDU Supported	This bit indicates support of Aggregated MSDU.	Set to 1 if dot11AMSDUImplemented is true. Set to 0 otherwise.
A-MPDU Supported	This bit indicates support of Aggregated MPDU.	Set to 1 if dot11AMPDUImplemented is true. Set to 0 otherwise.
Asymmetric BA Supported	This bit indicates support of Asymmetric BA.	Set to 1 if dot11AsymmetricBlockAckActivated is true. Set to 0 otherwise.
Flow Control Supported	Indicates support for flow control operation.	Set to 0 if not supported Set to 1 if supported
Sectorized Beam-Capable	The Sectorized Beam-Capable subfield indicates the type of sectorization operation supported by the STA.	If sent by an AP: Set to 0 if sectorization operation is not supported, Set to 1 if only TXOP-based sectorization operation is supported, Set to 2 if only group sectorization operation is supported, Set to 3 if both group sectorization and TXOP-based sectorization operations are supported. If sent by a non-AP STA: Set to 0 if not supported, Set to 1 if supported When equal to 1, a non-AP STA supports both group sectorization and TXOP-based sectorization operation.
OBSS Mitigation Support	The OBSS Mitigation Support subfield indicates whether the STA supports channel width reduction during a TXOP for OBSS mitigation.	Set to 1 to indicate that the STA supports channel width reduction during a TXOP for OBSS mitigation. Set to 0 otherwise.

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Table 9-300—Subfields of the S1G Capabilities Information field *(continued)*

Subfield	Definition	Encoding
Fragment BA Support	This bit indicates support for fragment BA.	Set to 1 if dot11FragmentBAOptionImplemented is true. Set to 0 otherwise.
NDP PS-Poll Supported	This bit indicates support for NDP PS-Poll frames.	Set to 1 if dot11NDPPSPollSupport is true. Set to 0 otherwise.
RAW Operation Support	This bit indicates support of RAW Participating as described in 10.23.5.1.	Set to 1 if dot11RAWOperationImplemented is true. Set to 0 otherwise.
Page Slicing Support	This bit indicates support of Page Slicing as described in 10.51.	Set to 1 if dot11PageSlicingImplemented is true. Set to 0 otherwise.
TXOP Sharing Implicit Ack Support	This bit indicates support of Implicit Ack in TXOP sharing.	Set to 1 if dot11TXOPSharingImplicitACKImplemented is true. Set to 0 otherwise.
VHT Link Adaptation Capable	Indicates whether or not the STA supports link adaptation using VHT variant HT Control field.	If +HTC-VHT Capable is 1: Set to 0 (No Feedback) if the STA does not provide VHT MFB. Set to 2 (Unsolicited) if the STA provides only unsolicited VHT MFB. Set to 3 (Both) if the STA can provide VHT MFB in response to VHT MRQ and if the STA provides unsolicited VHT MFB. The value 1 is reserved. Reserved if +HTC-VHT Capable is 0.
TACK Support as PS-Poll Response	This bit indicates whether the AP supports the using of TACK frame as the response to a PS-Poll frame with the Poll Type subfield equal to 1 as described in 10.48.2.	Set to 1 if dot11PollTACKResponseImplemented is true. Set to 0 otherwise.
Duplicate 1 MHz Support	This bit indicates support for transmission of S1G 1 MHz duplicate PPDUs.	Set to 1 if generation of a PPDU in duplicate 1 MHz format is supported as a response to an eliciting frame transmitted by the peer STA. Set to 0 otherwise.
MCS Negotiation Support	Indicates if the STA supports control response MCS negotiation feature.	Set to 0 if not supported. Set to 1 if supported.
1 MHz Control Response Preamble Support	Indicates if the STA supports transmitting control response frames with 1 MHz preamble as the response of ≥2 MHz PPDUs.	Set to 0 if not supported. Set to 1 if supported.
NDP Beamforming Report Poll Supported	Indicates support for reception of NDP Beamforming Report Poll frames.	Set to 0 if not supported. Set to 1 if supported.
Unsolicited Dynamic AID	The STA sets the Unsolicited Dynamic AID field to 1 when dot11UnsolicitedDynamicAIDActivated is true, and sets it to 0 otherwise. See 10.20.	Set to 1 if dot11UnsolicitedDynamicAIDActivated is true. Set to 0 otherwise.

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Table 9-300—Subfields of the S1G Capabilities Information field *(continued)*

Subfield	Definition	Encoding
Sector Training Operation Supported	This bit indicates support of sector training operation described in 10.53.5.	Set to 0 if not supported. Set to 1 if supported. When equal to 1, a STA supports sector training operation.
Temporary PS Mode Switch	This bit indicates whether the STA supports the temporary PS Mode switch as described in 10.48.2 while in non-TIM mode.	Set to 1 if supported. Set to 0 otherwise.
TWT Grouping Support	This bit indicates support of TWT grouping described in 10.47.5.	Set to 0 if not supported. Set to 1 if supported.
BDT Capable	Indicates the support of bidirectional TXOP operation described in 10.50.	Set to 0 if not supported. Set to 1 if supported.
COLOR	Indicates the value that is used for the TXVECTOR parameter COLOR in frames transmitted by members of this BSS, as described in 10.21.	Set to an unsigned integer if sent by an AP. Otherwise reserved.
TWT Requester Support	This bit indicates support for the role of TWT requesting STA as described in 10.47.	Set to 1 if dot11TWTOptionActivated is true and the STA supports TWT requester STA functionality (see 10.47). Set to 0 otherwise.
TWT Responder Support	This bit indicates support for the role of TWT responding STA	Set to 1 if dot11TWTOptionActivated is true and the STA supports TWT responding STA functionality (see 10.47). Set to 0 otherwise.
PV1 Frame Support	Indicates support for PV1 MPDUs	Set to 0 if not supported. Set to 1 if supported.
Link Adaptation Without NDP CMAC PPDU Capable	Indicate whether or not link adaptation through a Control frame that is not an NDP CMAC PPDU is allowed	Set to 0 if not supported. Set to 1 if supported.

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9.4.2.200.3 Supported S1G-MCS and NSS Set field

The Supported S1G-MCS and NSS Set field is used to convey the combinations of S1G-MCSs and spatial streams that a STA supports for reception and the combinations that it supports for transmission. The structure of the field is shown in Figure 9-693.

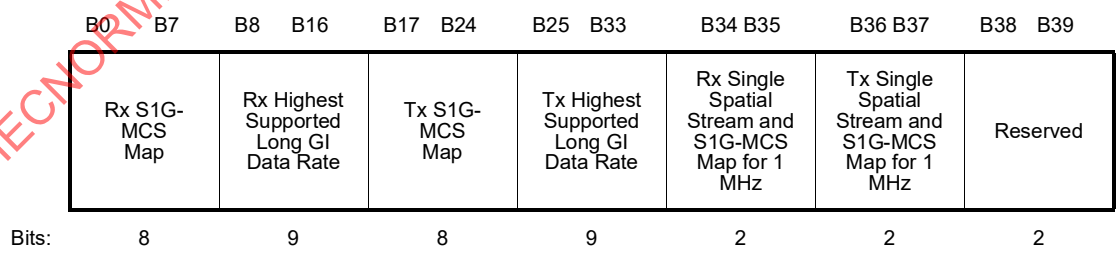

Figure 9-693—Supported S1G-MCS and NSS Set field format

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The Supported S1G-MCS and NSS Set subfields are defined in Table 9-301.

Table 9-301—Supported S1G-MCS and NSS Set subfields

Subfield	Definition	Encoding
Rx S1G-MCS Map	Indicates the maximum value of the RXVECTOR parameter MCS of a PPDU that can be received at all channel widths supported by this STA for each number of spatial streams.	The format and encoding of this subfield are defined in Figure 9-694 and the associated description. If Rx Single Spatial Stream and S1G-MCS Map for 1 MHz subfield is greater than or equal to 1, then only the value of the Max S1G-MCS For 1 SS subfield that is indicated by the Rx Single Spatial Stream and S1G-MCS Map subfield is applicable for 1 MHz channel width.
Rx Highest Supported Long GI Data Rate	Indicates the highest long GI S1G data rate that the STA is able to receive.	The largest integer value less than or equal to the highest long GI S1G PPDU data rate in Mb/s the STA is able to receive (see 10.6.14.1). The value 0 indicates that this subfield does not specify the highest long GI S1G PPDU data rate that the STA is able to receive.
Tx S1G-MCS Map	Indicates the maximum value of the TXVECTOR parameter MCS of a PPDU that can be transmitted at all channel widths supported by this STA for each number of spatial streams.	The format and encoding of this subfield are defined in Figure 9-694 and the associated description. If Tx Single Spatial Stream and S1G-MCS Map for 1 MHz subfield is greater than or equal to 1, then only the value of the Max S1G-MCS For 1 SS subfield that is indicated by the Tx Single Spatial Stream and S1G-MCS Map subfield is applicable for 1 MHz channel width.
Tx Highest Supported Long GI Data Rate	Indicates the highest long GI S1G PPDU data rate at which the STA is able to transmit.	The largest integer value less than or equal to the highest long GI S1G PPDU data rate in Mb/s that the STA is able to transmit (see 10.6.14.2). The value 0 indicates that this subfield does not specify the highest long GI S1G PPDU data rate that the STA is able to transmit.
Rx Single Spatial Stream and S1G-MCS Map for 1 MHz	Indicates whether only a single spatial stream PPDU can be received at 1 MHz channel width by this STA.	0: same number of spatial streams and same Max S1G-MCS as indicated by Rx S1G-MCS Map field. 1: single spatial stream only and with Max S1G-MCS as indicated by a 0 in the S1G-MCS for 1 SS subfield. 2: single spatial stream only and with Max S1G-MCS as indicated by a 1 in the S1G-MCS for 1 SS subfield. 3: single spatial stream only and with Max S1G-MCS as indicated by a 2 in the S1G-MCS for 1 SS subfield.
Tx Single Spatial Stream and S1G-MCS Map for 1 MHz	Indicates whether only a single spatial stream PPDU can be transmitted at 1 MHz channel width by this STA.	0: same number of spatial streams and same Max S1G-MCS as indicated by Tx S1G-MCS Map field. 1: single spatial stream only and with Max S1G-MCS as indicated by a 0 in the S1G-MCS for 1 SS subfield. 2: single spatial stream only and with Max S1G-MCS as indicated by a 1 in the S1G-MCS for 1 SS subfield. 3: single spatial stream only and with Max S1G-MCS as indicated by a 2 in the S1G-MCS for 1 SS subfield.

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The Rx S1G-MCS Map subfield and the Tx S1G-MCS Map subfield have the structure shown in Figure 9-694.

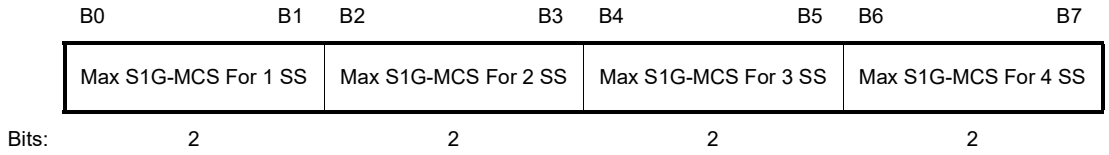

Figure 9-694—Rx S1G-MCS Map and Tx S1G-MCS Map subfields and Basic S1G-MCS and NSS Set field format

The Max S1G-MCS for *n* SS subfield (where *n*=1,...,4) is encoded as follows:

— 0 indicates support for S1G-MCS 2 for n spatial streams
— 1 indicates support for S1G-MCS 7 for n spatial streams
— 2 indicates support for S1G-MCS 9 for n spatial streams
— 3 indicates that n spatial streams is not supported

NOTE 1—An S1G-MCS indicated as supported in the S1G-MCS Map fields for a particular number of spatial streams might not be valid at all bandwidths (see 23.5) and might be limited by the declaration of Tx Highest Supported Long GI Data Rates and Rx Highest Supported Long GI Data Rates and might be affected by 10.6.14.3.

NOTE 2—For 1 MHz, MCS 10 is always supported.

9.4.2.201 Subchannel Selective Transmission (SST) element

The Subchannel Selective Transmission (SST) element is shown in Figure 9-695.

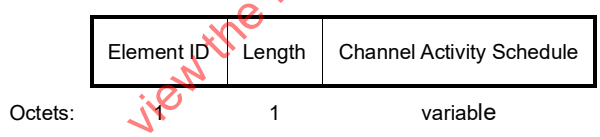

Figure 9-695—Subchannel Selective Transmission element format

The Element ID and Length fields are defined in 9.4.2.1.

The Channel Activity Schedule subfield contains one or more channel activity schedules.

The format of the Channel Activity Schedule subfield is shown in Figure 9-696 and Figure 9-697.

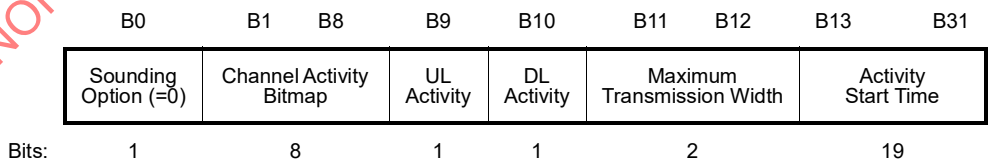

Figure 9-696—Channel Activity Schedule subfield format (Sounding Option = 0)

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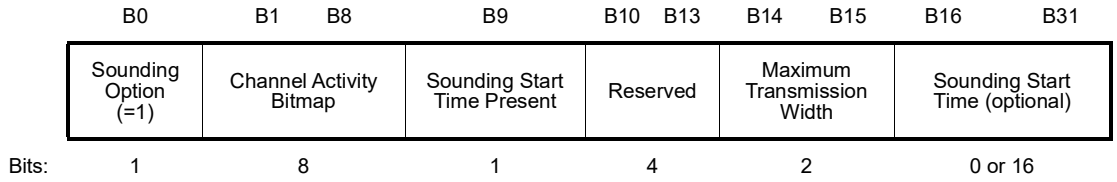

Figure 9-697—Channel Activity Schedule subfield format (Sounding Option = 1)

The Sounding Option subfield is set to 0 to indicate that the Channel Activity Schedule field is the AP Activity schedule.

When the Sounding Option subfield is equal to 0, the Channel Activity Bitmap subfield contains a bitmap indicating on which channels transmission is either expected or permitted by the AP during a given time period. Each bit in the bitmap corresponds to one minimum width channel for the band of operation with the LSB corresponding to the lowest numbered operating channel of the BSS. A 1 in a bit position in the bitmap means that the AP expects activity and/or permits transmissions with bandwidth less than or equal to the bandwidth indicated in the Maximum Transmission Width subfield and that include that channel, after the time indicated in the Activity Start Time subfield. Only one bit in the bitmap can be set to 1 within each channel activity schedule. The minimum width channel is equal to the SST Channel Unit field of the SST Operation element if such an element has been previously transmitted or is equal to 2 MHz if no such element has been previously received from the AP to which the SST STA is associated.

The UL Activity subfield is set to 1 to indicate that the SST AP (that transmits the SST element) permits the STAs associated with it to transmit frames that are not immediate response frames on the channel(s) identified by the Channel Activity Bitmap and Maximum Transmission Width subfields at the time indicated in the Activity Start Time subfield. Otherwise it is set to 0.

The DL Activity subfield is set to 1 to indicate that the AP that transmits the SST element intends to transmit frames that are not immediate response frames on the channel(s) identified by the Channel Activity Bitmap and Maximum Transmission Width subfields at the time indicated in the Activity Start Time subfield. Otherwise it is set to 0.

The Maximum Transmission Width subfield indicates the maximum PPDU bandwidth permitted by the AP for a transmission on the indicated channel and cannot exceed the BSS operating channel width specified by the AP in a transmitted S1G Operation element. In order to abide by the rules of each regulatory domain, the maximum operating channel width is limited by the BSS operating channel width even if the Maximum Transmission Width field specifies otherwise. The maximum permitted PPDU bandwidth is in MHz and is determined based on the Maximum Transmission Width subfield as shown in Table 9-302.

Table 9-302—Mapping between Maximum Transmission Width subfield and maximum permitted PPDU bandwidth

Maximum Transmission Width	Maximum permitted PPDU bandwidth (MHz)
0	channel width unit
1	4
2	8
3	16

NOTE—The channel width unit is equal to 1 MHz if the SST Channel Unit field of the most recently received SST Operation element from the SST AP is equal to 1. If no SST Operation element has been received or the SST Channel Unit field of the received SST Operation element is equal to 0 then the channel width unit is equal to 2 MHz.

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The Activity Start Time subfield contains a value that defines a start time for when the AP expects frame transmissions to begin on the channel(s) indicated in the corresponding Channel Activity Bitmap field. The start time is triggered when the 19 least significant bits of the TSF timer for the BSS match the value that is indicated in the Activity Start Time subfield of the SST element. The count down to the start time is initiated at the end of the transmission of the frame containing the SST element.

The Sounding Option subfield is set to 1 in order to indicate that the Channel Activity Schedule field is the SST sounding schedule.

When the Sounding Option subfield is equal to 1, the Channel Activity Bitmap subfield contains a bitmap indicating on which channels there is an SST sounding transmission activity at a given time. Each bit in the bitmap corresponds to one minimum width channel for the band of operation with the LSB corresponding to the lowest numbered operating channel of the BSS. A 1 in a bit position in the bitmap means that the AP transmits one more PIFS-separated sounding NDPs.

The Sounding Start Time Present subfield indicates whether the Sounding Start Time subfield is present in the Channel Activity Schedule field. If the subfield is equal to 1, the Sounding Start Time subfield is present. If this subfield is equal to 0, the Sounding Start Time subfield is not present.

The Maximum Transmission Width subfield indicates the channel bandwidth of the sounding NDP and is shown in Table 9-302.

The Sounding Start Time subfield contains a value that defines a start time when the AP transmits one or more sounding NDPs on the channel(s) indicated in the corresponding Channel Activity Bitmap subfield. If the Sounding Start Time subfield is not present, the AP transmits one or more PIFS-separated sounding NDPs starting after the transmission of the Beacon frame containing the SST element. If the Sounding Start Time subfield is present, the AP transmits one or more PIFS-separated sounding NDPs starting at the time indicated in the Sounding Start Time field. The start time is triggered when the 16 least significant bits of the TSF timer for the BSS match the value that is indicated in the Sounding Start Time subfield of the SST element. The count down to the start time is initiated at the end of the transmission of the frame containing the SST element.

9.4.2.202 Authentication Control element

The notation of Authentication-Request and Authentication-Response refers to the definition in Clause 13.

The Authentication Control element contains the information required to mitigate contention among Authentication Request frames (see 11.3.9).

Element ID	Length	Centralized Authentication Control Parameters
Octets: 1	1	2

Figure 9-698—Authentication Control element format (Control subfield equal to 0)

The Element ID and Length fields are defined in 9.4.2.1.

The Information field starts with a 1-bit Control subfield.

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When the Control subfield is equal to 0, the Authentication Control element format is as shown in Figure 9-698. The Authentication Control element indicates whether the recipient STA can transmit an Authentication Request frame to the AP that sends the element. The remaining part of the Centralized Authentication Control Parameters field Information field following the Control subfield contains the Deferral, Reserved and the Authentication Control Threshold subfields.

The Centralized Authentication Control Parameters field format is shown in Figure 9-699.

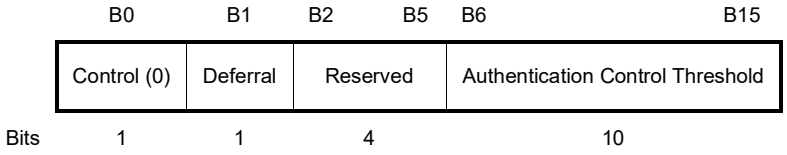

Figure 9-699—Centralized Authentication Control Parameters format

The Authentication Control Threshold subfield contains a number with a range from 0 to 1023. When the Deferral subfield is equal to 0, the value of the Authentication Control Threshold subfield is used by the recipient STA to determine whether or not the AP is allowing it to transmit an Authentication Request frame. When the Deferral subfield is equal to 1, the Authentication Control Threshold subfield value is a time value, expressed in TUs, indicating a minimum amount of deferred time for channel access that is required before the transmission of an Authentication-Request frame and is set as described in 11.3.9.2.

When the Control subfield is equal to 1, the Authentication Control element contains the Distributed Authentication Control Parameters field as shown in Figure 9-700.

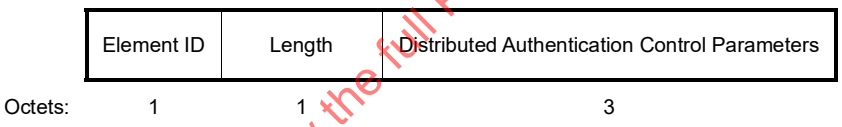

Figure 9-700—Authentication Control element format (Control subfield equal to 1)

The Distributed Authentication Control Parameters field format is shown Figure 9-701.

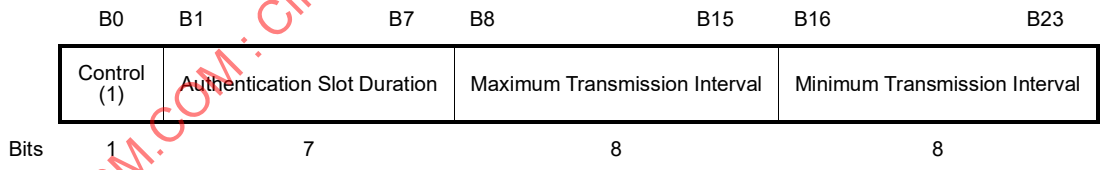

Figure 9-701—Distributed Authentication Control Parameters format

The Authentication Slot Duration subfield is expressed in units of TUs and indicates the authentication slot duration.

The Minimum Transmission Interval subfield is expressed in units of beacon intervals and indicates the minimum transmission interval (see 11.3.9.3).

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9.4.2.203 TSF Timer Accuracy element

The TSF Timer Accuracy element, shown in Figure 9-702, specifies fields describing the accuracy of TSF timer. This information is used by a receiving STA to estimate the clock accuracy of the transmitting STA and to schedule wake-up time for Beacon frame reception by taking this clock accuracy into account.

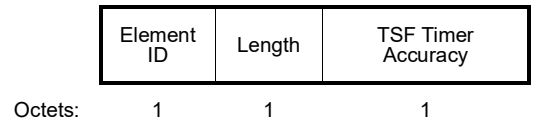

Figure 9-702—TSF Timer Accuracy element format

The Element ID and Length fields are defined in 9.4.2.1.

The TSF Timer Accuracy field is a 1-octet unsigned integer that specifies the accuracy of the TSF timer of transmitting STA. The unit of the TSF Timer Accuracy field is ppm. The values between 125 and 255 are reserved for future expansion.

9.4.2.204 S1G Relay element

The S1G Relay element contains parameters necessary to support the relay operation and its format is shown in Figure 9-703.

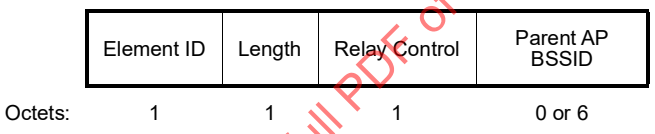

Figure 9-703—S1G Relay element format

The Element ID and Length fields are defined in 9.4.2.1.

The format of Relay Control field is shown in Figure 9-704.

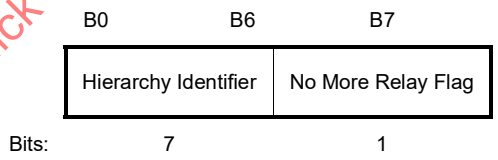

Figure 9-704—Relay Control field format

The Hierarchy Identifier subfield indicates whether the AP is a root AP or whether it relays an SSID, as specified in Table 9-303.

Table 9-303—Hierarchy Identifier subfield

Hierarchy Identifier	Meaning
0	Parent AP
1	S1G Relay AP that relays frames within the BSS identified by the BSSID contained in the RootAP BSSID field
2–127	Reserved

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The No More Relay Flag subfield is set to 1, to indicate that the AP does not accept any more requests for operating as relays from its associated non-AP STAs. Otherwise it is set to 0.

The Parent AP BSSID field indicates the BSSID of the parent AP's BSS. The Parent AP BSSID field is present if the Hierarchy Identifier subfield is set to a nonzero value. Otherwise the Parent AP BSSID field is not present.

9.4.2.205 Reachable Address element

The format of the Reachable Address element is shown in Figure 9-705.

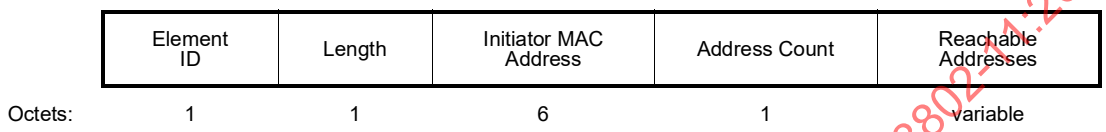

Figure 9-705—Reachable Address element format

The Element ID and Length fields are defined in 9.4.2.1.

The Initiator MAC Address field indicates the MAC address of the relay STA that transmits the Reachable Address element.

The Address Count field is an integer representing the number of addresses in the Reachable Addresses field.

The Reachable Addresses field contains one or more Reachable Address subfields

The Reachable Address subfields indicate the MAC addresses that can be reached through the relay STA. The format of the Reachable Address subfield is shown in Figure 9-706.

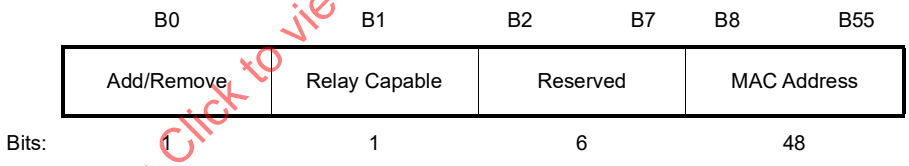

Figure 9-706—Reachable Address subfield format

The Add/Remove subfield is set to 1 if the MAC address is the address of a new STA joining the relay. Add/Remove subfield is set to 0 if the MAC address is the address of a STA leaving the relay. The Add/Remove subfield is set to 1 if the Reachable Address element is included within a (Re)Association Request frame.

The Relay Capable subfield is set to 1 if the STA is relay capable, otherwise it is set to 0.

The MAC Address subfield is set to the MAC address of the STA that joins or leaves the BSS.

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9.4.2.206 S1G Relay Activation element

The format of the S1G Relay Activation element is shown in Figure 9-707.

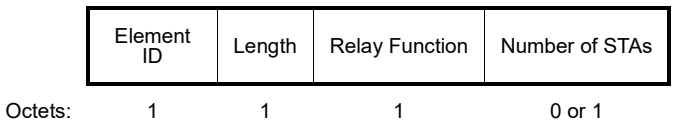

Figure 9-707—S1G Relay Activation element format

The Element ID and Length fields are defined in 9.4.2.1.

The format of the Relay Function field is shown in Figure 9-708.

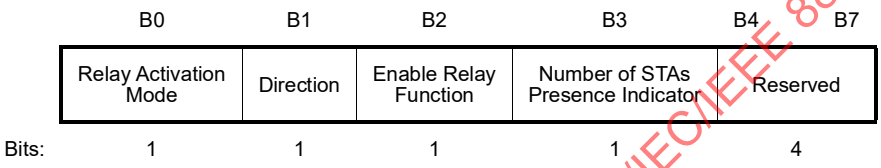

Figure 9-708—Relay Function field format

The Relay Activation Mode subfield is set to 1 to indicate that this element is a relay activation request. The Relay Activation Mode subfield is set to 0 to indicate the relay activation response.

The Direction subfield is set to 1 if the S1G Relay Activation element is sent by the AP. The Direction subfield is set to 0 if the S1G Relay Activation element is sent by the non-AP STA.

The Enable Relay Function subfield is set to a value based on the Direction and Relay Activation Mode subfield as described in Table 9-304.

Table 9-304—Enable Relay Function subfield values

	Relay Activation Mode=1 (Request)	**Relay Activation Mode=0 (Response)**
Direction=1 (from AP)	If the Enable Relay Function subfield is set to 1, it indicates that the non-AP STA can operate as a relay and if it is set to 0 it indicates AP demands the non-AP STA to terminate the relay function.	If the Enable Relay Function subfield is set to 1, it indicates that the non-AP STA is allowed to operate as a relay and if it is set to 0, it indicates that the non-AP STA cannot operate as a relay.
Direction=0 (from non-AP STA)	If the Enable Relay Function subfield is set to 1, it indicates that the non-AP STA requests to activate its relay function and if it is set to 0, it indicates that the non-AP STA requests to terminate its relay function.	If the Enable Relay Function subfield is set to 1, it indicates that the non-AP STA activates its relay function and if it is set to 0, it indicates that the non-AP STA terminates its relay function.

When the S1G Relay Activation element is sent by an AP, the Number of STAs Presence Indicator subfield is set to 1 to indicate that a Number of STAs field is included in the S1G Relay Activation element. Otherwise, it is set to 0.

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The Number of STAs field is 1 octet in length, and contains an unsigned integer. The Number of STAs field is used to calculate the maximum number of STAs, N_{max}, that an S1G relay AP is allowed to associate. N_{max} is determined as follows:

N_{max} = Number of STAs × 32

9.4.2.207 S1G Relay Discovery element

The S1G Relay Discovery element is shown in Figure 9-709.

	Element ID	Length	Relay Discovery Control	UL/DL Data Rate (optional)	Delay Bound Requirement/ Channel Utilization (optional)	Min PHY Rate Requirement/ Relay Station Count (optional)
Octets:	1	1	1	0 to 6	0 or 1	0 or 1

Figure 9-709—S1G Relay Discovery element format

The Element ID and Length fields are defined in 9.4.2.1.

The Relay Discovery Control field contains information indicating whether some or all following fields (see Figure 9-710) are included in the S1G Relay Discovery element. The structure of Relay Discovery Control field is shown later in this subclause in Figure 9-711.

	UL Min Data Rate (optional)	UL Mean Data Rate (optional)	UL Max Data Rate (optional)	DL Min Data Rate (optional)	DL Mean Data Rate (optional)	DL Max Data Rate (optional)
Octets:	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1

Figure 9-710—UL/DL Data Rate field format

When UL Min Data Rate field is included in an S1G Relay Discovery element in a Probe Request frame, it indicates the UL minimum data rate of the direct link between the non-AP STA and AP in the unit of 100 kb/s. When UL Min Data Rate field is included in an S1G Relay Discovery element in a Probe Response or Beacon frame, it indicates the UL minimum data rate of the relay link between the relay and its associated AP in the unit of 100 kb/s.

When UL Mean Data Rate field is included in an S1G Relay Discovery element in a Probe Request frame, it indicates the UL mean data rate of the direct link between the non-AP STA and AP in the unit of 100 kb/s. When UL Mean Data Rate field is included in an S1G Relay Discovery element in a Probe Response or Beacon frame, it indicates the UL mean data rate of the relay link between the relay and its associated AP in the unit of 100 kb/s.

When UL Max Data Rate field is included in an S1G Relay Discovery element in a Probe Request frame, it indicates the UL maximum data rate of the direct link between the non-AP STA and AP in the unit of 100 kb/s. When UL Max Data Rate field is included in an S1G Relay Discovery element in a Probe Response or Beacon frame, it indicates the UL maximum data rate of the relay link between the relay and its associated AP in the unit of 100 kb/s.

When DL Min Data Rate field is included in an S1G Relay Discovery element in a Probe Request frame, it indicates the DL minimum data rate of the direct link between the non-AP STA and AP in the unit of 100 kb/s. When DL Min Data Rate field is included in an S1G Relay Discovery element in a Probe

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Response or Beacon frame, it indicates the DL minimum data rate of the relay link between the relay and its associated AP in the unit of 100 kb/s.

When DL Mean Data Rate field is included in an S1G Relay Discovery element in a Probe Request frame, it indicates the DL mean data rate of the direct link between the non-AP STA and AP in the unit of 100 kb/s. When DL Mean Data Rate field is included in an S1G Relay Discovery element in a Probe Response or Beacon frame, it indicates the DL mean data rate of the relay link between the relay and its associated AP in the unit of 100 kb/s.

When DL Max Data Rate field is included in an S1G Relay Discovery element in a Probe Request frame, it indicates the DL maximum data rate of the direct link between the non-AP STA and AP in the unit of 100 kb/s. When DL Max Data Rate field is included in an S1G Relay Discovery element in a Probe Response or Beacon frame, it indicates the DL maximum data rate of the relay link between the relay and its associated AP in the unit of 100 kb/s.

When included in the S1G Relay Discovery element of a Probe Request frame and the Delay and Rate Requirement Included field in the Relay Discovery Control field of the S1G Relay Discovery element is equal to 1, the Delay Bound Requirement/Channel Utilization field indicates the delay bound requirement of the connection through the relay. When included in the S1G Relay Discovery element that is included in a Probe Response or a Beacon frame and the Utilization and Count Included field in the Relay Discovery Control field of the S1G Relay Discovery element is equal to 1, the Delay Bound Requirement/Channel Utilization field denotes the ratio of time that relay observes the busy level on the relay link between the relay and the AP, with value 100 indicating 100% busy level and value 0 indicating idle (values from 101 to 255 are reserved).

When included in the S1G Relay Discovery element of a Probe Request frame and the Delay and Min PHY Rate Requirement Included field in the Relay Discovery Control field of the S1G Relay Discovery element is equal to 1, the Min PHY Rate Requirement/Relay Station Count field indicates the minimum PHY data rate set required by the requesting STA. When included in the S1G Relay Discovery element of a Probe Response or a Beacon frame and the Utilization and Relay Count Included field in the Relay Discovery Control field of the S1G Relay Discovery element is equal to 1, the Min PHY Rate Requirement/Relay Station Count field denotes the number of non-AP STAs currently associated with the relay.

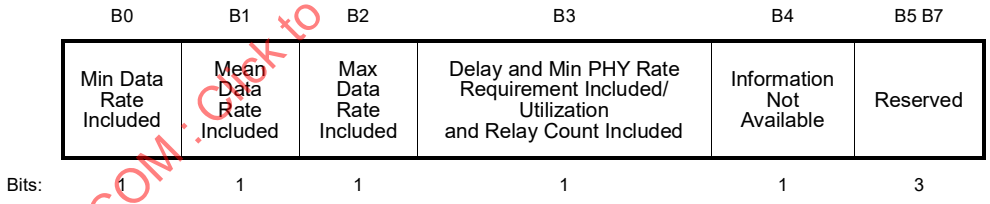

Figure 9-711—Relay Discovery Control field format

The Min Data Rate Included field is set to 1 if UL Min Data Rate field and DL Min Data Rate field are included in the S1G Relay Discovery element. Otherwise, the Min Data Rate Included field is set to 0.

The Mean Data Rate Included field is set to 1 if UL Mean Data Rate field and DL Mean Data Rate field are included in the S1G Relay Discovery element. Otherwise, the Mean Data Rate Included field is set to 0.

The Max Data Rate Included field is set to 1 if UL Max Data Rate field and DL Max Data Rate field are included in the S1G Relay Discovery element. Otherwise, the Max Data Rate Included field is set to 0.

The Delay and Rate Requirement Included/Utilization and Count Included field is set to 1 if Delay Bound Requirement/Channel Utilization field and Min PHY Rate Requirement/Relay Station Count field are

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included in the S1G Relay Discovery element. Otherwise, the Delay and Rate Requirement Included/ Utilization and Count Included field is set to 0.

The Information Not Available field is set to 1 if the relay does not provide the requested information. Otherwise, the Information Not Available field is set to 0.

9.4.2.208 AID Announcement element

The AID Announcement element is used to provide the mapping table between STA MAC Address and STA AID. The format of the AID Announcement element is shown in Figure 9-712.

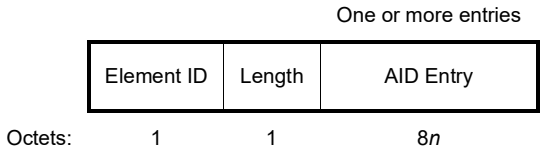

Figure 9-712—AID Announcement element format

The Element ID and Length fields are defined in 9.4.2.1.

The AID Entry field includes one or more STA MAC address and association ID pairs. The format of AID Entry field is shown in Figure 9-713.

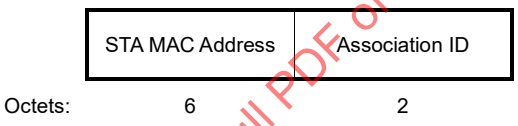

Figure 9-713—AID Entry field format

The STA MAC Address field indicates the MAC address of STA. The Association ID field, which has the same format as the AID field described in 9.4.1.8, includes the AID for the corresponding STA. If AID Announcement element is included in a frame that is transmitted by a relay STA and the Association ID field equals to 0, the STA MAC Address field indicates the BSSID of the relay AP's BSS.

9.4.2.209 PV1 Probe Response Option element

The PV1 Probe Response Option element is included in the Probe Request frame to indicate the optional information requested to be included in the PV1 Probe Response frame that is transmitted by the responding STAs.

The optional information requested by the STA is indicated as bitmaps in the PV1 Probe Response Option element.

The format of the PV1 Probe Response Option element is shown in Figure 9-714.

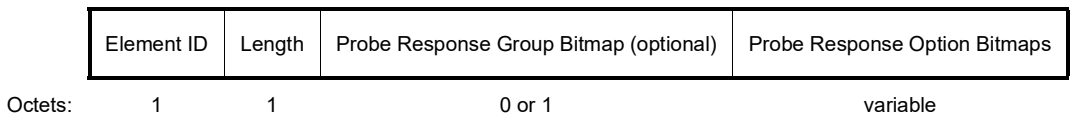

Figure 9-714—PV1 Probe Response Option element format

The Element ID and Length fields are defined in 9.4.2.1.

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The Probe Response Group Bitmap field indicates the Probe Response Option Bitmap subfield(s) included in the PV1 Probe Response Option element. If Probe Response Option Bitmap subfield *i* is included in the PV1 Probe Response Option element, then *i*-th bit in the Probe Response Group Bitmap field is set to 1.

The Probe Response Option Bitmaps field contains one or more Probe Response Option Bitmap subfields.

Each Probe Response Option Bitmap subfield is 1 octet and indicates the optional information requested to be included in the PV1 Probe Response frame by the responding STAs. Setting a bit in a Probe Response Option Bitmap subfield to 1 indicates that the corresponding information is requested to be included in the PV1 Probe Response frame if the responding STA supports the indicated information.The bit is set to 0 to indicate that the information is not requested.

The optional information requested to be included in the PV1 Probe Response is categorized into 8 bitmaps (Probe Response Option bitmap 0 ~ 7).

Only Probe Response Option Bitmap subfields with at least one bit equal to 1 is included in the PV1 Probe Response Option element. For example, if only Probe Response Option Bitmap subfield 0 and 2 have bits that are equal to 1, then these two Probe Response Group Bitmap fields are included in the PV1 Probe Response Option element and the Probe Response Group Bitmap field is set to 10100000 to indicate that only the Probe Response Option Bitmap subfields 0 and 2 are included in the PV1 Probe Response Option element. When the Probe Response Group Bitmap field is included in the PV1 Probe Response Option element, at least one bit of the Probe Response Group Bitmap field is equal to 1.

Probe Response Option Bitmap subfield 0 is defined to be a default bitmap that indicates most frequently requested information. If the default bitmap is the only Probe Response Option Bitmap subfield that is included in the PV1 Probe Response Option element, then the Probe Response Group Bitmap field is omitted. In that case, only Element ID, Length, and the default bitmap (Probe Response Option Bitmap subfield 0) are included in the PV1 Probe Response Option element.

Table 9-305 to Table 9-310 define the Probe Response Option bitmap from 0 to 5, respectively.

NOTE—Probe Response Option bitmap 6 and 7 are reserved for future extension.

Table 9-305—Probe Response Option Bitmap subfield 0 (Default Bitmap)

Bit position	Subfield	Item requested	Reference
0	Request Full SSID	Full SSID element if the bit is set to 1, and Compressed SSID field if the bit is set to 0	9.4.2.2 and 9.8.5.3
1	Request Next TBTT	Next TBTT field	9.8.5.3
2	Request Access Network Options	Access Network Options field	9.4.2.91
3	Request S1G Beacon Compatibility	S1G Beacon Compatibility element	9.4.2.196
4	Request Supported Rates	Supported Rates and BSS Membership Selectors element	9.4.2.3
5	Request S1G Capability	S1G Capabilities element	9.4.2.200
6	Request S1G Operation	S1G Operation element	9.4.2.212
7	Request RSN	RSN element	9.4.2.24

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Table 9-306—Probe Response Option Bitmap subfield 1

Bit position	Subfield	Item requested	Reference
0	Request RPS	RPS element	9.4.2.191
1	Request Page Slice	Page Slice element	9.4.2.192
2	Request TSF Timer Accuracy	TSF Timer Accuracy element	9.4.2.203
3	Request S1G Relay Discovery	S1G Relay Discovery element	9.4.2.207
4	Request S1G Sector Operation	S1G Sector Operation element	9.4.2.195
5	Request Short Beacon Interval	Short Beacon Interval element	9.4.2.197
6–7	Reserved		

Table 9-307—Probe Response Option Bitmap subfield 2

Bit position	Subfield	Item requested	Reference
0	Request Country	Country element	9.4.2.8
1	Request Power Constraint	Power Constraint element	9.4.2.13
2	Request TPC Report	TPC Report element	9.4.2.16
3	Request Extended Supported Rates	Extended Supported Rates and BSS Membership Selectors element	9.4.2.12
4	Request Extended Capabilities	Extended Capabilities element	9.4.2.26
5	Request BSS Load	BSS Load element	9.4.2.27
6	Request EDCA Parameter Set	EDCA Parameter Set element	9.4.2.28
7	Request Supported Operating Classes	Supported Operating Classes element	9.4.2.53

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Table 9-308—Probe Response Option Bitmap subfield 3

Bit position	Subfield	Item requested	Reference
0	Request Measurement Pilot Transmission	Measurement Pilot Transmission element	9.4.2.41
1	Request Multiple BSSID	Multiple BSSID element	9.4.2.45
2	Request RM Enabled Capabilities	RM Enabled Capabilities element	9.4.2.44
3	Request AP Channel Report	AP Channel Report element	9.4.2.35
4	Request BSS Average Access Delay	BSS Average Access Delay element	9.4.2.38
5	Request Antenna	Antenna element	9.4.2.39
6	Request BSS Available Admission Capacity	BSS Available Admission Capacity element	9.4.2.42
7	Request BSS AC Access Delay	BSS AC Access Delay element	9.4.2.43

Table 9-309—Probe Response Option Bitmap subfield 4

Bit position	Subfield	Item requested	Reference
0	Request Mobility Domain	Mobility Domain element	9.4.2.46
1	Request QoS Traffic Capability	QoS Traffic Capability element	9.4.2.77
2	Request Channel Usage	Channel Usage element	9.4.2.85
3	Request Time Advertisement	Time Advertisement element	9.4.2.60
4	Request Time Zone	Request Time Zone element	9.4.2.86
5	Request IBSS Parameter Set	IBSS Parameter Set element	9.4.2.6
6–7	Reserved		

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Table 9-310—Probe Response Option Bitmap subfield 5

Bit position	Subfield	Item requested	Reference
0	Request Interworking	Interworking element	9.4.2.91
1	Request Advertisement Protocol	Advertisement Protocol element	9.4.2.92
2	Request Roaming Consortium	Roaming Consortium element	9.4.2.95
3	Request Emergency Alert Identifier	Emergency Alert Identifier element	9.4.2.96
4	Request QLoad Report	QLoad Report element	9.4.2.122
5	Request Multi-band	Multi-band element	9.4.2.138
6	Request Multiple MAC Sublayers	Multiple MAC Sublayers element	9.4.2.152
7	Request Reduced Neighbor Report	Reduced Neighbor Report element	9.4.2.170

9.4.2.210 EL Operation element

The EL Operation element is used by a STA to inform the associated AP or peer TDLS STA about operating limitations of the STA, in terms of the maximum continuous time the STA is capable of being in the awake state, and the minimum continuous time the STA stays in doze state in between Awake periods. The format of the EL Operation element is presented in Figure 9-715.

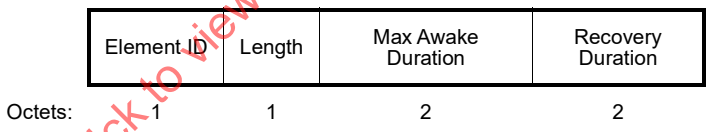

Figure 9-715—EL Operation element format

The Element ID and Length fields are defined in 9.4.2.1.

The Max Awake Duration field indicates a time in units of 40 μs, used as defined in 11.46; a value 0 indicates that no limit applies.

The Recovery Duration field indicates a time in units of 40 μs, used as defined in 11.46.

9.4.2.211 Sectorized Group ID List element

The Sectorized Group ID List element includes the information necessary for a receiving STA to determine its sectorization group membership. An example of group use is the sector operation. In sector operation, only a set of STA groups is allowed to transmit during the sector duration. The Sectorized Group ID List element can be provided in Probe Response or (Re)Association Response frame.

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The format of the Sectorized Group ID List element is presented in Figure 9-716.

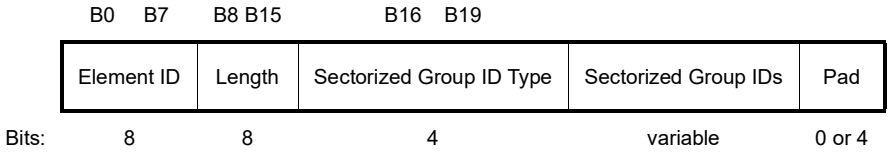

Figure 9-716—Sectorized Group ID List element format

The Element ID and Length fields are defined in 9.4.2.1.

The Sectorized Group ID Type field indicates the sectorized group IDs usage. Setting the Sectorized Group ID Type field to 0 indicates that the values in the Sectorized Group ID subfields refer to STAs in sectorization use. The values of the Sectorized Group ID Type field other than 0 are reserved for other purposes.

The Sectorized Group IDs field contains one or more Sectorized Group ID subfields.

Each Sectorized Group ID subfield is 4 bits and indicates a new sectorized group ID that is associated with the receiver STAs. A value of 15 in the Sectorized Group ID subfield is reserved for padding bits.

The Pad field contains 0 or 4 bits of 1s to make the total number of bits in the Sectorized Group ID List element equal to an integer number of octets.

9.4.2.212 S1G Operation element

The operation of S1G STAs in the BSS is controlled by the S1G Operation element. The format of the S1G Operation element is defined in Figure 9-717.

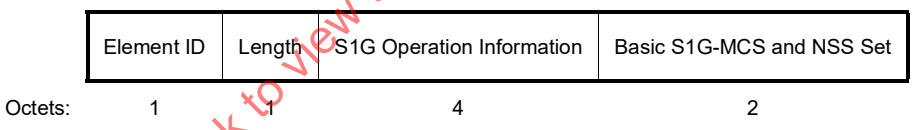

Figure 9-717—S1G Operation element format

The Element ID and Length fields are defined in 9.4.2.1.

The structure of the S1G Operation Information field is defined in Figure 9-718.

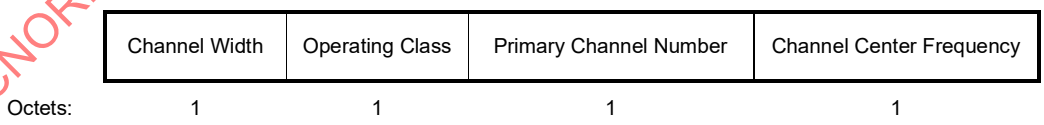

Figure 9-718—S1G Operation Information field format

The subfields of the S1G Operation Information field are defined in Table 9-311.

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Table 9-311—S1G Operation Information field

Fields	Definition	Encoding
Channel Width	This field defines the BSS operating channel width (see Table 10-32 in 10.46.1 also).	Bitmap of B0–B4 indicates the primary channel width, and the operating channel widths, 1/2/4/8/16 MHz. The Primary Channel Width subfield, located in B0 of this field, and the BSS Operating Channel Width subfield, located in B1–B4 of this field, are defined in Table 10-32. B5 bits indicates the location of 1 MHz primary channel within the 2 MHz primary channel — B5 is set to 0 to indicate that is located at the lower side of 2 MHz primary channel. — B5 is set to 1 to indicate that is located at the upper side of 2 MHz primary channel. B6 is reserved. B7 is set to 1 to indicate that it is recommended that a STA does not use MCS 10.
Operating Class	This field defines the operating class in which the BSS is operating.	The operating class of the BSS.
Primary Channel Number	Primary Channel Number field indicates the channel number of 2 MHz primary channel or 1 MHz primary channel.	Channel number of the primary channel.
Channel Center Frequency	Defines the channel center frequency.	Indicates the channel index of the BSS operating channel (see 23.3.14).

The Basic S1G-MCS and NSS Set field indicates the S1G-MCSs for each number of spatial streams in S1G PPDUs that are supported by all S1G STAs in the BSS. The format of the Basic S1G-MCS and NSS Set field is shown in Figure 9-719.

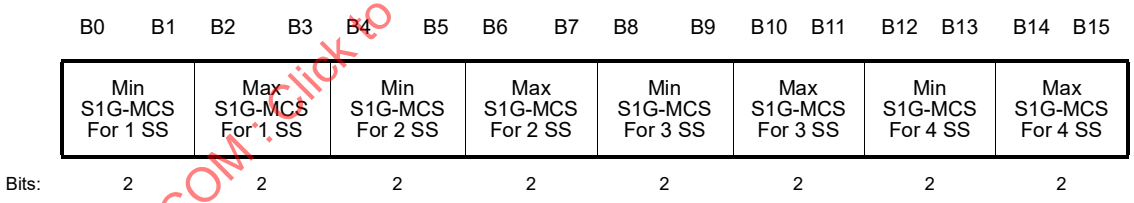

Figure 9-719—Basic S1G-MCS and NSS Set field format

Each Max S1G-MCS indicates the supported S1G-MCS set for NSS from 1 to 4 while each Min S1G-MCS indicates whether certain S1G-MCS values are not recommended for NSS from 1 to 4.

The Max S1G-MCS For *n* SS subfield (where *n* = 1,...,4) is same as the field with the same name that is defined in the S1G Capabilities element.

The Min S1G-MCS For *n* SS subfield (where *n* = 1,...,4) is encoded as follows:

— 0 indicates no minimum MCS restriction for n spatial streams.
— 1 indicates S1G-MCS 0 for *n* spatial streams is not recommended.
— 2 indicates S1G-MCS 0 and 1 for *n* spatial streams is not recommended.
— 3 is reserved.

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9.4.2.213 Header Compression element

The Header Compression element is used by a STA to inform its intended receiver regarding frame header fields that will be compressed and that it needs to store. The format of the Header Compression element is shown in Figure 9-720.

	Element ID	Length	Header Compression Control	A3 (optional)	A4 (optional)	CCMP Update (optional)
Octets:	1	1	1	0 or 6	0 or 6	0 or 5

Figure 9-720—Header Compression element format

The Element ID and Length fields are defined in 9.4.2.1.

The Header Compression Control field is shown in Figure 9-721.

	B0	B1	B2	B3	B4	B5 B7
	Request/ Response	Store A3	Store A4	CCMP Update Present	PV1 Data Type 3 Supported	Reserved
Bits:	1	1	1	1	1	3

Figure 9-721—Header Compression Control field format

The Request/Response subfield is set to 0 to indicate a header compression request and set to 1 to indicate a header compression response.

The Store A3 subfield is set to 1 in the header compression request to request the intended receiver of the frame to store the A3 field and is set to 1 in the header compression response to confirm storage of the A3 field. Otherwise, it is set to 0 in the header compression request to indicate no storage request for the A3 field and is set to 0 in the header compression response to indicate unsuccessful storage or release of the stored A3 field.

The Store A4 subfield is set to 1 to request the intended receiver of the header compression request to store the A4 field and is set to 1 in the header compression response to confirm storing of the A4 field. Otherwise, it is set to 0 in the header compression request to indicate no storage request for the A4 field and is set to 0 in the header compression response to indicate unsuccessful storage or release of the stored A4 field.

The CCMP Update Present subfield is set to 1 to indicate the intended receiver of the header compression request to update the base packet number (BPN) and Key ID fields for the specified TID/ACI in the CCMP Update field and is set to 1 in the header compression response to confirm the update of the fields or to indicate decryption error for the specified TID/ACI. Otherwise, it is set to 0 in the header compression request to indicate no CCMP update request and is set to 0 in the header compression response to indicate no CCMP update confirmation.

The PV1 Data Type 3 Supported subfield is set to 1 to indicate that reception of PV1 frames with Type field equal to 3 is enabled. Otherwise, it is set to 0.

The A3 field in the Header Compression element is present if the Request/Response subfield is 0 and the Store A3 subfield is 1. Otherwise, it is not present.

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The A4 field in the Header Compression element is present if the Request/Response subfield is 0 and the Store A4 subfield is 1. Otherwise, it is not present.

The CCMP Update field in the Header Compression element is present if the CCMP Update Present subfield is 1. Otherwise, it is not present.

The CCMP Update field contains the BPN and Key ID for a given TID/ACI, as shown in Figure 9-722.

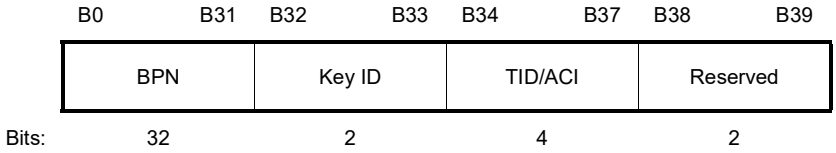

Figure 9-722—CCMP Update field format

The BPN subfield contains the BPN for the TID/ACI in the CCMP Update field. The BPN subfield consists of the PN2, PN3, PN4, and PN5 octets, as shown in Figure 9-723.

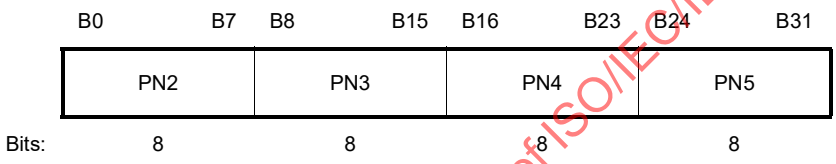

Figure 9-723—BPN subfield format

The Key ID subfield contains the Key ID for the TID/ACI included in the CCMP Update field.

The TID/ACI subfield contains the TID/ACI for which the BPN and the Key ID subfields apply.

9.4.2.214 SST Operation element

The Subchannel Selective Transmission (SST) Operation element is shown in Figure 9-724

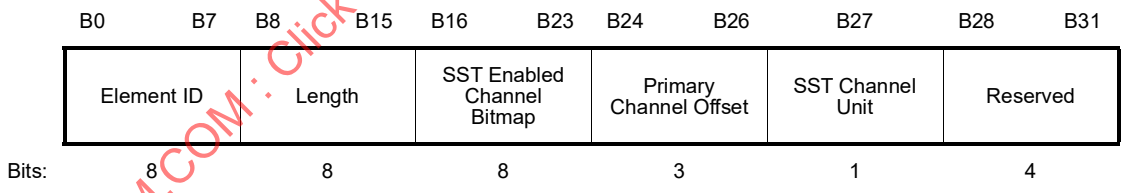

Figure 9-724—SST Operation element format

The Element ID and Length fields are defined in 9.4.2.1.

The SST Enabled Channel Bitmap field contains a bitmap indicating the channels that are enabled for SST operation. Each bit in the bitmap corresponds to one channel of width equal to the value of SST Channel Unit field, with the least significant bit corresponding to the lowest numbered subchannel in the SST Enabled Channel Bitmap field. The channel number of each of the channels in the SST Enabled Channel Bitmap field is equal to PCN minus OPC plus POS, where PCN is the value of the Primary Channel Number subfield in the most recently transmitted S1G Operation element, OPC is the offset of the primary channel relative to the lowest numbered subchannel in the bitmap as specified by the value of the Primary Channel Offset field and POS is the position of the channel in the bitmap. Setting a bit position in the bitmap to 1

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indicates that the subchannel is enabled for SST operation but transmissions from SST STAs in that subchannel are allowed subject to the rules defined in 10.52. More than one bit in the bitmap can be equal to 1.

The Primary Channel Offset field indicates the relative position of the primary channel with respect to the lowest numbered channel in the SST Enabled Channel Bitmap field. For example, setting the Primary Channel Offset field to 2 indicates that the primary channel is the third subchannel in the SST Enabled Channel Bitmap.

The SST Channel Unit field indicates the channel width unit of each SST channel. Setting the field to 1 indicates that the channel width unit is 1 MHz and setting the field to 0 indicates that the channel width unit is 2 MHz.

9.4.2.215 MAD element

The MAD element is shown in Figure 9-725.

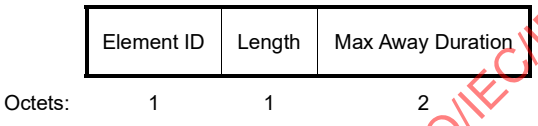

Figure 9-725—MAD element format

The Element ID and Length fields are defined in 9.4.2.1.

The Max Away Duration field indicates the maximum duration that the AP can be out of reach for the STA (operating in other channels, enter power save mode, or operating in other RAWs). The value of the Max Away Duration field is expressed in units of TU.

9.4.2.216 Password Identifier element

The Password Identifier element contains a string used to look up a password. The format of the element is defined in Figure 9-726.

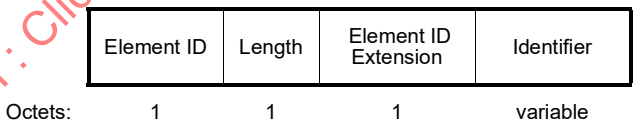

Figure 9-726—Password Identifier element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Identifier field is a variable-length string that identifies a password as specified in 12.4.

9.4.2.217 Max Channel Switch Time element

The Max Channel Switch Time element indicates the time delta between the time the last beacon is transmitted by the AP in the current channel and the expected time of the first beacon transmitted by the AP in the new channel. The format of the element is defined in Figure 9-727.

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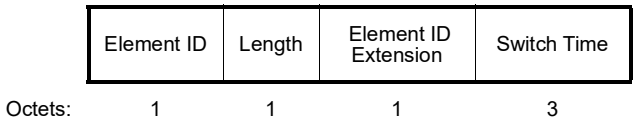

Figure 9-727—Max Channel Switch Time element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Length field is set to 4.

The Switch Time field is a 3-octet field indicating the maximum time delta between the time the last Beacon frame is transmitted by the AP in the current channel and the expected time of the first Beacon frame in the new channel, expressed in TUs.

This element is optionally present in Beacon and Probe Response frames when a Channel Switch Announcement or Extended Channel Switch Announcement element is also present.

9.4.2.218 Vendor Specific Request element

This element is placed in a Probe Request frame or Information Request frame to request that the responding STA include the requested information in the Probe Response frame or Information Response frame, respectively. It is used to make one or more requests to the responding STA using Vendor Specific Information. The format of the element is shown in Figure 9-728.

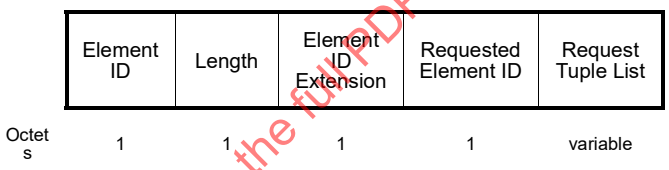

Figure 9-728—Extended Request element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Requested Element ID field is set to 221 (Vendor Specific as defined in 9.4.2.1).

The Request Tuple List field contains one or more Request Tuple fields. The format of a Request Tuple field is shown in Figure 9-729.

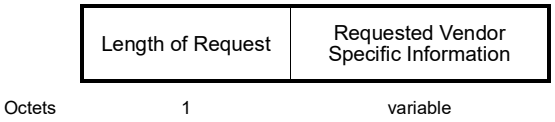

Figure 9-729—Request Tuple field format

The Length of Request field is the length of the Requested Vendor Specific Information field. The Requested Vendor Specific Information field is a sequence of octets that comprise individual requests. The requested vendor specific information sequence must start with an Organization Identifier field as described in 9.4.1.31 (Organization Identifier field).

See 11.1.4.3.9 for additional requirements.

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9.4.2.219 CDMG Capabilities element

9.4.2.219.1 General

The capabilities of a CDMG STA include the capabilities indicated by both the DMG Capabilities element (9.4.2.127) and the CDMG Capabilities element (9.4.2.219). The CDMG Capabilities element contains a STA identifier and several fields to indicate the capabilities that are applicable for a CDMG STA; they are not applicable for a DMG STA. A CDMG STA uses the CDMG Capabilities element to advertise the support of optional CDMG capabilities. The element is present in Association Request, Association Response, Reassociation Request, Reassociation Response, Probe Request, and Probe Response frames and is optionally present in DMG Beacon, Information Request, and Information Response frames. The CDMG Capabilities element is formatted as defined in Figure 9-730.

	Element ID	Length	Element ID Extension	STA Address	AID	CDMG STA Capability Information	CDMG AP Or PCP Capability Information
Octets:	1	1	1	6	1	4	1

Figure 9-730—CDMG Capabilities element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The STA Address field contains the MAC address of the STA.

The AID field contains the AID assigned to the STA by the AP or CP. The AID field is reserved in Association Request, Reassociation Request, and Probe Request frames and when used in an IBSS.

9.4.2.219.2 CDMG STA Capability Information field

The CDMG STA Capability Information field, shown in Figure 9-731, represents the transmitting STA capabilities irrespective of the role of the STA.

	B0 B23	B24	B25	B26	B27	B28 B31
	Supported MCS Set	Dynamic Channel Selection	Opportunistic Transmissions Capable	Selection of Candidate SPs Capable	CDMG Enhanced Beam Tracking Capable	Reserved
Bits:	24	1	1	1	1	4

Figure 9-731—CDMG STA Capability Information field format

The Supported MCS Set subfield indicates the MCSs a CDMG STA supports. A MCS is identified by a MCS index, which is represented by an integer in the range 0 to 23. The interpretation of the MCS index (i.e., the mapping from MCS to data rate) is PHY dependent. For the CDMG PHY, see Clause 24. The structure of the Supported MCS Set subfield is defined in Figure 9-732.

	B0 B4	B5 B9	B10 B14	B15 B19	B20	B21	B22 B23
	Maximum SC Rx MCS	Reserved	Maximum SC Tx_MCS	Reserved	Low Power SC Mode Supported	Code Rate 13/16	Reserved
Bits:	5	5	5	5	1	1	2

Figure 9-732—Supported MCS Set subfield format

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The Maximum SC Rx MCS subfield contains the value of the maximum MCS index the CDMG STA supports for reception of single-carrier frames. Values 0-8 of this subfield are reserved. Possible values for this subfield are shown in Table 24-4.

The Maximum SC Tx MCS subfield contains the value of the maximum MCS index the CDMG STA supports for transmission of single-carrier frames. Values 0-8 of this subfield are reserved. Possible values for this subfield are shown in Table 24-4.

The Low-Power SC Mode Supported subfield is set to 1 to indicate that the CDMG STA supports the low-power SC mode (24.6). Otherwise, it is set to 0. If the CDMG STA supports the low-power SC mode, it supports all low-power SC mode MCSs indicated in Table 24-6.

The Code Rate 13/16 subfield specifies whether the CDMG STA supports rate 13/16. It is set to 1 to indicate that the CDMG STA supports rate 13/16 and is set to 0 otherwise. If this subfield is 0, MCSs with 13/16 code rate specified in Table 24-4 is not supported regardless of the value in Maximum SC Tx/Rx MCSMCS subfields.

The Dynamic Channel Selection subfield is set to 1 if the STA supports DCS procedures as defined in 11.47 and is set to 0 otherwise.

The Opportunistic Transmissions Capable subfield is set to 1 if the STA supports opportunistic transmission in alternative channels for CDMG STAs as defined in 10.39.11 and is set to 0 otherwise.

The Selection of Candidate SPs Capable subfield is set to 1 if the STA supports selection of candidate SPs for spatial sharing as described in Annex W.1 and is set to 0 otherwise.

The CDMG Enhanced Beam Tracking Capable subfield is set to 1 if the STA supports CDMG enhanced beam tracking as defined in 10.42.9 and Annex W.3 and is set to 0 otherwise.

9.4.2.219.3 CDMG AP Or PCP Capability Information field

The CDMG AP Or PCP Capability Information field, defined in Figure 9-733, represents the capabilities, when the transmitting CDMG STA performs in the role of AP or PCP, that are in addition to the capabilities in the CDMG STA Capability Information field.

	B0	B1	B2	B3	B4 B5
	CDMG Decentralized AP or PCP Clustering	CDMG Centralized AP or PCP Clustering	Opportunistic Transmissions Capable	SPSH in CDMG Cluster	Reserved
Bits:	1	1	1	1	5

Figure 9-733—CDMG AP Or PCP Capability Information field format

The CDMG Decentralized AP or PCP Clustering subfield is set to 1 if the STA, when operating as an AP or PCP, is capable of performing decentralized AP or PCP clustering as described in 10.37 and is set to 0 otherwise.

The CDMG Centralized AP or PCP Clustering subfield is set to 1 if the STA, when operating as an AP or PCP, is capable of performing centralized AP or PCP clustering and is set to 0 otherwise. An AP or PCP that is incapable of performing centralized AP or PCP clustering is subject to requirements as described in 10.37.

The SPSH in CDMG Cluster subfield is set to 1 if the STA supports spatial sharing in a CDMG AP or PCP cluster as defined in 10.41.6 and is set to 0 otherwise. If both the CDMG Decentralized AP or PCP

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Clustering subfield and the CDMG Centralized AP or PCP Clustering subfield are equal to 0, the SPSH in CDMG Cluster subfield is reserved.

9.4.2.220 Dynamic Bandwidth Control element

The Dynamic Bandwidth Control element defines the information from the CDMG AP or PCP to support the dynamic bandwidth control mechanism described in 10.64 and the CDMG AP or PCP clustering mechanism described in 10.64. The format of the Dynamic Bandwidth Control element is shown in Figure 9-734.

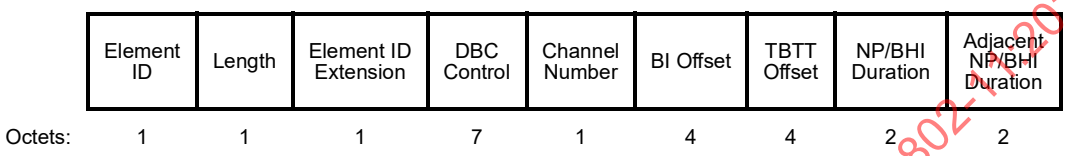

Figure 9-734—Dynamic Bandwidth Control element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The format of the DBC Control field is shown in Figure 9-735.

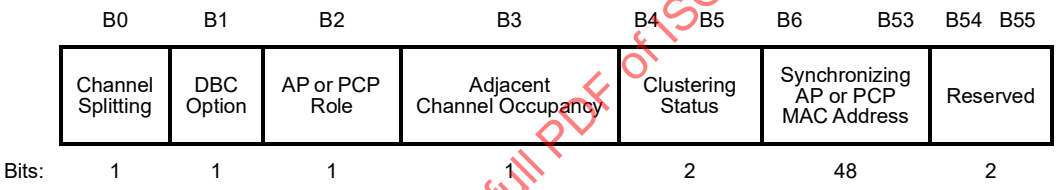

Figure 9-735—DBC Control field format

The Channel Splitting subfield is set to 0 to indicate that an AP or PCP operates on a 2.16 GHz channel and the following subfields are reserved. Otherwise, this subfield is set to 1 to indicate that an AP or PCP operates on a 1.08 GHz channel.

The DBC Option subfield indicates the DBC option that an AP or PCP selects to operate on a 1.08 GHz channel. It is set to 0 to indicate that beacon intervals or BHIs are present on the 1.08 GHz channel and otherwise set to 1.

The AP or PCP Role subfield is set to 0 to indicate that the transmitting AP or PCP operating on a 1.08 GHz channel can provide a time reference to the AP or PCP operating on the adjacent 1.08 GHz channel. Otherwise, this subfield is set to 1 to indicate that the transmitting AP or PCP scans for DMG Beacon frames transmitted from the AP or PCP operating on the adjacent 1.08 GHz channel to maintain synchronization among them following the rules defined in 10.64.2.3.

The Adjacent Channel Occupancy subfield is set to 0 to indicate that the adjacent 1.08 GHz channel of the transmitting AP or PCP is occupied by another AP or PCP. Otherwise, this subfield is set to 1.

The Clustering Status subfield indicates the cluster status of the two 1.08 GHz channel within the same 2.16 GHz channel. The first/second bit is set to 0 to indicate that a cluster starts in the current/adjacent 1.08 GHz channel. Otherwise, the first/second bit of this field is set to 1.

The Synchronizing AP or PCP MAC Address subfield indicates the MAC address of the AP or PCP that provides the time reference for the transmitting AP or PCP. If the AP or PCP Role subfield is 0, this subfield

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is set to the MAC address of itself. Otherwise, this subfield is set to the MAC address of the AP or PCP operating on the adjacent 1.08 GHz channel.

The Channel Number field is set to the number of the channel on which the transmitting STA is operating.

The BI Offset field contains the time offset of the TBTT of the first beacon interval that the transmitting AP or PCP starts on a 1.08 GHz channel relative to the TBTT of the beacon interval that the transmitting AP or PCP starts on the 2.16 GHz channel encompassing this 1.08 GHz channel. This field is reserved if the DBC Option subfield is 1.

The TBTT Offset field contains the time offset of the target starting time of the NP/BHI on a 2.16 GHz channel of the transmitting AP or PCP operating on one of the 1.08 GHz channels relative to that of another AP or PCP operating on the adjacent 1.08 GHz channel.

The NP/BHI Duration field is set to the length of the NP/ BHI duration on a 2.16 GHz channel by the transmitting AP or PCP operating on one of the 1.08 GHz channels.

The Adjacent NP/BHI Duration field is set to the length of the NP/ BHI duration on a 2.16 GHz channel by the AP or PCP operating on the adjacent 1.08 GHz channel of the transmitting AP or PCP.

9.4.2.221 CDMG Extended Schedule element

The CDMG Extended Schedule element is defined in Figure 9-736. Like the Extended Schedule element (9.4.2.131), the AP or PCP can split the Allocation fields in the CDMG Extended Schedule element into more than one CDMG Extended Schedule element entry in the same DMG Beacon frame or Announce frame. Despite this splitting, the set of CDMG Extended Schedule element entries conveyed within a DMG Beacon or Announce frame is considered to be a single schedule for the beacon interval and, in this standard, is referred to simply as CDMG Extended Schedule element unless otherwise noted.

	Element ID	Length	Element ID Extension	Allocation List
Octets:	1	1	1	$n \times 19$

Figure 9-736—CDMG Extended Schedule element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Allocation List field contains one or more (n) Allocation fields. The Allocation fields are ordered by increasing allocation start time with allocations beginning at the same time arbitrarily ordered.

The Allocation field is defined in Figure 9-737.

	Allocation Control	BF Control	Source AID	Destination AID	Allocation Start
Octets:	2	2	1	1	4

	Allocation Block Duration	Number of Blocks	Allocation Block Period	Number of Alternate TX BI	Number of Suspension BI
Octets:	2	1	2	2	2

Figure 9-737—Allocation field format

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The Allocation Control subfield format is the same as defined in 9.4.2.131, including Allocation ID, AllcationType, Pseudo-static, Truncatable, Extendable, PCP Active, and LP SC Used subfields and reserved bits.

The Allocation ID subfield is the same as defined in 9.4.2.131.

The AllocationType subfield defines the channel access mechanism during the allocation, with the possible values listed in Table 9-312 for CDMG STAs:

Table 9-312—AllocationType subfield values for CDMG STAs

Bit 4	Bit 5	Bit 6	Meaning
0	0	0	SP allocation in dedicated channel
1	0	0	CBAP allocation in dedicated channel
0	1	0	SP allocation in alternative channel
1	1	0	CBAP allocation in alternative channel
All other combinations			Reserved

The Pseudo-static, Truncatable, Extendable, PCP Active, and LP SC Used subfields are the same as defined in 9.4.2.131.

The BF Control subfield is defined in Figure 9-738 and Figure 9-739.

	B0	B1	B2	B3 B9	B10	B11	B12	B13 B15
	Beamforming Training	IsInitiator TXSS	IsResponder TXSS	Total Number of Sectors	Number of RX DMG Antennas	NoPrimary Channel	Reserved	
Bits:	1	1	1	7	2	1	3	

Figure 9-738—BF Control field format when both IsInitiatorTXSS and IsResponderTXSS subfields are equal to 1 and the BF Control field is transmitted in Grant or Grant Ack frames

	B0	B1	B2	B3 B8	B9 B10	B11	B12 B15
	Beamforming Training	IsInitiator TXSS	IsResponder TXSS	RXSS Length	RXSSTxRate	NoPrimary Channel	Reserved
Bits:	1	1	1	6	2	1	4

Figure 9-739—BF Control field format in all other cases

The BeamformingTraining, IsInitiatorTXSS, IsResponderTXSS, Total Number of Sectors, Number of RX DMG Antennas, RXSS Length, RXSSTxRate subfields are the same as defined in 9.5.5.

The NoPrimaryChannel subfield is set to 1 to indicate that the CDMG initiator does not need to perform SLS on the primary channel. It is set to 0 to indicate that the CDMG initiator needs to perform SLS on the primary channel. This subfield is reserved when it is transmitted by an AP or PCP.

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The Source AID, Destination AID, Allocation Start, Allocation Block Duration, Number of Blocks, and Allocation Block Period subfields are the same as defined in 9.4.2.131.

The Number of Alternate TX BI subfield indicates the duration of transmission phase in the alternate channel in terms of number of beacon intervals.

The Number of Suspension BI subfield indicates the duration of the suspension phase in the alternate channel in terms of the number of beacon intervals.

9.4.2.222 SSW Report element

The SSW Report element is used by a non-AP and non-PCP CDMG STA to report beamforming training information to an CDMG AP or PCP (see 11.30.1) or used by a responder STA to deliver the backup sector information to an initiator STA. The SSW Report element is defined in Figure 9-740.

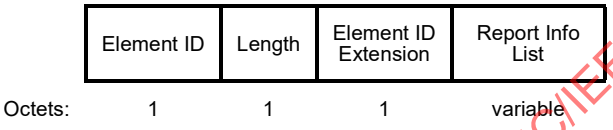

Figure 9-740—SSW Report element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Report Info List field contains one or more Report Info fields.

A Report Info field is formatted as defined in Figure 9-741 when its SSW Report Control subfield is 1; otherwise, a Report Info field is formatted as defined in Figure 9-742.

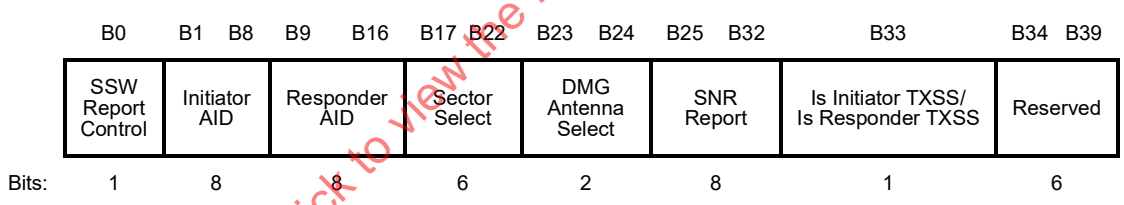

Figure 9-741—Report Info field format when the SSW Report Control subfield is 1

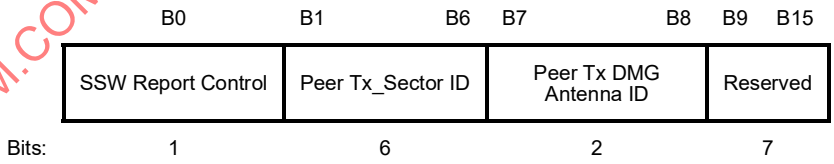

Figure 9-742—Report Info field format when the SSW Report Control subfield is 0

The SSW Report Control subfield indicates the format of the Report Info field.

The Initiator AID subfield identifies the STA that is the initiator of the beamforming training.

The Responder AID subfield identifies the STA that is the responder of the beamforming training.

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The Sector Select subfield is defined in 9.5.3.

The DMG Antenna Select subfield is defined in 9.5.3.

The SNR Report subfield is defined in 9.5.3.

The Is Initiator TXSS/Is Responder TXSS subfield is set to 1 to indicate that an initiator TXSS has been performed between the initiator and the responder. This subfield is set to 0 to indicate that a responder TXSS has been performed between the initiator and the responder.

If the SSW Report Control subfield is 0, the Peer Tx_Sector ID subfield indicates the Sector ID of the alternative Tx sector of the peer STA. The determination of the alternative Tx sector is implementation dependent. Possible values of this subfield range from 0 to 63. Otherwise, the Peer Tx_Sector ID subfield is reserved.

If the SSW Report Control subfield is 0, the Peer Tx DMG Antenna ID subfield indicates the alternative DMG antenna ID of the alternative Tx DMG antenna of the peer STA. The determination of the alternative Tx DMG antenna is implementation dependent. Otherwise, the Peer Tx DMG Antenna ID subfield is reserved.

9.4.2.223 Cluster Probe element

The Cluster Probe element is used to probe the presence of a CDMG AP or PCP cluster operating on the common 2.16 GHz channel by the CDMG AP or PCP operating on a 1.08 GHz channel. This element can be included in a DMG Beacon, Announce, or Probe Request frame. The Cluster Probe element is shown in Figure 9-743.

	Element ID	Length	Element ID Extension	Request Token	SP Offset	SP Space	SP Duration	Repetition Count
Octets:	1	1	1	2	2	4	2	1

Figure 9-743—Cluster Probe element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Request Token field is set to a nonzero value chosen by the requesting AP or PCP.

The SP Offset field is set to the offset of the start of the first SP from the frame that contains this element, expressed in TUs. The reference time is the start of the preamble of the PPDU that contains this element.

The SP interval field is set to the spacing between the start of two consecutive SP intervals, expressed in TUs.

The SP Duration field is set to duration of a single SP, expressed in TUs.

The Repetition Count field is set to the number of requested SPs.

9.4.2.224 Extended Cluster Report element

The Extended Cluster Report element is used to report the cluster synchronization and control information to the cluster probe requesting CDMG AP or PCP by the S-AP or S-PCP of a CDMG AP or PCP cluster. The Extended Cluster Report element is also used by an S-AP to report the cluster information of the S-APs

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within the same CCSS for an AP or PCP that intends to join the centralized cluster. This element can be included in a DMG Beacon, Announce, or Probe Response frame transmitted by a CDMG AP or PCP. The Extended Cluster Report element is shown in Figure 9-744.

	Element ID	Length	Element ID Extension	Extended Cluster Report Control	Request Token	Next BTI Offset	Reported Clustering Control	Reported BI Duration	Cluster Channel Number	Available Cluster Offset Bitmap
Octets:	1	1	1	1	0 or 2	4	8	0 or 2	0 or 1	0 or 4

Figure 9-744—Extended Cluster Report element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

If the Extended Cluster Report Control field is 0, this element is used in decentralized clustering mechanism, and the Reported BI Duration, Cluster Channel Number, and Available Cluster Offset Bitmap fields are not present in this element. Otherwise, this element is used in centralized clustering mechanism, and the Request Token field is not present in this element.

The Request Token field value is copied from the corresponding received Cluster Probe element.

The Next BTI Offset field contains the low order 4 octets of the TSF for the earliest time at which the next BTI in a subsequent beacon interval starts.

The Reported Clustering Control field is defined in 9.3.4.1 and contains the Clustering Control field in the last transmitted DMG Beacon frame of the S-AP or S-PCP or the reported S-AP.

The Reported BI Duration field is set to the beacon interval value of the reported S-AP, expressed in TUs.

The Cluster Channel Number field is set to the operating channel number of the reported S-AP.

The Available Cluster Time Offset Bitmap field is set to the Available Cluster Time Offset Bitmap field of the reported S-AP's ECAPC Policy element.

9.4.2.225 Cluster Switch Announcement element

A CDMG AP or PCP transmits the Cluster Switch Announcement element to its original cluster before switching from a cluster to another. One of the synchronization pair APs or PCPs also transmits the Cluster Switch Announcement element to its peer CDMG AP or PCP before joining a cluster. The Cluster Switch Announcement element can be included in the DMG Beacon frame or Announce frame transmitted by a CDMG AP or PCP and received by other member CDMG APs or member CDMG PCPs. The format of the Cluster Switch Announcement element is shown in Figure 9-745.

	Element ID	Length	Element ID Extension	New Channel Number	Reference Timestamp	Reported Clustering Control	Reported BI Duration	Cluster Switch Count
Octets:	1	1	1	2	2	4	2	1

Figure 9-745—Cluster Switch Announcement element format

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The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The New Channel Number field is set to the operating channel number of the target cluster after cluster switching.

The Reference Timestamp field contains the lower 4 octets of the TSF timer value sampled at the instant that the STA's MAC received the DMG Beacon frame of the S-AP or S-PCP of the target cluster.

The Reported Clustering Control field contains the Clustering Control field included in the received DMG Beacon frame of the S-AP or S-PCP.

The Reported BI Duration field is set to the beacon interval value of the reported S-AP or S-PCP, expressed in TUs.

The Cluster Switch Count field either is set to the number of TBTTs until the AP or PCP sending the Cluster Switch Announcement element switches to the new cluster or is set to 0. This field is set to 1 to indicate that the switch occurs immediately before the next TBTT. It is set to 0 to indicate that the switch occurs at any time after the frame containing the element is transmitted.

9.4.2.226 Enhanced Beam Tracking element

The Enhanced Beam Tracking element is used to configure the alternative link of a CDMG STA, track the alternative link of the enhanced beam tracking initiator and responder, and switch to an alternative link from the current link. The element can be included in a BRP, DMG Beacon, Information Request, or Information Response frame transmitted by a CDMG STA.

The format of the Enhanced Beam Tracking element is shown in Figure 9-746.

	Element ID	Length	Element ID Extension	E-BT Control	Peer Tx Antenna Parameter
Octets:	1	1	1	1	1

Figure 9-746—Enhanced Beam Tracking element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.225.

The E-BT Control field is defined in Figure 9-747.

	B0 B1	B2	B3	B4	B5	B6	B7
	Backup AWV Setting	Peer E-BT-R Request	E-BT-R Enabled	Peer E-BT-T Request	E-BT-T Enabled	Switching to Backup AWV Request	Switching to Backup AWV Enabled
Bits:	2	1	1	1	1	1	1

Figure 9-747—E-BT Control field format

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The Backup AWV Setting subfield is used to set the alternative AWV of the peer STA. The default alternative AWV of the peer STA is set to omnidirectional. If the Backup AWV Setting subfield is 0, the peer STA does not update the alternative AWV. If the Backup AWV Setting subfield is 1, the peer STA set the alternative AWV according to the AWV specified by the Peer Tx Antenna Parameter field. If the Backup AWV Setting subfield is 2, the current received AWV of peer is used to update the alternative AWV; if the Backup AWV Setting subfield is 3, the last transmitted AWV of peer is used to update the alternative AWV.

The Peer E-BT-R Request subfield is set to 1 to indicate that the peer STA is requested to enable enhanced beam tracking to receive the e-TRN-R training sequences; otherwise, it is set to 0.

The E-BT-R Enabled subfield is set to 1 to indicate that the requested peer STA acknowledges that it has enabled enhanced receive beam tracking to receive the e-TRN-R training sequences; otherwise, it is set to 0.

The Peer E-BT-T Request subfield is set to 1 to indicate that the peer STA is requested to enable enhanced transmit beam tracking to transmit the e-TRN-T training sequences; otherwise, it is set to 0.

The E-BT-T Enabled subfield is set to 1 to indicate that the requested peer STA acknowledges that it has enabled enhanced transmit beam tracking to transmit the e-TRN-T training sequences; otherwise, it is set to 0.

The Switching to Backup AWV Request subfield is set to 1 to indicate that the peer STA is requested to switch to the alternative AWV; otherwise, it is set to 0.

The Switching to Backup AWV Enabled subfield is set to 1 to indicate that the requested STA acknowledges that its antenna setting is to be switched to the alternative AWV before the next frame and to set the AWV of the current link as the new alternative AWV; otherwise, it is set to 0.

The Peer TX Antenna Parameter field is defined in Figure 9-748.

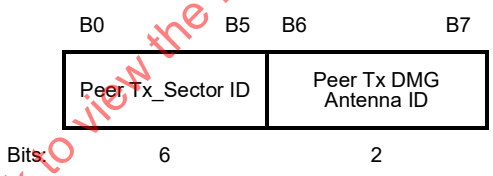

Figure 9-748—Peer TX Antenna Parameter field format

If the Backup AWV Setting subfield is 1, the Peer Tx_Sector ID field is set to the Sector ID of the alternative Tx AWV of the peer STA. Otherwise, the Peer Tx_Sector ID field is reserved.

If the Backup AWV Setting subfield is 1, the Peer Tx DMG Antenna ID field indicates the DMG antenna ID of the alternative Tx AWV of the peer STA. Otherwise, the Peer Tx DMG Antenna ID field is reserved.

9.4.2.227 SPSH Report element

The SPSH Report element is used for an AP or PCP in a cluster to report the possibility of spatial sharing and coexistence between links in other BSSs and links in its own BSS. The SPSH Report element is transmitted in the DMG Beacon frame by a CDMG AP or PCP and is defined in Figure 9-749. Because the length parameter supports only 255 octets of payload in an element, the AP or PCP can split the SPSH List fields into more than one SPSH Report element entry in the same DMG Beacon or Announce frame.

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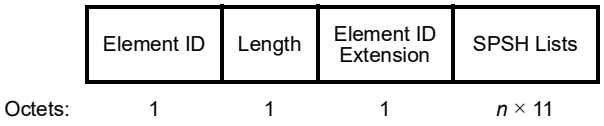

Figure 9-749—SPSH Report element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The SPSH Lists field contains one or more (*n*) SPSH List fields.

The SPSH List field contains information of non-interfering links and is defined in Figure 9-750.

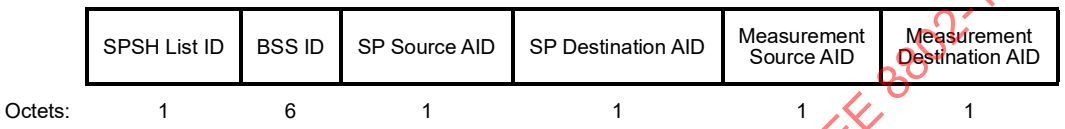

Figure 9-750—SPSH List field format

The SPSH List ID subfield indicates the identification of the SPSH List field, which is the same as the index of the corresponding field in the SPSH Report Element. It indicates that the channel measurement, between the two STAs indicated by the following Measurement Source AID subfield and the Measurement Destination AID subfield, shows no severe interference while the STA indicated by the SP Source AID subfield communicates with the STA indicated by the SP Destination AID subfield.

The BSS ID subfield indicates the identification of the measured infrastructure BSS or PBSS, which is the MAC address of the AP or PCP in the measured infrastructure BSS or PBSS.

The SP Source AID subfield indicates the AID of the transmitter STA of the link in the measured infrastructure BSS or PBSS.

The SP Destination AID subfield indicates the AID of the receiver STA of the link in the measured infrastructure BSS or PBSS. The SP Source AID and SP Destination AID subfields uniquely identify the link from the source AID STA to the destination AID STA in the BSS identified by the BSSID field.

The Measuring Source AID subfield indicates the AID of the transmitter of the link that is conducting SPSH measurement in the measured infrastructure BSS or PBSS, and the measured link does not interfere with it.

The Measuring Destination AID subfield indicates the AID of the receiver of the link that is conducting SPSH measurement in the measured infrastructure BSS or PBSS, and the measured link does not interfere with it. The Measuring Source AID and Measuring Destination AID subfields uniquely identify the link from the measuring source AID STA to the measuring destination AID STA in the BSS.

9.4.2.228 Clustering Interference Assessment element

The S-AP or S-PCP in a CDMG AP or PCP cluster uses a Clustering Interference Assessment element to enable spatial sharing in the cluster and sets channel quality measurement and control parameters of spatial sharing for their member APs or member PCPs. The Clustering Interference Assessment element can be included in the DMG Beacon frames transmitted by the CDMG S-AP or S-PCP, as shown in Figure 9-751.

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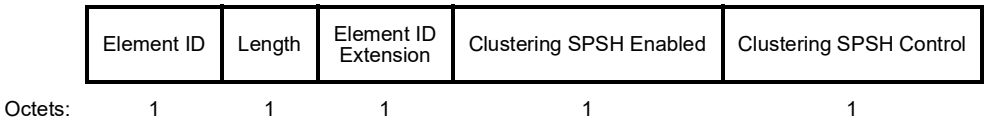

Figure 9-751—Clustering Interference Assessment element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Clustering SPSH Enabled field is set to 0 to indicate that a SPSH measurement phase starts. The Clustering SPSH Enabled field is set to 1 to indicate that the SPSH measurement phase for all member APs or member PCPs terminates and SP spatial sharing among BSSs starts. Other values are reserved. The Clustering SPSH Enabled field is set as the same as the SPSH Measurement Enabled subfield in the Clustering Control field defined in 9.3.4.2.

The Clustering SPSH Control field is defined in Figure 9-752.

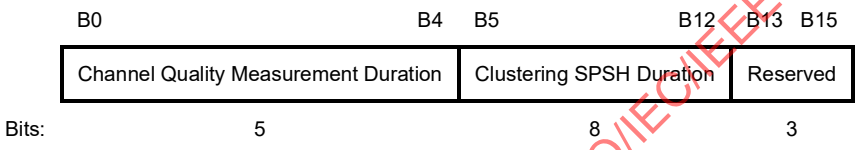

Figure 9-752—Clustering SPSH Control field format

The Channel Quality Measurement Duration subfield is set to a duration of directional channel quality measurement for all member APs or member PCPs in a CDMG AP or PCP cluster, in units of beacon intervals.

The Clustering SPSH Duration subfield is set to a duration of spatial sharing among BSSs for all member APs or member PCPs in a CDMG AP or PCP cluster, in units of beacon intervals.

9.4.2.229 CMMG Capabilities element

9.4.2.229.1 CMMG Capabilities element structure

The CMMG Capabilities element contains a number of fields that are used to advertise the CMMG capabilities of STA. The CMMG Capabilities element is defined in Figure 9-753.

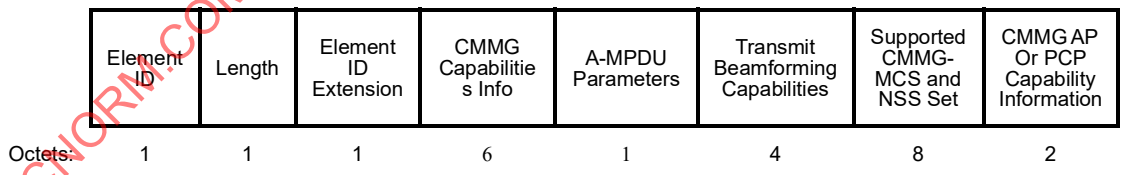

Figure 9-753—CMMG Capabilities element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

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9.4.2.229.2 CMMG Capabilities Info field

The structure of the CMMG Capabilities Info field is defined in Figure 9-754.

B0 B1	B2	B3	B4 B5	B6	B7	B8	B9
Maximum MPDU Length	Supported Channel Width Set	Tx STBC	Rx STBC	Short GI for 540 MHz	Short GI for 1080 MHz	Supported MIMO	Heartbeat
Bits: 2	1	1	2	1	1	1	1

B10 B11	B12	B13	B14	B15	B16	B17	B18 B23
TPC	Number of Sounding Dimensions CMMG	TXOP PS	Protected Block Ack	CMMG Link Adaptation Capable	Rx Antenna Pattern Consistency	Tx Antenna Pattern Consistency	Fast Link Adaptation
Bits: 2	1	1	1	1	1	1	6

B24 B29	B30 B31	B32	B33 B34	B35	B36	B37	B38 B44
RXSS Length	Color	PSH and Interference Mitigation	Number of Rx Antennas	Supports Other_AID	RXSS Tx Rate Supported	Antenna Pattern Reciprocity	Total Number of Sectors
Bits: 6	2	1	2	1	1	1	7

B45 B47	B48 B50	B51	B52 B55
Heartbeat Elapsed Indication	MCS Feedback	RD Responder	Reserved
Bits: 3	3	1	5

Figure 9-754—CMMG Capabilities Info field format

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The subfields of the CMMG Capabilities Info field are defined in Table 9-313.

Table 9-313—Subfields of the CMMG Capabilities Info field

Subfield	Definition	Encoding
Maximum MPDU Length	Indicates the maximum MPDU length (see 10.12).	Set to 0 for 3895 octets. Set to 1 for 7991 octets. Set to 2 for 11 454 octets. The value 3 is reserved.
Supported Channel Width Set	Indicates the channel widths supported by the STA. See 11.47.	Set to 0 if the STA does not support 1080 MHz. Set to 1 if the STA supports 1080 MHz.
Tx STBC	Indicates support for the transmission of at least 2x1 STBC.	Set to 0 if not supported. Set to 1 if supported.
Rx STBC	Indicates support for the reception of PPDUs using STBC.	Set to 0 for no support. Set to 1 for support of one spatial stream. Set to 2 for support of one and two spatial streams. The value 3 is reserved.
Short GI for 540 MHz	Indicates short GI support for the reception of PPDUs transmitted with the TXVECTOR parameter CH_BANDWIDTH set to CMMG_CBW540.	Set to 0 if not supported. Set to 1 if supported.
Short GI for 1080 MHz	Indicates short GI support for the reception of PPDUs transmitted with the TXVECTOR parameter CH_BANDWIDTH set to CMMG_CBW1080.	Set to 0 if not supported. Set to 1 if supported.
Supported MIMO	Indicates whether the STA supports MIMO.	The Supported MIMO field is set to 1 if the STA supports the SC and OFDM MIMO and is set to 0 otherwise.
Heartbeat	Indicate that whether the STA expects to receive a frame from the AP or PCP during the ATI and expects to receive a frame with the CMMG Control modulation from a source CMMG STA at the beginning of an SP or TXOP.	Set to 1 to indicate that the STA expects to receive a frame from the AP or PCP during the ATI and expects to receive a frame with the CMMG Control modulation from a source CMMG STA at the beginning of an SP or TXOP. Otherwise, this field is set to 0.
TPC	Indicates whether the STA supports TPC.	The TPC field is set to 1 if the STA supports the TPC as defined in 11.7 and is set to 0 otherwise.
Number of Sounding Dimensions	Beamformer's capability indicating the maximum value of the TXVECTOR parameter NUM_STS for a CMMG NDP.	If beamformer capable, set to the maximum supported value of the TXVECTOR parameter NUM_STS minus 1. Otherwise, reserved.
TXOP PS	Indicates whether the AP supports CMMG TXOP power save mode or whether the non-AP STA has enabled CMMG TXOP power save mode.	Set to 0 if the AP does not support TXOP power save mode. Set to 1 if the AP supports TXOP power save mode. Set to 0 if the non-AP STA does not enable TXOP power save mode. Set to 1 if the non-AP STA enables TXOP power save mode.

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Table 9-313—Subfields of the CMMG Capabilities Info field *(continued)*

Subfield	Definition	Encoding
Protected Block Ack	Indicates support for protected block ack operation. See 10.25.7.	Set to 0 if not supported. Set to 1 if supported. Support indicates that the STA is able to accept an ADDBA request for protected block ack.
CMMG Link Adaptation Capable	Indicates whether the STA supports link adaptation using CMMG variant HT Control field.	Set to 0 (No Feedback) if the STA does not provide CMMG MFB. Set to 2 (Unsolicited) if the STA provides only unsolicited CMMG MFB. Set to 3 (Both) if the STA can provide CMMG MFB in response to CMMG MRQ and if the STA provides unsolicited CMMG MFB. The value 1 is reserved.
Rx Antenna Pattern Consistency	Indicates the possibility of a receive antenna pattern change.	Set to 0 if the receive antenna pattern might change during the lifetime of the current association. Set to 1 if the receive antenna pattern does not change during the lifetime of the current association. See 11.48.6.
Tx Antenna Pattern Consistency	Indicates the possibility of a transmit antenna pattern change.	Set to 0 if the transmit antenna pattern might change during the lifetime of the current association. Set to 1 if the transmit antenna pattern does not change during the lifetime of the current association. See 11.48.6.
Fast Link Adaptation	Indicates whether the STA supports fast link adaptation.	The Fast Link Adaptation field is set to 1 to indicate that the STA supports the CMMG fast link adaptation procedure described in 10.44.3. Otherwise, it is set to 0.
RXSS Length	Specifies the total number of receive sectors combined over all receive antennas of the STA.	The value represented by this field is in the range 2 to 128 and is given by (RXSS Length+1)×2. The maximum number of SSW frames transmitted during an RXSS is equal to the value of (RXSS Length+1)×2 times the total number of transmit antennas of the peer device.
Color	Indicates the value that is used for the TXVECTOR parameter COLOR in frames transmitted by members of this BSS, as described in 10.19.	Set to an unsigned integer if sent by an AP. Otherwise reserved.
SPSH and Interference Mitigation	Indicate whether the STA is capable of performing the function of SPSH and interference mitigation or not.	Set to 1 if the STA is capable of performing the function of SPSH and interference mitigation and if dot11RadioMeasurementActivated is true and is set to 0 otherwise (see 10.34).
Number of Rx Antennas	Indicates the total number of receive antennas of the STA.	Set to the number of antennas minus 1.
Supports Other_AID	Indicate that the STA sets its AWV configuration according to the Other_AID subfield in the BRP Request field.	Set to 1 if the value of the Other_AID subfield is different from zero. Otherwise, this field is set to 0.
RXSSTxRate Supported	Indicate whether the STA can perform an RXSS with the SSW frames transmitted at MCS 1 of the CMMG SC modulation class or not.	Set to 1 to indicate that the STA can perform an RXSS with the SSW frames transmitted at MCS 1 of the CMMG SC modulation class. Otherwise, it is set to 0.

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Table 9-313—Subfields of the CMMG Capabilities Info field *(continued)*

Subfield	Definition	Encoding
Antenna Pattern Reciprocity	Indicate whether the transmit antenna pattern associated with an AWV is the same as the receive antenna pattern for the same AWV or not.	Set to 1 to indicate that the transmit antenna pattern associated with an AWV is the same as the receive antenna pattern for the same AWV. Otherwise, this field is set to 0.
Total Number of Sectors	Indicates the total number of transmit sectors the STA uses in a transmit sector sweep combined over all antennas.	Set to the number of transmit sectors minus 1.
Heartbeat Elapsed Indication	Used to calculate the value of the heartbeat elapsed time.	The heartbeat elapsed time is computed according to the following equation: $T_{HE} = \begin{cases} 0, F_{HE} = 0 \\ \frac{2^{F_{HE}}}{4}, F_{HE} > 0 \end{cases}$ where T_{HE} is the heartbeat elapsed time (in milliseconds); F_{HE} is the value of the Heartbeat Elapsed Indication subfield.
MCS Feedback	Indicates whether the STA can provide MFB.	Set to 0 (No Feedback) if the STA does not provide MFB. Set to 2 (Unsolicited) if the STA provides only unsolicited MFB. Set to 3 (Both) if the STA can provide MFB in response to MRQ (either Delayed or Immediate, see 10.32) as well as unsolicited MFB The value 1 is reserved.
RD Responder	Indicates support for acting as a reverse direction responder, i.e., the STA might use an offered RDG to transmit data to an RD initiator using the reverse direction protocol described in 10.27.	Set to 0 if not supported. Set to 1 if supported.
NOTE—The value for the Maximum MPDU Length subfield in the CMMG Capabilities Info field imposes a constraint on the allowed value of the Maximum MPDU Length in the CMMG Capabilities Info field of the CMMG Capabilities element carried in the same frame (see 10.11).		

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9.4.2.229.3 A-MPDU Parameters field

The structure of the A-MPDU Parameters field of the CMMG Capabilities element is shown in Figure 9-755. The definition for the subfields of the A-MPDU Parameters field is shown in Table 9-314.

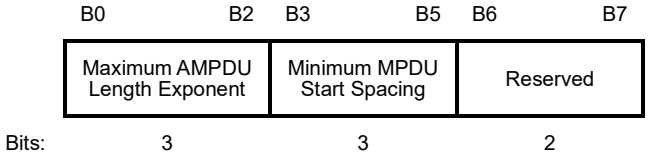

Figure 9-755—A-MPDU Parameters field format

Table 9-314—Subfields of the A-MPDU Parameters field

Subfield	Definition	Encoding
Maximum AMPDU Length Exponent	Indicates the maximum length of A-MPDU that the STA can receive. EOF padding is not included in this limit.	The length defined by this field is equal to $2^{(13 + \text{MaximumAPPDUULenghtExponent})}$ octets.
Minimum MPDU Start Spacing	Determines the minimum time between the start of adjacent MPDUs within an A-MPDU that the STA can receive, measured at the PHY SAP. See 9.7.3.	Set to 0 for no restriction. Set to 1 for 16 ns. Set to 2 for 32 ns. Set to 3 for 64 ns. Set to 4 for 128 ns. Set to 5 for 256 ns. Set to 6 for 512 ns. Set to 7 for 1024 ns.

9.4.2.229.4 Supported CMMG-MCS and NSS Set field

The Supported CMMG-MCS and NSS Set field is used to convey the combinations of CMMG-MCSs and spatial streams that a STA supports for reception and the combinations that it supports for transmission. The structure of the field is shown in Figure 9-756.

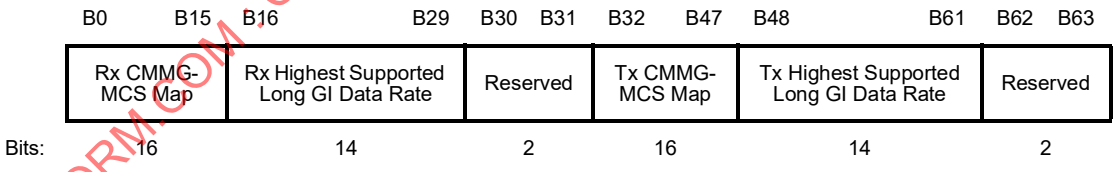

Figure 9-756—Supported CMMG-MCS and NSS Set field format

The Supported CMMG-MCS and NSS Set subfields are defined in Table 9-315.

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Table 9-315—Supported CMMG-MCS and NSS Set subfields

Subfield	Definition	Encoding
Rx CMMG-MCS Map	Indicates the maximum value of the RXVECTOR parameter MCS of a PPDU that can be received at all channel widths supported by this STA for each number of spatial streams.	The format and encoding of this subfield are defined in Figure 9-757 and the associated description.
Rx Highest Supported Long GI Data Rate	Indicates the highest CMMG PPDU data rate that the STA is able to receive.	The largest integer value less than or equal to the highest CMMG PPDU data rate in Mb/s the STA is able to receive (see 10.6.15.1). The value 0 indicates that this subfield does not specify the highest CMMG PPDU data rate that the STA is able to receive.
Tx CMMG-MCS Map	Indicates the maximum value of the TXVECTOR parameter MCS of a PPDU that can be received at all channel widths supported by this STA for each number of spatial streams.	The format and encoding of this subfield are defined in Figure 9-757 and the associated description.
Tx Highest Supported Long GI Data Rate	Indicates the highest CMMG PPDU data rate at which the STA is able to transmit.	The largest integer value less than or equal to the highest CMMG PPDU data rate in Mb/s the STA is able to receive/transmit (see 10.6.15.2). The value 0 indicates that this subfield does not specify the highest CMMG PPDU data rate that the STA is able to receive transmit.

The Rx CMMG-MCS Map subfield and the Tx CMMG-MCS Map subfield have the structure shown in Figure 9-757.

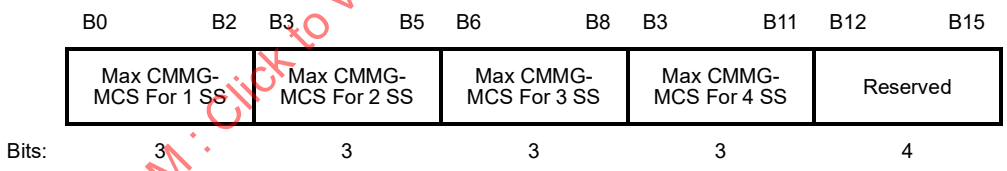

Figure 9-757—Rx CMMG-MCS Map and Tx CMMG-MCS Map subfields and Basic CMMG-MCS and NSS Set field format

The Max CMMG-MCS For *n* SS subfield (where *n* = 1, 2, 3, 4) is encoded as follows:

— 0 indicates support for SC CMMG-MCSs 1 to 5 or OFDM CMMG-MCSs 9 to 13 for *n* spatial streams
— 1 indicates support for SC CMMG-MCSs 1 to 6 or OFDM CMMG-MCSs 9 to 14 for *n* spatial streams
— 2 indicates support for SC CMMG-MCSs 1 to 7 or OFDM CMMG-MCSs 9 to 15 for *n* spatial streams
— 3 indicates support for SC CMMG-MCSs 1 to 8 or OFDM CMMG-MCSs 9 to 16 for *n* spatial streams
— 4–7 indicate that *n* spatial streams are not supported

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9.4.2.229.5 Transmit Beamforming Capabilities field

The structure of the Transmit Beamforming Capabilities field is defined in Figure 9-758.

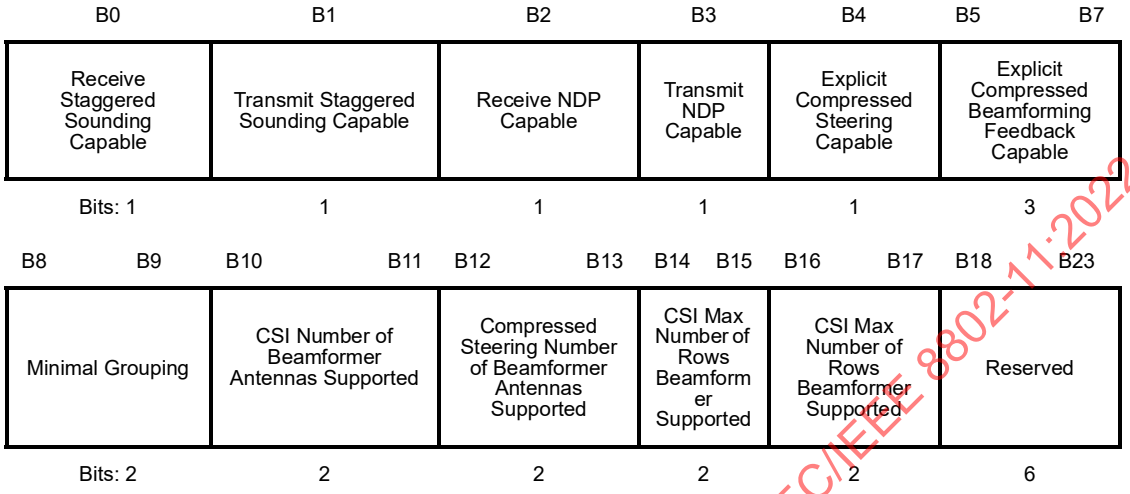

Figure 9-758—Transmit Beamforming Capabilities field format

The subfields of the Transmit Beamforming Capabilities field are defined in Table 9-316.

Table 9-316—Subfields of the Transmit Beamforming Capabilities field

Subfield	Definition	Encoding
Receive Staggered Sounding Capable	Indicates whether this STA can receive staggered sounding frames.	Set to 0 if not supported. Set to 1 if supported.
Transmit Staggered Sounding Capable	Indicates whether this STA can transmit staggered sounding frames.	Set to 0 if not supported. Set to 1 if supported.
Receive NDP Capable	Indicates whether this receiver can interpret null data PPDUs as sounding frames.	Set to 0 if not supported. Set to 1 if supported.
Transmit NDP Capable	Indicates whether this STA can transmit null data PPDUs as sounding frames.	Set to 0 if not supported. Set to 1 if supported.
Explicit Compressed Steering Capable	Indicates whether this STA can apply transmit beamforming using compressed beamforming feedback matrix explicit feedback in its transmission.	Set to 0 if not supported. Set to 1 if supported.
Explicit Compressed Beamforming Feedback Capable	Indicates whether this receiver can return compressed beamforming feedback matrix explicit feedback.	Set to 0 if not supported. Set to 1 for delayed feedback. Set to 2 for immediate feedback. Set to 3 for delayed and immediate feedback.

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Table 9-316—Subfields of the Transmit Beamforming Capabilities field *(continued)*

Subfield	Definition	Encoding
Minimal Grouping	Indicates the minimal grouping used for explicit feedback reports.	Set to 0 if the STA supports groups of 1 (no grouping). Set to 1 indicates groups of 1, 2. Set to 2 indicates groups of 1, 4. Set to 3 indicates groups of 1, 2, 4. Set to 4 indicates groups of 1, 6. Set to 5 indicates groups of 1, 2, 6. Set to 6 indicates groups of 1, 4, 6. Set to 7 indicates groups of 1, 2, 4, 6.
CSI Number of Beamformer Antennas Supported	Indicates the maximum number of beamformer antennas the CMMG beamformee can support when CSI feedback is required.	Set to 0 for single Tx antenna sounding. Set to 1 for 2 Tx antenna sounding. Set to 2 for 3 Tx antenna sounding. Set to 3 for 4 Tx antenna sounding.
Compressed Steering Number of Beamformer Antennas Supported	Indicates the maximum number of beamformer antennas the beamformee can support when compressed beamforming feedback matrix is required.	Set to 0 for single Tx antenna sounding. Set to 1 for 2 Tx antenna sounding. Set to 2 for 3 Tx antenna sounding. Set to 3 for 4 Tx antenna sounding.
CSI Max Number of Rows Beamformer Supported	Indicates the maximum number of rows of CSI explicit feedback from the CMMG beamformee that a CMMG beamformer can support when CSI feedback is required.	Set to 0 for a single row of CSI. Set to 1 for 2 rows of CSI. Set to 2 for 3 rows of CSI. Set to 3 for 4 rows of CSI.
Channel Estimation Capability	Indicates the maximum number of space-time streams (columns of the MIMO channel matrix) for which channel dimensions can be simultaneously estimated when receiving an NDP sounding PPDU or the extension portion of the MCTFs in a staggered sounding PPDU.	Set 0 for 1 space-time stream. Set 1 for 2 space-time streams. Set 2 for 3 space-time streams. Set 3 for 4 space-time streams.
NOTE—The maximum number of space-time streams for which channel coefficients can be simultaneously estimated using the MCTFs corresponding to the data portion of the packet is limited by the Rx MCS Bitmask subfield of the Supported MCS Set field and by the Rx STBC subfield of the CMMG Capabilities Info field. Both fields are part of the CMMG Capabilities element.		

9.4.2.229.6 CMMG AP Or PCP Capability Information field

The CMMG AP Or PCP Capability Information field, defined in Figure 9-759, represents the capabilities, when the transmitting STA performs in the role of AP or PCP, that are in addition to the capabilities in the CMMG Capabilities Info field.

The TDDTI (time division data transfer interval) subfield is set to 1 if the STA, while operating as an AP or PCP, is capable of providing channel access as defined in 10.39.6 and 11.4 and is set to 0 otherwise.

The Pseudo-static Allocations subfield is set to 1 if the STA, while operating as an AP or PCP, is capable of providing pseudo-static allocations as defined in 10.39.6.4 and is set to 0 otherwise. The Pseudo-static Allocations subfield is set to 1 only if the TDDTI subfield in the CMMG AP Or PCP Capability Information field is equal to 1. The Pseudo-static Allocations subfield is reserved if the TDDTI subfield in the CMMG AP Or PCP Capability Information field is equal to 0.

The PCP Handover field is set to 1 if the STA, while operating as a PCP, is capable of performing a PCP handover as defined in 11.29.2 and is set to 0 if the STA does not support PCP handover.

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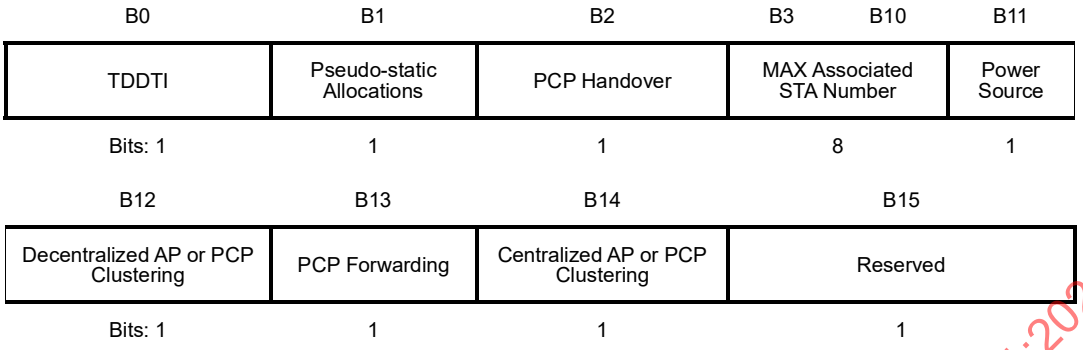

Figure 9-759—CMMG AP Or PCP Capability Information field format

The MAX Associated STA Number field indicates the maximum number of STAs that the STA can perform association with if operating as an AP or PCP. The value of this field includes the STAs, if any, that are collocated with the AP or PCP.

The Power Source field is set to 0 if the STA is battery powered and is set to 1 otherwise.

The Decentralized AP or PCP Clustering field is set to 1 if the STA, when operating as an AP or PCP, is capable of performing decentralized AP or PCP clustering and is set to 0 otherwise.

The PCP Forwarding field is set to 1 if the STA, while operating as a PCP, is capable of forwarding frames it receives from a non-PCP STA and destined to another non-PCP STA in the PBSS. This field is set to 0 otherwise.

The Centralized AP or PCP Clustering field is set to 1 if the STA, when operating as an AP or PCP, is capable of performing centralized AP or PCP clustering and is set to 0 otherwise. An AP or PCP that is incapable of performing centralized AP or PCP clustering is subject to requirements as described in 10.40.2.2.

9.4.2.230 CMMG Operation element

The operation of CMMG STAs in the BSS is controlled by the CMMG Operation element. The format of the CMMG Operation element is defined in Figure 9-760.

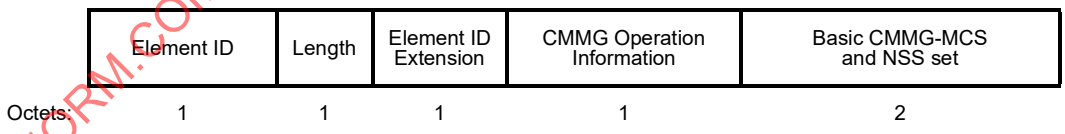

Figure 9-760—CMMG Operation element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

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The structure of the CMMG Operation Information field is defined in Figure 9-761.

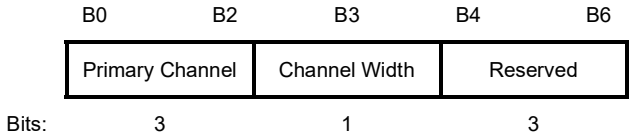

Figure 9-761—CMMG Operation Information field format

The subfields of the CMMG Operation Information field are defined in Table 9-317.

Table 9-317—CMMG Operation Information field format

Subfield	Definition	Encoding
Primary Channel	Indicates the channel number of the primary channel; see 25.10.	Channel number of the primary channel.
Channel Width	This field defines the BSS operating channel width.	Set to 0 for 540 MHz operating channel width. Set to 1 for 1080 MHz operating channel width.

The Basic CMMG-MCS and NSS Set field indicates the CMMG-MCSs for each number of spatial streams in CMMG PPDUs that are supported by all CMMG STAs in the BSS (including IBSS and MBSS). The Basic CMMG-MCS and NSS Set field is a bitmap of size 2 bits. The Basic CMMG-MCS and NSS Set field is defined in Figure 9-757.

9.4.2.231 CMMG Operating Mode Notification element

The CMMG Operating Mode Notification element is used to notify STAs that the transmitting STA is changing its operating channel width, the maximum number of spatial streams it can receive, or both. The format of the CMMG Operating Mode Notification element is defined in Figure 9-762.

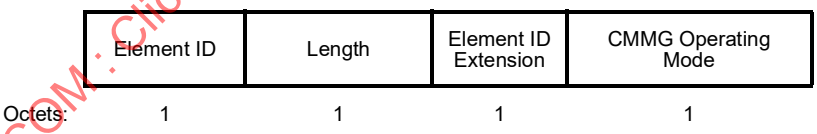

Figure 9-762—CMMG Operating Mode Notification element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The CMMG Operating Mode field is defined in 9.4.1.63.

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9.4.2.232 CMMG Link Margin element

9.4.2.232.1 General

The format of the CMMG Link Margin element is shown in Figure 9-763. The CMMG Link Margin element is included in a Link Measurement Report frame.

	Element	Length	Element ID Extension	Activity	MCS	Link Margin	SNR	Reference Timestamp
Octets:	1	1	1	1	1	1	1	4

Figure 9-763—CMMG Link Margin element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Activity field is set to a preferred action that the STA sending this element recommends that the peer STA indicated in the RA field of the Link Measurement Report frame execute. The method by which the sending STA determines a suitable action for the peer STA is implementation specific. The Activity field is defined in 9.4.2.232.2.

The MCS field is set to an MCS value that the STA sending this element recommends that the peer STA indicated in the RA field of the Link Measurement Report frame use to transmit frames to this STA. The reference PER for selection of the MCS is for an MPDU length of 4096 octets. The method by which the sending STA determines a suitable MCS for the peer STA is implementation specific. The Link Margin field contains the measured link margin of the Data frames received from the peer STA indicated in the RA field of the Link Measurement Report frame and is coded as a 2s complement signed integer in units of decibels. Setting the field to –128 indicates that no link margin is provided. The measurement method of link margin is beyond the scope of this standard.

The SNR field indicates the SNR measured during the reception of a PPDU. Values are from –13 dB to 50.75 dB in 0.25 dB steps.

The Reference Timestamp field contains the lower 4 octets of the TSF timer value sampled at the instant that the MAC received the PHY-CCA.indication (IDLE) signal that corresponds to the end of the reception of the PPDU that was used to generate the feedback information contained in the Link Measurement Report frame.

9.4.2.232.2 Activity field

The Activity field values are defined in Table 9-318.

Table 9-318—Activity field values

Preferred Action value	Meaning
0	No change preferred
1	Change(d) MCS
2	Decrease(d) transmit power
3	Increase(d) transmit power

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Table 9-318—Activity field values *(continued)*

Preferred Action value	Meaning
4	Fast session transfer (FST)
5	Power conserve mode
6	Perform SLS
7–255	Reserved

9.4.2.233 CMMG Link Adaptation Acknowledgment element

The format of the CMMG Link Adaptation Acknowledgment element is shown in Figure 9-764. The CMMG Link Adaptation Acknowledgment element is carried in the Optional Subelements field of the Link Measurement Report frame.

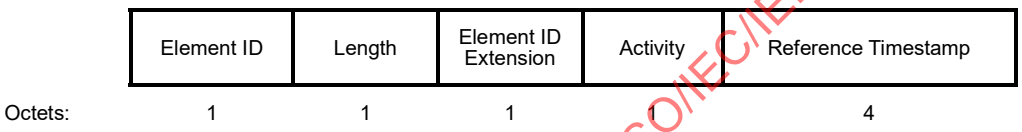

Figure 9-764—CMMG Link Adaptation Acknowledgment element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Activity field is set to the action that the STA sending this element has executed following the reception of the recommended activity in a Link Measurement Report frame. The method by which the sending STA determines the action is described in 10.32, and the Activity field is defined in 9.4.2.232.2.

The Reference Timestamp field contains the lower 4 octets of the TSF timer value sampled at the instant that the MAC received the PHY-CCA indication (IDLE) signal that corresponds to the end of the reception of the PPDU that was used to generate the feedback information contained in the Link Measurement Report frame.

9.4.2.234 GLK-GCR Parameter Set element

The GLK-GCR Parameter Set element is included in an Association Request or a Reassociation Request frame transmitted by a non-AP STA to indicate its buffering capability to support GLK-GCR. The GLK-GCR Parameter Set element is included in the corresponding Association Response or Reassociation Response frame transmitted by an AP to define the parameters that are used when the GLK AP transmits groupcast frames using GLK-GCR to the associated GLK non-AP STAs. Figure 9-765 shows the fields that make up the GLK-GCR Parameter Set element.

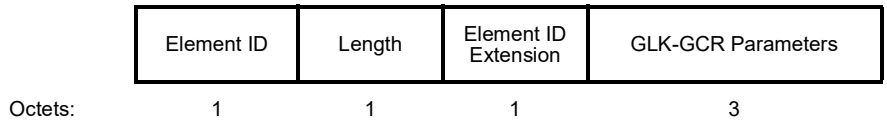

Figure 9-765—GLK-GCR Parameter Set element format

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The GLK-GCR Parameters field is shown in Figure 9-766.

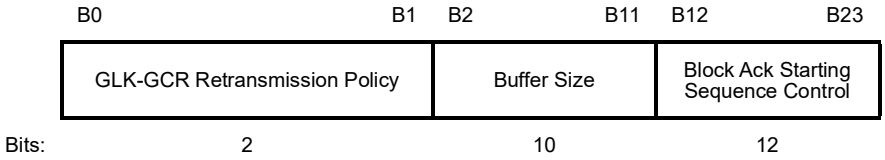

Figure 9-766—GLK-GCR Parameters field format

The GLK-GCR Retransmission Policy subfield is described in Table 9-319. This subfield is reserved when the corresponding GLK-GCR Parameters Set element is part of an Association Request or a Reassociation Request frame.

Table 9-319—GLK-GCR Retransmission Policy subfield

B0	B1	Description of the corresponding GLK-GCR mode
0	0	Reserved
0	1	GLK-GCR not operational
1	0	Operating in GLK-GCR unsolicited retry mode
1	1	Operating in GLK-GCR block ack mode

The Buffer Size subfield indicates the maximum number of buffers in the GLK-GCR block ack block. Each buffer is capable of holding a number of octets equal to the maximum size of an A-MSDU that is supported by the STA.

In an Association Request or a Reassociation Request frame, the Buffer Size subfield in a GLK-GCR Parameter Set element is intended to provide guidance for the recipient to decide its reordering buffer size. If the transmitter has no guidance for the receivers reordering buffer size it sets the Buffer Size subfield to 0.

In an Association Response or Reassociation Response frame, the Buffer Size subfield in a GLK-GCR Parameters field in the GLK-GCR Parameter Set element is set to a value greater than or equal to 1, if the GLK-GCR retransmission policy indicates GLK-GCR block ack mode. Otherwise this subfield is reserved.

The Block Ack Starting Sequence Control subfield indicates the sequence number of the first MSDU or A-MSDU for this GLK-GCR block ack agreement, and is defined in 9.3.1.8. This subfield is reserved when the corresponding GLK-GCR Parameters Set element is part of an Association Request or Reassociation Request frame.

9.4.2.235 Estimated Service Parameters Outbound element

The Estimated Service Parameters Outbound element is used by a STA to provide information to another STA that can then use the information as input to an algorithm to generate an estimate of outbound throughput between the two STAs.

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The format of the Estimated Service Parameters Outbound element is shown in Figure 9-767.

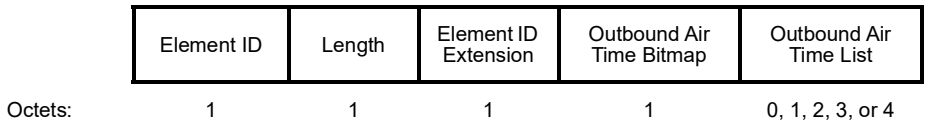

Figure 9-767—Estimated Service Parameters Outbound element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Outbound Air Time Bitmap field contains a bitmap indicating the presence or absence of an Outbound Air Time Information field for each of the four EDCA Access Categories. The format of the Outbound Air Time Bitmap field is shown in Figure 9-768.

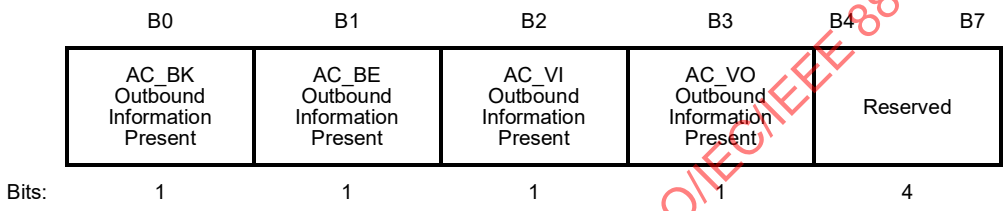

Figure 9-768—Outbound Air Time Bitmap field format

The Outbound Air Time List field contains from 0 to 4 Outbound Air Time Information fields, each corresponding to an access category for which estimated air time information for outbound traffic is provided. The Outbound Air Time Information field with the lowest numbered bits of the Outbound Air Time List field contains the outbound information corresponding to the AC of the lowest numbered bit of the Outbound Air Time Bitmap field that has a value of 1. The next Outbound Air Time Information field, if present, corresponds to the next higher numbered Outbound Air Time Bitmap field bit that has a value of 1, and so forth. If no Outbound Air Time Bitmap field bit has the value of 1, then no Outbound Air Time Information field is present. The format of the Outbound Air Time Information field is shown in Figure 9-769.

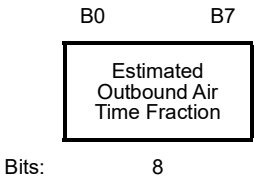

Figure 9-769—Outbound Air Time Information field format

The Estimated Outbound Air Time Fraction subfield of the Outbound Air Time Information field contains an unsigned integer that represents the predicted percentage of time, linearly scaled with 255 representing 100% and 0 representing 0%, that a new STA joining the BSS can expect to be available for the transmission of PPDUs by that STA, including overhead, where such PPDUs contain MPDUs with the Type subfield equal to Data that belong to the access category corresponding to the position of the Outbound Air Time Information field in the Outbound Air Time Bitmap field and any other MPDUs in the PPDU are considered to be overhead. A new STA joining the BSS might have a different view of the medium than the STA transmitting the Estimated Outbound Air Time Fraction, e.g. due to hidden nodes. In such cases, the new STA might experience a different actual outbound airtime fraction than that advertised in the element.

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9.4.2.236 OCI element

The format of the OCI element is shown in Figure 9-770.

	Element ID	Length	Element ID Extension	Operating Class	Primary Channel Number	Frequency Segment 1 Channel Number	OCT Operating Class (optional)	OCT Primary Channel Number (optional)	OCT Frequency Segment 1 Channel Number (optional)
Octets:	1	1	1	1	1	1	0 or 1	0 or 1	0 or 1

Figure 9-770—OCI element format

The Element ID and Length fields are defined in 9.4.2.1.

The Operating Class field is set to the global operating class that corresponds to the widest bandwidth currently being used by the transmitting STA. See Annex E, Table E-4 for description of the global operating classes.

The Primary Channel Number field is set to the primary channel being used currently. The Primary Channel Number field is one of the channels from the row corresponding to the operating class as defined in Annex E or the primary 20 MHz (sub)channel allowed for HT or non-HT operation for operating classes that specify only channel center frequency indices.

The Frequency Segment 1 Channel Number field is set to the channel center frequency index of the secondary segment (frequency segment 1) being used currently, if applicable, or set to 0 otherwise. The value of the Frequency Segment 1 Channel Number field is one of the center frequency indices from the row corresponding to the operating class as defined in Annex E.

The OCT Operating Class, OCT Primary Channel Number and OCT Frequency Segment 1 fields are present if the OCI element is contained in a frame sent using the OCT procedure, i.e. an MMPDU included in an MLME-OCTunnel.request or MLME-OCTunnel.response primitive (see 11.31.5); otherwise they are not present. They have the same definition as the Operating Class, Primary Channel Number and Frequency Segment 1 fields, except that they pertain to the channel used by the STAs corresponding to the TR-MLMEs to transmit and receive PPDUs containing On-channel Tunnel Request frames.

9.4.2.237 Service Hint element

The Service Hint element provides a probabilistic representation of a set of services that are available to the BSS. The format of the Service Hint element is shown in Figure 9-771.

	Element ID	Length	Element ID Extension	Bloom Filter Information	Bloom Filter Bit Array
Octets:	1	1	1	1	variable

Figure 9-771—Service Hint element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

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The Bloom Filter Information field represents the stochastic characteristics of a Bloom filter (Tarkoma et al. [B59]) that conveys the probabilistic data. The format of the Bloom Filter Information field is shown in Figure 9-772.

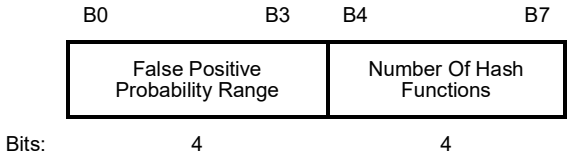

Figure 9-772—Bloom Filter Information field format

The False Positive Probability Range subfield represents the false positive probability range of the Bloom filter. The False Positive Probability Range subfield is shown in Table 9-320.

Table 9-320—False Positive Probability Range subfield values

Value	False positive probability range, p
0	$p > 25\%$
1	$20\% < p \leq 25\%$
2	$15\% < p \leq 20\%$
3	$10\% < p \leq 15\%$
4	$5\% < p \leq 10\%$
5	$1\% < p \leq 5\%$
6	$0.5\% < p \leq 1\%$
7	$0.1\% < p \leq 0.5\%$
8	$0.05\% < p \leq 0.1\%$
9	$0.01\% < p \leq 0.05\%$
10	$p \leq 0.01\%$
11–15	Reserved

The Number Of Hash Functions subfield is set to a value equal to k-1, where k is the number of hash functions used by the Bloom filter as described in 11.23.5.

The Bloom Filter Bit Array field provides an indication of the services offered by or through the AP or PCP with a target probability of false positive p. The length of the Bloom Filter Bit Array field in octets is $\lceil m/8 \rceil$ where m is the size of the Bloom filter in bits. How the size of the Bloom filter is determined is out of the scope of this standard. The maximum length of the Bloom Filter Bit Array field is 128 octets.

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9.4.2.238 Service Hash element

The Service Hash element contains one or more service hashes. The format of the Service Hash element is shown in Figure 9-773.

	Element ID	Length	Element ID Extension	Service Hashes
Octets:	1	1	1	variable

Figure 9-773—Service Hash element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Service Hashes field contains one or more 6-octet service hash values. See 11.23.4 for procedures for generating a service hash used in the Service Hash element.

9.4.2.239 GAS Extension element

The GAS Extension element is defined in 9-774. When present in the GAS Initial Request frame, the GAS Extension element indicates whether the STA is capable of receiving a Group Addressed GAS Response frame.

	Element ID	Length	Element ID Extension	GAS Flags	Maximum Channel Time	Fragment ID	Number of Response Map Duples	Response Map Duples
Octets:	1	1	1	0 or 1	0 or 1	0 or 1	0 or 1	variable

Figure 9-774—GAS Extension element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The GAS Flags field is defined in Figure 9-775.

	B0	B1	B2	B3	B4	B5 B7
	Group-addressed GAS	Fragment Retransmission	Maximum Channel Time Flag	Fragment ID Flag	Response Map Flag	Reserved
Bits:	1	1	1	1	1	3

Figure 9-775—GAS Flags field format

The Group-addressed GAS subfield is set to 1 to indicate that the STA is capable of receiving Group Addressed GAS Request and Group Addressed GAS Response frames and is set to 0 otherwise.

The Fragment Retransmission subfield, when present in a GAS Initial Response frame, is set to 1 to indicate that the responding STA is capable of retransmitting a GAS Query Response fragment upon request and is set to 0 otherwise.

The Maximum Channel Time Flag subfield is set to 1 to indicate that the Maximum Channel Time field is present in the element and is set to 0 otherwise.

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The Fragment ID Flag subfield is set to 1 to indicate that Fragment ID field is present in the element and is set to 0 otherwise.

The Response Map Flag subfield is set to 1 to indicate that the Number of Response Map Duples field and the Response Map Duples field are present in the element and is set to 0 otherwise.

The Maximum Channel Time field indicates the maximum duration the STA will, or needs to, remain on the channel to receive a GAS Initial Response, a GAS Comeback Response, or Group Addressed GAS Response, expressed as a multiple of 10 TUs beginning from the end of the PPDU carrying this element. The field has a valid range of 1–255.

The Fragment ID field, when present in the GAS Comeback Request, indicates the fragment the STA is requesting. It is present only when the Fragment ID Flag subfield is set to 1 in the GAS Flags field.

The Number of Response Map Duples field indicates the number of Response Map Duple subfields contained in the Response Map Duples field. It is present only when the Response Map Flag subfield is set to 1 in the GAS Flags field. When present, the Number of Response Map Duples field is set to a nonzero value and the value of zero is reserved.

The Response Map Duples field is present only when the Number of Response Map Duples field is present and contains a nonzero value. The Response Map Duples field, when present, contains one or more Response Map Duple subfields as indicated by the Number of Response Map Duples field. The format of the Response Map Duple subfield is shown in Figure 9-776. The Response Map Duples field is included in a Group Addressed GAS Response frame.

	Requester MAC Address	Requester Dialog Token
Octets:	6	1

Figure 9-776—Response Map Duple subfield format

The Response Map Duple subfield contains a Requester MAC Address subfield and a Requester Dialog Token subfield. An AP or PCP includes one or more Response Map Duple subfields in a Group Addressed GAS Response frame.

9.4.2.240 Non-Inheritance element

The Non-Inheritance element when present in the Nontransmitted BSSID Profile subelement of a Multiple BSSID element identifies one or more elements that are not inherited by the BSS corresponding to the nontransmitted BSSID profile that carried it. The identified elements are present in the Management frame of the transmitted BSSID that carried the Multiple BSSID element.

The format of the Non-Inheritance element is shown in Figure 9-777.

	Element ID	Length	Element ID extension	List Of Element IDs	List of Element ID Extensions
Octets:	1	1	1	1 or more	1 or more

Figure 9-777—Non-Inheritance element format

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The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The format of the List Of Element IDs field is shown in Figure 9-778. The Length subfield of the List of Element IDs field is set to the number of elements listed in the Element ID List subfield. If the Element ID List subfield is not present, the Length subfield is set to 0. The Element ID List subfield consists of a list of Element ID values, each one octet in length. Element ID values are in increasing order and no value occurs more than once. The List Of Element IDs field does not list elements that contain an Element ID Extension field (see 9.4.2.1).

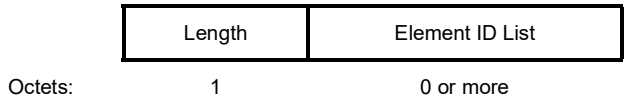

Figure 9-778—List Of Element IDs field format

The format of the List Of Element ID Extensions field is shown in Figure 9-779. The Length subfield of the List Of Element ID Extensions field is set to the number of elements listed in the Element ID Extension List subfield. If the Element ID Extension List subfield is not present, the Length subfield is set to 0. The Element ID Extension List subfield consists of a list of Element ID Extension values, each one octet in length. Element ID Extension values are in increasing order and no value occurs more than once. The List of Element ID Extensions field lists only elements that have an Element ID value of 255 (see 9.4.2.1).

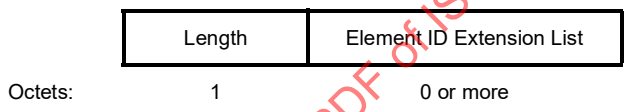

Figure 9-779—List Of Element ID Extensions field format

9.4.2.241 RSN Extension element (RSNXE)

The RSNXE field contains additional information required to establish an RSNA. The format of the RSNXE field is defined in Figure 9-780.

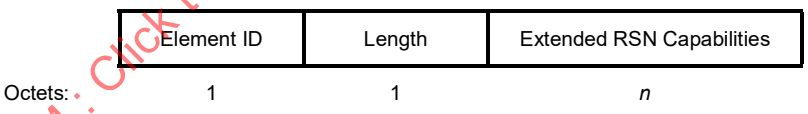

Figure 9-780—RSNXE format

The Element ID and Length fields are defined in 9.4.2.1.

The Extended RSN Capabilities field, except its first 4 bits, is a bit field indicating the extended RSN capabilities being advertised by the STA transmitting the element. The length of the Extended RSN Capabilities field is a variable *n*, in octets, as indicated by the first 4 bits in the field. The Extended RSN Capabilities field is shown in Table 9-321.

If a STA does not support any of capabilities defined in the RSNXE, then the RSNXE is not present.

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Table 9-321—Extended RSN Capabilities field

Bit	Information	Notes
0–3	Field length	The length of the Extended RSN Capabilities field, in octets, minus 1, i.e., $n - 1$.
4	Protected TWT Operations Support	The STA sets the Protected TWT Operations Support field to 1 when dot11ProtectedTWTOperationsImplemented is true, and sets it to 0 otherwise. See 10.47.1.
5	SAE hash-to-element	The STA supports directly hashing to obtain the PWE instead of looping. See 12.4.4.2.3 and 12.4.4.3.3.
6– (8×n – 1)	Reserved	

9.4.2.242 TCLAS Mask element

The TCLAS Mask element contains a set of parameters necessary to classify incoming MSDUs into streams based on a classifier mask. The structure of this element is shown in Figure 9-781.

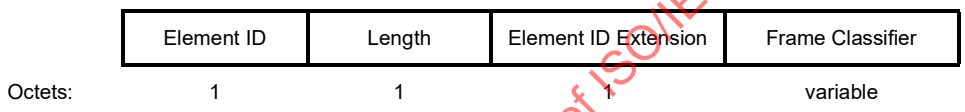

Figure 9-781—TCLAS Mask element format

The Element ID, Length and Element ID Extension fields are defined in 9.4.2.1.

The Frame Classifier field specifies the parameters that are used to classify incoming MSDUs into streams. The field is defined in 9.4.2.30 (see Figure 9-303), except that, in the Classifier Parameters subfield, all subfields other than the following (if present) are reserved:

— Filter Offset subfield
— Filter Mask subfield(s) (including MAC Header Filters in Match Specification subfields)
— Protocol Number or Next Header subfield

9.4.2.243 MSCS Descriptor element

The MSCS Descriptor element defines information about the parameters used to classify streams using the procedures defined in 11.25.3. The format of the MSCS Descriptor element is shown in Figure 9-782.

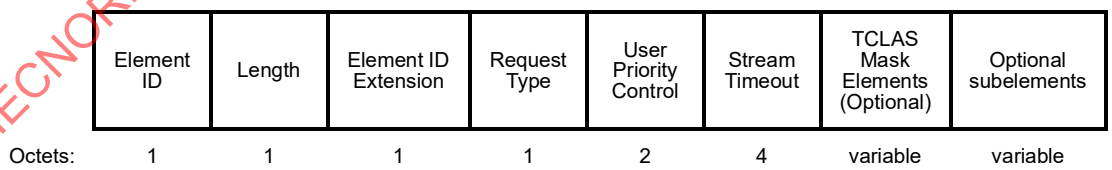

Figure 9-782—MSCS Descriptor element format

The Element ID, Length and Element ID Extension fields are defined in 9.4.2.1.

The Request Type field is defined in 9.4.2.121.

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The User Priority Control field is shown in Figure 9-783. This field is reserved when the Request Type field is "Remove", when the element is present in a (Re)Association Response frame with a value of "SUCCESS" in the Data field of the MSCS Status subelement, or when the element is present in a (Re)Association Response frame with a value other than "SUCCESS" in the Data field of the MSCS Status subelement and a value of "Add" in the Request Type field.

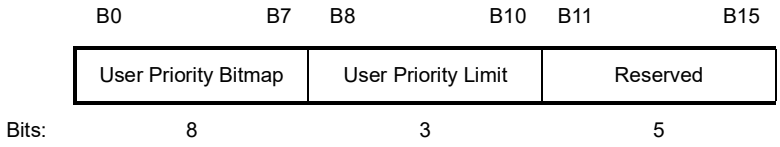

Figure 9-783—User Priority Control field format

Each bit in the User Priority Bitmap subfield corresponds to a user priority (UP), with the least significant bit corresponding to UP value of 0, and the most significant bit corresponding to UP value of 7. A value of 1 in a bit position in the bitmap indicates that the corresponding UP is used when assigning a UP to streams classified by MSCS; a value of 0 in a bit position indicates that the corresponding UP is not used for this purpose.

The User Priority Limit subfield has a value between 0 and 7; it defines the maximum limit for the UP that is assigned to incoming MSDUs in the streams classified by MSCS.

The Stream Timeout subfield indicates the minimum timeout value, in TUs, for maintaining a variable *UP{tuple}* in the MSCS list. This subfield is reserved when the Request Type field is "Remove", when the element is present in a (Re)Association Response frame with a value of "SUCCESS" in the Data field of the MSCS Status subelement, or when the element is present in a (Re)Association Response frame with a value other than "SUCCESS" in the Data field of the MSCS Status subelement and a value of "Add" in the Request Type field.

The TCLAS Mask Elements field contains zero or more TCLAS Mask elements to specify how incoming MSDUs are classified into streams in MSCS, as defined in 9.4.2.242. One or more TCLAS Mask elements are present when the Request Type field is "Add" or "Change"; no TCLAS Mask elements are present when the Request Type field is "Remove", when the element is present in a (Re)Association Response frame with a value of "SUCCESS" in the Data field of the MSCS Status subelement, or when the element is present in a (Re)Association Response frame with a value other than "SUCCESS" in the Data field of the MSCS Status subelement and a value of "Add" in the Request Type field.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3. The subelements allowed in the MSCS Descriptor element are defined in Table 9-322.

Table 9-322—Optional subelement IDs for MSCS Descriptor element

Subelement ID	Name	Extensible
0	Reserved	
1	MSCS Status	No
2–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

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The MSCS Status subelement Data field has the same format as the Status Code field shown in Figure 9-92 and contains the status of the requested MSCS setup, as indicated in Table 9-50.

The use of the MSCS Descriptor element is described in 11.25.3.

9.4.2.244 Supplemental Class 2 Capabilities element

The Supplemental Class 2 Capabilities element contains a number of fields that advertise supported rates of a Class 2 ERP or Class 2 HT STA. The Supplemental Class 2 Capabilities element is defined in Figure 9-784.

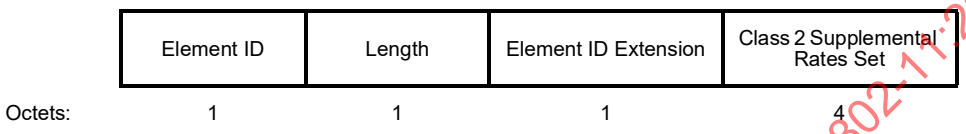

Figure 9-784—Supplemental Class 2 Capabilities element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The format of the Class 2 Supplemental Rates Set field is defined in Figure 9-785.

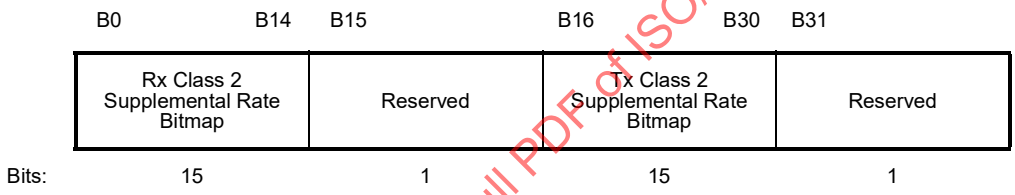

Figure 9-785—Class 2 Supplemental Rates Set field format

The Rx Class 2 Supplemental Rate Bitmap field is encoded as follows:

a) Bits B0-B1 represent support for receiving 1, 2 Mb/s (DSSS), respectively;
b) Bits B2-B3 represent support for receiving 5.5, 11 Mb/s (HR/DSSS), respectively;
c) Bits B4-B6 represent support for receiving 6, 12, 24 Mb/s (ERP-OFDM), respectively;
d) Bits B7-B14 represent support for receiving 6.5, 13, 19.5, 26, 39, 52, 58.5, 65 Mb/s $N_{SS} = 1$ (HT), respectively.

The Tx Class 2 Supplemental Rate Bitmap field is encoded as follows:

a) Bits 16-17 represent support for transmitting 1, 2 Mb/s (DSSS), respectively;
b) Bits 18-19 represent support for transmitting 5.5, 11 Mb/s (HR/DSSS), respectively;
c) Bits 20-22 represent support for transmitting 6, 12, 24 Mb/s (ERP-OFDM), respectively;
d) Bits 23-30 represent support for transmitting 6.5, 13, 19.5, 26, 39, 52, 58.5, 65 Mb/s $N_{SS} = 1$ (HT), respectively.

9.4.2.245 OCT Source element

The OCT Source element is used to specify the MLME that is the source of an OCT MMPDU. The format of the OCT Source element is shown in Figure 9-786.

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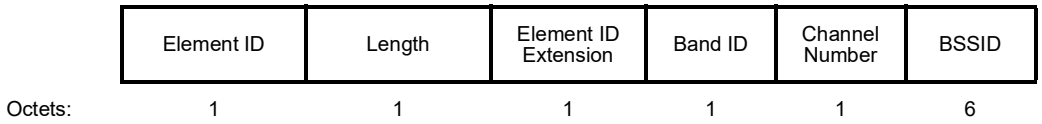

Figure 9-786—OCT Source element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Band ID field identifies the band on which the source MLME operates, as defined in Table 9-67.

The Channel Number field contains the channel number on which the source MLME operates.

The BSSID field contains the BSSID of the BSS in which the source MLME operates.

9.4.2.246 Rejected Groups element

The Rejected Groups element lists the finite cyclic groups, using the octet ordering conventions of 9.2.2, that have been rejected by a peer for use in SAE. The format of the Rejected Groups element is shown in Figure 9-787.

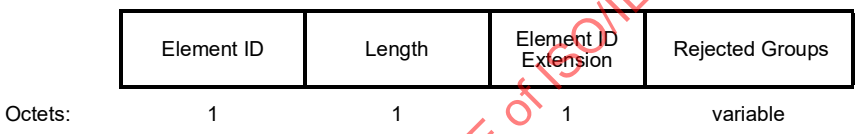

Figure 9-787—Rejected Groups element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Rejected Groups field contains a list of Finite Cyclic Group fields indicating finite cyclic groups that have been rejected by a peer in a previous authentication attempt.

9.4.2.247 Anti-Clogging Token Container element

The Anti-Clogging Token Container element is used to carry an Anti-Clogging Token field in contexts where an information element is needed. The format of an Anti-Clogging Token Container element is shown in Figure 9-788.

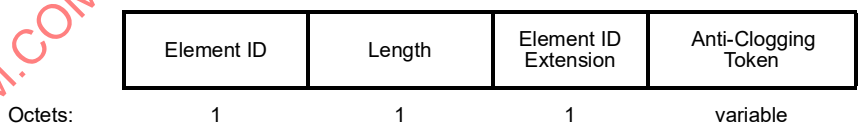

Figure 9-788—Anti-Clogging Token Container element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1.

The Anti-Clogging Token field is defined in 9.4.1.38.

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9.4.3 Subelements

Subelements are defined to have a common general format consisting of a 1-octet element-specific Subelement ID field, a 1-octet Length field, and a variable length subelement-specific Data field. Each subelement is assigned a subelement ID that is unique within the containing element or subelement. The Length field specifies the number of octets in the Data field. See Figure 9-789.

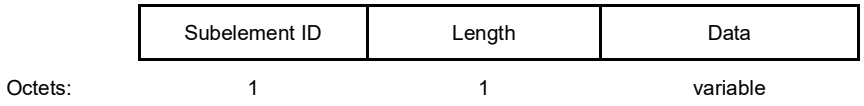

Figure 9-789—Subelement format

At the location in this standard that a subelement is defined, the definition might indicate if the subelement is extensible, typically using a table column called Extensible in the table in which subelement IDs are defined. A subelement that is indicated as extensible (typically with Yes in the Extensible column) might be extended in future revisions or amendments of this standard. A subelement that is indicated as extensible through subelements (typically with Subelements in the Extensible column) might be extended in future revisions or amendments of this standard by defining (additional) subelements within the subelement.

If the definition of a subelement does not indicate whether it is extensible (e.g., there is no Extensible column in a table defining it) that subelement is not extensible.

A subelement that is not defined as extensible will not be extended in future revisions or amendments of this standard.

Subelements within an element and subelements in a field outside of an element are in each case ordered by nondecreasing Subelement ID. See 10.28.9.

Unless stated otherwise, no more than one subelement with the same Subelement ID, apart from Vendor Specific subelements, is present within an element.

9.4.4 TLV encodings

9.4.4.1 General

The following TLV encodings are used to convey parameters within MAC Management frames (9.3.3, 9.4, and 9.6). TLV tuples with type values that are unknown, not specified in this subclause, or specified as "reserved" are discarded upon receipt. The form of TLVs is shown in Table 9-323.

Table 9-323—General TLV format

Name	Type	Length (octets)	Value	Scope/ Country code
The name of the TLV	1	variable	Single Octet, Single Value, or Compound TLV tuples.	

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NOTE—This standard is complete regarding the endianness of multi-octet fields as they are covered by 9.2.2. Be aware that most protocols above the MAC operate in the opposite endianness.

The Name field is the name of the TLV tuple.

The '*m.n*' syntax in the Type field means that the TLV has type *n*, an unsigned 1-octet integer, and is embedded in the Value field of a TLV of type *m*. The length of the Type field is 1 octet.

The format of the Length field is an unsigned number of size 1 octet, and the value in the Length field specifies the number of octets in the Value field.

A single octet TLV has a Value field that is 1 octet, a single value TLV has a Value field larger than 1-octet, and a compound TLV has a Value field that represents more than 1-octet fields.

When a Scope field entry contains two characters, it identifies the country or other entity to which the STA's operation is bound. If the two-character value stands for a country or other entity, then the value matches a code defined in ISO 3166-1. When a Scope field entry contains more than two characters, it identifies a scope for the TLV tuple.

9.4.4.2 Common TLVs

9.4.4.2.1 General

The general form of common TLVs is shown in Table 9-323 and is used in 9.4.4.2.2 to 9.4.4.2.6.

9.4.4.2.2 Device Class

This parameter contains the intended class of device for operation in TVWS band after it receives the available channel list at its location. The Device Class field format is shown in Table 9-324.

Table 9-324—Device Class field definition

Name	Type	Length (octets)	Value	Scope/ Country code
Device Class	2	1	The Device Class field contains an integer that indicates the device's TVWS band mode of operation as follows: 0: GDD non-AP STA 1: GDD geolocated non-AP STA 2: GDD AP 3: GDD fixed STA 4–255: Reserved	CAQ, GDDENABLEMENT, WSM

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9.4.4.2.3 Device Identification Information

This parameter contains the identification information of the device initiating the channel availability query. The Device Identification Information field format is shown in Table 9-325 and related Device Identification Information Value fields tables in E.2 for specific regulatory domains.

Table 9-325—Device Identification Information field definition

Name	Type	Length (octets)	Value	Scope/ Country code
Device Identification Information	3	variable	One or more TLV fields as defined in Table E-9 for a specific regulatory domain.	CAQ, GDDENABLEMENT, CSM

9.4.4.2.4 Device Location Information

This parameter contains the location information of the device initiating the channel availability query. The Device Location Information field format is shown in Table 9-326.

Table 9-326—Device Location Information field definition

Name	Type	Length (octets)	Value	Scope/ Country code
Device Location Information	10	16	The Device Location Information field contains the latitude, longitude, and altitude information of the device in the format specified by the Device Location Information Body fields in Figure 9-139. When the Device Type subfield (see Table 9-324) is not GDD fixed STA, the altitude information (Altitude Type, Altitude Uncertainty, and Altitude subfields) of the Device Location Information field remain unused.	CAQ

9.4.4.2.5 Channel Schedule Descriptor

This parameter contains the channel number associated with channel schedule information used for channel schedule management. The Channel Schedule Descriptor Tuple attribute format is shown in Table 9-327 and Table 9-328. Channel Schedule Descriptor field is constructed with either Channel Availability Starting Time field or Channel Availability Starting Timestamp field present or neither of these two fields present.

Table 9-327—Channel Schedule Descriptor Tuple attribute definition

Name	Type	Length (octets)	Value	Scope/ Country code
Channel Schedule Descriptor	11	variable	Compound TLVs in Table 9-328.	CSM

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Table 9-328—Channel Schedule Descriptor Value fields

Name	Subtype	Length (octets)	Value	Scope/ Country code
Operating Class	1	1	The Operating Class field is the number of the operating class of the channel, which is defined in E.1.	CSM
Channel Number	2	1	The Channel Number field is the number of the channel, which is the subject of the value of Channel Schedule Management Mode field. If the Channel Schedule Management Mode field indicates the schedule information is based on WLAN channels, the Channel Number is a channel from the STA's operating class as defined in E.1; otherwise, the Operating Class compound TLV is not present, and the Channel Number is a positive integer value as defined in D.1 to indicate the available TV channel for WLAN operation.	CSM
Channel Availability Starting Time	3	8	The Channel Availability Starting Time field indicates the starting time in Coordinated Universal Time (UTC) from when the channel indicated in the Channel Number field is available for operation. When neither this field nor a Channel Availability Starting Timestamp is present, the STA takes the time that the response element is received as the starting time of the channel availability. NOTE—The Channel Availability Starting Time field follows the UTC time definition of the Time Value field of the Time Advertisement element in 9.4.2.60, and the first 6 octets are used to indicate the UTC time until minutes. The left 2 octets are reserved.	CSM
Channel Availability Starting Timestamp	4	8	The Channel Availability Starting Timestamp field indicates the starting timestamp from when the channel indicated in the Channel Number field is available for operation. When neither this field nor a Channel Availability Starting Time field is present, the STA takes the time that the response element is received as the starting time of the channel availability.	CSM
Channel Availability Offset Time	5	2	The Channel Availability Offset Time field indicates the offset of channel availability time with respect to the time that the Channel Schedule Descriptor is received. This field is present when the Channel Availability Starting Time field is not present in the response TLV and the channel is not available at the moment the TLV is received.	CSM
Channel Availability Duration	6	2	The Channel Availability Duration field indicates the duration in minutes of the availability of the channel that indicated in the Channel Number field.	CSM

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9.4.4.2.6 WSM information values

The format of the WSM information values is shown in Table 9-329. If the WSM Type field of the White Space Map element (9.4.1.57) is set to 1, the WSM Information field specifies available channel information for TVWS, which is country-specific.

Table 9-329—WSM information values

Name	Type	Length (octets)	Value	Scope/ Country code
WSM Information	12	variable	Single value TLV comprising fields in related table in E.2 for a specific regulatory domain.	WSM

The format of the WSM Information Value fields is shown in Table 9-330.

Table 9-330—WSM Information Value fields

Name	Length (octets)	Value	Scope/ Country code
Device Class	1	Single octet TLV comprising fields in Table 9-324.	WSM
Map ID	1	Bit 0: Type bit indicates whether the following channel list is a full channel list or a partial channel list. If the Type bit is 1, the following channel list is a full channel list; and if the Type bit is 0, the following channel list is a partial channel list. Bits 1–7: Map version identifies the version of the WSM.	WSM
Channel Number	1	Channel Number field in related WSM Information Value fields table in E.2.	WSM
Maximum Power Level	1	Maximum Power Level field in related WSM Information Value fields table in E.2.	WSM
Validity	1	The Validity field indicates the duration in minutes for which the Channel Number is available with the allowed maximum power level, where the Validity field is provided for each available Channel Number.	WSM, UK
Maximum Channel Bandwidth	2	Limits on the maximum contiguous and maximum noncontiguous instantaneous bandwidths of STA specified as $n \times 0.1$ MHz, where $n > 0$.	WSM, UK

The Device Class field is defined in 9.4.4.2.2 and identifies the device class used by the WSM. It determines the length of the channel availability tuple consisting of the Channel Number, Maximum Power Level, and Validity fields, which is repeated as indicated by the Length field of the WSM element. If the Device Class field is 0, the Validity field in WSM Information Value field is not present. Otherwise, the Validity field exists in the WSM Information Value field.

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9.4.5 Access network query protocol (ANQP) elements

9.4.5.1 General

ANQP-elements are defined to have a common format consisting of a 2-octet Info ID field (information identifier), a 2-octet Length field, and a variable length ANQP-element-specific Information field. Each element is assigned a unique Info ID as defined in this standard. The ANQP-element format is shown in Figure 9-790. See R.2 for the ANQP usage.

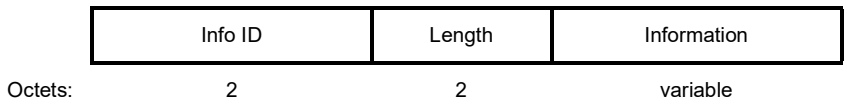

Figure 9-790—ANQP-element format

Each ANQP-element in 9.4.5 is assigned a unique 2-octet Info ID. The set of valid Info IDs are defined in Table 9-331.

Table 9-331—ANQP-element definitions

ANQP-element name	InfoID	ANQP-element (subclause)
Reserved	0–255	—
Query List	256	9.4.5.2
Capability List	257	9.4.5.3
Venue Name	258	9.4.5.4
Emergency Call Number	259	9.4.5.5
Network Authentication Type	260	9.4.5.6
Roaming Consortium	261	9.4.5.7
IP Address Type Availability	262	9.4.5.9
NAI Realm	263	9.4.5.10
3GPP Cellular Network	264	9.4.5.11
AP Geospatial Location	265	9.4.5.12
AP Civic Location	266	9.4.5.13
AP Location Public Identifier URI/FQDN	267	9.4.5.14
Domain Name	268	9.4.5.15
Emergency Alert Identifier URI	269	9.4.5.16
TDLS Capability	270	9.4.5.18
Emergency NAI	271	9.4.5.17
Neighbor Report	272	9.4.5.19
Query AP List	273	9.4.5.24
AP List Response	274	9.4.5.25
Reserved	275	—

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Table 9-331—ANQP-element definitions *(continued)*

ANQP-element name	InfoID	ANQP-element (subclause)
CAG	276	9.4.5.26
Venue URL	277	9.4.5.20
Advice of Charge	278	9.4.5.21
Local Content	279	9.4.5.22
Network Authentication Type with Timestamp	280	9.4.5.23
Service Information Request	281	9.4.5.27
Service Information Response	282	9.4.5.28
Local MAC Address Policy	283	9.4.5.29
Reserved	284–56 796	—
Vendor Specific	56 797	9.4.5.8
Reserved	56 798–65 535	—

The Length field specifies the number of octets in the Information field.

The ANQP-elements that can be configured are shown in Table 9-331. If information is not configured for a particular ANQP-element, then a query for that element will return that element with all optional fields not present.

9.4.5.2 Query List ANQP-element

The Query List ANQP-element provides a list of identifiers of ANQP-elements for which the requesting STA is querying; see 11.22.3.3.2.

The format of the Query List ANQP-element is shown in Figure 9-791.

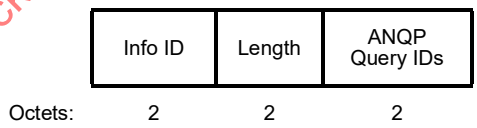

Figure 9-791—Query List ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The ANQP Query IDs field contains one or more 2-octet ANQP Query ID subfields.

Each ANQP Query ID subfield value is an Info ID drawn from Table 9-331. Including an Info ID in the Query List ANQP-element declares that the STA performing the ANQP request is requesting the ANQP-element corresponding to that Info ID be returned in the ANQP response. The Info IDs included in the Query List ANQP-element are ordered by monotonically increasing Info ID value. The ANQP response is defined in 11.22.3.3.1.

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9.4.5.3 Capability List ANQP-element

The Capability List ANQP-element provides a list of information/capabilities that has been configured on a STA. The Capability List ANQP-element is returned in response to a Query List ANQP-element containing the Info ID of the Capability List ANQP-element.

The format of the Capability List ANQP-element is shown in Figure 9-792.

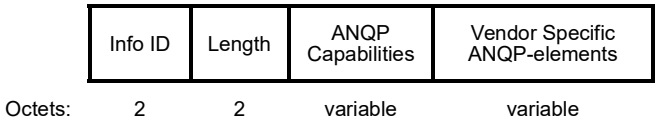

Figure 9-792—Capability List ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The ANQP Capabilities field contains one or more 2-octet ANQP Capability subfields.

Each ANQP Capability subfield value is an Info ID drawn from Table 9-331. If included in the Capability List ANQP-element, it declares that a Query List ANQP-element including that Info ID will return the requested ANQP-element. The Info ID for Capability List ANQP-element is always included in the Capability List ANQP-element returned in a GAS Query Response. The list does not include any duplicate Info IDs, except possibly the Info ID for each Vendor Specific ANQP-element. The Info IDs returned in the Capability List ANQP-element are ordered by nondecreasing Info ID value.

The Vendor Specific ANQP-elements field contains one or more variable length Vendor Specific ANQP-elements.

The Vendor Specific ANQP-element is defined in 9.4.5.8. The Vendor Specific ANQP-element is structured such that the first 2 octets of the Vendor Specific ANQP-element is the Info ID whose value corresponds to the Vendor Specific ANQP-element (see Table 9-331). When a Vendor Specific ANQP-element is present in the Capability List ANQP-element, the Vendor Specific ANQP-element contains the capabilities of that vendor-specific query protocol.

9.4.5.4 Venue Name ANQP-element

The Venue Name ANQP-element provides zero or more venue names associated with the BSS. The format of the Venue Name ANQP-element is shown in Figure 9-793. The Venue Name ANQP-element might be used to provide additional metadata on the BSS. For example, the information might be used to assist a user in selecting the appropriate BSS of which to become a member.

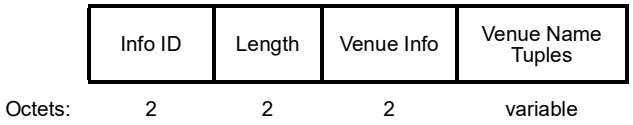

Figure 9-793—Venue Name ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The Venue Info field is defined in 9.4.1.34.

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The Venue Name Tuples field contains zero or more variable length Venue Name Tuple subfields.

The format of the Venue Name Tuple subfield is shown in Figure 9-794.

— The Length field is equal to 3 plus the number of octets in the Venue Name field.
— The Language Code field contains an ASCII-encoded language code selected from ISO 639, and defines the language used in the Venue Name field. A two character language code has 0 (ASCII NUL) appended.
— The Venue Name field is a UTF-8 string containing the venue's name. The maximum length of this field is 252 octets.

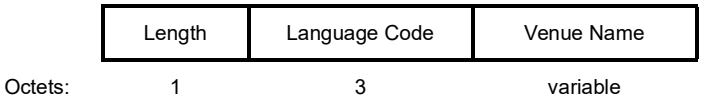

Figure 9-794—Venue Name Tuple subfield

A URL associated with the Venue Name field can be specified by the Venue URL ANQP-element defined in 9.4.5.20.

9.4.5.5 Emergency Call Number ANQP-element

The Emergency Call Number ANQP-element provides a list of emergency phone numbers to an emergency responder, such as directed by a public safety answering point (PSAP), that is used in the geographic location of the STA. The format of the Emergency Call Number ANQP-element is shown in Figure 9-795.

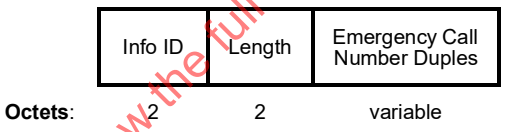

Figure 9-795—Emergency Call Number ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The Emergency Call Number Duples field contains zero or more variable length Emergency Call Number Duple subfields.

Each Emergency Call Number Duple subfield has the structure shown in Figure 9-796.

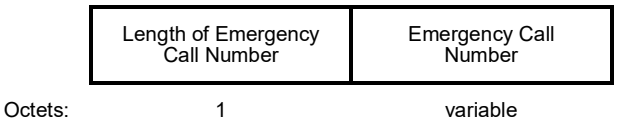

Figure 9-796—Emergency Call Number Duple subfield format

The Length of Emergency Call Number field is set to the length of the Emergency Call Number field.

The Emergency Call Number field is a UTF-8 string containing information, used to reach emergency services, from the network [e.g., dialed digits, emergency service URN label (IETF RFC 5031 [B44])].

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When this field is transmitted by an AP, with the intention of the field being received by a STA in a 3GPP capable device, the recommended format and content of this field is defined in Annex I of 3GPP TS 24.302.

9.4.5.6 Network Authentication Type ANQP-element

The Network Authentication Type ANQP-element provides a list of authentication types when ASRA is set to 1. The format of the Network Authentication Type ANQP-element is shown in Figure 9-797.

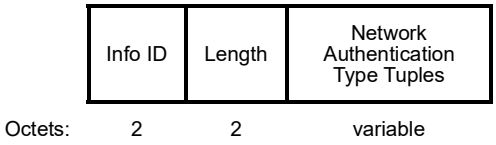

Figure 9-797—Network Authentication Type ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The Network Authentication Type Tuples field contains zero or more variable length Network Authentication Type Tuple subfields.

Each Network Authentication Type Tuple subfield has the structure shown in Figure 9-798.

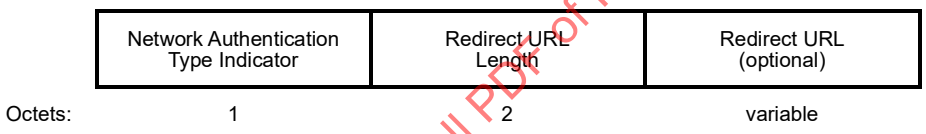

Figure 9-798—Network Authentication Type Tuple subfield format

The Network Authentication Type Indicator field is set to one of the values shown in Table 9-332.

Table 9-332—Network Authentication Type Indicator definitions

Value	Meaning
0	Acceptance of terms and conditions
1	On-line enrollment supported
2	http/https redirection
3	DNS redirection
4–255	Reserved

Each Network Authentication Type Indicator defines additional information that can be communicated.

If the Network Authentication Type Indicator field is 0, the network requires the user to accept terms and conditions. The Redirect URL can be used by the non-AP STA to obtain the terms and conditions. If the Redirect URL is not present, then the Redirect URL Length is set to 0.

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If the Network Authentication Type Indicator field is 1, the network supports on-line enrollment. Higher layer protocols on the non-AP STA might indicate to the user that accounts might be created. When the Network Authentication Type Indicator is 1, the Redirect URL Length is set to 0 and the Redirect URL is not present.

If the Network Authentication Type Indicator field is 2, the network infrastructure performs http/https redirect. The ReDirect URL is used by the non-AP STA to perform additional steps required for network access.

If the Network Authentication Type Indicator field is 3, the network supports DNS redirection. Higher layer software on the non-AP STA exchanges credentials with the network, the Redirect URL Length is set to 0 and the Redirect URL is not present.

The Redirect URL Length field contains the length of the Redirect URL. The the Redirect URL Length field is set to 0 whenever the Redirect URL is not present.

The Redirect URL field is a variable length field that is optionally included if the Network Authentication Type Indicator is either 0 or 2. If the Network Authentication Type Indicator is other than 0 or 2, a Redirect URL is not included. The URL is formatted in accordance with IETF RFC 3986.

9.4.5.7 Roaming Consortium ANQP-element

The Roaming Consortium ANQP-element provides a list of information about the Roaming Consortium and/or SSPs whose networks are accessible via this AP. This list can be returned in response to a GAS Query Request using procedures in 11.22.3.3.3. The format of the Roaming Consortium ANQP-element is shown in Figure 9-799.

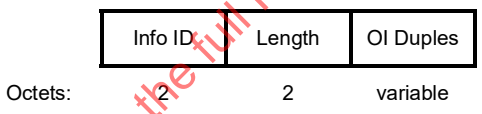

Figure 9-799—Roaming Consortium ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

OIs contained within the Roaming Consortium element (see 9.4.2.95) are also included in this ANQP-element. The value of the OI subfield(s) in this ANQP-element are equal to the values of the OI(s) in the dot11RoamingConsortiumTable.

The OI Duples field contains zero or more variable length OI Duple subfields.

The format of the OI Duple subfield is shown in Figure 9-800.

— The OI Length field is set to the number of octets in the OI field.
— The OI field is defined in 9.4.1.31. Each OI identifies a roaming consortium (group of SSPs with inter-SSP roaming agreement) or a single SSP.

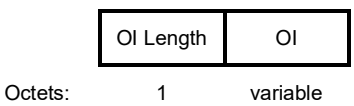

Figure 9-800—OI Duple subfield format

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9.4.5.8 Vendor Specific ANQP-element

The Vendor Specific ANQP-element is used to query for information not defined in this standard within a single defined format, so that reserved Info IDs are not usurped for nonstandard purposes and interoperability is more easily achieved in the presence of nonstandard information. The ANQP-element is in the format shown in Figure 9-801.

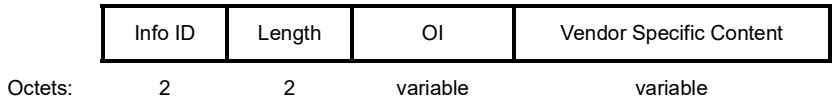

Figure 9-801—Vendor Specific ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The OI field is defined in 9.4.1.31.

The Vendor Specific Content field is a variable length field whose content is defined by the entity identified in the OI field.

9.4.5.9 IP Address Type Availability ANQP-element

The IP Address Type Availability ANQP-element provides STA with the information about the availability of IP address version and type that could be allocated to the STA after successful association. The format of the IP Address Type Availability ANQP-element is shown in Figure 9-802.

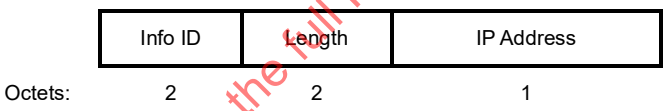

Figure 9-802—IP Address Type Availability ANQP-element

The Info ID and Length fields are defined in 9.4.5.1.

The format of the IP Address field shown in Figure 9-803.

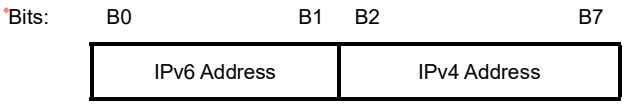

Figure 9-803—IP Address field format

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The IPv6 Address field values are shown in Table 9-333.

Table 9-333—IPv6 Address field values

Address value	Meaning
0	Address type not available
1	Address type available
2	Availability of the address type not known
3	Reserved

The IPv4 Address field values are shown in Table 9-334.

Table 9-334—IPv4 Address field values

Address value	Meaning
0	Address type not available
1	Public IPv4 address available
2	Port-restricted IPv4 address available
3	Single NATed private IPv4 address available
4	Double NATed private IPv4 address available
5	Port-restricted IPv4 address and single NATed IPv4 address available
6	Port-restricted IPv4 address and double NATed IPv4 address available
7	Availability of the address type is not known
8–63	Reserved

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9.4.5.10 NAI Realm ANQP-element

The NAI Realm ANQP-element provides a list of network access identifier (NAI) realms corresponding to SSPs or other entities whose networks or services are accessible via this AP; optionally included for each NAI realm is a list of one or more EAP Method subfields, which that NAI realm uses for authentication. The format of the NAI Realm ANQP-element is shown in Figure 9-804.

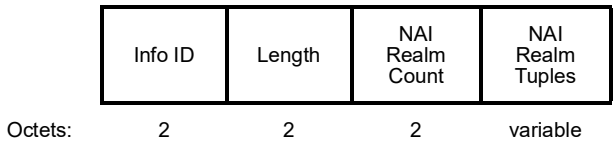

Figure 9-804—NAI Realm ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The NAI Realm Count field specifies the number of NAI realms included in the NAI Realm ANQP-element.

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The NAI Realm Tuples field contains zero or more variable length NAI Realm Tuple subfields.

The format of the NAI Realm Tuple subfield is shown in Figure 9-805.

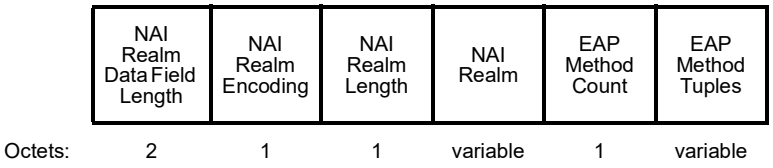

Figure 9-805—NAI Realm Tuple subfield format

The NAI Realm Data Field Length subfield is equal to 3 plus the length of the NAI Realm subfield plus the sum of the lengths of the EAP Method subfields.

The NAI Realm Encoding subfield is shown in Figure 9-806.

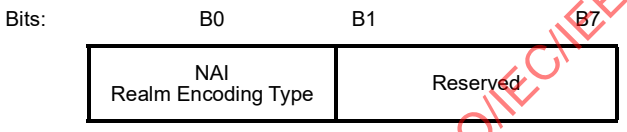

Figure 9-806—NAI Realm Encoding subfield format

The NAI Realm Encoding Type subfield is set to 0 to indicate that the NAI Realm in the NAI Realm subfield is formatted in accordance with IETF RFC 4282. It is set to 1 to indicate it is a UTF-8 string that is not formatted in accordance with IETF RFC 4282.

NOTE—This encoding is to facilitate roaming consortium or other entities that use nonstandard NAI Realm formats.

The NAI Realm Length subfield is the length in octets of the NAI Realm subfield.

The NAI Realm subfield is one or more NAI Realms formatted as defined in the NAI Realm Encoding Type bit of the NAI Realm Encoding subfield. If there is more than one NAI Realm in this subfield, the NAI Realms are delimited by a semicolon character (i.e., ";", which is encoded in UTF-8 as 0x3B). All of the realms included in the NAI Realm subfield support all of the EAP methods identified by the EAP Method subfields, if present. The maximum length of this subfield is 255 octets.

The EAP Method Count subfield specifies the number of EAP methods subfields for the NAI realm. If the count is 0, there is no EAP method information provided for the NAI realm.

The EAP Method Tuples field contains zero or more variable length EAP Method Tuple subfields.

The format of the optional EAP Method Tuple subfield is shown in Figure 9-807. Each EAP Method subfield contains a set of Authentication Parameters associated with the EAP-Method.

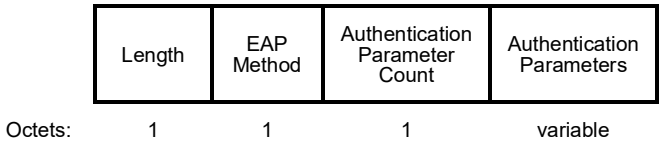

Figure 9-807—EAP Method Tuple subfield format

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The Length subfield is 2 plus the length of the Authentication Parameters subfield.

The EAP method subfield is set to the EAP Type value as given in IANA EAP Method Type Numbers.

The Authentication Parameter Count indicates how many additional Authentication Parameter subfields are specified for the supported EAP Method. If the Authentication Parameters Count subfield is 0, there are no Authentication Parameters subfields present, meaning no additional Authentication Parameters are specified for the EAP Method.

The Authentication Parameters field contains zero or more variable length Authentication Parameter subfields.

The format of the Authentication Parameter subfield is shown in Figure 9-808.

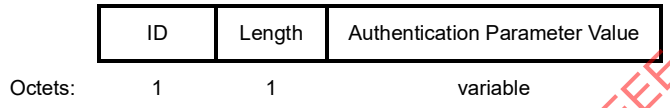

Figure 9-808—Authentication Parameter subfield format

The ID subfield indicates the type of authentication information provided.

The Length subfield indicates the length of the Authentication Parameter Value subfield.

The Authentication Parameter Value subfield is a variable length subfield containing the value of the parameter indicated by the ID.

The ID and its associated formats are specified in Table 9-335. Each ID indicates a different type of information. Use of multiple Authentication Parameter subfields allows all of the required authentication parameter requirements to be provided.

Table 9-335—Authentication Parameter types

Authentication information	ID	Description	Length (octets)
Reserved	0		
Expanded EAP Method	1	Expanded EAP Method Subfield	7
Non-EAP Inner Authentication Type	2	Enum (0 - Reserved, 1 - PAP, 2 - CHAP, 3 - MSCHAP, 4 - MSCHAPV2)	1
Inner Authentication EAP Method Type	3	Value drawn from IANA EAP Method Type Numbers	1
Expanded Inner EAP Method	4	Expanded EAP Method Subfield	7
Credential Type	5	Enum (1 - SIM, 2 - USIM, 3 - NFC Secure Element, 4 - Hardware Token, 5 - Softoken, 6 - Certificate, 7 - username/password, 8 - none [see NOTE], 9 - Reserved, 10 - Vendor Specific)	1

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Table 9-335—Authentication Parameter types *(continued)*

Authentication information	ID	Description	Length (octets)
Tunneled EAP Method Credential Type	6	Enum (1 - SIM, 2 - USIM, 3 - NFC Secure Element, 4 - Hardware Token, 5 - Softoken, 6 - Certificate, 7 - username/password, 8 - Reserved, 9 - Anonymous, 10 - Vendor Specific)	1
Reserved	7–220		
Vendor Specific	221	Variable	variable
Reserved	222–255		
NOTE—None means server-side authentication only.			

If the EAP Method type is an Expanded EAP type (the EAP Method value is 254), the Authentication Parameter is used to specify additional information on the EAP method. Table 9-336 describes the Authentication Parameter format for the Expanded EAP method; values for the Vendor ID and Vendor Type are specified in IETF RFC 3748. The Vendor ID and Vendor Type fields are expressed in big endian octet order.

Table 9-336—Authentication Parameter format for the Expanded EAP method

Parameters	Length (octets)
ID	1
Length	1
Vendor ID	3
Vendor Type	4

The Non-EAP Inner Authentication Type is specified as a single enumerated value given in Table 9-335. This Authentication Information type is used for non-EAP Inner Authentication methods. The possible values are PAP (as specified in IETF RFC 1334 [B24]), CHAP (as specified in IETF RFC 1994 [B25]), MSCHAP (as specified in IETF RFC 2433 [B29]), and MSCHAPv2 (as specified in IETF RFC 2759 [B32]).

The Inner Authentication EAP Method Type is specified as the EAP number as defined in IANA EAP Method Type Numbers. This Authentication Information type is used when the Inner Authentication method is an EAP method. If the Inner Authentication EAP Method Type is equal to 254 indicating an Expanded EAP Type, then the Expanded EAP Method Authentication Parameter is included.

A Credential Type is specified as a single enumerated value as shown in Table 9-335. If the value is equal to the “Vendor Specific” value, then a Vendor-Specific Authentication Parameter is included.

Vendor-Specific Authentication Parameters are specified as shown in Table 9-337.

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Table 9-337—Vendor Specific Authentication Parameters

Parameters	Length (octets)
ID	1
Length	1
OI	variable
Authentication Parameter Value	Vendor-specific content

9.4.5.11 3GPP Cellular Network ANQP-element

The 3GPP Cellular Network ANQP-element contains cellular information such as network advertisement information e.g., network codes and country codes to assist a non-AP STA in selecting an AP to access 3GPP networks. The format of the 3GPP Cellular Network ANQP-element is shown in Figure 9-809.

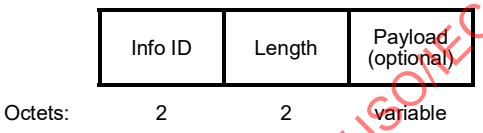

Figure 9-809—3GPP Cellular Network ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The Payload field is a variable length field and is a generic container. An example of the format and content is defined in Annex H of 3GPP TS 24.302.

9.4.5.12 AP Geospatial Location ANQP-element

The AP Geospatial Location ANQP-element provides the AP's location in LCI format; see 9.4.2.21.10. This information is taken from dot11APLCITable.

The format of the AP Geospatial Location ANQP-element is shown in Figure 9-810.

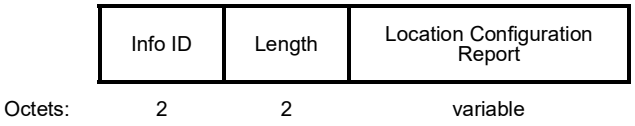

Figure 9-810—AP Geospatial Location ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The Location Configuration Report field is of variable length and defined in 9.4.2.21.10. The Z and Usage Rules/Policy subelements are optionally present in the Location Configuration Report field, when it is used in the AP Geospatial Location ANQP element. The Co-Located BSSID List subelement is present when there is at least one other BSS that is co-located within the same physical device as the reporting BSS.

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9.4.5.13 AP Civic Location ANQP-element

The AP Civic Location ANQP-element provides the AP's location in civic format. The format of the AP Civic Location ANQP-element is shown in Figure 9-811.

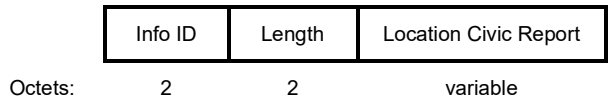

Figure 9-811—AP Civic Location ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The Location Civic Report field is a variable length field and the format is provided in 9.4.2.21.13. This information is taken from dot11APCivicLocationTable. The Co-Located BSSID List subelement is present when there is at least one other BSS that is co-located within the same physical device as the reporting BSS and the Co-Located BSSID List subelement is not present in the Geospatial Location ANQP-element; this subelement is not present otherwise.

9.4.5.14 AP Location Public Identifier URI/FQDN ANQP-element

The AP Location Public Identifier URI/FQDN ANQP-element provides an indirect reference to the location information for the AP. This list element can be returned in response to a GAS Query Request using the procedures in 11.22.3.3. The format of the AP Location Public Identifier URI/FQDN ANQP-element is shown in Figure 9-812.

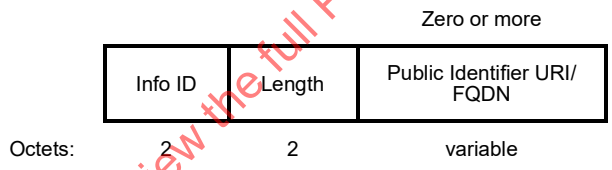

Figure 9-812—AP Location Public Identifier URI/FQDN ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The Public Identifier URI/FQDN field is a variable length field containing zero or more Public Identifier URI/FQDN subelements, as defined in 9.4.2.21.14.

9.4.5.15 Domain Name ANQP-element

The Domain Name ANQP-element provides a list of one or more domain names of the entity operating the IEEE 802.11 access network. Domain Names in this ANQP-element are taken from dot11DomainNameTable. The format of the Domain Name ANQP-element is shown in Figure 9-813.

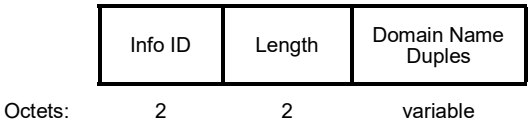

Figure 9-813—Domain Name ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

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The Domain Name Duples field contains zero or more variable length Domain Name Duple subfields.

The format of the Domain Name Duple subfield is shown in Figure 9-814.

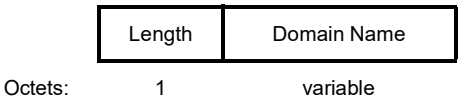

Figure 9-814—Domain Name Duple subfield format

The Length subfield indicates the length in octets of the Domain Name subfield.

The Domain Name subfield is of variable length and contains a domain name compliant with the "Preferred Name Syntax" as defined in IETF RFC 1035. The maximum length of this field is 255 octets.

9.4.5.16 Emergency Alert URI ANQP-element

The Emergency Alert URI ANQP-element provides a URI for EAS message retrieval.

The format of the Emergency Alert URI ANQP-element is shown in Figure 9-815.

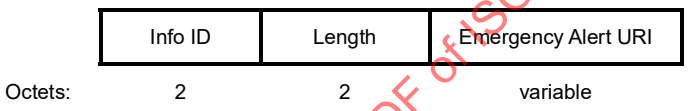

Figure 9-815—Emergency Alert URI ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The Emergency Alert URI field is a variable length field used to indicate the URI at which an EAS message can be retrieved as described in 11.22.7. The Emergency Alert URI field is formatted in accordance with IETF RFC 3986.

9.4.5.17 Emergency NAI ANQP-element

The Emergency NAI ANQP-element contains an emergency string that is available for use by a STA as its identity to indicate emergency access request. The format of the Emergency NAI ANQP-element is shown in Figure 9-816.

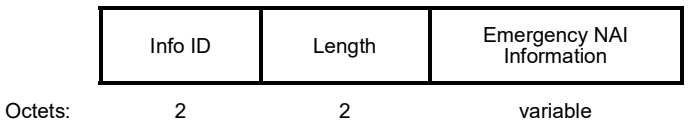

Figure 9-816—Emergency NAI ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The Emergency NAI Information field is a UTF-8 string formatted in accordance with IETF RFC 4282.

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9.4.5.18 TDLS Capability ANQP-element

The TDLS Capability ANQP-element is used by a STA to discover the TDLS capabilities of a peer STA. The format of the TDLS Capability ANQP-element is shown in Figure 9-817.

	Info ID	Length	Peer Information
Octets:	2	2	variable

Figure 9-817—TDLS Capability ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The Peer Information field is a variable length field containing information that a STA can use to establish a TDLS link and is defined as an XML schema (see R.6). An example of the peer information is described in 11.22.3.3.10.

9.4.5.19 Neighbor Report ANQP-element

The Neighbor Report ANQP-element provides zero or more neighbor reports about neighboring APs. This is of benefit to a STA in a preassociated state. The format of the Neighbor Report ANQP-element is defined in Figure 9-818.

	Info ID	Length	Neighbor Report element (optional)
Octets:	2	2	variable

Figure 9-818—Neighbor Report ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The format of the Neighbor Report element is shown in Figure 9-336 defined in 9.4.2.36. The Co-Located BSSID List subelement is present in the Measurement Report subelement when there is at least one other BSS that is co-located within the same physical device as the reporting BSS.

9.4.5.20 Venue URL ANQP-element

The Venue URL ANQP-element provides a list of one or more URLs that can be used for web page advertising services or providing information, particular to a venue's BSS, to a STA. The format of the Venue URL ANQP-element is defined in Figure 9-819.

	Info ID	Length	Venue URL Duples
Octets:	2	2	variable

Figure 9-819—Venue URL ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

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The Venue URL Duples field contains one or more Venue URL Duple fields as shown in Figure 9-820.

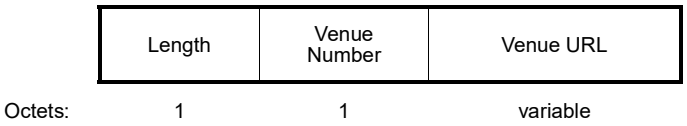

Figure 9-820—Venue URL Duple field

The Length field is set to 1 plus the number of octets in the Venue URL field.

The Venue Number field identifies the position (1 = 1st, 2 = 2nd, and so on) of the corresponding Venue Name Tuple subfield in the Venue Name ANQP-element from the same STA, as defined in 9.4.5.4. If that same STA does not advertise a Venue Name ANQP-element, or does not advertise any Venue Name Tuple subfields in the Venue Name ANQP-element, then the Venue Number field is set to 0.

The Venue URL field is a variable length field that indicates the URL at which information relevant to the corresponding Venue Name Tuple subfield, indicated by the Venue Number, might be retrieved. This is further described in 11.22.3.3.11. If no Venue URL is provided this field is left empty. The Venue URL field is formatted in accordance with IETF RFC 3986.

9.4.5.21 Advice of Charge ANQP-element

The Advice of Charge ANQP-element provides a list of one or more financial advice of charges related to access to a BSS. The format of the Advice of Charge ANQP-element is defined in Figure 9-821.

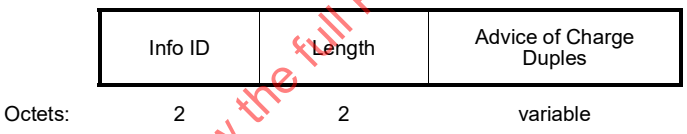

Figure 9-821—Advice of Charge ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The Advice of Charge Duples field contains one or more Advice of Charge Duple fields as shown in Figure 9-822.

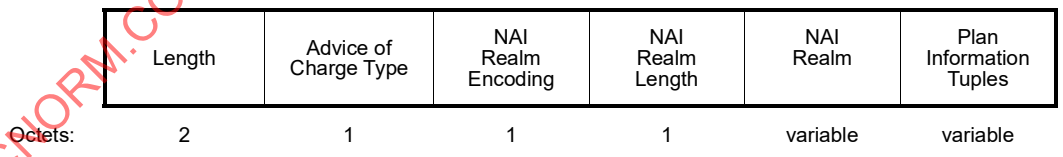

Figure 9-822—Advice of Charge Duple field

The Length field is set to 3 plus the number of octets in the NAI Realm and Plan Information Tuples fields.

The Advice of Charge Type field is set to one of the values defined in Table 9-338.

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Table 9-338—Advice of Charge Type field values

Advice of Charge Type Value	Description
0	Time-based
1	Data-volume-based
2	Time-and-data-volume-based
3	Unlimited
4–255	Reserved

The NAI Realm Encoding and NAI Realm Length are defined in 9.4.5.10. The NAI Realm subfield is one or more NAI Realms formatted as defined in 9.4.5.10.

The format of the Plan Information Tuples field is defined in Figure 9-823.

	Length	Language	Currency Code	Plan Information
Octets:	2	3	3	variable

Figure 9-823—Plan Information Tuple field format

The Length field is set to the number of octets in the Language, Currency Code, and Plan Information fields.

The Language Code field contains an ASCII-encoded language code selected from ISO 639, and defines the language used in the Cost Information field. A two character language code has 0 (ASCII NUL) appended.

The Currency Code field is a 3-octet string (e.g., "USD") representing an ISO 4217 currency numeric code.

The Plan Information field is a UTF-8 string that carries an XML description of an Advice of Charge plan. The schema and semantics of this description are outside the scope of this standard.

9.4.5.22 Local Content ANQP-element

The Local Content ANQP-element provides a list of one or more URLs that can be used to display local content related to the BSS. The format of the Local Content ANQP-element is defined in Figure 9-824.

	Info ID	Length	Local Content Duples
Octets:	2	2	variable

Figure 9-824—Local Content ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

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The Local Content Duples field contains one or more Local Content Duple fields as shown in Figure 9-825.

	Length	State	Local Content URL Length	Local Content URL	Label Length (optional)	Label (optional)
Octets:	1	1	1	variable	0 or 1	variable

Figure 9-825—Local Content Duple field format

The Length field is set to 2 plus the number of octets in the Local Content URL, Label Length and Label fields.

The State field is defined in Table 9-339.

Table 9-339—Local Content State values

State	Name
0	Not authenticated
1	Authenticated
2	Failure during authentication
3	Incorrect credentials
4	Credentials expired
5–255	Reserved

The Local Content URL Length field contains the length of the Local Content URL field in octets.

The Local Content URL field is a variable length field containing a URL that is used for directing the device to local content. The Local Content URL field is formatted in accordance with IETF RFC 3986.

The Label Length field contains the value of the length of the Label field in octets. If the Label field is not present, this field is not present.

The Label field is a UTF-8 string containing a text description of the URL suitable for display on a user interface. It provides the type and potential usage of the URL.

9.4.5.23 Network Authentication Type with Timestamp ANQP-element

The Network Authentication Type with Timestamp ANQP-element provides similar information to that of the Network Authentication Type as defined in 9.4.5.6. In addition, a timestamp field is optionally provided to indicate to the requesting STA a timestamp corresponding to the time at which the received terms and conditions were most recently modified. With this timestamp, the requesting STA can determine if previously received information is stale.

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The format of the Network Authentication Type with Time ANQP-element is shown in Figure 9-826.

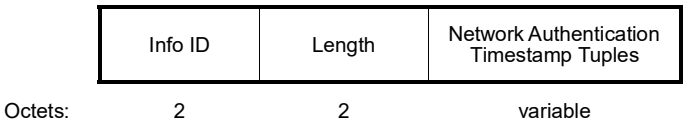

Figure 9-826—Network Authentication Type with Timestamp ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The Network Authentication Timestamp Tuples field contains zero or more variable length Network Authentication Timestamp Tuple subfields.

Each Network Authentication Timestamp Tuple subfield has the structure shown in Figure 9-827.

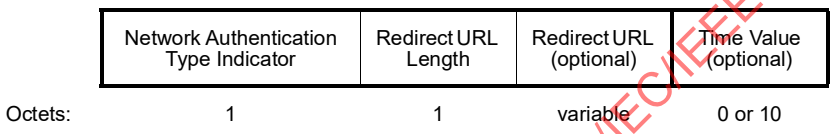

Figure 9-827—Network Authentication Timestamp Tuple subfield format

The Network Authentication Type Indicator field is defined in 9.4.5.6

The Redirect URL Length field and the Redirect URL field are defined in 9.4.5.6.

The Time Value field is defined in Table 9-192 using the Timing Capability equal to 2 encoding. This field is used by the responding STA to set a time of the ANQP response.

9.4.5.24 Query AP List ANQP-element

The Query AP List ANQP-element provides a list of APs and a list of Info IDs of ANQP-elements that the requesting STA is requesting from each AP in the list. The Query AP List ANQP-element declares that the STA performing the ANQP request is requesting that the ANQP-element corresponding to each Info ID be returned in the AP List Response ANQP-element. This element allows an optimization of the single ANQP request procedure (see 9.4.5.2) by having multiple ANQP requests in a single ANQP-element thus reducing the time necessary for network discovery and selection. See 11.22.3.3.14 for information on the Query AP list procedure.

The format of the Query AP List ANQP-element is shown in Figure 9-828.

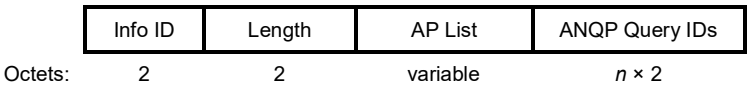

Figure 9-828—Query AP List ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

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The AP List field is a variable length field defined in Figure 9-829 that contains the list of BSSIDs for requested information.

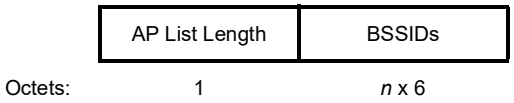

Figure 9-829—AP List field format

The AP List Length field indicates the length of the BSSIDs field.

The BSSIDs field contains one or more BSSID fields. Each BSSID field is 6 octets in length and indicates the BSSID of the BSS of an AP that the requesting STA wants to query.

The ANQP Query IDs field contains one or more ANQP Query ID fields that are ordered by increasing info ID value. Each ANQP Query ID field is an unsigned integer of length two octets.

The ANQP Query ID field value is drawn from Table 9-331.

9.4.5.25 AP List Response ANQP-element

The AP List Response ANQP-element provides the response to the Query AP List ANQP-element request. The ANQP response is defined in 11.22.3.3. The format of the AP List Response ANQP-element is defined in Figure 9-830.

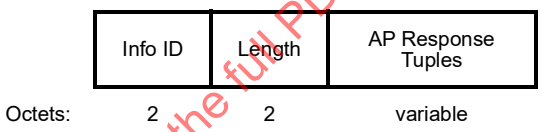

Figure 9-830—AP List Response ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The AP Response Tuples field contains zero or more AP Response Tuple fields.

The format of the AP Response Tuple field is defined in Figure 9-831.

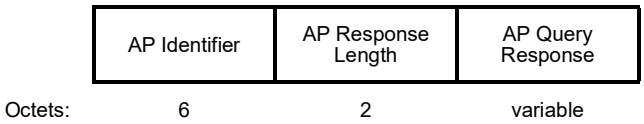

Figure 9-831—AP Response Tuple field format

The AP Identifier field indicates the BSSID of the BSS of the AP that the requesting STA queries.

The AP Response Length field indicates the number of octets in the following AP Query Response field.

The AP Query Response field contains an ANQP response corresponding to the ANQP Query ID in the received Query AP List ANQP-element as specified in 9.4.5.24. Each ANQP response comprises one or more ANQP-elements (Table 9-331).

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9.4.5.26 CAG ANQP-element

The CAG ANQP-element provides the info IDs for the ANQP-elements contained within a CAG associated with ANQP, or ANQP with Service Information Registry, and the current value of the ANQP CAG version, indicating the version of information within the CAG associated with ANQP, or ANQP with Service Information Registry. The format of the CAG ANQP-element is defined in Figure 9-832. The selection of the specific number of info IDs and the specific values of info IDs in a CAG associated with ANQP is left to the implementation and is beyond the scope of this standard.

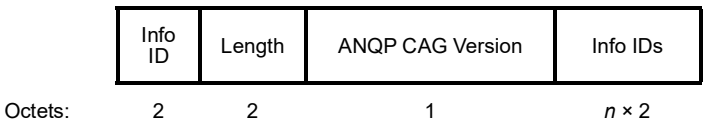

Figure 9-832—CAG ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The ANQP CAG Version field indicates the current version of the CAG associated with ANQP, or ANQP with Service Information Registry.

The Info IDs field contains zero or more Info ID fields. The Info ID field is an unsigned integer of length two octets and contains the info ID of an ANQP-element Info ID specified in Table 9-294.

9.4.5.27 Service Information Request ANQP-element

The Service Information Request ANQP-element contains a generic request for service information associated with the service hash(es) provided.

The format of the Service Information Request ANQP-element is shown in Figure 9-833.

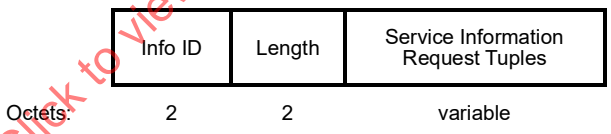

Figure 9-833—Service Information Request ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The Service Information Request Tuples field contains one or more Service Information Request Tuple subfields. The format of the Service Information Request Tuple subfield is shown in Figure 9-834.

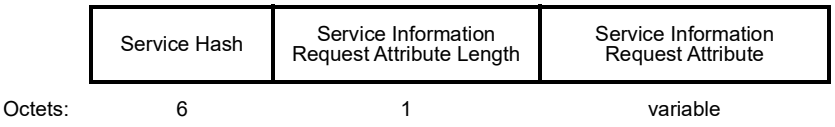

Figure 9-834—Service Information Request Tuple subfield format

The Service Hash field contains a 6-octet service hash value. See 11.23.4 for procedures for generating a service hash.

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The Service Information Request Attribute Length subfield indicates the length of the Service Information Request Attribute subfield.

The Service Information Request Attribute subfield contains a service-specific query. The value of this subfield is out of the scope of this standard.

9.4.5.28 Service Information Response ANQP-element

The Service Information Response ANQP-element contains the detailed service information in response to a Service Information Request ANQP-element.

The format of the Service Information Response ANQP-element is shown in Figure 9-835.

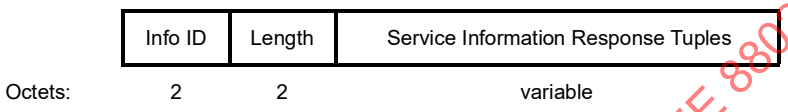

Figure 9-835—Service Information Response ANQP-element format

The Info ID and Length fields are defined in 9.4.5.1.

The Service Information Response Tuples field contains zero or more Service Information Response Tuple subfields.

The format of the Service Information Response Tuple subfield is shown in Figure 9-836.

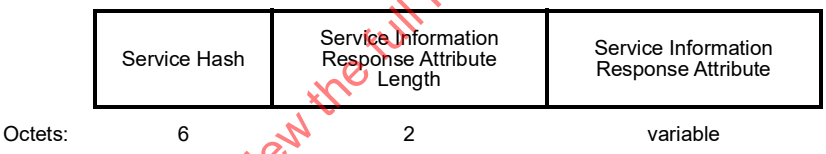

Figure 9-836—Service Information Response Tuple subfield format

The Service Hash field contains a 6-octet service hash value. See 11.23.4 for procedures for generating a service hash.

The Service Information Response Attribute Length subfield indicates the length of the Service Information Response Attribute subfield.

The content of the Service Information Response Attribute subfield is service specific based on the corresponding Service Information Request Attribute subfield in the Service Information Request Tuples of the Service Information Request ANQP-element as described in 9.4.5.27.

9.4.5.29 Local MAC Address Policy ANQP-element

The Local MAC Address Policy ANQP-element provides an indication of the local MAC address policy of the ESS.

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The format of the Local MAC Address Policy ANQP-element is specified in Figure 9-837.

	Info ID	Length	Local MAC Address Policy	Number Of Restricted Prefixes	Restricted Address Prefix
Octets:	2	2	1	1	variable

Figure 9-837—Local MAC Address Policy ANQP-element format

The Info ID and Length fields are specified in 9.4.5.1.

The Local MAC Address Policy field is a bitmap advertising policies supported by the ESS regarding its support for local MAC address. The values of the bits are specified in Table 9-340.

Table 9-340—Local MAC Address Policy field bits

Bitmap value	Description
Bit 0 (MSB)	Reserved
Bit 1	Randomization subject to Restricted Address Prefixes supported in SLAP Quadrant 00
Bit 2	Randomization subject to Restricted Address Prefixes supported in SLAP Quadrant 01
Bit 3	Randomization subject to Restricted Address Prefixes supported in SLAP Quadrant 10
Bit 4	Randomization subject to Restricted Address Prefixes supported in SLAP Quadrant 11
Bit 5	Reserved
Bit 6	Reserved
Bit 7	Reserved

The bitmap values provided in Table 9-340 indicate, to the receiving STA, aspects of the local MAC address policy of the ESS. The bits are independent and not mutually exclusive. They make reference to the Structured Local Address Plan (SLAP) introduced into IEEE Std 802 via the amendment IEEE Std 802c-2017. The bit value indications are as follows:

— Bit 0 is reserved.

— Bit 1, when set to 1, indicates the support of an address chosen by the STA randomly, in SLAP Quadrant 00 (i.e., the SLAP AAI quadrant, with 0100 as the M, X, Y, and Z bits, respectively) but avoiding addresses beginning with any prefix specified in the Restricted Address Prefix field. Bit 1, when set to 0, indicates that the ESS provides no rules on MAC address use within SLAP Quadrant 00.

— Bit 2, when set to 1, represents the support of an address chosen by the STA randomly, in SLAP Quadrant 01 (i.e., the SLAP ELI quadrant, with 0101 as the M, X, Y, and Z bits, respectively) but avoiding addresses beginning with any prefix specified in the Restricted Address Prefix field. Bit 2, when set to 0, indicates that the ESS provides no rules on MAC address use within SLAP Quadrant 01.

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— Bit 3, when set to 1, represents the support of an address chosen by the STA randomly, in SLAP Quadrant 10 (i.e., the SLAP Reserved quadrant, with 0110 as the M, X, Y, and Z bits, respectively) but avoiding addresses beginning with any prefix specified in the Restricted Address Prefix field. Bit 3, when set to 0, indicates that the ESS provides no rules on MAC address use within SLAP Quadrant 10.

— Bit 4, when set to 1, represents the support of an address chosen by the STA randomly, in SLAP Quadrant 11 (i.e., the SLAP SAI quadrant, with 0111 as the M, X, Y, and Z bits, respectively) but avoiding addresses beginning with any prefix specified in the Restricted Address Prefix field. Bit 4, when set to 0, indicates that the ESS provides no rules on MAC address use within SLAP Quadrant 11.

The Number Of Restricted Prefixes field specifies the number of Restricted Address Prefix subfields in the Restricted Address Prefix field.

NOTE 1—If Local MAC Address Policy field bits 1-4 are set to 1 and Number Of Restricted Prefixes to 0, the Local MAC Address Policy ANQP-element indicates that the ESS supports randomized address throughout local address range. In this case, the AP STA sets the Local MAC Address Policy field in the Extended Capabilities field to 0, indicating that local MAC addresses are not restricted, and consequently the Local MAC Address Policy ANQP-element is redundant.

The Restricted Address Prefix field contains zero or more Restricted Address Prefix subfields, each specifying the prefix of local MAC addresses supported in the ESS. Each such prefix indicates support for MAC addresses assigned as extensions of the indicated prefix, provided that the assignment is made according to the procedures specified for the use of that prefix, or, in the case that a MAC address is an extension of multiple indicated prefixes, the longest of those prefixes.

NOTE 2—The detailed specification of the use of local MAC addresses is provided in IEEE Std 802. Per its amendment IEEE Std 802c-2017, an SAI is assigned by a protocol specified in an IEEE 802 standard, and specification of the use of ELI addresses is provided by the assignee of a CID duly assigned by the IEEE Registration Authority.

The format of the Restricted Address Prefix subfield is described in Figure 9-838.

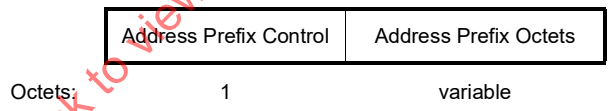

Figure 9-838—Restricted Address Prefix subfield format

The format of the Address Prefix Control subfield is described in Figure 9-839.

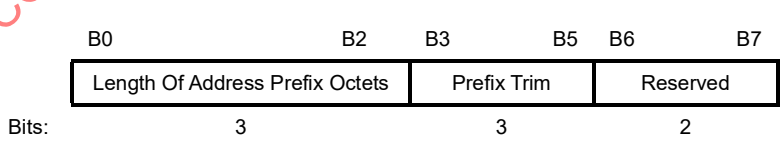

Figure 9-839—Address Prefix Control subfield format

The Length Of Address Prefix Octets subfield indicates the length (in octets) of the Address Prefix Octets field. Values 0 and 7 are reserved.

The Prefix Trim subfield indicates the number of bits to be truncated from the end of the value of the Address Prefix Octets subfield in order to obtain the MAC address prefix. In other words, the MAC address prefix is the value of the Address Prefix Octets subfield after truncation of some of the most significant bits of the last octet, with the number of truncated bits equal to the value of the Prefix Trim subfield. If the

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Length of Address Prefix Octets subfield is set to 1, then the value of the Prefix Trim subfield is not be set to 7; this provides that the length of the MAC address prefix is at least two bits. The bit and octet ordering of the MAC address prefix is per Figure 9-1.

9.4.6 Registered location query protocol (RLQP) elements

9.4.6.1 General

RLQP-elements are defined to have a common format consisting of a 2-octet Info ID field, a 2-octet Length field, and a variable length RLQP-element-specific Information field. Each element is assigned a unique Info ID as defined in this standard. The RLQP-element format is shown in Figure 9-840.

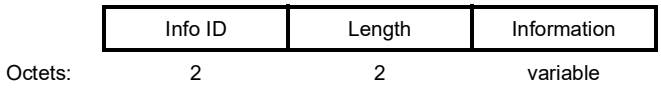

Figure 9-840—RLQP-element format

Each RLQP-element in 9.4.6 is assigned a unique 2-octet Info ID. The set of valid Info IDs is defined in Figure 9-840.

The Length field indicates the number of octets in the Information field.

The RLQP-elements are shown in Table 9-341. Info ID 56 797 stands for Vendor Specific information.

Table 9-341—RLQP-element definitions

RLQP-element name	Info ID	RLQP-element (subclause)
Reserved	0–272	N/A
Channel Availability Query	273	9.4.6.2
Channel Schedule Management	274	9.4.6.3
Network Channel Control	275	9.4.6.4
Reserved	276–56 796	N/A
Vendor Specific	56 797	9.4.6.5
Reserved	56 798–65 535	N/A

9.4.6.2 Channel Availability Query RLQP-element

The Channel Availability Query element is used to exchange the requests and responses for the channel availability query process using the GAS protocol. The Channel Availability Query RLQP-element is included in a GAS Query Request or returned in a response to a GAS Query Request.

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The element is in the format shown in Figure 9-841.

	Info ID	Length	Requester STA Address	Responder STA Address	Reason Result Code	Channel Query Info	Device Class	Device Identification Information	Device Location Information	WSM Information
Octets:	2	2	6	6	1	1	variable	variable	variable	variable

Figure 9-841—Channel Availability Query RLQP-element format

The Info ID and Length fields are defined in 9.4.6.1.

The RequesterSTAAddress field is the MAC address of the requesting STA that initiates the channel query process. The length of the RequesterSTAAddress field is 6 octets.

The ResponderSTAAddress field is the MAC address of the responding STA that responds to the channel query requesting STA. The length of the ResponderSTAAddress field is 6 octets.

The Reason Result Code field is used to indicate the reason that a channel availability query was generated. It also indicates the result of the query as successful or not and the reason when the query is not successful. The length of the Reason Result Code field is 1 octet. The Reason Result Code field values that have been allocated are shown in Table 9-342.

Table 9-342—Reason Result Code field values

Reason Result Code field value	Name	Description
0		Reserved.
1		Channel availability list requested.
2	SUCCESS	Success with the available channel list result for a Device Location Information field.
3	SUCCESS_MULTIPLE	Success with an available channel list result for a bounded geographic area defined by multiple Device Location Information fields.
4	REFUSED	Request declined.
5	DEVICE_VERIFICATION_FAILURE	Request not successful because of device identification verification failure. NOTE—Failure of providing an authorized identification of the corresponding regulatory organization can cause the responding STA to reject the query and return such a Reason Result Code.
6	Continuation frame	This frame continues the fields from the previous CAQ frame.
7–255		Reserved.

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The Channel Query Info field is used to indicate the type of Channel Query request and associated parameters. The format of the Channel Query Info field is shown in Figure 9-842.

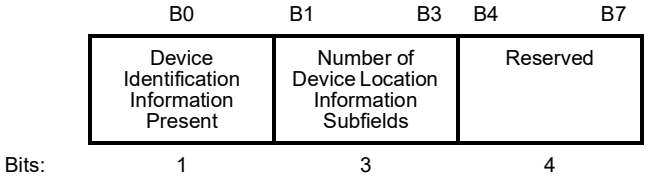

Figure 9-842—Channel Query Info field format

The Device Identification Information Present subfield value is set to 1 to indicate that the Device Identification Information field is present in the Channel Availability Query element; otherwise it is set to 0 to indicate that the Device Identification Information field is not provided.

The Number of Device Location Information Subfields subfield indicates the number of device location information subfields presented in the Channel Availability Query element. When no device location is present, the Number of Device Location Information Subfields subfield is set to 0.

The Device Class field is used to indicate the characteristics of STA requesting the channel availability query. The format of the Device Class field is specified in 9.4.4.2.2. The Device Class field is present only when the Reason Result Code field value is 1.

The Device Identification Information field is used to indicate the identification of the STA requesting the channel availability query. The format of the Device Identification Information field is specified in 9.4.4.2.3.

The Device Location Information field is used to provide the location of the STA requesting the channel availability query, which is provided in the format specified in 9.4.4.2.4.

The WSM Information field is defined in the White Space Map element (see 9.4.2.169). The WSM Information field is present only when the Reason Result Code field value is 2 or 3, as the successful result of the query.

9.4.6.3 Channel Schedule Management RLQP-element

The Channel Schedule Management element is used by an GDD enabling STA to query the RLSS or another GDD enabling STA for channel schedule information. The element is in the format shown in Figure 9-843.

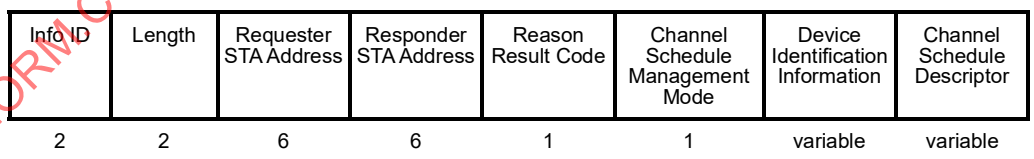

Figure 9-843—Channel Schedule Management RLQP-element format

The Info ID and Length fields are defined in 9.4.6.1.

The Requester STA Address field is the MAC address of the requesting STA that initiates the channel schedule management process.

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The Responder STA Address field is the MAC address of the STA that responds to the STA that requested channel schedule management.

The remaining fields are as defined in the Channel Schedule Management element (see 9.6.7.26).

9.4.6.4 Network Channel Control RLQP-element

The Network Channel Control element is used to request network channel control and respond to network channel requests using the GAS protocol. The element is in the format shown in Figure 9-844.

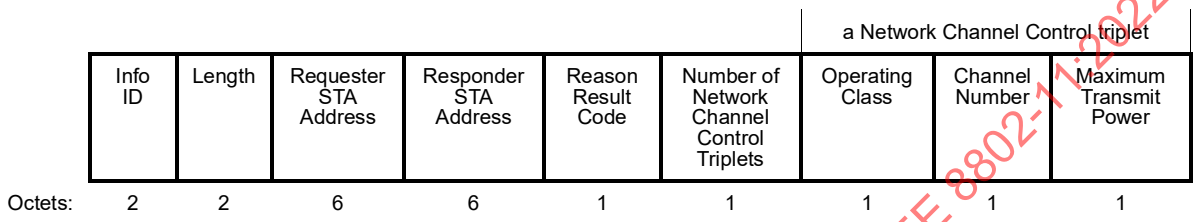

Figure 9-844—Network Channel Control RLQP-element format

The Info ID and Length fields are defined in 9.4.6.1.

The RequesterSTAAddress field is the MAC address of the requesting STA that initiates the network channel control process.

The ResponderSTAAddress field is the MAC address of the STA that responds to the STA that requested network channel control.

The Reason Result Code field is used to indicate the reason that a Network Channel Control frame was generated. The length of the Reason Result Code field is 1 octet. The encoding of the Reason Result Code field is shown in Table 9-343.

Table 9-343—Reason Result Code field values

Reason Result Code field value	Name	Description
0	REQUEST	Network channel request.
1	SUCCESS	Success.
2	REFUSED	Request declined.
3	TOO_MANY_SIMULTANEOUS_REQUESTS	Network channel request denied because the GDD enabling STA is unable to handle additional GDD dependent STAs.
4	Continuation frame	This frame continues the fields from the previous NCC frame.
5–255		Reserved.

The Number of Network Channel Control Triplets field indicates the number of triplets of Operating Class, Channel Number, and Transmit Power Constraint fields.

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The Operating Class field indicates the channel set for which the network channel control request applies. The Operating Class field and Channel Number field are used together to specify the channel frequency and channel bandwidth for which the network channel control applies. Values for the Operating Class field are shown in E.1.

In a request, the Channel Number field of a Network Channel Control frame indicates the channel that the requesting STA intends to operate on. In a response, the Channel Number field in the Network Channel Control frame indicates the channels that the responding STA permits the requesting STA to operate on. The Channel Number is defined within an Operating Class as shown in E.1.

The Maximum Transmit Power field gives the intended maximum transmit power in dBm for operation in the request frame and indicates the maximum allowable transmit power in dBm for operation in the response frame. The field is coded as a 2s complement signed integer in units of 0.5 dBm. The field is set to –128 when a requesting STA requests a responding STA to provide a network channel control response without specifying in the request the intended maximum transmit power.

9.4.6.5 Vendor Specific RLQP-element

The Vendor Specific RLQP-element is used to carry information not defined in this standard within a single defined format, so that reserved Info IDs are not usurped for nonstandard purposes and so that interoperability is more easily achieved in the presence of nonstandard information. The RLQP-element is in the format shown in Figure 9-845.

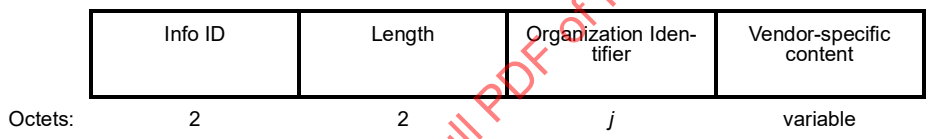

Figure 9-845—Vendor Specific RLQP-element format

The Info ID and Length fields are defined in 9.4.6.1.

The Organization Identifier field identifies (see 9.4.1.31) the entity that has defined the content of the particular Vendor Specific RLQP-element. See 9.4.1.31 for the definition of *j*.

9.5 Fields used in Management and Extension frame bodies and Control frames

9.5.1 Sector Sweep field

The format of the sector sweep (SSW) field is shown in Figure 9-846.

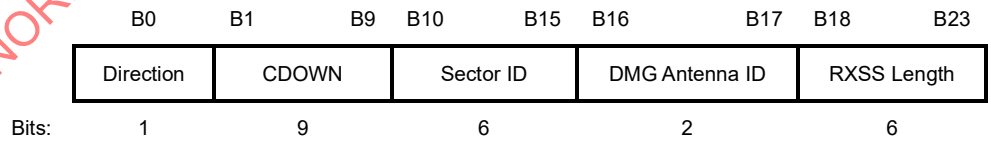

Figure 9-846—SSW field format

The Direction subfield is set to 0 to indicate that the frame is transmitted by the beamforming initiator and set to 1 to indicate that the frame is transmitted by the beamforming responder.

The CDOWN subfield is a down counter indicating the number of remaining DMG Beacon frame transmissions to the end of the TXSS, or the number of remaining SSW frame transmissions to the end of

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the TXSS/RXSS. This subfield is set to 0 in the last frame DMG Beacon and SSW frame transmission. Possible values range from 0 to 511.

The Sector ID subfield is set to indicate the sector number through which the frame containing this SSW field is transmitted.

The DMG Antenna ID subfield indicates the antenna (for a CMMG STA) or DMG antenna (for a DMG STA) the transmitter is currently using for this transmission.

The RXSS Length subfield is valid only when transmitted in a CBAP and is reserved otherwise. The RXSS Length subfield specifies the length of a receive sector sweep as required by the transmitting STA and is defined in units of an SSW frame. The length of the sector sweep is given by (RXSS Length + 1) × 2.

9.5.2 Dynamic Allocation Info field

The format of the Dynamic Allocation Info field is shown in Figure 9-847.

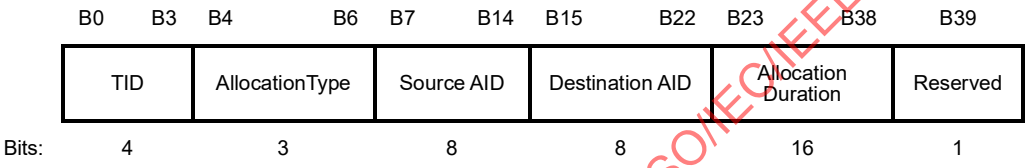

Figure 9-847—Dynamic Allocation Info field format

The TID subfield identifies the TC or TS for the allocation request or grant.

NOTE—Unlike pseudo-static allocations, nonpseudo-static allocations are not labeled with an allocation ID, and are associated to a TID.

The AllocationType subfield is defined in 9.4.2.131.

The Source AID subfield identifies the STA that is the source of the allocation.

The Destination AID subfield identifies the STA that is the destination of the allocation.

When the Dynamic Allocation Info field is transmitted within an SPR frame, the Allocation Duration subfield contains the requested duration in microseconds. When the Dynamic Allocation Info subfield is transmitted within a Grant frame by an AP or PCP in an ATI or GP, the Allocation Duration subfield contains the granted duration of the SP or CBAP allocation in microseconds (see 10.39.3, 10.39.7, 10.39.8, and 10.39.9). Possible values range from 0 to 32 767 for an SP allocation and a CBAP allocation. Setting the Allocation Duration subfield transmitted to 0 within a Grant frame means that the STA can transmit one PPDU followed by any relevant acknowledgment plus one RTS/DMG CTS handshake.

When the Dynamic Allocation Info subfield is transmitted within a Grant frame in a CBAP, the value of the Allocation Duration field indicates the purpose of the Grant frame transmission. Two purposes are possible:

a) Beyond current TXOP: in this case, the Allocation Duration subfield values range from 0 to 32 767. The value of the Allocation Duration field plus the Duration field of the Grant frame indicates the time offset from the PHY-TXEND.indication primitive of the Grant frame when the STA transmitting the Grant frame will attempt to initiate access for communication with the STA indicated by the RA field of the Grant frame.

b) Within current TXOP: in this case, the Allocation Duration subfield is set to 32 768.

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When the Dynamic Allocation Info subfield is transmitted within a Grant frame with RA set to broadcast address by a source or destination STA of an SP, the Allocation Duration subfield values range from 0 to 32 767.

When the Dynamic Allocation Info subfield is transmitted within a Grant frame with RA set to individual address by a source STA of an SP, the Allocation Duration subfield is set to 32 768.

9.5.3 Sector Sweep Feedback field

When the SSW Feedback field is transmitted as part of an ISS, the format of the field is as shown in Figure 9-848. Otherwise, the format of the SSW Feedback field is as shown in Figure 9-849.

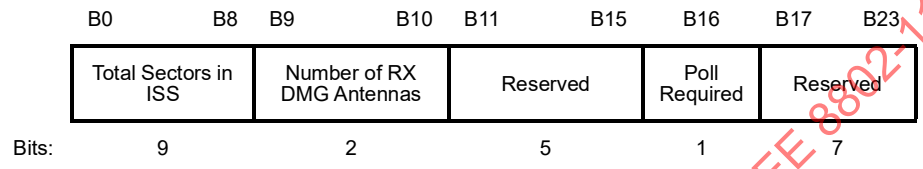

Figure 9-848—SSW Feedback field format when transmitted as part of an ISS

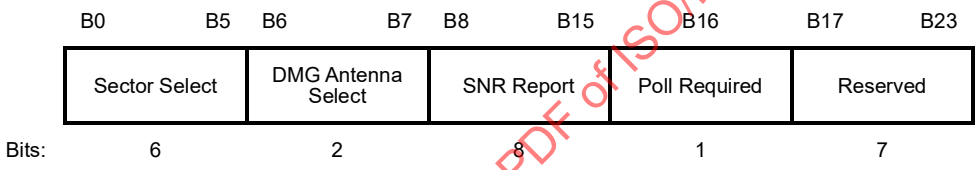

Figure 9-849—SSW Feedback field format when not transmitted as part of an ISS

The Total Sectors in ISS subfield indicates the total number of sectors that the initiator uses in the ISS, including any repetition performed as part of multi-antenna beamforming. Possible values range from 0 to 511, representing 1 to 512 sectors.

The Number of RX DMG Antennas subfield indicates the number of receive DMG antennas the initiator uses during the following RSS. This subfield is set to the number of receive DMG antennas used minus 1.

The Sector Select subfield contains the value of the Sector ID subfield of the SSW field within the frame that was received with best quality in the immediately preceding sector sweep. The determination of which frame was received with best quality is implementation dependent. Possible values of this subfield range from 0 to 63.

The DMG Antenna Select subfield indicates the value of the DMG Antenna ID subfield of the SSW field within the frame that was received with best quality in the immediately preceding sector sweep. The determination of which frame was received with best quality is implementation dependent.

The SNR Report subfield is set to the value of the SNR from the frame that was received with best quality during the immediately preceding sector sweep and is indicated in the Sector Select field. This subfield is encoded as 8-bit 2s complement value of 4×(SNR-19), where SNR is measured in dB. This covers from –13 dB to 50.75 dB in 0.25 dB steps.

The Poll Required subfield is set to 1 by a non-AP and non-PCP STA to indicate that it requires the AP or PCP to initiate communication with the non-AP and non-PCP. This subfield is set to 0 to indicate that the

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non-AP and non-PCP has no preference about whether the AP or PCP initiates the communication. This subfield is reserved when transmitted by an AP or PCP.

9.5.4 BRP Request field

The BRP Request field is defined in Figure 9-850.

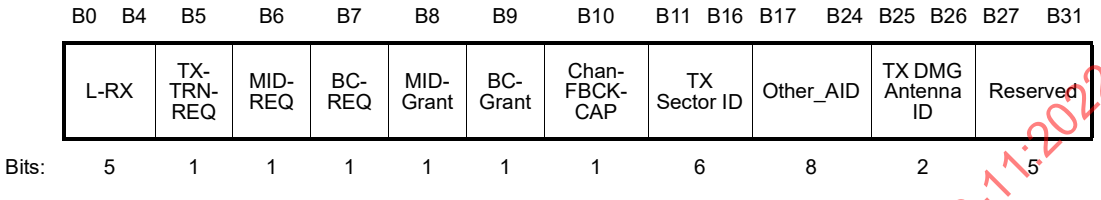

Figure 9-850—BRP Request field format

If the MID-REQ subfield is set to 0, the L-RX subfield indicates the number of TRN units requested by the transmitting STA for RX training as part of beam refinement. The L-RX subfield contains an unsigned integer between 0 and 16. Values outside this range are reserved. The number of requested TRN-R subfields is equal to the value of the L-RX subfield multiplied by 4. Other values are reserved. If the subfield is set to 0, the transmitting STA does not request receive training as part of beam refinement. If the MID-REQ subfield is set to 1, the L-RX subfield indicates the number of TRN units the STA uses during the MID phase for each TX sector/AWV.

The TX-TRN-REQ subfield is set to 1 to indicate that the STA requests transmit training as part of beam refinement. Otherwise, it is set to 0.

A STA sets the MID-REQ subfield to 1 in SSW-Feedback or BRP frames to indicate a request for an I-MID subphase or R-MID subphase; otherwise, the STA sets the subfield to 0 to indicate it is not requesting an I-MID subphase or R-MID subphase. In case an R-MID subphase is requested, the STA can include information on the TX sector IDs to be used by the STA receiving this request. The STA receiving this request sets the MID-grant subfield in SSW-Ack or BRP frames to 1 to grant this request or otherwise sets it to 0.

A STA sets the BC-REQ subfield to 1 in SSW-Feedback or BRP frames to indicate a request for an I/R-BC subphase; otherwise, the STA sets the subfield to 0 to indicate it is not requesting an I/R-BC subphase. In case an R-BC subphase is requested, the STA can include information on the TX sector IDs to be used by the STA receiving this request. The STA receiving this request sets the BC-grant subfield in SSW-Ack or BRP frames to 1 to grant this request; otherwise, the STA sets it to 0 to reject the request.

The Chan-FBCK-CAP subfield is set to 1 to indicate the STA is capable to return channel measurement during beam refinement. The Chan-FBCK-CAP subfield is set to 0 to indicate the STA is able to return only BS-FBCK during beam refinement.

NOTE—Regardless of the value of the Chan-FBCK-CAP subfield, 10.42.6.4 requires a DMG STA to return the SNR values from the last TXSS if it receives a BRP frame with the TXSS-FBCK-REQ field and the SNR Requested subfield within the FBCK-REQ field both set to 1.

The TX Sector ID subfield indicates the sector ID that is used when transmitting the PPDU. If the PPDU is transmitted using a pattern that is not a sector that has been used in the sector sweep, this subfield is set to 0x63.

The Other_AID subfield is set to the AID of an additional STA referenced in the BRP procedure as described in 10.42.6.4.4 and 20.9.2.2.6. Otherwise, if the additional STA is not used, this subfield is set to 0.

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The TX DMG Antenna ID subfield indicates the DMG antenna ID that is used when transmitting the PPDU.

9.5.5 Beamforming Control field

The Beamforming Control field is formatted as shown in Figure 9-851 when both the IsInitiatorTXSS and IsResponderTXSS subfields are equal to 1, and the Beamforming Control field is transmitted in either a Grant or Grant Ack frames. In all other cases, the Beamforming Control field is formatted as shown in Figure 9-852.

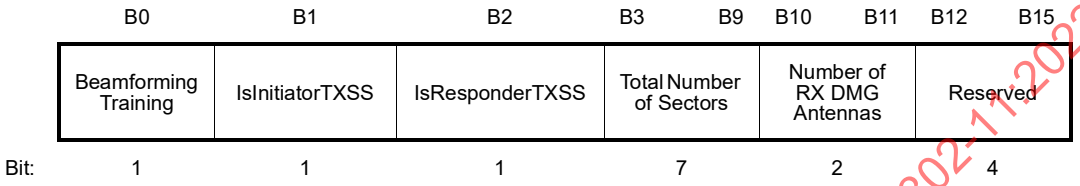

Figure 9-851—BF Control field format when both IsInitiatorTXSS and IsResponderTXSS subfields are equal to 1 and the BF Control field is transmitted in Grant or Grant Ack frames

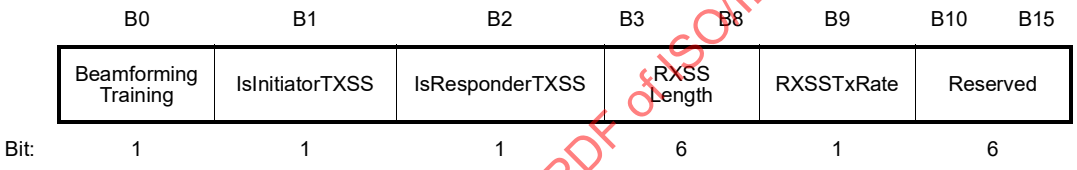

Figure 9-852—BF Control field format in all other cases

The Beamforming Training subfield is set to 1 to indicate that the source DMG STA intends to initiate beamforming training with the destination DMG STA at the start of the allocation and is set to 0 otherwise. If the Beamforming Training subfield is set to 0, all other subfields of the Beamforming Control field are reserved.

The IsInitiatorTXSS subfield is set to 1 to indicate that the source DMG STA starts the beamforming training with an initiator TXSS. This subfield is set to 0 to indicate that the source DMG STA starts the BF training with an initiator RXSS.

The IsResponderTXSS subfield is set to 1 to indicate that the destination DMG STA starts the RSS with a responder TXSS. This subfield is set to 0 to indicate that the destination DMG STA is to initiate the RSS with a responder RXSS.

When the Beamforming Control field is transmitted within an Extended Schedule element, either the IsInitiatorTXSS subfield or the IsResponderTXSS subfield is set to 0, but not both.

The RXSS Length subfield is valid only if at least one of IsInitiatorTXSS subfield or IsResponderTXSS subfield is equal to 0 and is reserved otherwise. The value represented by the RXSS Length subfield specifies the total number of receive sectors combined over all receive DMG antennas of the STA, including any LBIFS as necessary for DMG antenna switching. The value represented by this subfield is in the range 2 to 128 and is given by (RXSS Length+1)×2.

The RXSSTxRate subfield is valid only if the RXSS Length subfield is valid and the value of the RXSS Length subfield is greater than 0. Otherwise, the RXSSTxRate subfield is reserved. The RXSSTxRate subfield is set to 0 to indicate that all frames transmitted as part of the RXSS use the DMG Control

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modulation class (10.6.7.1). The RXSSTxRate subfield is set to 1 to indicate that only the first frame transmitted as part of the RXSS use the DMG Control modulation class and the remaining frames use MCS 1 of the DMG SC modulation class. If both the IsInitiatorTXSS and IsResponderTXSS subfields are set to 0 and the BF Control field is sent within a Grant frame, the RXSSTxRate subfield refers to the RSS only. If both the IsInitiatorTXSS and IsResponderTXSS subfields are set to 0 and the BF Control field is sent within a Grant Ack frame, the RXSSTxRate subfield refers to the ISS only.

When the BF Control field is transmitted in a Grant frame, the Total Number of Sectors subfield indicates the total number of sectors the initiator uses during the ISS, including any LBIFS required for DMG antenna switching (see 10.42). When the BF Control field is transmitted in a Grant Ack frame, the Total Number of Sectors subfield indicates the total number of sectors the responder uses during the RSS. In both cases, this field is set to the total number of sectors used minus 1.

When the BF Control field is transmitted in a Grant frame, the Number of RX DMG Antennas subfield indicates the number of receive DMG antennas the initiator uses during the RSS. When the BF Control field is transmitted in a Grant Ack frame, the Number of RX DMG Antennas subfield indicates the number of receive DMG antennas the responder uses during the ISS. In both cases, this subfield is set to the number of receive DMG antennas used minus 1.

When the BF Control field is transmitted in a Grant Ack frame in response to a Grant frame with the Beamforming Training field equal to 0, the following fields are reserved: IsInitiatorTXSS, IsResponderTXSS, Total Number of Sectors, and Number of RX DMG Antennas.

9.5.6 Beamformed Link Maintenance field

The Beamformed Link Maintenance field is shown in Figure 9-853 and provides a DMG STA with the value of dot11BeamLinkMaintenanceTime.

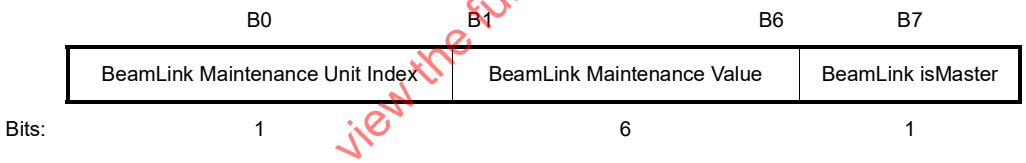

Figure 9-853—Beamformed Link Maintenance field format

The encoding of the BeamLink Maintenance Unit Index subfield is specified in Table 9-344.

Table 9-344—Encoding of BeamLink Maintenance Unit Index

BeamLink Maintenance Unit Index	BeamLink Maintenance Unit (μs)
0	32
1	2000

If the content of the BeamLink Maintenance Value subfield is greater than 0, it is used to calculate dot11BeamLinkMaintenanceTime as follows:

$$dot11BeamLinkMaintenanceTime = BLMU \times BLMV$$

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where

BLMU is the value of the BeamLink Maintenance Unit corresponding to the value of the BeamLink Maintenance Unit Index subfield (see Table 9-344)

BLMV is the value of the BeamLink Maintenance Value subfield

Otherwise, if the BeamLink Maintenance Value subfield is set to 0, the dot11BeamLinkMaintenanceTime is left undefined. An undefined value of the dot11BeamLinkMaintenanceTime indicates that the STA does not participate in beamformed link maintenance.

The BeamLink isMaster subfield is set to 1 to indicate that the STA is the master of the data transfer and set to 0 otherwise. The STAs use the BeamLink isMaster subfield to negotiate the dot11BeamLinkMaintenanceTime as specified in Table 9-345.

NOTE—In Table 9-345, STA-A and STA-B refer to any of the STAs performing the Beamformed Link Maintenance negotiation procedure in no particular order.

Table 9-345—The Beamformed Link Maintenance negotiation

BeamLink isMaster subfield (STA-A)	BeamLink isMaster subfield (STA-B)	dot11BeamLinkMaintenanceTime (STA-A) vs. dot11BeamLinkMaintenanceTime (STA-B)	Result
0	0	≥	dot11BeamLinkMaintenanceTime (STA-A)
1	0	>, <, =	dot11BeamLinkMaintenanceTime (STA-A)
1	1	=	dot11BeamLinkMaintenanceTime (STA-A)
0 or 1	0 or 1	If either dot11BeamLinkMaintenanceTime (STA-A) or dot11BeamLinkMaintenanceTime (STA-B) is undefined	Undefined

9.6 Action frame format details

9.6.1 Introduction

Subclause 9.6 describes the Action field formats allowed in each of the action categories defined in Table 9-51 in 9.4.1.11. The frames defined in this subclause are Action frames, unless stated explicitly to be Action No Ack frames.

9.6.2 Spectrum Management Action frames

9.6.2.1 General

Five Action frame formats are defined for spectrum management. A Spectrum Management Action field, in the field immediately after the Category field, differentiates the five formats. The Spectrum Management Action field values associated with each frame format are defined in Table 9-346.

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Table 9-346—Spectrum Management Action field values

Spectrum Management Action field value	Description
0	Spectrum Measurement Request
1	Spectrum Measurement Report
2	TPC Request
3	TPC Report
4	Channel Switch Announcement
5–255	Reserved

9.6.2.2 Spectrum Measurement Request frame format

The Spectrum Measurement Request frame is transmitted to request another STA to measure one or more channels. The format of the Spectrum Measurement Request frame Action field is shown in Figure 9-854.

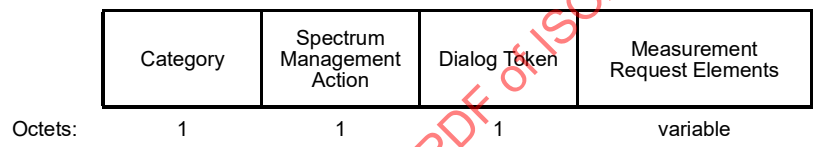

Figure 9-854—Spectrum Measurement Request frame Action field format

The Category field is defined in 9.4.1.11.

The Spectrum Management Action field is defined in 9.6.2.1.

The Dialog Token field is set to a nonzero value chosen by the STA sending the measurement request to identify the request/report transaction.

The Measurement Request Elements field contains one or more of the Measurement Request elements described in 9.4.2.20. The number and length of the Measurement Request elements in a Spectrum Measurement Request frame are limited by the maximum allowed MMPDU size.

9.6.2.3 Spectrum Measurement Report frame format

The Spectrum Measurement Report frame is transmitted in response to a Spectrum Measurement Request frame or transmitted autonomously providing measurement information. The format of the Spectrum Measurement Report frame Action field is shown in Figure 9-855.

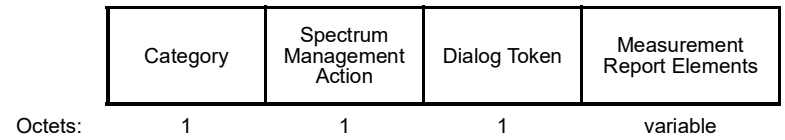

Figure 9-855—Spectrum Measurement Report frame Action field format

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The Category field is defined in 9.4.1.11.

The Spectrum Management Action field is defined in 9.6.2.1.

The Dialog Token field is set to the same value as the Dialog Token field of the corresponding Spectrum Measurement Request frame. If the Spectrum Measurement Report frame is not being transmitted in response to a Spectrum Measurement Request frame, then the dialog token is set to 0.

The Measurement Report Elements field contains one or more of the Measurement Report elements described in 9.4.2.21. The number and length of the Measurement Report elements in a Spectrum Measurement Report frame are limited by the maximum allowed MMPDU size.

9.6.2.4 TPC Request frame format

The TPC Request frame is transmitted requesting another STA for transmit power and link margin information. The format of the TPC Request frame Action field is shown in Figure 9-856.

	Category	Spectrum Management Action	Dialog Token	TPC Request element
Octets:	1	1	1	2

Figure 9-856—TPC Request frame Action field format

The Category field is defined in 9.4.1.11.

The Spectrum Management Action field is defined in 9.6.2.1.

The Dialog Token field is set to a nonzero value chosen by the STA sending the request to identify the transaction.

The TPC Request element is set as described in 9.4.2.15.

9.6.2.5 TPC Report frame format

The TPC Report frame is transmitted in response to a TPC Request frame. The format of the TPC Report frame Action field is shown in Figure 9-857.

	Category	Spectrum Management Action	Dialog Token	TPC Report element
Octets:	1	1	1	4

Figure 9-857—TPC Report frame Action field format

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The Category field is defined in 9.4.1.11.

The Spectrum Management Action field is defined in 9.6.2.1.

The Dialog Token field is set to the value of the Dialog Token field in the corresponding TPC Request frame.

The TPC Report element is set as described 9.4.2.16.

9.6.2.6 Channel Switch Announcement frame format

The Channel Switch Announcement frame is transmitted by a non-DMG AP, non-DMG IBSS STA, or mesh STA to advertise a channel switch. The format of the Channel Switch Announcement frame Action field is shown in Figure 9-858.

						Optional	Zero or more
	Category	Spectrum Management Action	Channel Switch Announcement element	Secondary Channel Offset element	Mesh Channel Switch Parameters element	Wide Bandwidth Channel Switch element	New Transmit Power Envelope element
Octets:	1	1	5	0 or 3	0 or 8	0 or 5	variable

Figure 9-858—Channel Switch Announcement frame Action field format

The Category field is defined in 9.4.1.11.

The Spectrum Management Action field is defined in 9.6.2.1.

The Channel Switch Announcement element is set as described 9.4.2.18.

The Secondary Channel Offset element is defined in 9.4.2.19. This element is present when switching to a 40 MHz or wider channel. It can be present when switching to a 20 MHz channel (in which case the Secondary Channel Offset field is set to SCN); see 11.38.4.

The Mesh Channel Switch Parameters element is defined in 9.4.2.102. This element is present when a mesh STA performs MBSS channel switching. Otherwise, the Mesh Channel Switch Parameters element is not present.

The Wide Bandwidth Channel Switch element is defined in 9.4.2.160. This element is present when switching to a channel width wider than 40 MHz.

Each New Transmit Power Envelope element that is present is defined to have the same format as the Transmit Power Envelope element (see 9.4.2.161) and includes a distinct value of the Local Maximum Transmit Power Unit Interpretation subfield. If present, the New Transmit Power Envelope element indicates the local maximum transmit powers for the BSS for the indicated bandwidths with an indicated unit interpretation after channel switching (see 11.38.1).

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9.6.3 QoS Action frame details

9.6.3.1 General

Several Action frame formats are defined for QoS purposes. These frames are identified by the single octet QoS Action field, which follows immediately after the Category field. The values of the QoS Action field are defined in Table 9-347.

Table 9-347—QoS Action field values

QoS Action field value	Meaning
0	ADDTS Request
1	ADDTS Response
2	DELTS
3	Schedule
4	QoS Map Configure
5	ADDTS Reserve Request
6	ADDTS Reserve Response
7–255	Reserved

Two variants are defined for the ADDTS frames: a Basic ADDTS frame variant and a DMG ADDTS frame variant. These variants use different TSPEC formats. The variant of the frame is indicated by the Element ID in the fourth field of the ADDTS Request frame Action field format (see Table 9-350 and Table 9-351) and sixth field of the ADDTS Response frame Action field format (see Table 9-352 and Table 9-353). The Element ID is the first octet of each of these fields. The encoding of the ADDTS frame variants is shown in Table 9-348 and Table 9-349.

Table 9-348—Encoding of the ADDTS Request frame variant

Element ID of fourth field of ADDTS Request frame	ADDTS Request frame variant
13 (TSPEC)	Basic ADDTS Request frame
146 (DMG TSPEC)	DMG ADDTS Request frame

Table 9-349—Encoding of the ADDTS Response frame variant

Element ID of sixth field of ADDTS Response frame	ADDTS Response frame variant
13 (TSPEC)	Basic ADDTS Response frame
146 (DMG TSPEC)	DMG ADDTS Response frame

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9.6.3.2 Basic and DMG ADDTS Request frame format

9.6.3.2.1 Basic ADDTS Request frame variant

The ADDTS frames are used to carry TSPEC and optionally TCLAS elements to set up and maintain TSs using the procedures defined in 11.4.

The Action field of the ADDTS Request frame contains the information shown in Table 9-350.

Table 9-350—Basic ADDTS Request frame variant Action field format

Order	Information	Notes
1	Category	
2	QoS Action	
3	Dialog token	
4	TSPEC	
5	TCLAS	Optional
6	TCLAS Processing	Optional
7	U-APSD Coexistence	Optional
8	Expedited Bandwidth Request	Optional
9	Intra-Access Category Priority	Optional
10	Higher Layer Stream ID	Only in AP-initiated TS setup
11	Multi-band	Optional
12	U-PID	Optional
13	Multiple MAC Sublayers	Optional

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The Category field is defined in 9.4.1.11.

The QoS Action field is defined in 9.6.3.1.

The values of the Dialog Token, TCLAS, and subsequent fields of this frame are the same as the values of the corresponding parameters in the invocation of the MLME-ADDTS.request primitive that causes the frame to be sent. Some of the TSPEC parameters have the same values as the corresponding parameters in the invocation of the MLME-ADDTS.request primitive, while the values of the other fields (i.e., Surplus Bandwidth Allowance, Minimum Service Interval, Maximum Service Interval, and Minimum PHY Rate) are generated within the MAC.

The TSPEC element, defined in 9.4.2.29, and the optional TCLAS element, defined in 9.4.2.30, contain the QoS parameters that define the TS. The TS is identified by the TSID and Direction fields within the TSPEC element. The TCLAS element is optional at the discretion of the STA that sends the ADDTS Request frame, regardless of the setting of the access policy (EDCA, SPCA, or HCCA). There are zero or more TCLAS elements in the ADDTS frame. The TCLAS Processing element is present when there is more than one TCLAS element and is defined in 9.4.2.32. An Expedited Bandwidth Request element is optionally present, which is defined in 9.4.2.93.

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The U-APSD Coexistence element, defined in 9.4.2.90, contains the coexistence parameters requested by the non-AP STA when using the U-APSD coexistence capability as described in 11.2.3.5.2. The U-APSD Coexistence element is optionally present.

An Intra-Access Category Priority element is optionally present, which is defined in 9.4.2.120 and described in 11.4.1.

The Higher Layer Stream ID element (9.4.2.124) provides the stream identifier from a higher layer protocol. The Higher Layer Stream ID element is present only in the AP-initiated TS setup (11.4.4.3).

When present in an ADDTS Request frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the ADDTS Request frame applies and contains band-specific information.

When present in the ADDTS Request frame, the U-PID element indicates the upper layer protocol associated with the TID/TSID specified within the TSPEC element contained in this frame.

When present in the ADDTS Request frame, the Multiple MAC Sublayers element is used to establish an MMSL cluster.

9.6.3.2.2 DMG ADDTS Request frame variant

The DMG ADDTS Request frame is used by DMG STAs in a PBSS and in an infrastructure BSS. The Action field of the DMG ADDTS Request frame contains the information shown in Table 9-351.

Table 9-351—DMG ADDTS Request frame variant Action field format

Order	Information	Notes
1	Category	
2	Action	
3	Dialog Token	
4	DMG TSPEC	
5	TSPEC	Optional
6	TCLAS	Optional
7	TCLAS Processing	Optional
8	Multi-band	Optional
9	U-PID	Optional
10	Multiple MAC Sublayers	Optional
11	Higher Layer Stream ID	Optional

The values of the Dialog Token, DMG TSPEC, TSPEC, TCLAS, and subsequent fields of this frame are the same as the values of the corresponding parameters in the invocation of the MLME-ADDTS.request primitive that causes the frame to be sent.

The DMG TSPEC element contains the parameters that define an allocation. The allocation uniquely identified by the Source AID, Allocation ID, and Destination AID subfields within the DMG TSPEC element.

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The optional TSPEC element defines a TS that can use the allocation if the allocation is created successfully.

The optional TCLAS element is used to identify the destination non-AP and non-PCP DMG STA of the ADDTS Request frame. If a TSPEC element is not present, then the TCLAS element is not present. There can be one or more TCLAS elements in the DMG ADDTS Request frame. The TCLAS Processing element is present if there is more than one TCLAS element.

When present in a DMG ADDTS Request frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the TS identified by the optional TSPEC element applies.

When present in the DMG ADDTS Request frame, the U-PID element indicates the upper layer protocol associated with the TS identified by the optional TSPEC element contained in this frame. If a TSPEC element is not present in the frame, the U-PID element is not present in the frame.

When present in the DMG ADDTS Request frame, the Multiple MAC Sublayers element is used to establish an MMSL cluster.

9.6.3.3 Basic and DMG ADDTS Response frame format

9.6.3.3.1 Basic ADDTS Response frame variant

The ADDTS Response frame is transmitted in response to an ADDTS Request frame. The Action field of the ADDTS Response frame contains the information shown in Table 9-352.

Table 9-352—Basic ADDTS Response frame variant Action field format

Order	Information	Notes
1	Category	
2	QoS Action	
3	Dialog Token	
4	Status Code	
5	TS Delay	
6	TSPEC	
7	TCLAS	Optional
8	TCLAS Processing	Optional
9	Schedule	Optionally present if the status code is equal to SUCCESS; otherwise not present
10	Expedited Bandwidth Request	Optional
11	Higher Layer Stream ID	Only in AP-initiated TS setup
12	Multi-band	Optional
13	U-PID	Optional
14	Multiple MAC Sublayers	Optional

The Category field is defined in 9.4.1.11.

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The QoS Action field is defined in 9.6.3.1.

The Status Code field is defined in 9.4.1.9.

The values the Dialog Token, TS Delay, TSPEC, TCLAS, and subsequent fields in this frame are the same as the values of the corresponding parameters in the invocation of the MLME-ADDTS.response primitive that causes the frame to be sent. The TS Delay element is present in an ADDTS Response frame only if the status code is equal to REJECTED_FOR_DELAY_PERIOD.

The Schedule element, defined in 9.4.2.33, is present in an ADDTS Response frame only if the status code is equal to SUCCESS(i.e., when the TS is admitted).

The Higher Layer Stream ID element is present only in AP-initiated TS setup. The Higher Layer Stream ID element (9.4.2.124) contains the stream identifier provided by a higher layer protocol.

When present in an ADDTS Response frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the ADDTS Response frame applies and contains band-specific information.

When present in the ADDTS Response frame, the U-PID element indicates the upper layer protocol associated with the TID/TSID specified within the TSPEC contained in this frame.

When present in the ADDTS Response frame, the Multiple MAC Sublayers element is used to establish an MMSL cluster (see 11.32).

9.6.3.3.2 DMG ADDTS Response frame variant

The DMG ADDTS Response frame is used by DMG STAs in a PBSS and in an infrastructure BSS. The Action field of the DMG ADDTS Response frame contains the information shown in Table 9-353.

Table 9-353—DMG ADDTS Response frame variant Action field format

Order	Information	Notes
1	Category	
2	Action	
3	Dialog Token	
4	Status code	
5	TS Delay	
6	DMG TSPEC	
7	TSPEC	Optional
8	TCLAS	Optional
9	TCLAS Processing	Optional
10	Multi-band	Optional
11	U-PID	Optional
12	Multiple MAC Sublayers	Optional
13	Higher Layer Stream ID	Optional

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The values of the Dialog Token, TS Delay, DMG TSPEC, TSPEC, TCLAS, and subsequent fields in this frame are the same as the values of the corresponding parameters in the invocation of the MLME-ADDTS.response primitive that causes the frame to be sent. The TS Delay element is present in a DMG ADDTS Response frame only if the status code is set to REJECTED_FOR_DELAY_PERIOD (9.4.1.9).

When present in a DMG ADDTS Response frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the TS identified by the optional TSPEC element applies.

When present in the DMG ADDTS Response frame, the U-PID element indicates the upper layer protocol associated with the TS identified by the optional TSPEC contained in this frame. If a TSPEC element is not present in the frame, the U-PID element is not present in the frame.

When present in the DMG ADDTS Response frame, the Multiple MAC Sublayers element is used to establish an MMSL cluster (see 11.32).

9.6.3.4 DELTS frame format

The DELTS frame is used to delete a TS or an allocation using the procedures defined in 11.4.9.

The Action field of a DELTS frame contains the information shown in Table 9-354.

Table 9-354—DELTS frame Action field format

Order	Information
1	Category
2	QoS Action
3	TS Info
4	Reason Code
5	DMG Allocation Info (optional)
6	Multi-band (optional)

The Category field is defined in 9.4.1.11.

The QoS Action field is defined in 9.6.3.1.

The TS Info field is defined in 9.4.2.29. Either the field identifies an existing TS created using the TSPEC element, or all its subfields are set to 0. The DMG Allocation Info field, defined in 9.4.2.133, is present when an existing DMG allocation is being deleted. When a DMG allocation is being deleted, the DMG Allocation Info field identifies an existing allocation created using the DMG TSPEC element. When a DMG allocation is not being deleted, all subfields in the DMG Allocation Info field are set to 0.

The Reason Code field is defined in 9.4.1.7.

A DELTS frame is used to delete a TS characterized by the TS Info field or to delete a DMG allocation identified by the DMG Allocation Info field in the frame. A DELTS frame can be sent from the HC or PCP to the source STA of that TS, or vice versa, to indicate an imperative request, to which no response is required from the recipient STA.

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When present in an DELTS frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the DELTS frame applies.

9.6.3.5 Schedule frame format

The Schedule frame is transmitted by the HC to announce the schedule of delivery of data and polls. The Action field of the Schedule frame contains the information shown in Table 9-355.

Table 9-355—Schedule frame Action field format

Order	Information
1	Category
2	QoS Action
3	Schedule

The Category field is defined in 9.4.1.11.

The QoS Action field is defined in 9.6.3.1.

The Schedule element is defined in 9.4.2.33.

9.6.3.6 QoS Map Configure frame format

The QoS Map Configure frame is used by an AP to provide the QoS Map information to a non-AP STA using the procedures defined in 11.22.9.

The Action field of the QoS Map Configure frame contains the information shown in Table 9-356.

Table 9-356—QoS Map Configure frame Action field format

Order	Information
0	Category
1	QoS Action
2	QoS Map
3	Intra-Access Category Priority elements (optional)

The Category field is defined in 9.4.1.11.

The QoS Action field is defined in 9.6.3.1.

The QoS Map element is defined in 9.4.2.94.

Zero or more Intra-Access Category Priority elements are present, which are defined in 9.4.2.120.

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9.6.3.7 ADDTS Reserve Request frame format

The ADDTS Reserve Request frame is transmitted by an AP to a non-AP STA in response to a higher layer protocol. See 11.4.4.3.

The Action field of the ADDTS Reserve Request frame contains the information shown in Table 9-357.

Table 9-357—ADDTS Reserve Request frame Action field format

Order	Information
1	Category
2	QoS Action
3	TSPEC
4	Schedule
5	Higher Layer Stream ID

The Category field is defined in 9.4.1.11.

The QoS Action field is defined in 9.6.3.1.

The TSPEC element contains the QoS parameters that define the TS. The QoS parameters in the TSPEC are equivalent to the QoS parameters of the higher level stream identified by the Higher Level Stream ID. The TS is identified by the TSID and Direction fields within the TSPEC element.

The Schedule element is defined in 9.4.2.33 and set to reflect schedule information corresponding to the TSPEC specification.

The Higher Layer Stream ID element (defined in 9.4.2.124) provides the stream identifier from a higher layer protocol.

9.6.3.8 ADDTS Reserve Response frame format

An ADDTS Reserve Response frame is used by a non-AP STA to indicate the completion of an AP-initiated TS setup procedure (11.4.4.3). The Action field of the ADDTS Reserve Response frame contains the information shown in Table 9-358.

Table 9-358—ADDTS Reserve Response frame Action field format

Order	Information
1	Category
2	QoS Action
3	Higher Layer Stream ID
4	Status Code

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The Category field is defined in 9.4.1.11.

The QoS Action field is defined in 9.6.3.1.

The Higher Layer Stream ID field contains a Higher Layer Stream ID element (see 9.4.2.124).

The Status Code field is defined in 9.4.1.9.

9.6.4 Block Ack Action frame details

9.6.4.1 General

ADDBA Request and ADDBA Response frames are used to set up or, if a STA is PBAC, to modify Block Ack operation for a specific TC, TS, or GCR group address. A Block Ack Action field, in the octet immediately after the Category field, differentiates the Block Ack Action frame formats. The Block Ack Action frames are used to negotiate several parameters of a block ack agreement and the type of BlockAck frames that are used: BlockAck, NDP BlockAck and Block Acknowledgment TWT frames (see 10.25.2). The Block Ack Action field values associated with each frame format within the Block Ack category are defined in Table 9-359.

Table 9-359—Block Ack Action field values

Block Ack Action field values	Meaning
0	ADDBA Request
1	ADDBA Response
2	DELBA
3–127	Reserved
128	NDP ADDBA Request
129	NDP ADDBA Response
130	NDP DELBA
131	Reserved
132	BAT ADDBA Request
133	BAT ADDBA Response
134	BAT DELBA
135–255	Reserved

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9.6.4.2 ADDBA Request frame format

An ADDBA Request frame is sent by an originator of block ack to another STA. The Action field of an ADDBA Request frame contains the information shown in Table 9-360.

Table 9-360—ADDBA Request frame Action field format

Order	Information
1	Category
2	Block Ack Action
3	Dialog Token
4	Block Ack Parameter Set
5	Block Ack Timeout Value
6	Block Ack Starting Sequence Control
7	GCR Group Address element (optional)
8	Multi-band (optional)
9	TCLAS (optional)
10	ADDBA Extension (optional)

The Category field is defined in 9.4.1.11.

The Block Ack Action field is set to 0, 128, or 132 (representing ADDBA request). The meaning for each value is described in 9.6.4.1.

The Dialog Token field is set to a nonzero value chosen by the STA.

The Block Ack Parameter Set field is defined in 9.4.1.13.

The Block Ack Timeout Value field is defined in 9.4.1.14.

The Starting Sequence Number subfield of the Block Ack Starting Sequence Control field (see Figure 9-37) contains the sequence number of the first or next (in the case of a renegotiation of a block ack agreement) MSDU to be sent under this block ack agreement. The Fragment Number subfield is set to 0.

If the GCR Group Address element is present, the TID field within the Block Ack Parameter Set field is reserved.

The GCR Group Address element contains the group address for which a block ack agreement is requested.

When present in an ADDBA Request frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the ADDBA Request frame applies and contains band-specific information.

The ADDBA Extension element is defined in 9.4.2.139.

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9.6.4.3 ADDBA Response frame format

The ADDBA Response frame is sent in response to an ADDBA Request frame. The Action field of an ADDBA Response frame contains the information shown in Table 9-361.

Table 9-361—ADDBA Response frame Action field format

Order	Information
1	Category
2	Block Ack Action
3	Dialog Token
4	Status Code
5	Block Ack Parameter Set
6	Block Ack Timeout Value
7	GCR Group Address element (optional)
8	Multi-band (optional)
9	TCLAS (optional)
10	ADDBA Extension (optional)
11	Originator Preferred MCS (optional)

The Category field is defined in 9.4.1.11.

The Block Ack Action field is set to 1, 129, or 133 (representing ADDBA response). The meaning for each value is described in 9.6.4.1.

The Dialog Token field value is copied from the corresponding received ADDBA Request frame.

The Status Code field is defined in 9.4.1.9.

The Block Ack Parameter Set field is defined in 9.4.1.13.

The Block Ack Timeout Value field is defined in 9.4.1.14.

If the GCR Group Address element is present, the TID field within the Block Ack Parameter Set field is reserved.

The GCR Group Address element contains the group address for which a block ack agreement is requested.

When present in an ADDBA Response frame, the Multi-band element indicates the frequency band ID, operating class, and channel number to which the ADDBA Response frame applies and contains band-specific information.

The ADDBA Extension element is defined in 9.4.2.139.

The Originator Preferred MCS field is present if dot11S1GOptionImplemented is true, and the Block Ack Action field is 1, and it is defined in 9.4.1.15. Otherwise, it is not present.

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9.6.4.4 DELBA frame format

The DELBA frame is sent by either the originator of the traffic or the recipient to terminate the block ack participation. The Action field of a DELBA frame contains the information shown in Table 9-362.

Table 9-362—DELBA frame Action field format

Order	Information
1	Category
2	Block Ack Action
3	DELBA Parameter Set
4	Reason Code
5	DELBA GCR Group Address
6	Multi-band (optional)
7	TCLAS (optional)

The Category field is defined in 9.4.1.11.

The Block Ack Action field is set to 2, 130, or 134 (representing DELBA). The meaning for each value is described in 9.6.4.1.

The DELBA Parameter Set field is defined in 9.4.1.16.

The Reason Code field is defined in 9.4.1.7.

The DELBA GCR Group Address field is defined in 9.4.2.125 and contains the GCR group address whose block ack agreement is being terminated.

When present in an DELBA frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the DELBA frame applies.

9.6.5 Vendor-specific action details

The Vendor Specific frame is defined for vendor-specific signaling. The format of the Action field of the Vendor Specific frame is shown in Figure 9-859.

NOTE—If management frame protection is negotiated, then Vendor Specific Protected Action frames (see Table 9-51) are protected; otherwise they are unprotected.

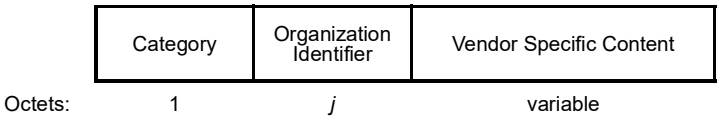

Figure 9-859—Vendor Specific frame Action field format

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The Category field is defined in 9.4.1.11.

The Organization Identifier field contains a organization identifier assigned by the IEEE and is specified in 9.4.1.31. The order of the Organization Identifier field is described in 9.2.2.

The Vendor Specific Content field contains vendor-specific field(s). The length of the vendor specific content in a Vendor Specific frame is limited by the maximum allowed MMPDU size.

9.6.6 Radio Measurement action details

9.6.6.1 General

Several Action frame formats are defined for radio measurement purposes. A Radio Measurement Action field, in the field immediately after the Category field, differentiates the formats. The Radio Measurement Action field values associated with each frame format are defined in Table 9-363.

Table 9-363—Radio Measurement Action field values

Radio Measurement Action field value	Description
0	Radio Measurement Request
1	Radio Measurement Report
2	Link Measurement Request
3	Link Measurement Report
4	Neighbor Report Request
5	Neighbor Report Response
6–255	Reserved

9.6.6.2 Radio Measurement Request frame format

The Radio Measurement Request frame is transmitted to another STA to request that it makes one or more measurements on one or more channels. The format of the Action field in the Radio Measurement Request frame is shown in Figure 9-860.

	Category	Radio Measurement Action	Dialog Token	Number of Repetitions	Measurement Request Elements
Octets:	1	1	1	2	variable

Figure 9-860—Radio Measurement Request frame Action field format

The Category field is defined in 9.4.1.11.

The Radio Measurement Action field is defined in 9.6.6.1.

The Dialog Token field is set to a nonzero value chosen by the STA sending the radio measurement request to identify the request/report transaction.

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The Number of Repetitions field contains the requested number of repetitions for all of the Measurement Request elements in this frame. Setting the Number of Repetitions field to 0 indicates Measurement Request elements are executed once without repetition. Setting the Number of Repetitions field to 65 535 indicates Measurement Request elements are repeated until the measurement is canceled or superseded.

The Measurement Request Elements field contains zero or more of the Measurement Request elements described in 9.4.2.20. The number and length of the Measurement Request elements in a Measurement Request frame are limited by the maximum allowed MMPDU size.

9.6.6.3 Radio Measurement Report frame format

The Radio Measurement Report frame is transmitted in response to a Radio Measurement Request frame or by a STA providing a triggered autonomous measurement report. The format of the Action field in the Radio Measurement Report frame is shown in Figure 9-861.

	Category	Radio Measurement Action	Dialog Token	Measurement Report Elements
Octets:	1	1	1	variable

Figure 9-861—Radio Measurement Report frame Action field format

The Category field is defined in 9.4.1.11.

The Radio Measurement Action field is defined in 9.6.6.1.

The Dialog Token field is set to the value in the corresponding Radio Measurement Request frame. If the Radio Measurement Report frame is not being transmitted in response to a Radio Measurement Request frame then the dialog token is set to 0.

The Measurement Report Elements field contains one or more Measurement Report elements described in 9.4.2.21. The number and length of the Measurement Report elements in a single Radio Measurement Report frame are limited by the maximum allowed MMPDU size. Subclause 11.10.6 describes the required behavior for multiframe Radio Measurement Report frame responses.

9.6.6.4 Link Measurement Request frame format

The Link Measurement Request frame is transmitted by a STA to request another STA to respond with a Link Measurement Report frame to enable measurement of link path loss and estimation of link margin. In a non-DMG BSS, a Link Measurement Request frame is an Action frame and in a DMG BSS, a Link Measurement Request frame is an Action or an Action No Ack frame. The format of the Action field in the Link Measurement Request frame is shown in Figure 9-862.

	Category	Radio Measurement Action	Dialog Token	Transmit Power Used	Max Transmit Power
Octets:	1	1	1	1	1

Figure 9-862—Link Measurement Request frame Action field format

The Category field is defined in 9.4.1.11.

The Radio Measurement Action field is defined in 9.6.6.1.

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The Dialog Token field is set to a nonzero value chosen by the STA sending the request to identify the transaction.

The Transmit Power Used field is set to the transmit power used to transmit the frame containing the Link Measurement Request, as described in 9.4.1.20.

The Max Transmit Power field provides the upper limit on the transmit power as measured at the antenna connector to be used by the transmitting STA on its operating channel. This field is described in 9.4.1.19. The Max Transmit Power field is a 2s complement signed integer, providing an upper limit, in a dBm scale, on the transmit power as measured at the antenna connector to be used by the transmitting STA on its operating channel. The Max Transmit Power field is set to the minimum of the maximum powers at which the STA is permitted to transmit in the operating channel by device capability, policy, and regulatory authority.

9.6.6.5 Link Measurement Report frame format

The Link Measurement Report frame is transmitted in response to a Link Measurement Request frame. In a non-DMG BSS, a Link Measurement Report frame is an Action frame and in a DMG BSS, a Link Measurement Report frame is an Action or an Action No Ack frame. The format of the Action field in the Link Measurement Report frame is shown in Figure 9-863.

	Category	Radio Measurement Action	Dialog Token	TPC Report element	Receive Antenna ID	Transmit Antenna ID	RCPI	RSNI	DMG Link Margin	DMG Link Adaptation Acknowledgment
Octets:	1	1	1	4	1	1	1	1	variable	variable

Figure 9-863—Link Measurement Report frame Action field format

The Category field is defined in 9.4.1.11.

The Radio Measurement Action field is defined in 9.6.6.1.

The Dialog Token field is set to the value of the Dialog Token field in the corresponding Link Measurement Request frame.

The TPC Report element is set as described in 9.4.2.16.

The Receive Antenna ID field contains the identifying number for the antenna(s) or DMG antenna used to receive the corresponding Link Measurement Request frame. The antenna ID or DMG antenna ID is defined in 9.4.2.39.

The Transmit Antenna ID field contains the identifying number for the antenna(s) or DMG antenna used to transmit this Link Measurement Report frame. The antenna ID or DMG antenna ID is defined in 9.4.2.39.

The RCPI field indicates the received channel power of the corresponding Link Measurement Request frame, which is a logarithmic function of the received signal power, as defined in 9.4.2.37.

The RSNI field indicates the received signal-to-noise indication for the corresponding Link Measurement Request frame, as described in 9.4.2.40.

The DMG Link Margin field is optionally present. When present, it contains a DMG Link Margin element (see 9.4.2.142).

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The DMG Link Margin Adaptation Acknowledgment field is optionally present. When present, it contains a DMG Link Margin Adaptation Acknowledgment element (see 9.4.2.143).

9.6.6.6 Neighbor Report Request frame format

The Neighbor Report Request frame is transmitted requesting information in the neighbor report about neighboring APs. The format of the Action field in the Neighbor Report Request frame is shown in Figure 9-864.

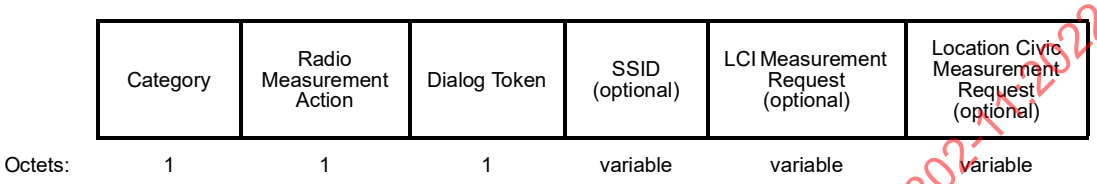

Figure 9-864—Neighbor Report Request frame Action field format

The Category field is defined in 9.4.1.11.

The Radio Measurement Action field is defined in 9.6.6.1.

The Dialog Token field is set to a nonzero value chosen by the STA sending the measurement request to identify the request/report transaction.

The SSID field is optionally present. If present, it contains an SSID element. The presence of an SSID element in a Neighbor Report Request frame indicates a request for a list of neighbor reports for the specified SSID in the SSID element. The absence of an SSID element indicates the request is for the ESS of which the transmitting STA is a member.

The LCI Measurement Request field is optionally present. If present, it contains a Measurement Request element with Measurement Type field equal to LCI (see Table 9-98), which indicates a request for a Measurement Report subelement with Measurement Type field equal to LCI for each Neighbor Report element (see 11.10.10.2). The Enable bit in the Measurement Request Mode field in the Measurement Request element is set to 0. The Location Subject field in the Measurement Request field of the Measurement Request element is set to Location Subject Remote (see Table 9-110). The Request, Report and Duration Mandatory bits within the Measurement Request Mode field in the Measurement Request element are reserved (see 9.4.2.20.1).

The Location Civic Measurement Request field is optionally present. If present, it contains a Measurement Request element with Measurement Type field equal to Location Civic (see Table 9-98). The element indicates a request for a Measurement Report subelement with Measurement Type field equal to Location Civic for each Neighbor Report element (see 11.10.10.2). The Enable bit in the Measurement Request Mode field within the Measurement Request element is set to 0. The Location Subject field in the Measurement Request field of the Measurement Request element is equal to Location Subject Remote (see Table 9-110). The Location Service Interval Units field in the Measurement Request field of the Measurement Request element is set to 0. The Request, Report and Duration Mandatory bits in the Measurement Request Mode field in the Measurement Request element are reserved (see 9.4.2.20.1).

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9.6.6.7 Neighbor Report Response frame format

The Neighbor Report Response frame is transmitted in response to a Neighbor Report Request frame. The format of the Action field in the Neighbor Report Response frame is shown in Figure 9-865.

	Category	Radio Measurement Action	Dialog Token	Neighbor Report Elements
Octets:	1	1	1	variable

Figure 9-865—Neighbor Report Response frame Action field format

The Category field is defined in 9.4.1.11.

The Radio Measurement Action field is defined in 9.6.6.1.

The Dialog Token field set to the value in the corresponding Neighbor Report Request frame. If the Neighbor Report Response frame is not being transmitted in response to a Neighbor Report Request frame, then the dialog token is set to 0.

The Neighbor Report Elements field contains the Neighbor Report elements for validated APs described in 9.4.2.36. If the STA has no information in response to the Neighbor Report Request, the Neighbor Report elements are omitted. The number and length of the Neighbor Report elements in a Neighbor Report Response frame is limited by the maximum allowed MMPDU size.

NOTE—Under some circumstances, a Neighbor Report element is included for the STA transmitting the frame. See 11.10.10.3.

9.6.7 Public Action details

9.6.7.1 Public Action frames

The Public Action frame is defined to allow the following:

— Inter-BSS and AP to unassociated-STA communications
— Intra-BSS communication
— GAS

A Public Action field in the octet immediately after the Category field, differentiates the Public Action frame formats. The defined Public Action frames are listed in Table 9-364.

Table 9-364—Public Action field values

Public Action field value	Description
0	20/40 BSS Coexistence Management
1	DSE Enablement
2	DSE Deenablement
3	DSE Registered Location Announcement
4	Extended Channel Switch Announcement

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Table 9-364—Public Action field values *(continued)*

Public Action field value	Description
5	DSE Measurement Request
6	DSE Measurement Report
7	Measurement Pilot
8	DSE Power Constraint
9	Vendor Specific
10	GAS Initial Request
11	GAS Initial Response
12	GAS Comeback Request
13	GAS Comeback Response
14	TDLS Discovery Response
15	Location Track Notification
16	QAB Request frame
17	QAB Response frame
18	QMF Policy
19	QMF Policy Change
20	QLoad Request
21	QLoad Report
22	HCCA TXOP Advertisement
23	HCCA TXOP Response
24	Public Key
25	Channel Availability Query
26	Channel Schedule Management
27	Contact Verification Signal
28	GDD Enablement Request
29	GDD Enablement Response
30	Network Channel Control
31	White Space Map Announcement
32	Fine Timing Measurement Request
33	Fine Timing Measurement
34	FILS Discovery
35	DCS Measurement Request
36	DCS Measurement Report
37	DCS Request

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Table 9-364—Public Action field values *(continued)*

Public Action field value	Description
38	DCS Response
39	Extended Notification Period Request
40	Extended Notification Period Response
41	Extended Channel Splitting Request
42	Extended Channel Splitting Response
43	Group Addressed GAS Request
44	Group Addressed GAS Response
45	On-channel Tunnel Request
46–255	Reserved

9.6.7.2 20/40 BSS Coexistence Management frame format

The format of the 20/40 BSS Coexistence Management frame Action field is defined in Table 9-365.

Table 9-365—20/40 BSS Coexistence Management frame Action field format

Order	Information	Notes
1	Category	
2	Public Action	
3	20/40 BSS Coexistence (see 9.4.2.59)	
4	20/40 BSS Intolerant Channel Report (see 9.4.2.57)	Appears zero or more times

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

9.6.7.3 Measurement Pilot frame format

The format of the Action field of the Measurement Pilot frame is shown in Figure 9-866.

	Category	Public Action	Condensed Capability Information	Condensed Country String	Operating Class	Channel	Measurement Pilot Interval	Optional Subelements
Octets:	1	1	1	2	1	1	1	variable

Figure 9-866—Measurement Pilot frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

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The Condensed Capability Information field contains two subfields as shown in Figure 9-867.

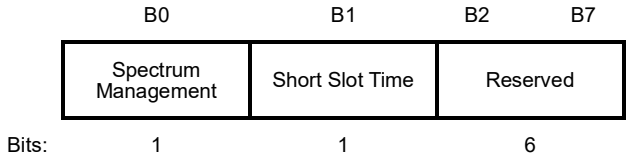

Figure 9-867—Condensed Capability Information field

The Spectrum Management subfield is set to 1 if dot11SpectrumManagementRequired is true; otherwise, it is set to 0.

The Short Slot Time subfield is set to 1 if dot11ShortSlotTimeOptionImplemented and dot11ShortSlotTimeOptionActivated are true. Otherwise, the Short Slot Time subfield is set to 0.

The Condensed Country String field is set to the first two octets of the value contained in dot11CountryString.

If the Wide Bandwidth Channel Switch subelement is not included, the Operating Class field indicates the operating class value for the operating channel. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing for the operating channel. Valid operating classes are listed in Annex E, excluding Operating Classes that encompass a primary channel but do not identify the location of the primary channel. The Channel Number field indicates the operating channel. Channel number is defined within an operating class as shown in Annex E.

If the Wide Bandwidth Channel Switch subelement is included, the fields in the Wide Bandwidth Channel Switch subelement indicate the operating channel, and the Operating Class and Channel Number together specify the primary channel and primary 40 MHz channel within the channel identified by the Wide Bandwidth Channel Switch subelement.

The Measurement Pilot Interval field is set to the value contained in dot11RMMeasurementPilotPeriod.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-366.

Table 9-366—Optional subelement IDs for Measurement Pilot frame

Subelement ID	Name	Extensible
0–70	Reserved	
71	Multiple BSSID	Subelements
72–162	Reserved	
163	Wide Bandwidth Channel Switch	Yes
164–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

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The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.160) with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

The Multiple BSSID and Vendor Specific subelements have the same format as the Multiple BSSID and Vendor Specific elements (see 9.4.2.45 and 9.4.2.25, respectively). Zero or more Vendor Specific subelements are included in the list of optional subelements.

9.6.7.4 DSE Enablement frame format

The DSE Enablement frame is transmitted as part of enablement. The format of the DSE Enablement frame Action field is shown in Figure 9-868.

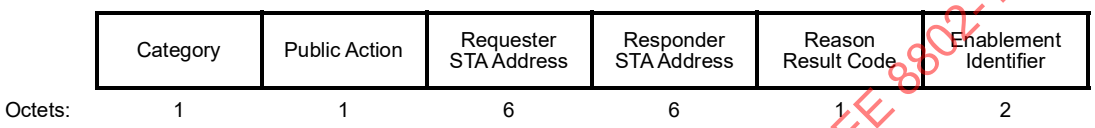

Figure 9-868—DSE Enablement frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The RequesterSTAAddress field is the MAC address of the requesting STA that initiates the enablement process. The length of the RequesterSTAAddress field is 6 octets.

The ResponderSTAAddress field is the MAC address of the enablement responder. The length of the ResponderSTAAddress field is 6 octets.

The Reason Result Code field is used to indicate the reason that a DSE Enablement frame was generated. The length of the Reason Result Code field is 1 octet. The reason result codes that have been allocated are shown in Table 9-367.

Table 9-367—Reason Result Code field values

Reason Result Code field value	Name	Description
0		Reserved
1		Reserved
2		Enablement requested
3	SUCCESS	Success
4	REFUSED	Request declined
5	INVALID_PARAMETERS	Request not successful as one or more parameters have invalid values
6	TOO_MANY_ SIMULTANEOUS_REQUESTS	Enablement denied because the enabling STA is unable to handle additional dependent STAs
7–255		Reserved

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The Enablement Identifier field is a 16-bit number assigned by an enabling STA to a dependent STA; otherwise, it is 0, set using the procedures defined in 11.11.

9.6.7.5 DSE Deenablement frame format

The DSE Deenablement frame is transmitted as part of deenablement. The format of the DSE Deenablement frame Action field is shown in Figure 9-869.

	Category	Public Action	Requester STA Address	Responder STA Address	Reason Result Code
Octets:	1	1	6	6	1

Figure 9-869—DSE Deenablement frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The RequesterSTAAddress field is the MAC address of the requesting STA that initiates the deenablement process. The length of the RequesterSTAAddress field is 6 octets.

The ResponderSTAAddress field is the MAC address of the responding STA that becomes deenabled. The length of the ResponderSTAAddress field is 6 octets.

The Reason Result Code field is used to indicate the reason that a DSE Deenablement frame was generated. The length of the Reason Result Code field is 1 octet. The reason result codes that have been allocated are shown in Table 9-368.

Table 9-368—Reason Result Code field values

Reason Result Code field value	Description
0	Reserved
1	Reserved
2	Deenablement requested
3–255	Reserved

9.6.7.6 DSE Registered Location Announcement frame format

The DSE Registered Location Announcement frame is transmitted by a dependent STA to advertise the registered location of its enabling STA. The format of the DSE Registered Location Announcement frame Action field is shown in Figure 9-870.

	Category	Public Action	DSE Registered Location Information
Octets:	1	1	20

Figure 9-870—DSE Registered Location Announcement frame Action field format

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The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The DSE Registered Location Information field is defined in 9.4.2.51.

9.6.7.7 Extended Channel Switch Announcement frame format

The Extended Channel Switch Announcement frame is transmitted by an AP, IBSS STA, or mesh STA to advertise a channel switch. The format of the Extended Channel Switch Announcement frame Action field is shown in Figure 9-871.

								Zero or one	Zero or one	Zero or more
	Category	Public Action	Channel Switch Mode	New Operating Class	New Channel Number	Channel Switch Count	Mesh Channel Switch Parameters element	New Country element	Wide Bandwidth Channel Switch element	New Transmit Power Envelope element
Octets:	1	1	1	1	1	1	0 or 8	variable	variable	variable

Figure 9-871—Extended Channel Switch Announcement frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Channel Switch Mode, New Operating Class, New Channel Number, and Channel Switch Count fields are as described in the Extended Channel Switch Announcement element (see 9.4.2.52).

The Mesh Channel Switch Parameters element is defined in 9.4.2.102. This element is present when a mesh STA performs MBSS channel switching. The Mesh Channel Switch Parameters element is not included for channel switching other than for an MBSS channel switch.

The New Country element is present when an AP or mesh STA performs extended channel switching to a new Country, new Operating Class Table, or a changed set of operating classes relative to the contents of the Country element sent in the Beacon; otherwise, this element is not present. The format of the New Country element is defined to be the same as the format of the Country element (see 9.4.2.8), except that no Subband Triplet fields are present in the New Country element. The Country String field in the New Country element indicates the Country and Operating Class Table of the BSS after extended channel switching and Operating Triplet fields within the New Country element indicate the operating classes of the BSS after extended channel switching (see 11.38.1).

This Wide Bandwidth Channel Switch element is present when extended channel switching to a channel width wider than 40 MHz, or when extended channel switching is to a channel width wider than 1 MHz and the frame carrying the element is an S1G PPDU; otherwise, this element is not present. The Wide Bandwidth Channel Switch element is defined in 9.4.2.160. The Wide Bandwidth Channel Switch element indicates the BSS bandwidth after extended channel switching (see 11.38.1 and 10.46.1).

Each New Transmit Power Envelope element that is present is defined to have the same format as the Transmit Power Envelope element (see 9.4.2.161) and includes a distinct value of the Local Maximum Transmit Power Unit Interpretation subfield. If present, the New Transmit Power Envelope element indicates the maximum transmit powers for the BSS for the indicated bandwidths with an indicated unit interpretation after extended channel switching (see 11.38.1).

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9.6.7.8 DSE Measurement Request frame format

The DSE Measurement Request frame requests a DSE measurement report. It is transmitted using the procedures defined in 11.11. The format of the DSE Measurement Request frame Action field is shown in Figure 9-872.

	Category	Public Action	Requester STA Address	Responder STA Address	Operating Class	Channel Number	Measurement Start Time	Measurement Duration
Octets:	1	1	6	6	1	1	8	2

Figure 9-872—DSE Measurement Request frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The RequesterSTAAddress field is the MAC address of the STA that requests the DSE measurement report. The length of the RequesterSTAAddress field is 6 octets.

The ResponderSTAAddress field is the MAC address of the responding STA that operates based on the enablement. The length of the ResponderSTAAddress field is 6 octets.

The Operating Class field indicates the channel set for which the measurement request applies. The Operating Class and Channel Number fields together specify the channel frequency and channel bandwidth for which the measurement request applies. Valid values for the Operating Class field are shown in Annex E.

The Measurement Start Time field is set to the timing synchronization function (TSF) at the time (± 1 TU) at which the requested DSE request measurement starts. Setting the field to 0 indicates it starts immediately.

The Measurement Duration field is set to the duration of the requested measurement, expressed in number of time units (TUs).

9.6.7.9 DSE Measurement Report frame format

The DSE Measurement Report frame is transmitted using the procedures defined in 11.11. The format of the DSE Measurement Report frame Action field is shown in Figure 9-873.

	Category	Public Action	Requester STA Address	Responder STA Address	Length	Operating Class	Channel Number	Measurement Report Mode	Actual Measurement Start Time	Measurement Duration	Reported DSE LCI fields
Octets:	1	1	6	6	2	1	1	1	8	2	n × 26

Figure 9-873—DSE Measurement Report frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The RequesterSTAAddress field is the MAC address of the STA that requested the DSE measurement report. The length of the RequesterSTAAddress field is 6 octets.

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The ResponderSTAAddress field is the MAC address of the responding STA that operates based on the enablement. The length of the ResponderSTAAddress field is 6 octets.

The Length field indicates the length of the remaining frame fields in octets, and the value is variable. The minimum value of the Length field is 13.

The Operating Class field indicates the channel set for which the measurement report applies. The Operating Class and Channel Number fields together specify the channel frequency and spacing for which the measurement request applies. Valid values for the Operating Class field are shown in Annex E.

The Measurement Report Mode field is defined in 9.4.2.21 (see Figure 9-223).

The Actual Measurement Start Time field is set to the value of the measuring STA's TSF timer at the time (± 1 TU) at which the DSE measurement started.

The Measurement Duration field is set to the duration over which the requested measurement was measured, expressed in number of TUs.

The reported DSE LCI fields contain the DSE LCI received at the measuring STA. If the reported DSE LCI fields would cause the frame to exceed the maximum MAC management protocol data unit (MMPDU) size, then the reported DSE LCI fields are truncated so that the last reported DSE LCI field is complete. The DSE LCI field format is shown in Figure 9-874.

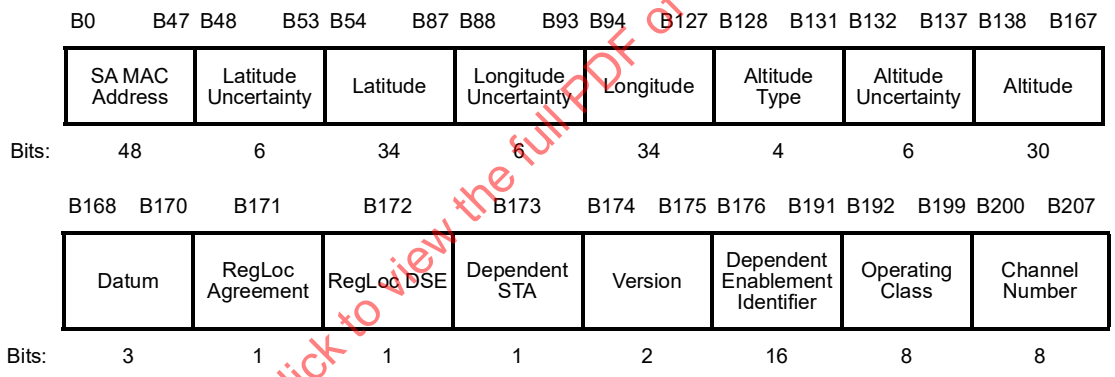

Figure 9-874—DSE LCI field format

The SA MAC Address field contains the SA MAC address from the Beacon or Public Action frame containing a DSE Registered Location element being reported.

The remaining fields are as defined in the DSE Registered Location Information field (see 9.4.2.51).

9.6.7.10 DSE Power Constraint frame format

The DSE Power Constraint frame requests that a dependent STA constrain transmit power below the regulatory limit. It is transmitted by an enabling STA as part of enablement. The format of the DSE Power Constraint frame Action field is shown in Figure 9-875.

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	Category	Public Action	Requester STA Address	Responder STA Address	Reason Result Code	Local Power Constraint
Octets:	1	1	6	6	1	1

Figure 9-875—DSE Power Constraint frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The RequesterSTAAddress field is the MAC address of the STA that requests the DSE power constraint. The length of the RequesterSTAAddress field is 6 octets.

The ResponderSTAAddress field is the MAC address of the responding STA that initiates the enablement. The length of the ResponderSTAAddress field is 6 octets.

The Reason Result Code field is used to indicate the reason that a DSE Power Constraint frame was generated. The length of the Reason Result Code field is 1 octet. The reason result codes that have been allocated are shown in Table 9-369.

Table 9-369—Reason Result Code field values

Reason Result Code field value	Name	Description
0		Reserved
1		Reserved
2		Power constraint requested
3	SUCCESS	Success
4	REFUSED	Refused — no reason specified
5	INVALID_PARAMETERS	Request not successful as one or more parameters have invalid values
6–255		Reserved

The Local Power Constraint field is coded as an unsigned integer in units of decibels relative to 1 mW. The local maximum transmit power for a channel is thus defined as the maximum transmit power level specified for the channel in the Country element minus the local power constraint specified for the channel in the DSE Power Constraint frame.

9.6.7.11 Vendor Specific Public Action frame format

The Vendor Specific Public Action frame is defined for vendor-specific signaling between unassociated STAs. The format of the Action field of the Vendor Specific Public Action frame is shown in Figure 9-876.

	Category	Public Action	Organization Identifier	Vendor Specific Content
Octets:	1	1	variable	variable

Figure 9-876—Vendor Specific Public Action frame Action field format

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The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Organization Identifier field contains a organization identifier assigned by the IEEE and is specified in 9.4.1.31. The order of the Organization Identifier field is described in 9.2.2. The length of the Organization Identifier field is variable, as specified in 9.4.1.31.

The Vendor Specific Content field contains vendor-specific field(s). The length of the vendor specific content in a Vendor Specific frame is limited by the maximum allowed MMPDU size.

9.6.7.12 GAS Initial Request frame format

The GAS Initial Request frame is transmitted by a requesting STA to request information from another STA. The format of the GAS Initial Request frame Action field is shown in Table 9-370.

Table 9-370—GAS Initial Request frame Action field format

Order	Information
0	Category
1	Public Action
2	Dialog Token
3	Advertisement Protocol element
4	Query Request Length
5	Query Request
6	Multi-band (optional)
7	CAG Number (optional)
8	GAS Extension (optional)

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is defined in 9.4.1.12 and set by the requesting STA.

The Advertisement Protocol element is defined in 9.4.2.92. The Advertisement Protocol element includes exactly one advertisement protocol ID.

The Query Request Length field is defined in Figure 9-877. The value of the Query Request Length field is set to the total number of octets in the Query Request field.

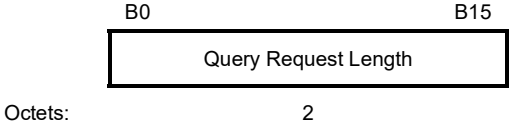

Figure 9-877—Query Request Length field

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The Query Request field is defined in Figure 9-878. The Query Request field is a generic container whose value is formatted in accordance with the protocol identified in the Advertisement Protocol element.

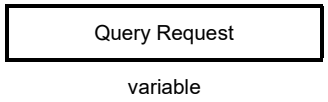

Figure 9-878—Query Request field

When present in a GAS Initial Request frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the GAS Initial Request frame applies.

When present in a GAS Initial Request frame, the CAG Number element includes one or more Common Advertisement Group (CAG) tuples. Each CAG tuple specifies a pair of CAG Version and CAG Information Type cached by the requesting STA and associated with the query request contained in the Query Request field.

The GAS Extension element indicating the STA support for GAS extension in GAS frame exchanges is optionally present if dot11GASExtensionImplemented is true.

9.6.7.13 GAS Initial Response frame format

The GAS Initial Response frame is transmitted in response to a GAS Initial Request frame or a Group Addressed GAS Request frame. The format of the GAS Initial Response frame Action field is shown in Table 9-371.

Table 9-371—GAS Initial Response frame Action field format

Order	Information
0	Category
1	Public Action
2	Dialog Token
3	Status Code
4	GAS Comeback Delay
5	Advertisement Protocol element
6	Query Response Length
7	Query Response (optional)
8	Multi-band (optional)
9	GAS Extension (optional)

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

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The Dialog Token field is copied from the corresponding GAS Initial Request frame or Group Addressed GAS Request frame.

The Status Code values are defined in Table 9-50.

The GAS Comeback Delay field specifies the delay time value in TUs. The GAS Comeback Delay field format is shown in Figure 9-879. The behavior is described in 11.22.3.2. The value 0 will be returned by the STA when a Query Response is provided in this frame.

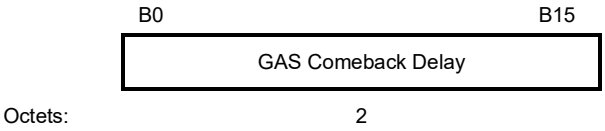

Figure 9-879—GAS Comeback Delay field format

The Advertisement Protocol element is defined in 9.4.2.92. The Advertisement Protocol element includes exactly one advertisement protocol ID.

The Query Response Length field is defined in Figure 9-880. The Query Response Length field is set to the total number of octets in the Query Response field. If the Query Response Length field is set to 0, then there is no Query Response included in this Action frame.

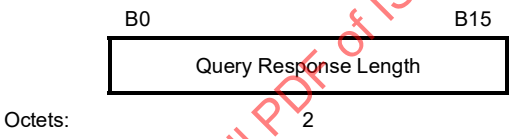

Figure 9-880—Query Response Length field format

The Query Response field is defined in Figure 9-881. The Query Response field is a generic container whose value is formatted in accordance with the protocol specified in the Advertisement Protocol element.

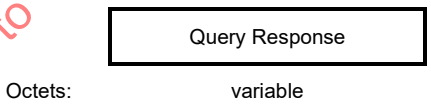

Figure 9-881—Query Response field format

When present in a GAS Initial Response frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the GAS Initial Response frame applies.

The GAS Extension element indicating the STA support for GAS extension in GAS frame exchanges is optionally present if dot11GASExtensionImplemented is true. It is included as a response to a GAS Initial Request frame containing a GAS Extension element.

9.6.7.14 GAS Comeback Request frame format

The GAS Comeback Request frame is transmitted by a requesting STA to a responding STA. The format of the GAS Comeback Request frame Action field is shown in Table 9-372.

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Table 9-372—GAS Comeback Request frame Action field(format

Order	Information
0	Category
1	Public Action
2	Dialog Token
3	Multi-band (optional)
4	GAS Extension (optional)

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is copied from the corresponding GAS Initial Request frame.

When present in a GAS Comeback Request frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the GAS Comeback Request frame applies.

When present in a GAS Comeback Request frame, the GAS Extension element indicates a request to retransmit a GAS Query Response fragment.

9.6.7.15 GAS Comeback Response frame format

The GAS Comeback Response frame is transmitted by a responding STA to a requesting STA. The format of the GAS Comeback Response frame Action field is shown in Table 9-373.

Table 9-373—GAS Comeback Response frame Action field format

Order	Information
0	Category
1	Public Action
2	Dialog Token
3	Status Code
4	GAS Query Response Fragment ID
5	GAS Comeback Delay
6	Advertisement Protocol element
7	Query Response Length
8	Query Response (optional)
9	Multi-band (optional)

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The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is copied from the Dialog Token field of the corresponding GAS Comeback Request frame. The same value of the Dialog Token field is present in all fragments of a multi-fragment query response.

The Status Code values are defined in Table 9-50. The same status code value is present in all fragments of a multi-fragment query response.

The GAS Query Response Fragment ID is defined in 9.4.1.33. If the responding STA has not received a response to the query that it posted on behalf of a requesting STA, then the responding STA sets the GAS Query Response Fragment ID to 0. When there is more than one query response fragment, the responding STA sets the GAS Query Response Fragment ID to 0 for the initial fragment and increments it by 1 for each subsequent fragment in a multi-fragment Query Response. The More GAS Fragments field is set to 0 whenever the final fragment of a query response is being transmitted. A GAS Query Response Fragment ID field having a nonzero Fragment ID and the More GAS Fragments field set to 1 indicates to the requesting STA that another GAS Comeback frame exchange should be performed to continue the retrieval of the query response.

The GAS Comeback Delay field format is shown in Figure 9-879. A nonzero GAS Comeback Delay value is returned by the responding STA in this frame to indicate that the GAS Query Request being carried out on behalf of the requesting STA is still in progress.

— A nonzero value indicates to the requesting STA that another GAS Comeback frame exchange should be performed after the expiration of the GAS Comeback Delay timer in order to retrieve the query response.
— This field is set to 0 for all GAS Comeback Response frames containing a query response or a fragment of a multi-fragment query response.

The Advertisement Protocol element is defined in 9.4.2.92. The Advertisement Protocol element includes exactly one advertisement protocol ID.

The Query Response Length field is defined in Figure 9-880. The Query Response Length field is set to the total number of octets in the Query Response field. If the Query Response Length field is set to 0, then there is no Query Response included in this Action frame.

The Query Response field is defined in Figure 9-881. The Query Response field is a generic container dependent on the advertisement protocol specified in the Advertisement Protocol element and the query itself. In a multi-fragment query response, the response to the query posted on behalf of a requesting STA is fragmented such that each fragment to be transmitted fits within the MMPDU size limitation.

When present in a GAS Comeback Response frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the GAS Comeback Response frame applies.

9.6.7.16 TDLS Discovery Response frame format

The format of the TDLS Discovery Response frame Action field is shown in Table 9-374.

The TDLS Discovery Response frame is transmitted directly (i.e., not via the AP) to the TDLS peer STA that sent the corresponding TDLS Discovery Request frame. See 11.20.

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Table 9-374—TDLS Discovery Response frame Action field format

Order	Information	Notes
1	Category	The Category field is defined in 9.4.1.11.
2	Public Action	The Public Action field is defined in 9.6.7.1.
3	Dialog Token	The dialog token is copied from the corresponding TDLS Discovery Request frame. The dialog token is specified in 9.4.1.12.
4	Capability	The Capability field indicates the capabilities of the STA. The Capability field is defined in 9.4.1.4.
5	Supported Rates and BSS Membership Selectors	The Supported Rates and BSS Membership Selectors element indicates the rates supported by the STA. The Supported Rates and BSS Membership Selectors element is defined in 9.4.2.3.
6	Extended Supported Rates and BSS Membership Selectors	The Extended Supported Rates and BSS Membership Selectors element is present whenever there are more than eight supported rates, and it is optional otherwise. The Extended Supported Rates and BSS Membership Selectors element is defined in 9.4.2.12.
7	Supported Channels	The Supported Channels element is present if the TDLS Channel Switching subfield is equal to 1. The Supported Channels element is defined in 9.4.2.17.
8	RSNE	The RSNE is present if security is required on the TDLS direct link (see 12.7.8.1). The RSNE is defined in 9.4.2.24.
9	Extended Capabilities	The Extended Capabilities element is present if any of the fields in this element are nonzero. The Extended Capabilities element is defined in 9.4.2.26.
10	Timeout Interval (TPK key lifetime)	The Timeout Interval element contains the TPK key lifetime. It is present if security is required on the TDLS direct link (see 12.7.8.1). The Timeout Interval element is defined in 9.4.2.48.
11	Supported Operating Classes	The Supported Operating Classes element is present if the TDLS Channel Switching subfield is equal to 1.
12	HT Capabilities	The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true. The HT Capabilities element is defined in 9.4.2.55.
13	20/40 BSS Coexistence	The 20/40 BSS Coexistence element is present when dot112040BSSCoexistenceManagementSupport is true. The 20/40 BSS Coexistence element is defined in 9.4.2.59.
14	Link Identifier	The Link Identifier element is defined in 9.4.2.61.
15	Multi-band	The Multi-band element is optionally present if dot11MultibandImplemented is true.
16	VHT Capabilities	VHT Capabilities element (optional). The VHT Capabilities element is present if dot11VHTOptionImplemented is true. The VHT Capabilities element is defined in 9.4.2.157.

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9.6.7.17 Location Track Notification frame format

The Location Track Notification frame is transmitted to allow remote location determination to occur by another STA. The format of the Location Track Notification frame Action field is shown in Figure 9-882.

	Category	Public Action	Location Parameters Element	Measurement Report Element (optional)
Octets:	1	1	variable	variable

Figure 9-882—Location Track Notification frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Location Parameters Element field contains the Location Parameters subelements, described in Table 9-213. Table 9-375 defines the allowed Location Parameters subelements for a Location Parameters element that is included in the frame.

Table 9-375—Location Parameters Element field for Location Track Notification frame

Allowed subelements	Subelement ID	Notes
Location Indication Channels	2	The Location Indication Channels subelement is included in the Location Track Notification frame.
Radio Information	4	The Radio subelement is included in the Location Track Notification frame.
Motion	5	The Motion subelement is included in the Location Track Notification frame if dot11MotionDetectionActivated is true.
Time of Departure	7	The Time of Departure subelement is included in the Location Track Notification frame if dot11TODActivated is true.
Location Indication Options	8	The Location Indication Options subelement is included in the Location Track Notification frame if the successful Location Configuration Request frame that configured the STA included a Location Indication Options subelement.

The Measurement Report Element field contains a Measurement Report element of type Beacon report as defined in 9.4.2.21.7. The Measurement Report Element field is included in the Location Track Notification frame if the Location Parameters Element field contains a Location Indication Options subelement. The Measurement Report element Measurement Token field is set to the same value of the dialog token in the Location Configuration Request frame that configured the STA.

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9.6.7.18 QMF Policy frame format

The QMF Policy frame is transmitted by a requesting STA to a receiving STA with the included QMF policy. It is either sent unsolicited by the requesting STA or in response to a QMF Policy Change frame from a receiving STA. The format of the Action field of the QMF Policy frame is shown in Figure 9-883.

	Category	Public Action	Dialog Token	Status Code	QMF Policy element (optional)
Octets:	1	1	1	2	0 or 3-257

Figure 9-883—QMF Policy frame Action field contents

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is set to the value in the corresponding QMF Policy Change frame. If the QMF Policy frame is not being transmitted in response to a QMF Policy Change frame, then the Dialog Token field is set to 0.

The Status Code field is defined in Table 9.4.1.9.

The QMF Policy element is set as described in 9.4.2.119. It indicates the new access categories configured for Management frame(s). This field is included if the Status Code is SUCCESS and this frame is not being transmitted in response to a QMF Policy Change frame, and optionally included if the Status Code is REQUEST_DECLINED.

9.6.7.19 QMF Policy Change frame format

The QMF Policy Change frame is transmitted by a requesting STA to request a change to the QMF policy it most recently received from the destination STA. The format of the Action field of the QMF Policy Change frame is shown in Figure 9-884.

	Category	Public Action	Dialog Token	QMF Policy element
Octets:	1	1	1	3-257

Figure 9-884—QMF Policy Change frame Action field contents

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is set to a nonzero value chosen by the STA sending the QMF Policy Change frame to identify the transaction.

The QMF Policy element is set as described in 9.4.2.119. It indicates the access categories requested for Management frame(s), including any changes to the QMF policy it most recently received from the destination STA.

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9.6.7.20 QLoad Request frame format

The QLoad Request frame is transmitted by an AP to request information from another AP. The format of the Action field of the QLoad Request frame is shown in Table 9-376.

Table 9-376—QLoad Request frame Action field format

Order	Information
1	Category
2	Public Action
3	Dialog Token
4	QLoad Report element

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is defined in 9.4.1.12 and set by the requesting STA to a nonzero value that is used for matching action responses with action requests. See 10.28.5.

The QLoad Report element is defined in 9.4.2.122 and contains the QLoad report corresponding to the AP sending the request.

9.6.7.21 QLoad Report frame format

The QLoad Report frame is transmitted by an AP responding to a QLoad Request frame. The format of the Action field of the QLoad Report frame is shown in Table 9-377.

Table 9-377—QLoad Report frame Action field format

Order	Information
1	Category
2	Public Action
3	Dialog Token
4	QLoad Report element

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is defined in 9.4.1.12 and set by the requesting STA to a nonzero value that is used for matching action responses with action requests. See 10.28.5. The Dialog Token field is set to 0 when an unsolicited QLoad Report frame is sent by the AP.

The QLoad Report element is defined in 9.4.2.122.

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9.6.7.22 HCCA TXOP Advertisement frame

The HCCA TXOP Advertisement frame is transmitted by an AP to another AP to inform it of active and pending TXOP reservations. The format of the Action field of the HCCA TXOP Advertisement frame is shown in Figure 9-885.

	Category	Public Action	Dialog Token	Number of Reported TXOP Reservations	Number of Pending TXOP Reservations	Active TXOP Reservations	Pending TXOP Reservations
Octets:	1	1	1	1	1	variable	variable

Figure 9-885—HCCA TXOP Advertisement frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is defined in 9.4.1.12 and is set by the AP to a nonzero value that is used for matching action responses with action requests. See 10.28.5.

The Number of Reported TXOP Reservations field contains a positive integer that specifies the number of active TXOP reservations reported in this frame. Setting the field to 0 indicates that no TXOP reservations are active.

The Number of Pending Reported TXOP Reservations field contains a positive integer that specifies the number of pending TXOP reservations reported in this frame. Setting the field to 0 indicates that no TXOP reservations are in the process of being activated.

The Active TXOP Reservation field contains zero or more TXOP Reservation fields as defined in 9.4.1.43. This field indicates active HCCA TXOPs that the AP has scheduled. The Start Time subfield of the TXOP Reservation field is relative to the TSF of the sending AP.

The Pending TXOP Reservation field contains zero or more TXOP Reservation fields as defined in 9.4.1.43. This field indicates new HCCA TXOPs that the AP is scheduling. The Start Time subfield of the TXOP Reservation field is relative to the TSF of the sending AP.

The use of the HCCA TXOP Advertisement frame is described in 11.26.3.

9.6.7.23 HCCA TXOP Response frame

The HCCA TXOP Response frame is transmitted by an AP to another AP to respond to an HCCA TXOP Advertisement frame. The format of the Action field of the HCCA TXOP Response frame is shown in Figure 9-886.

	Category	Public Action	Dialog Token	Status Code	Schedule Conflict	Alternate Schedule	Avoidance Request
Octets:	1	1	1	2	0 or 1	0 or 6	0 or 6

Figure 9-886—HCCA TXOP Response frame Action field format

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The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is set to the value of the Dialog Token field from the corresponding HCCA TXOP Advertisement frame.

The Status Code field is defined in 9.4.1.9 and is set to either the value SUCCESS or TS_SCHEDULE_CONFLICT.

The Schedule Conflict field is present only when the Status Code field is not SUCCESS. The Schedule Conflict field indicates the TXOP reservation from the HCCA TXOP Advertisement frame that conflicts with an existing or in-progress schedule. Its value is between 1 and the summation of the values from the Number of Reported TXOP Reservations and Number of Pending TXOP Reservations fields of the HCCA TXOP Advertisement frame. Setting the field to 1 indicates the first TXOP reservation in the HCCA TXOP Advertisement frame, setting the field to 2 indicates the second TXOP reservation in the HCCA TXOP Advertisement frame, and so on. The value of zero is reserved.

The optional Alternate Schedule field contains a TXOP Reservation field, as defined in 9.4.1.43 and is present only when the Status Code field is not SUCCESS. When the Alternate Schedule field is present, it contains an alternate to the TXOP reservation given in the corresponding HCCA TXOP Advertisement frame. The Start Time subfield of the Alternate Schedule field is relative to the TSF of the destination AP.

The optional Avoidance Request field contains a TXOP Reservation field, as defined in 9.4.1.43 and is optionally present when the Status Code field is not SUCCESS. When the Avoidance Request field is present, it indicates a TXOP schedule that the AP sending the TXOP Response frame is requesting to be avoided by the AP that is the destination of the TXOP Response frame. The Start Time subfield of the Avoidance Request field is relative to the TSF of the destination AP.

The use of the HCCA TXOP Response frame is described in 11.26.3.

9.6.7.24 Public Key frame

The Public Key frame is transmitted by an AP to provide its public key to peer APs and to request the peer's public key. The format of the Public Key frame Action field is defined in Figure 9-887.

	Category	Public Action	Public Key Frame Usage	Finite Cyclic Group	Public Key (optional)
Octets:	1	1	1	2	variable

Figure 9-887—Public Key frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Public Key Frame Usage field is set to a number to signify the usage mode of this frame. The Request Types are shown in Table 9-378.

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Table 9-378—Public Key Frame Usage field values

Public Key Frame Usage	Value
Request	0
Response	1
NAK	2
Refused	3
Reserved	4–255

The Public Key Frame Usage field is set to "Request" to indicate that a public key is being requested from a peer AP.

The Public Key Frame Usage field is set to "Response" to indicate that this frame is in response to a Public Key frame.

The Public Key Frame Usage field is set to "NAK" to indicate rejection of a received Public Key frame.

The Finite Cyclic Group field is used to indicate the cryptographic group used when generating the public key and is defined in 9.4.1.42), or the preferred group when the Public Key Frame Usage field is set to "NAK".

When the Public Key Frame Usage field is set to "NAK" or "Refused", the Public Key field is not included. In all other cases, the Public Key field contains the public key of the AP that is sending this Public Key frame encoded as an octet string according to 12.4.7.2.5.

The use of the Public Key frame is described in 12.10.

9.6.7.25 Channel Availability Query frame format

The Channel Availability Query frame is transmitted as part of a channel query. The format of the Channel Availability Query frame Action field is shown in Figure 9-888.

	Category	Public Action	Requester STA Address	Responder STA Address	Reason Result Code	Length	Channel Query Info	Device Class	Device Identification Information	Device Location Information	WSM Information
Octets:	1	1	6	6	1	1	1	variable	variable	variable	variable

Figure 9-888—Channel Availability Query frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Length field indicates the length of the remaining frame fields in octets, and the value is variable.

The remaining fields are as defined in the Channel Availability Query element (see 9.4.6.2) and White Space Map element (see 9.4.2.169).

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9.6.7.26 Channel Schedule Management frame format

The Channel Schedule Management frame is transmitted to exchange the channel schedule information as part of the channel schedule management procedure. The format of the Channel Schedule Management frame Action field is shown in Figure 9-889.

	Category	Public Action	Requester STA Address	Responder STA Address	Length	Reason Result Code	Channel Schedule Management Mode	Device Identification Information	Channel Schedule Descriptor
Octets:	1	1	6	6	1	1	1	variable	variable

Figure 9-889—Channel Schedule Management frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Requester STA Address field is the MAC address of the requesting STA that initiates the Channel Schedule Management process.

The Responder STA Address field is the MAC address of the STA that responds to the STA that requested channel schedule management.

The Length field indicates the length of the remaining fields in octets, and the value is variable.

The Reason Result Code field indicates the reason for transmitting a query request for channel schedule information. It also indicates the result of a query as successful or not and the reason when the query is not successful. This field is defined in Table 9-379.

Table 9-379—Reason Result Code field values

Reason Result Code field values	Description
0	Request for channel schedule information from a RLSS.
1	Request for channel schedule information from a GDD enabling STA.
2	Success, returning full channel schedule information on the requested channels.
3	Success, returning additional timeslots from the list of the last query on the requested channels.
4	Success, returning timeslots deleted from the list of last query on the requested channels.
5	Success, returning deleted and added timeslots from the list of last query on the requested channels.
6	Success, returning no channel schedule changes from last query.
7	Request declined by the GDD enabling STA for unspecified reason.
8	Request declined by the GDD enabling STA because of no capability for providing schedule information on WLAN channels.
9	Request declined by RLSS for unspecified reason.

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Table 9-379—Reason Result Code field values *(continued)*

Reason Result Code field values	Description
10	Request declined by RLSS because of no capability for providing schedule information on WLAN channels.
11	Unknown reason.
12	Continuation frame. This frame continues the fields from the previous CSM frame.
13–63	Reserved.

The Channel Schedule Management Mode field indicates if the schedule information of the channel availability is based on TV channels or WLAN channels. If the schedule information is based on WLAN channels, the optional Operating Class field is present in the Channel Schedule Descriptor field as defined in E.1. This field also indicates whether the optional Channel Availability Starting Time field is present in the Channel Schedule Descriptor field. This field is defined in Table 9-380.

Table 9-380—Channel Schedule Management Mode field values

Channel Schedule Management Mode value	Description
0	The channel schedule information is based on TV channels. The Reason Result Code field is set to either 0 or 1.
1	The channel schedule information is based on WLAN channels. The Reason Result Code field is set to either 0 or 1.
2–3	Reserved.

The Device Identification Information field indicates the regulatory identification of the STA that is requesting the schedule information. The Device Identification Information field is present only when Reason Result Code is either 0 or 1. The field is defined in 9.4.4.2.3.

The Channel Schedule Descriptor field indicates the channels for which the schedule information is requested, and the channel schedule information is provided in the response. The field is defined in 9.4.4.2.5. The Channel Schedule Descriptor field is repeated, as determined by the Length field.

9.6.7.27 Contact Verification Signal frame format

The Contact Verification Signal frame is transmitted by a GDD enabling STA to notify whether the available channel information from the GDB has been updated. The format of the Contact Verification Signal frame Action field is shown in Figure 9-890.

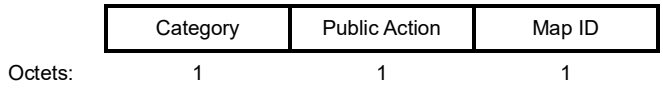

Figure 9-890—Contact Verification Signal frame Action field format

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The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Map ID field is set to a number that is equal to the Map ID of the recently received WSM. The WSM is defined in Table 9-329 in 9.4.4.2.6.

9.6.7.28 GDD Enablement Request frame format

The format of the Action field of the GDD Enablement Request frame is shown in Figure 9-891.

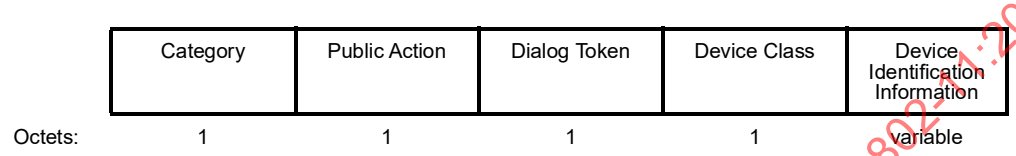

Figure 9-891—GDD Enablement Request frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is a nonzero value chosen by the STA sending the GDD Enablement Request frame to identify the request/response transaction.

The Device Class field is used to indicate the characteristic of the STA requesting the GDD Enablement Request frame. The format of the Device Class field is specified in 9.4.4.2.2.

The Device Identification Information field is used to indicate the identification of the STA requesting the GDD Enablement Request frame. The format of the Device Identification Information field is specified in 9.4.4.2.3.

9.6.7.29 GDD Enablement Response frame format

The format of the Action field of the GDD Enablement Response frame is shown in Figure 9-892.

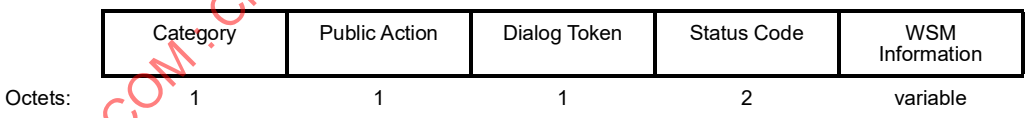

Figure 9-892—GDD Enablement Response frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is a nonzero value of the corresponding GDD Enablement Request frame. If a GDD Enablement Response frame is being transmitted other than in response to an GDD Enablement Request frame, then the Dialog Token field is 0.

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The Status Code field contains the status code in response to a GDD Enablement Request frame as defined in Table 9-50.

The remaining field is defined in the WSM element (see 9.4.2.169).

9.6.7.30 Network Channel Control frame format

The Network Channel Control frame is transmitted by a GDD dependent STA and a GDD enabling STA as part of the procedure that allows a GDD enabling STA to control the frequency usage of a GDD dependent STA's WLAN channels. The format of the Network Channel Control frame is shown in Figure 9-893.

								a Network Channel Control triplet		
	Category	Public Action	Length	Requester STA Address	Responder STA Address	Reason Result Code	Number of Network Channel Control Triplets	Operating Class	Channel Number	Maximum Transmit Power
Octets:	1	1	1	6	6	1	1	1	1	1

Figure 9-893—Network Channel Control frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Length field indicates the length of the remaining frame fields in octets, and the value is variable. The minimum value of the Length field is 14.

The Requester STA Address field is the MAC address of the requesting STA that initiates the network channel control process.

The Responder STA Address field is the MAC address of the STA that responds to the STA that requested network channel control.

The Reason Result Code field is used to indicate the reason that a Network Channel Control frame was generated. The length of the Reason Result Code field is 1 octet. The encoding of the Reason Result Code field is shown in Table 9-343.

The Number of Network Channel Control Triplets field indicates the number of triplets of Operating Class, Channel Number, and Maximum Transmit Power fields.

The Operating Class field indicates the channel set for which the network channel control request applies. The Operating Class and Channel Number fields together specify the channel frequency and channel bandwidth for which the network channel control applies. Values for the Operating Class field are shown in E.1.

In a request, the Channel Number field of the Network Channel Control frame indicates the channel that the requesting STA intends to operate on. In the response, the Channel Number field in the Network Channel Control frame indicates the channels that the responding STA permits the requesting STA to operate on. The Channel Number is defined within an Operating Class as shown in E.1.

The Maximum Transmit Power field gives the intended maximum transmit power in dBm for operation in the request frame and indicates the maximum allowable transmit power in dBm for operation in the response frame. The field contains EIRP per channel bandwidth and is coded as a 2s complement signed integer in

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units of 0.5 dBm. The field is set to 0 when a requesting STA requests a responding STA to provide a network channel control response without specifying in the request the intended maximum transmit power.

9.6.7.31 White Space Map Announcement frame format

The format of the Action field of the White Space Map Announcement frame is shown in Figure 9-894.

	Category	Public Action	Reason Result Code	White Space Map
Octets:	1	1	1	variable

Figure 9-894—White Space Map Announcement frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

Setting the Reason Result Code field to 1 indicates the Public Action frame is a continuation of the previous WSM Public Action frame, and any other value indicates this is not a continuation of the previous WSM Public Action frame.

The White Space Map field contains a White Space Map element (see 9.4.2.169).

9.6.7.32 Fine Timing Measurement Request frame format

The format of the Fine Timing Measurement Request frame Action field is shown in Figure 9-895.

	Category	Public Action	Trigger	LCI Measurement Request (optional)	Location Civic Measurement Request (optional)	Fine Timing Measurement Parameters (optional)
Octets:	1	1	1	variable	variable	variable

Figure 9-895—Fine Timing Measurement Request frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Trigger field set to 1 indicates that the initiating STA requests that the responding STA start or continue sending Fine Timing Measurement frames (see 11.21.6). The Trigger field set to 0 indicates that the initiating STA requests that the responding STA stop sending Fine Timing Measurement frames. Trigger field values 2–255 are reserved.

The LCI Measurement Request field is optionally present. If present, it contains a Measurement Request element with Measurement Type field equal to LCI (see Table 9-98), which indicates a request for a Measurement Report element with Measurement Type field equal to LCI (see 11.21.6.7). The Enable bit in the Measurement Request Mode field in the Measurement Request element is set to 0. The Location Subject field in the Measurement Request field of the Measurement Request element is set to Location Subject Remote (see Table 9-110). The Request, Report and Duration Mandatory bits in the Measurement Request Mode field in the Measurement Request element are reserved (see 9.4.2.20.1).

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The Location Civic Measurement Request field is optionally present. If present, it contains a Measurement Request element with Measurement Type field equal to Location Civic (see Table 9-98), which indicates a request for a Measurement Report element with Measurement Type field equal to Location Civic (see 11.21.6.7). The Enable bit in the Measurement Request Mode field in the Measurement Request element is set to 0. The Location Subject field in the Measurement Request field of the Measurement Request element is set to Location Subject Remote (see Table 9-110). The Location Service Interval Units field in the Measurement Request field of the Measurement Request element is set to 0. The Request, Report and Duration Mandatory bits in the Measurement Request Mode field within the Measurement Request element are reserved (see 9.4.2.20.1).

The Fine Timing Measurement Parameters field is present in the initial Fine Timing Measurement Request frame (see 11.21.6.3) and its retransmissions and is not present in subsequent Fine Timing Measurement Request frames. If present, it contains a Fine Timing Measurement Parameters element as defined in 9.4.2.167.

9.6.7.33 Fine Timing Measurement frame format

The Fine Timing Measurement frame is used to support the FTM procedure described in 11.21.6. The format of the Fine Timing Measurement frame Action field is shown in Figure 9-896.

	Category	Public Action	Dialog Token	Follow Up Dialog Token	TOD	TOA
Octets:	1	1	1	1	6	6

	TOD Error	TOA Error	LCI Report (optional)	Location Civic Report (optional)	Fine Timing Measurement Parameters (optional)	FTM Synchronization Information (optional)
Octets:	2	2	variable	variable	variable	variable

Figure 9-896—Fine Timing Measurement frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The TOD Error field is structured as shown in Figure 9-897.

	B0 B4	B5 B14	B15
	Max TOD Error Exponent	Reserved	TOD Not Continuous
Bits:	5	10	1

Figure 9-897—Format of the TOD Error field

The TOA Error field is structured as shown in 9-898.

	B0 B4	B5 B15
	Max TOA Error Exponent	Reserved
Bits:	5	11

Figure 9-898—Format of the TOA Error field

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The Dialog Token field is a nonzero value chosen by the responding STA to identify the Fine Timing Measurement frame as the first of a pair, with the second or follow-up Fine Timing Measurement frame to be sent later. The Dialog Token field is set to 0 to indicate the end of the FTM session (see 11.21.6.6 and 11.21.6.4).

The Follow Up Dialog Token field is the nonzero value of the Dialog Token field of the last transmitted Fine Timing Measurement frame to indicate that it is the follow up Fine Timing Measurement frame and that the TOD, TOA, Max TOD Error Exponent and Max TOA Error Exponent fields contain the values of the timestamps captured with the first Fine Timing Measurement frame of the pair. The Follow Up Dialog Token field is 0 to indicate that the Fine Timing Measurement frame is not a follow up to a last transmitted Fine Timing Measurement frame. The value 0 in this field also indicates that TOD, TOA, TOD Error, and TOA Error fields are reserved. See 11.21.6.

The TOD and TOA fields are expressed in units of picoseconds.

The maximum errors in the TOD and TOA values are represented using the function defined in Equation (9-4).

$$E_{max} = \begin{cases} \text{unknown}, & F = 0 \\ 2^{F-1}, & 1 \le F \le 30 \\ \ge 2^{30}, & F = 31 \end{cases} \tag{9-4}$$

where

F is the Max Error Exponent

E_{max} is the maximum TOD or TOA error, respectively, in units of picoseconds

The TOD field contains a timestamp that represents the time, with respect to a time base, at which the start of the preamble of the last transmitted Fine Timing Measurement frame appeared at the transmit antenna connector.

The TOA field contains a timestamp that represents the time, with respect to a time base, at which the start of the preamble of the Ack frame to the last transmitted Fine Timing Measurement frame arrived at the receive antenna connector.

NOTE 1—The values specified in the TOD and TOA fields are described in 6.3.56.

The Max TOD Error Exponent field contains an upper bound for the error exponent in the value specified in the TOD field.

NOTE 2—For instance, setting the Max TOD Error Exponent field to 2 indicates that the value in the TOD field has a maximum error of ± 2 ps.

The TOD Not Continuous field indicates that the TOD value is with respect to a different underlying time base than the last transmitted TOA value. It is set to 1 when a discontinuity is present. Otherwise, it is set to 0.

The Max TOA Error Exponent field contains an upper bound for the error exponent in the value specified in the TOA field.

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Setting the Max TOD Error Exponent or the Max TOA Error Exponent field to 1 indicates that the upper bound on the error in the corresponding TOD or TOA value is unknown. Setting either field to 31 indicates that the upper bound on the error is greater than or equal to 1.073 741 824 ms.

The LCI Report field is optionally present. If present, it contains a Measurement Report element with Measurement Type field equal to LCI (see Table 9-125), which either indicates the LCI of the transmitting STA and includes the Z and Usage Rules/Policy subelement or indicates an unknown LCI (see 11.21.6.7). The Late, Incapable and Refused bits in the Measurement Report Mode field are set to 0. The Co-Located BSSID List subelement is present in the Measurement Report element with Measurement Type field equal to LCI, when there is at least one other BSS that shares the same antenna connector with the reporting BSS.

The Location Civic Report field is optionally present. If present, it contains a Measurement Report element with Measurement Type field equal to Location Civic (see Table 9-125), which either indicates the Civic address of the transmitting STA or an unknown Civic address (see 11.21.6.7). The Late, Incapable and Refused bits in the Measurement Report Mode field are set to 0. The Co-Located BSSID List subelement is present in the Measurement Report element with Measurement Type field equal to LCI, when there is at least one other BSS that shares the same antenna connector with the reporting BSS. When the LCI Report field contains a Co-Located BSSID List subelement, the Co-Located BSSID List subelement is not present in the Location Civic Report field.

The Fine Timing Measurement Parameters field is present in the initial Fine Timing Measurement Frame and is not present in subsequent Fine Timing Measurement frames. If present, it contains a Fine Timing Measurement Parameters element as defined in 9.4.2.167.

The FTM Synchronization Information field is present in the initial Fine Timing Measurement frame and its retransmissions if any, and in the first Fine Timing Measurement frame within each burst and its retransmissions if any; otherwise it is not present. If present, it contains an FTM Synchronization Information element with a TSF Sync Info field containing the 4 least significant octets of the TSF at the responding STA corresponding to the time the responding STA received the last Fine Timing Measurement Request frame with the Trigger field equal to 1.

9.6.7.34 QAB Request frame format

The QAB Request frame is transmitted by an AP to another AP to schedule quiet periods that facilitate the detection of other system operating in the same band. The format of the QAB Request frame Action field is shown in Table 9-381.

Table 9-381—QAB Request frame Action field format

Order	Information
1	Category
2	Public Action
3	Dialog Token
4	RequesterAP Address
5	ResponderAP Address
6	Quiet Period Request element

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The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is set to a nonzero value chosen by the AP.

The RequesterAP Address field is the MAC address of the AP that initiates the process. The length of this field is 6 octets.

The ResponderAP Address field is the MAC address of the responding AP. The length of this field is 6 octets. This field can be set to the broadcast address if the request is sent to multiple APs.

The Quiet Period Request element is defined in 9.4.2.149.

9.6.7.35 QAB Response frame format

A QAB Response frame is sent in response to a QAB Request frame. The format of a QAB Response frame Action field contains the information shown in Table 9-382.

Table 9-382—QAB Response frame Action field format

Order	Information
1	Category
2	Public Action
3	Dialog Token
4	RequesterAP Address
5	ResponderAP Address
6	Quiet Period Response element

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field value is copied from the corresponding received QAB Request frame.

The RequesterAP Address field is the MAC address of the AP that initiates the process. The length of this field is 6 octets.

The ResponderAP Address field is the MAC address of the responding AP. The length of this field is 6 octets.

The Quiet Period Response element is defined in 9.4.2.150.

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9.6.7.36 FILS Discovery frame format

The format of the FILS Discovery frame Action field is defined in Table 9-383.

Table 9-383—FILS Discovery frame format

Order	Information	Notes
1	Category	
2	Public Action	
3	FILS Discovery Information field	
4	Reduced Neighbor Report element	The Reduced Neighbor Report element is optionally present.
5	FILS Indication element	The FILS Indication element is optionally present.
6	Roaming Consortium element	The Roaming Consortium element is optionally present.

The Category field indicates the public category specified in Table 9-51.

The Public Action field indicates the value of the FILS Discovery frame, as specified in Table 9-364 in Table 9.6.7.1.

The FILS Discovery Information field is shown in Figure 9-899.

	FILS Discovery Frame Control	Timestamp	Beacon Interval	SSID/Short SSID	Length	FD Capability
Octets:	2	8	2	1-32	0 or 1	0 or 2

	Operating Class	Primary Channel	AP Configuration Sequence Number	Access Network Options	FD RSN Information	Channel Center Frequency Segment 1	Mobility Domain
Octets:	0 or 1	0 or 1	0 or 1	0 or 1	0 or 5	0 or 1	0 or 3

Figure 9-899—FILS Discovery Information field format

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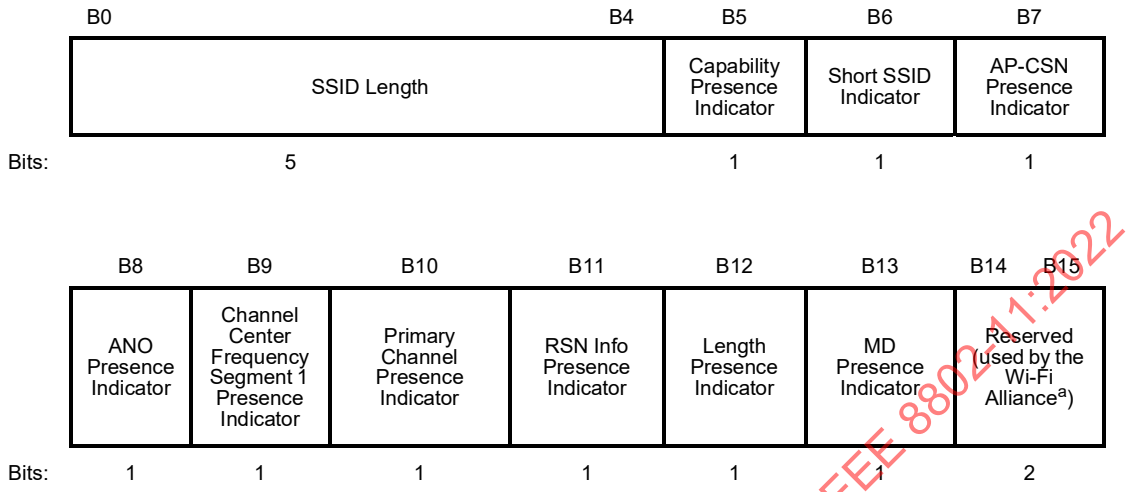
The format of the FILS Discovery Frame Control subfield is shown in Figure 9-900.



[a] Information on the Wi-Fi Alliance can be found at http://www.wi-fi.org.

Figure 9-900—FILS Discovery Frame Control subfield format

The SSID Length subfield of the FILS Discovery Frame Control subfield indicates the length, in octets, of the SSID/Short SSID subfield in the FILS Discovery frame. This subfield is equal to the length of the SSID/Short SSID subfield in octets minus 1.

NOTE 1—When the Short SSID Indicator subfield is equal to 1, the SSID Length subfield is equal to 3.

When the Capability Presence Indicator subfield is set to 1, it indicates that the FILS Discovery (FD) Capability subfield is present in the FILS Discovery frame. Setting the subfield to 0 indicates that the FD capability subfield is not present in the FILS Discovery frame.

A value of 1 in the Short SSID Indicator subfield indicates that a short SSID is contained in the SSID/Short SSID field of the FILS Discovery frame. A value of 0 indicates that an SSID is contained in the SSID/Short SSID field of the FILS Discovery frame.

A value of 1 in the AP-CSN Presence Indicator subfield indicates that the AP Configuration Sequence Number subfield is present in the FILS Discovery frame. Setting the subfield to 0 indicates that the AP-CSN subfield is not present in the FILS Discovery frame.

A value of 1 in the Access Network Options (ANO) Presence Indicator subfield indicates that the Access Network Options subfield is present in the FILS Discovery frame. Setting the subfield to 0 indicates that the ANO subfield is not present in the FILS Discovery frame.

A value of 1 in the Channel Center Frequency Segment 1 Presence Indicator subfield indicates that the Channel Center Frequency Segment 1 subfield is present in the FILS Discovery frame. Setting the subfield to 0 indicates that Channel Center Frequency Segment 1 subfield is not present.

A value of 1 in the Primary Channel Presence Indicator subfield indicates that the Primary Channel and the Operating Class subfields are present in the FILS Discovery frame. Setting the subfield to 0 indicates that the Primary Channel and the Operating Class subfields are not present in the FILS Discovery frame.

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A value of 1 in the RSN Information Presence Indicator subfield indicates that the FD RSN Information subfield is present in the FILS Discovery frame. Setting the subfield to 0 indicates that the FD RSN Information subfield is not present in the FILS Discovery frame.

A value of 1 in the Length Presence Indicator subfield indicates that the Length field is present in the FILS Discovery frame. Setting the subfield to 0 indicates that the Length field is not present in the FILS Discovery frame.

Setting the MD Presence Indicator subfield to 1 indicates that the Mobility Domain subfield is present in the FILS Discovery frame. Setting the subfield to 0 indicates that the Mobility Domain subfield is not present in the FILS Discovery frame.

The Timestamp subfield carries the value of the TSF timer at the time that the start of the data symbol containing the first bit of the Timestamp field appears at the transmit antenna connector.

The Beacon Interval subfield carries the beacon interval in TUs.

The SSID/Short SSID subfield is variable length between 1 and 32 octets. When the Short SSID Indicator subfield is 1, the SSID/Short SSID field contains the short SSID (see 9.4.2.170). Otherwise, the SSID/Short SSID field contains the SSID, whose length is specified by the 5-bit SSID Length subfield in the FILS Discovery Frame Control of the FILS Discovery frame (see 9.4.2.2).

The Length subfield indicates the length of the remaining fields in the FILS Discovery Information field in octets. Its value is variable.

NOTE 2—The Length field is used to facilitate STAs parsing the FILS Discovery frame in case of future expansions of the FILS Discovery Information field; STAs can determine the end of the FILS Discovery Information field using the value indicated in the Length field even if they do not recognize one or more subfields in the FILS Discovery Information field.

The FD Capability subfield contains the information that advertises the capabilities and operational indications of the STA transmitting the FILS Discovery frame. Its presence is indicated by the Capability Presence Indicator subfield in the FILS Discovery Frame Control subfield being equal to 1. The format of the FD Capability subfield is shown in Figure 9-901.

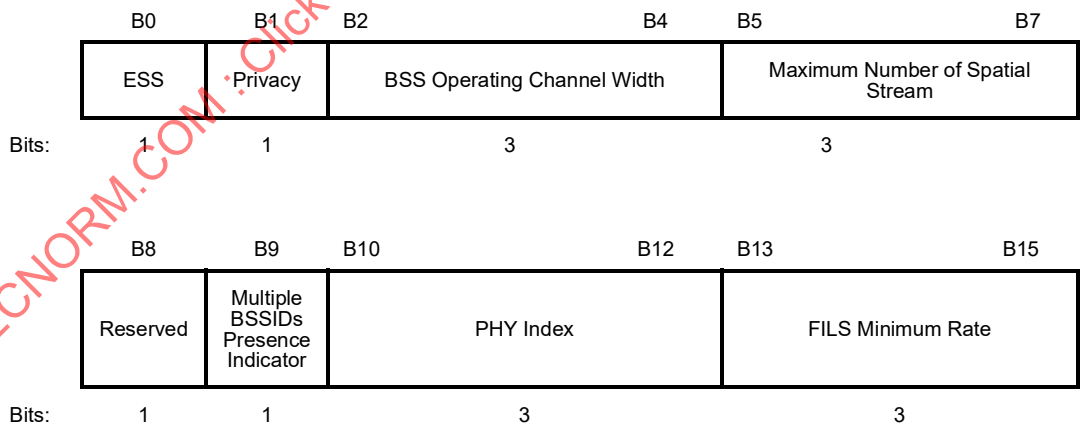

Figure 9-901—FD Capability subfield format

The ESS and Privacy subfields are interpreted as specified in 9.4.1.4.

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The BSS Operating Channel Width subfield indicates the BSS operating channel width as defined in Table 9-384.

Table 9-384—BSS Operating Channel Width

BSS Operating Channel Width field	HR/DSSS, OFDM, ERP, HT, or VHT BSS operating channel width	TVHT BSS operating channel width
0	20 MHz or 22 MHz	TVHT_W
1	40 MHz	TVHT_W+W
2	80 MHz	TVHT_2W
3	160 MHz or 80+80 MHz	TVHT_4W or TVHT_2W+2W
4–7	Reserved	Reserved

The Maximum Number of Spatial Streams subfield indicates the number of the spatial streams supported by the AP. The Maximum Number of Spatial Streams subfield is coded per Table 9-385.

Table 9-385—Maximum Number of Spatial Streams

Number of Spatial Streams subfield	Maximum Number of Spatial Streams subfield
0	1
1	2
2	3
3	4
4	5–8
5–7	Reserved

The Multiple BSSIDs Presence Indicator subfield is set to 1 to indicate that the Multiple BSSID element is present in the Beacon and Probe Response frames. It is set to 0 to indicate that the Multiple BSSID element is not present in the Beacon and Probe Response frames.

The PHY Index subfield is defined as in Table 9-386.

Table 9-386—PHY Index subfield

PHY Index subfield	PHY
0	HR/DSSS (see Clause 16)
1	ERP-OFDM (see Clause 17 and Clause 18)
2	HT (see Clause 19)
3	VHT (see Clause 21) or TVHT (see Clause 22)
4–7	Reserved

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The FILS Minimum Rate subfield indicates the minimum rate to be used by the AP transmitting the FILS Discovery frame and by FILS STAs in subsequent transmissions between the AP and FILS STAs. Depending on the PHY Index subfield of the received FILS Discovery frame, the minimum rate is represented as a bit rate value or as an MCS value as shown in Table 9-387. If an MCS value is provided, then the minimum rate is derived from the MCS value and the PHY Index in the FD Capability subfield.

Table 9-387—FILS Minimum Rate

FILS Minimum Rate subfield	PHY Index subfield is 0 (HR/DSSS)	PHY Index subfield is 1 (ERP-OFDM)	PHY Index subfield is 2 (HT)	PHY Index subfield is 3 (VHT or TVHT)
0	1 Mb/s	6 Mb/s	HT-MCS 0	VHT-MCS 0
1	2 Mb/s	9 Mb/s	HT-MCS 1	VHT-MCS 1
2	5.5 Mb/s	12 Mb/s	HT-MCS 2	VHT-MCS 2
3	11 Mb/s	18 Mb/s	HT-MCS 3	VHT-MCS 3
4	Reserved	24 Mb/s	HT-MCS 4	VHT-MCS 4
5–7	Reserved	Reserved	Reserved	Reserved

The Operating Class subfield specifies the operating class of the Primary Channel of the transmitting AP (see 9.4.1.36).

The Primary Channel subfield is set to the channel number of the primary channel (see 11.15.2) if the FILS Discovery frame is transmitted as a non-HT duplicate PPDU; otherwise, the subfield is not present.

The AP Configuration Sequence Number (AP-CSN) subfield format is defined in 9.4.2.181.

The Access Network Options (ANO) subfield format is defined in Figure 9-484 (in 9.4.2.91).

The Primary Channel subfield is set to the channel number of the primary channel (see 11.15.2) if the FILS Discovery frame is transmitted as a non-HT duplicate PPDU; otherwise, the subfield is not present.

The FD RSN Information subfield is defined in Figure 9-902.

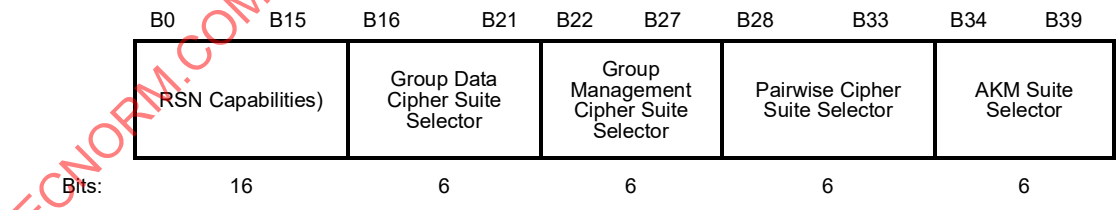

Figure 9-902—FD RSN Information subfield format

The FD RSN Information subfield contains an RSN Capabilities) subfield, as specified in Figure 9-289 (in 9.4.2.24.4).

The FD RSN Information subfield also contains three cipher suite selectors. The Group Data Cipher Suite Selector subfield contains one group data cipher suite selector. The Group Management Cipher Suite

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Selector subfield contains one group management cipher suite selector. The Pairwise Cipher Suite Selector subfield contains one pairwise cipher suite selector. Each of these subfields contains a code identifying a Cipher Suite Type as specified in Table 9-149. The definition of the cipher suite selectors is shown in Table 9-388.

Table 9-388—Cipher suite selector definitions

Cipher suite selector	Cipher suite type
0–13	Cipher suite type 0 to 13 in Table 9-149
14–61	Reserved
62	Vendor Specific
63	No cipher suite selected

The FD RSN Information subfield also contains one AKM suite selector. An AKM suite selector is a code identifying a AKM suite type as specified in Table 9-151. The definition of the AKM suite selectors is shown in Table 9-389.

Table 9-389—AKM suite selector definitions

AKM suite selector	AKM suite type
0	Use AKM from RSN IE Beacon/Probe Response frame
1	Set AKM suite to 14 of Table 9-151
2	Set AKM suite to 15 of Table 9-151
3	Set AKM suite to either 14 or 15 of Table 9-151
4	Set AKM suite to 17 of Table 9-151
5–61	Reserved
62	Vendor Specific
63	No AKM suite selected

The Channel Center Frequency Segment 1 subfield is set to the index of the channel center frequency of the frequency segment 1 for an 80+80 MHz VHT BSS, if the FILS Discovery frame is transmitted as a non-HT duplicate PPDUs at an 80+80 MHz channel bandwidth; otherwise, the subfield is not present.

The format of the Mobility Domain subfield is shown in Figure 9-903.

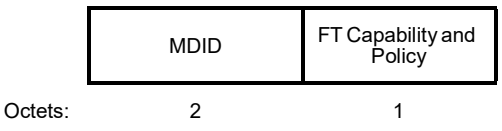

Figure 9-903—Mobility Domain subfield format

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The MDID field is defined in 9.4.2.46.

The FT Capability and Policy field is defined in 9.4.2.46.

The Reduced Neighbor Report element is defined in 9.4.2.170.

The FILS Indication element is defined in 9.4.2.182.

9.6.7.37 DCS Measurement Request frame format

The DCS Measurement Request frame is transmitted by a DCS requesting CDMG AP or PCP to a DCS responder CDMG AP or PCP to request all of the STAs in the DCS responder AP's infrastructure BSS or PCP's PBSS to measure a specified channel or all other channels within the supported operating class (as defined in 9.4.2.53). The format of the DCS Measurement Request frame Action field is shown in Figure 9-904.

	Category	Public Action	Dialog Token	DCS Measurement Request Mode	Operating Class	Optional Subelements
Octets:	1	1	1	1	1	variable

Figure 9-904—DCS Measurement Request frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is defined in 9.4.1.12 and set by the requesting STA.

The Measurement Request Mode field is set to 1 to indicate that the DCS requesting AP or PCP requests all STAs within the DCS responder AP's or PCP's infrastructure BSS or PBSS to measure all channels within the operating class specified in the following Operating Class field. The Measurement Request Mode field is set to 2 to indicate that the DCS requesting AP or PCP requests all STAs within the DCS responder AP's infrastructure BSS or PCP's PBSS to measure the specified channel(s) indicated within the list of optional subelements. Other values are reserved.

The Operating Class field is valid when the Measurement Request Mode field is 1. In all other cases, the Operating Class field is reserved. The Operating Class and Channel Number fields together specify the channel frequency and channel bandwidth for which the DCS procedure applies. Valid values of the Operating Class field are shown in Annex E.

The Optional Subelements field is present when the Measurement Request Mode field is 2. The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3. The optional subelements are ordered by nondecreasing subelement ID.

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The Subelement ID field values for the defined optional subelements are shown in Table 9-390.

Table 9-390—Optional subelement IDs for DCS Measurement Request frame

Subelement ID	Name	Extensible
0	Reserved	
1	Channel Measurement Request	Yes
2–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Channel Measurement Request subelement is used to specify the channel(s) to be measured. The format of the DCS Channel Measurement Request subelement is shown in Figure 9-905.

	Subelement ID	Length	Measurement Token	Operating Class	Channel Number
Octets:	1	1	1	1	1

Figure 9-905—DCS Channel Measurement Request subelement format

The Subelement ID field is defined in Figure 9-390.

The Length field is defined in 9.4.3.

The Measurement Token field is set to a nonzero value that is unique among the Channel Measurement Request subelements in a particular DCS Measurement Request frame.

The Operating Class and Channel Number fields together specify the channel frequency and channel bandwidth for which the DCS procedure applies. Valid values of the Operating Class field are shown in Annex E (Country elements and operating classes).

The Channel Number field is set to the channel number for which the Channel Measurement Request applies (as defined in 17.3.8.4.3).

9.6.7.38 DCS Measurement Response frame format

The DCS Measurement Response frame is transmitted by a DCS responder AP or PCP to a DCS requesting AP or PCP to report the results of measuring one or more channels. The format of the DCS Measurement Response frame Action field is shown in Figure 9-906.

	Category	Public Action	Dialog Token	DCS Measurement Report Mode	Operating Class	Optional Subelements
Octets:	1	1	1	1	1	variable

Figure 9-906—DCS Measurement Response frame Action field format

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The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is copied from the corresponding DCS Measurement Request frame.

The Measurement Report Mode field is set to 0 to indicate no clear channel to which the DCS responder AP's or PCP's BSS can move within the operating class specified in the following Operating Class field, or the DCS request has been declined by the DCS responder AP or PCP. The Measurement Report Mode field is set to 1 to indicate that all other channels within the operating class specified in the following Operating Class field are available for the DCS responder AP's or PCP's BSS. The Measurement Report Mode field is set to 2 to indicate that the clear channel for the DCS responder AP's or PCP's BSS is indicated by the Optional Subelement field in the DCS Measurement Response frame. Other values are reserved.

The Operating Class field is valid when the Measurement Report Mode field is 1. In all other cases, the Operating Class field is reserved. The Operating Class and Channel Number fields together specify the channel frequency and channel bandwidth for which the DCS procedure applies. Valid values of the Operating Class field are shown in Annex E.

The Optional Subelements field is present when the Measurement Report Mode field is 2. The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3. The optional subelements are ordered by nondecreasing subelement ID.

The Subelement ID field values for the defined optional subelements are shown in Table 9-391.

Table 9-391—Optional subelement IDs for DCS Measurement Response frame

Subelement ID	Name	Extensible
0	Reserved	
1	Channel Measurement Report	Yes
2–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

The Channel Measurement Report subelement is used to report the number of available channel to which the DCS responder AP's or PCP's BSS can move. The DCS Channel Measurement Report subelement format is as shown in Figure 9-907.

	Subelement ID	Length	Measurement Token	Operating Class	Channel Number
Octets:	1	1	1	1	1

Figure 9-907—DCS Channel Measurement Report subelement format

The Subelement ID field is defined in Table 9-391.

The Length field is defined in 9.4.3.

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The Measurement Token field is copied from the corresponding Channel Measurement Request subelement in the received DCS Measurement Request frame.

The Operating Class and Channel Number fields together specify the channel frequency and channel bandwidth for which the DCS procedure applies. Valid values of the Operating Class field are shown in Annex E.

The Channel Number field is set to the channel number to which the DCS responder AP's or PCP's BSS can move (as defined in 17.3.8.4.3).

9.6.7.39 DCS Request frame format

The DCS Request frame is transmitted by a DCS requesting AP or PCP to a DCS responder AP or PCP to request the DCS responder AP's or PCP's BSS to move to an available channel indicated in the DCS Measurement Response frame. The format of the DCS Request frame Action field is shown in Figure 9-908.

	Category	Public Action	Dialog Token	Request Type	Operating Class	New Channel Number
Octets:	1	1	1	1	1	1

Figure 9-908—DCS Request frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field value is copied from the corresponding DCS Measurement Response frame.

The Request Type field value is set to 0 to indicate that the requesting AP or PCP requests the responder AP or PCP to tear down the DCS procedure or the DCS request is refused by the responder AP or PCP; then the following Operation Class field and New Channel Number field are reserved. The Request Type field value is set to 1 to indicate that the DCS requesting AP or PCP to request the DCS responder AP's or PCP's BSS to move to an available channel indicated by the following Operating Class field and New Channel Number field. Other values are reserved.

The Operating Class and Channel Number fields together specify the channel frequency and channel bandwidth for which the DCS procedure applies. Valid values of the Operating Class field are shown in Annex E. This field is valid when the Request Type field is set to 1; otherwise, it is reserved.

The New Channel Number field is set to the channel number to which the DCS requesting AP or PCP request the DCS responder AP's or PCP's BSS to move (as defined in 17.3.8.4.3). This field is valid when the Request Type field is set to 1; otherwise, it is reserved.

9.6.7.40 DCS Response frame format

The DCS Response frame is transmitted by a DCS responder AP or PCP to a DCS requesting AP or PCP to confirm that the DCS responder AP's or PCP's BSS is moving to the channel specified in the DCS request frame. The format of the DCS Response frame Action field is shown in Figure 9-909.

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	Category	Public Action	Dialog Token	Responder Type	Operating Class	New Channel Number	Channel Switch Count
Octets:	1	1	1	1		1	1

Figure 9-909—DCS Response frame Action field format

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is copied from the corresponding DCS Request frame.

The Operating Class and Channel Number fields together specify the channel frequency and channel bandwidth for which the DCS procedure applies. Valid values of the Operating Class field are shown in Annex E.

The New Channel Number field is set to the channel number copied from the corresponding received DCS Request frame.

The Channel Switch Count field either is set to the number of TBTTs until the DCS responder AP or PCP sending the Channel Switch Announcement frame or element within its BSS switches to the new channel or is set to 0. It is set to 1 to indicate that the switch occurs immediately before the next TBTT. It is set to 0 to indicate that the switch occurs at any time after the frame containing the element is transmitted.

9.6.7.41 Extended Notification Period Request frame format

The format of the Extended Notification Period Request frame Action field is defined in Table 9-392.

Table 9-392—Extended Notification Period Request frame Action field format

Order	Information
0	Category
1	Public Action
2	Dialog Token
3	NP/BHI Duration

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is defined in 9.4.1.12 and set by the requesting STA.

The NP/BHI Duration field is set to the length of the NP/BHI duration requested by the STA intending to establish its BSS on a free 1.08 GHz channel to the peer STA operating on the adjacent 1.08 GHz channel. The length of this field is 2 octets.

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9.6.7.42 Extended Notification Period Response frame format

The format of the Extended Notification Period Response frame Action field is defined in Table 9-393.

Table 9-393—Extended Notification Period Response frame Action field format

Order	Information
0	Category
1	Public Action
2	Dialog Token
3	Status Code
4	Dynamic Bandwidth Control

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is copied from the corresponding Extended Notification Period Response frame.

The Status Code field indicates the result of the notification period allocation request and is defined in 9.4.1.9.

The Dynamic Bandwidth Control element specifies the information of the STA operating on a 1.08 GHz channel after channel splitting and is defined in 9.4.2.220. This element is present if the Status Code field indicates successful; otherwise, it is not present.

9.6.7.43 Extended Channel Splitting Request frame format

The format of the Extended Channel Splitting Request frame Action field is defined in Table 9-394.

Table 9-394—Extended Channel Splitting Request frame Action field format

Order	Information
0	Category
1	Public Action
2	Dialog Token
3	NP/BHI Duration

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is defined in 9.4.1.12 and set by the requesting STA.

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The NP/BHI Duration field is set to the length of the NP/BHI duration requested by the STA intending to establish its BSS on a free 1.08 GHz channel to the peer STA operating on the adjacent 1.08 GHz channel. The length of this field is 2 octets.

9.6.7.44 Extended Channel Splitting Response frame format

The format of the Extended Channel Splitting Response frame Action field is defined in Table 9-395.

Table 9-395—Extended Channel Splitting Response frame Action field format

Order	Information
0	Category
1	Public Action
2	Dialog Token
3	Status Code
4	Channel Switch Announcement
5	Beacon Interval
6	Dynamic Bandwidth Control

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is copied from the corresponding Extended Channel Splitting Response frame.

The Status Code field indicates the result of the notification period allocation request and is defined in 9.4.1.9.

The Channel Switch Announcement element is defined in 9.4.2.18. This element is present if the Status Code field indicates successful; otherwise, it is not present.

The Beacon Interval field specifies the beacon interval length on a 2.16 GHz channel set by the STA operating on one of the 1.08 GHz channel after channel splitting and is defined in 9.4.1.3. This field is present if the Status Code field indicates successful; otherwise, it is not present.

The Dynamic Bandwidth Control element specifies the information of the STA operating on a 1.08 GHz channel after channel splitting and is defined in 9.4.2.220. This element is present if the Status Code field indicates successful; otherwise, it is not present.

9.6.7.45 Group Addressed GAS Request frame format

The Group Addressed GAS Request frame is transmitted by a requesting STA to request information from another STA. The format of the Group Addressed GAS Request frame Action field is defined in Table 9-396.

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Table 9-396—Group Addressed GAS Request frame Action field format

Order	Information
0	Category
1	Public Action
2	Dialog Token
3	Advertisement Protocol element
4	Query Request Length
5	Query Request
6	Multi-band (optional)
7	GAS Extension

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is defined in 9.4.1.12 and set by the requesting STA.

The Advertisement Protocol element is defined in 9.4.2.92. The Advertisement Protocol element includes exactly one advertisement protocol ID.

The Query Request Length field format is provided in Figure 9-877. The Query Request Length field is set to the total number of octets in the Query Request field.

The Query Request field format is provided in Figure 9-878. The Query Request field is a generic container whose value is formatted in accordance with the protocol identified in the Advertisement Protocol element.

When present in a Group Addressed GAS Request frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the Group Addressed GAS Request frame applies.

The GAS Extension element indicates parameters that the AP or PCP may use to transmit a response back to the requesting STA.

9.6.7.46 Group Addressed GAS Response frame format

The Group Addressed GAS Response frame is transmitted in response to a GAS Initial Request frame or Group Addressed GAS Request frame. The format of the Group Addressed GAS Response frame Action field is defined in Table 9-397.

Table 9-397—Group Addressed GAS Response frame Action field format

Order	Information
0	Category
1	Public Action
2	Dialog Token

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Table 9-397—Group Addressed GAS Response frame Action field format *(continued)*

Order	Information
3	Status Code
4	Advertisement Protocol element
5	Query Response Length
6	Query Response
7	Multi-band (optional)
8	GAS Extension

The Category field is defined in 9.4.1.11.

The Public Action field is defined in 9.6.7.1.

The Dialog Token field is copied from the corresponding GAS Initial Request frame or Group Addressed GAS Request frame.

The Status Code values are defined in 9.4.1.9.

The Advertisement Protocol element is defined in 9.4.2.92. The Advertisement Protocol element includes exactly one advertisement protocol ID.

The Query Response Length field format is provided in Figure 9-880. The value of the Query Response Length field is set to the total number of octets in the Query Response field.

The Query Response field format is provided in Figure 9-881. The Query Response field is a generic container whose value is formatted in accordance with the protocol specified in the Advertisement Protocol element.

When present in a Group Addressed GAS Response frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the GAS Initial Response frame applies.

When present in a Group Addressed GAS Response frame, the GAS Extension element indicates parameters to which STA and which Query Request of the STA the response is responding.

9.6.7.47 On-channel Tunnel Request frame format

The On-channel Tunnel Request frame allows nonrobust STA-STA communications of the same information that is conveyed in the robust On-channel Tunnel Request frame (see 9.6.20.7).

The format of the robust and nonrobust On-channel Tunnel Request frame is the same and defined in 9.6.20.7. The Category field value differentiates whether an On-channel Tunnel Request frame is robust or not.

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9.6.8 FT Action frame details

9.6.8.1 General

Four Action frame formats are defined to support fast BSS transitions over the DS, which are initiated through the currently associated AP. The FT Action frames are sent over the air between the STA and the current AP. The Action frame is used as a transport mechanism for data that are destined for the target AP. An FT Action field, in the octet immediately after the Category field, differentiates the FT Action frame formats. The FT Action field values associated with each FT Action frame format are defined in Table 9-398.

Table 9-398—FT Action field values

FT Action field value	Description
0	Reserved
1	FT Request frames
2	FT Response frames
3	FT Confirm frames
4	FT Ack frames
5–255	Reserved

9.6.8.2 FT Request frame

The FT Request frame is sent by the STA to its associated AP to initiate an over-the-DS fast BSS transition.

Figure 9-910 shows the format of the FT Request frame Action field.

	Category	FT Action	STA Address	Target AP Address	FT Request frame body
Octets:	1	1	6	6	variable

Figure 9-910—FT Request frame Action field format

The Category field is defined in 9.4.1.11.

The FT Action field is defined in 9.6.8.1.

The STA Address field is set to the fast BSS transition originator's (FTO's) MAC address.

The Target AP Address field is set to the BSSID value of the target AP.

The FT Request frame body contains the information shown in Table 9-399.

The usage of these elements is defined in 13.8.2.

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Table 9-399—FT Request frame body

Order	Information	Notes
1	RSN	A RSNE is present if dot11RSNAActivated is true.
2	Mobility Domain	The MDE is present.
3	Fast BSS Transition	An FTE is present if dot11RSNAActivated is true.

9.6.8.3 FT Response frame

The FT Response frame is transmitted by the currently associated AP as a response to the STA's FT Request frame. Figure 9-911 shows the format of the FT Response frame Action field.

	Category	FT Action	STA Address	Target AP Address	Status Code	FT Response frame body
Octets:	1	1	6	6	2	variable

Figure 9-911—FT Response frame Action field format

The Category field is defined in 9.4.1.11.

The FT Action field is defined in 9.6.8.1.

The STA Address field is set to the FTO's MAC address.

The Target AP Address field is set to the BSSID value of the target AP.

The Status Code field is a value from the options listed in 9.4.1.9.

If the Status Code field is SUCCESS, then the FT Response frame body contains the information shown in Table 9-400.

Table 9-400—FT Response frame body

Order	Information	Notes
1	RSN	The RSNE is present if dot11RSNAActivated is true.
2	Mobility Domain	The MDE is present.
3	Fast BSS Transition	An FTE is present if dot11RSNAActivated is true.

The usage of these elements is defined in 13.8.3.

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9.6.8.4 FT Confirm frame

The FT Confirm frame in an RSN is confirmation to the target AP of receipt of the ANonce and indicates the liveness of the PTKSA. The FT Confirm frame is optionally used by the FTO to request resources. Figure 9-912 shows the FT Confirm frame Action field format.

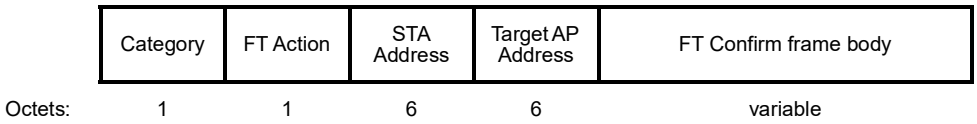

Figure 9-912—FT Confirm frame Action field format

The Category field is defined in 9.4.1.11.

The FT Action field is defined in 9.6.8.1.

The STA Address field is set to the FTO's MAC address.

The Target AP Address field is set to the BSSID value of the target AP.

The FT Confirm frame body contains the information shown in Table 9-401.

Table 9-401—FT Confirm frame body

Order	Information	Notes
1	RSN	The RSNE is present if dot11RSNAActivated is true.
2	Mobility Domain	The MDE is present.
3	Fast BSS Transition	An FTE is present if dot11RSNAActivated is true.
4	RIC	The RIC Request field is present if resources are being requested.

The usage of these elements is defined in 13.8.4.

9.6.8.5 FT Ack frame

The FT Ack frame is transmitted by the currently associated AP as a response to the STA's FT Confirm frame. Figure 9-913 shows the FT Ack frame Action field format.

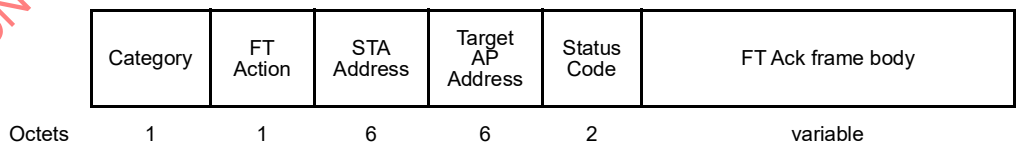

Figure 9-913—FT Ack frame Action field format

The Category field is defined in 9.4.1.11.

The FT Action field is defined in 9.6.8.1.

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The STA Address field is set to the FTO's MAC address.

The Target AP Address field is set to the BSSID value of the target AP.

The Status Code field is a value from the options listed in 9.4.1.9.

If the Status Code field is SUCCESS, then the FT Ack frame body contains the information shown in Table 9-402.

Table 9-402—FT Ack frame body

Order	Information	Notes
1	RSN	The RSNE is present if dot11RSNAActivated is true.
2	Mobility Domain	The MDE is present.
3	Fast BSS Transition	An FTE is present if dot11RSNAActivated is true.
4	Timeout Interval (reassociation deadline)	A TIE containing the reassociation deadline interval is present if resources were requested in the FT Confirm frame and dot11RSNAActivated is false.
5	RIC	The RIC Response field is present if resources were requested in the FT Confirm frame.

The usage of these elements is defined in 13.8.5.

9.6.9 SA Query Action frame details

9.6.9.1 General

Two Action frame formats are defined for the SA Query procedure. An SA Query Action field, in the field immediately after the Category field, differentiates the formats. The Action field values associated with each frame format are defined in Table 9-403.

NOTE—The SA query functionality defined in this standard is used to prevent the Association Lockout problem (defined in 11.3).

Table 9-403—SA Query Action field values

SA Query Action field value	Description
0	SA Query Request
1	SA Query Response

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9.6.9.2 SA Query Request frame

The SA Query Request frame is used to request an SA Query Response from the receiving STA. The format of the Action field of the SA Query Request frame is shown in Figure 9-914.

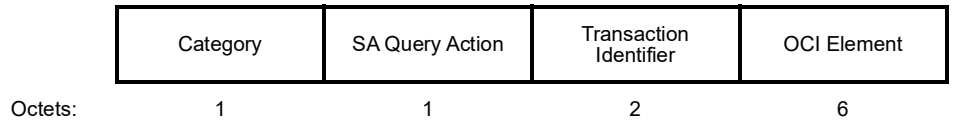

Figure 9-914—SA Query Request frame Action field format

The Category field is defined in 9.4.1.11.

The SA Query Action field is defined in 9.6.9.1.

The Transaction Identifier field is a 16-bit non-negative counter value set by the STA sending the SA Query Request frame to identify any outstanding request/response transaction.

The OCI Element field includes the OCI element (see 9.4.2.236) and is included if dot11RSNAOperatingChannelValidationActivated is true.

9.6.9.3 SA Query Response frame

The SA Query Response frame is used to respond to an SA Query Request frame from another STA. The format of the Action field of the SA Query Response frame is shown in Figure 9-915.

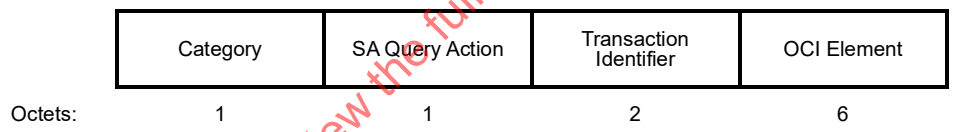

Figure 9-915—SA Query Response frame Action field format

The Category field is defined in 9.4.1.11.

The SA Query Action field is defined in 9.6.9.1.

The Transaction Identifier field is set to the same value as the Transaction Identifier field in the corresponding SA Query Request frame.

The OCI Element field includes the OCI element (see 9.4.2.236) and is included if dot11RSNAOperatingChannelValidationActivated is true.

9.6.10 Protected Dual of Public Action frames

The Protected Dual of Public Action frame is defined to allow robust STA-STA communications of the same information that is conveyed in Action frames that are not robust (see 9.4.1.11). A Public Action field, in the octet immediately after the Category field, differentiates the Protected Dual of Public Action frame formats. The defined Protected Dual of Public Action frames are listed in Table 9-404.

The Protected Dual of Public Action frames have the same format as the corresponding nonprotected Public Action frame.

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Table 9-404—Public Action field values defined for Protected Dual of Public Action frames

Public Action field value	Description	Defined in
0	Reserved	
1	Protected DSE Enablement	9.6.7.4
2	Protected DSE Deenablement	9.6.7.5
3	Reserved	
4	Protected Extended Channel Switch Announcement	9.6.7.7
5	Protected Measurement Request	9.6.7.8
6	Protected Measurement Report	9.6.7.9
7	Reserved	
8	Protected DSE Power Constraint	9.6.7.10
9	Protected Vendor Specific	9.6.7.11
10	Protected GAS Initial Request	9.6.7.12
11	Protected GAS Initial Response	9.6.7.13
12	Protected GAS Comeback Request	9.6.7.14
13	Protected GAS Comeback Response	9.6.7.15
14–15	Reserved	
16	QAB Request	9.6.7.34
17	QAB Response	9.6.7.35
18	Protected QMF Policy	9.6.7.18
19	Protected QMF Policy Change	9.6.7.19
20	Protected QLoad Request	9.6.7.20
21	Protected QLoad Report	9.6.7.21
22	Protected HCCA TXOP Advertisement	9.6.7.22
23	Protected HCCA TXOP Response	9.6.7.23
24	Reserved	
25	Protected Channel Availability Query	9.6.7.25
26	Protected Channel Schedule Management	9.6.7.26
27	Protected Contact Verification Signal	9.6.7.27
28	Protected GDD Enablement Request	9.6.7.28
29	Protected GDD Enablement Response	9.6.7.29
30	Protected Network Channel Control	9.6.7.30
31	Protected White Space Map Announcement	9.6.7.31
32–255	Reserved	

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9.6.11 HT Action frame details

9.6.11.1 HT Action field

Several Action frame formats are defined to support HT features. An HT Action field, in the octet immediately after the Category field, differentiates the HT Action frame formats. The HT Action field values associated with each frame format within the HT category are defined in Table 9-405. The frame formats are defined in 9.6.11.2 to 9.6.11.8.

Table 9-405—HT Action field values

HT Action field value	Meaning	Time priority
0	Notify Channel Width	No
1	SM Power Save	No
2	PSMP	Yes
3	Reserved	—
4	CSI	Yes
5	Noncompressed Beamforming	Yes
6	Compressed Beamforming	Yes
7	ASEL Indices Feedback	Yes
8–255	Reserved	—

9.6.11.2 Notify Channel Width frame format

A STA sends the Notify Channel Width frame to another STA if it wants to change the channel width of frames that the other STA sends to it. See definition in 11.15.2.

The format of the Notify Channel Width frame Action field is defined in Table 9-406.

Table 9-406—Notify Channel Width frame Action field format

Order	Information
1	Category
2	HT Action
3	Channel Width (see 9.4.1.21)

This frame can be sent by both non-AP STA and AP.

The Category field is defined in 9.4.1.11.

The HT Action field is defined in 9.6.11.1.

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9.6.11.3 SM Power Save frame format

The SM Power Save frame is of category HT. The SM Power Save frame is used to manage SM power-saving state transitions as defined in 11.2.6.

The Action field of the SM Power Save frame is defined in Table 9-407.

Table 9-407—SM Power Save frame Action field format

Order	Information
1	Category
2	HT Action
3	SM Power Control (see 9.4.1.23)

The Category field is defined in 9.4.1.11.

The HT Action field is defined in 9.6.11.1.

9.6.11.4 PSMP frame format

PSMP is obsolete. Support for this mechanism might be removed in a later revision of the standard.

The DA field of this frame is a group address. (See 10.3022.8.)

The PSMP Parameter Set field and PSMP STA Info fields define zero or more PSMP-DTT and PSMP-UTT time allocations that follow immediately after the PSMP frame.

The Action field of this frame is defined in Table 9-408. The PSMP Parameter Set field is followed by zero or more PSMP STA Info fields.

Table 9-408—PSMP frame Action field format

Order	Information
1	Category
2	HT Action
3	PSMP Parameter Set (see 9.4.1.24)
4	PSMP STA Info (see 9.4.1.25) Repeated N_STA times (N_STA is a subfield of the PSMP Parameter Set field)

The Category field is defined in 9.4.1.11.

The HT Action field is defined in 9.6.11.1.

The PSMP STA Info fields within a PSMP frame are ordered by STA_INFO Type as follows: group addressed (STA_INFO Type=1) and then individually addressed (STA_INFO Type=2).

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9.6.11.5 CSI frame format

The CSI frame is an Action or an Action No Ack frame of category HT. The format of its Action field is defined in Table 9-409.

Table 9-409—CSI frame Action field format

Order	Information
1	Category
2	HT Action
3	MIMO Control (see 9.4.1.26)
4	CSI Report (see 9.4.1.27)

The Category field is defined in 9.4.1.11.

The HT Action field is defined in 9.6.11.1.

In a CSI frame, the fields of the MIMO Control field (see 9.4.1.26) are used as described in Table 9-55. The Codebook Information subfield is reserved in this frame.

9.6.11.6 Noncompressed Beamforming frame format

The Noncompressed Beamforming frame is an Action or an Action No Ack frame of category HT. The format of its Action field is defined in Table 9-410.

Table 9-410—Noncompressed Beamforming frame Action field format

Order	Information
1	Category
2	HT Action
3	MIMO Control (see 9.4.1.26)
4	Noncompressed Beamforming Report (see 9.4.1.28)

The Category field is defined in 9.4.1.11.

The HT Action field is defined in 9.6.11.1.

In a Noncompressed Beamforming frame, the fields of the MIMO Control field (see 9.4.1.26) are used as described in Table 9-55. The Codebook Information subfield is reserved in this frame.

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9.6.11.7 Compressed Beamforming frame format

The Compressed Beamforming frame is an Action or an Action No Ack frame of category HT. The format of its Action field is defined in Table 9-411.

Table 9-411—Compressed Beamforming frame Action field format

Order	Information
1	Category
2	HT Action
3	MIMO Control (see 9.4.1.26)
4	Compressed Beamforming Report (see 9.4.1.29)

The Category field is defined in 9.4.1.11.

The HT Action field is defined in 9.6.11.1.

In a Compressed Beamforming frame, the fields of the MIMO Control field (see 9.4.1.26) are used as described in Table 9-55. The Coefficient Size subfield is reserved in this frame.

9.6.11.8 Antenna Selection Indices Feedback frame format

The Antenna Selection Indices Feedback frame is an Action or Action No Ack frame of category HT. The format of its Action field is defined in Table 9-412.

Table 9-412—Antenna Selection Indices Feedback frame Action field format

Order	Information
1	Category
2	HT Action
3	Antenna Selection Indices (see 9.4.1.30)

The Category field is defined in 9.4.1.11.

The HT Action field is defined in 9.6.11.1.

9.6.12 TDLS Action field formats

9.6.12.1 General

Several Action field formats are defined to support TDLS. A TDLS Action field, in the octet immediately after the Category field, differentiates the TDLS Action field formats. The TDLS Action field values associated with each Action field format within the TDLS category are defined in Table 9-413.

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Table 9-413—TDLS Action field values

Action field value	Meaning
0	TDLS Setup Request
1	TDLS Setup Response
2	TDLS Setup Confirm
3	TDLS Teardown
4	TDLS Peer Traffic Indication
5	TDLS Channel Switch Request
6	TDLS Channel Switch Response
7	TDLS Peer PSM Request
8	TDLS Peer PSM Response
9	TDLS Peer Traffic Response
10	TDLS Discovery Request
11–255	Reserved

References to one of the TDLS Action field values as a frame, e.g., "TDLS Setup Request frame," denote a Data frame carrying a TDLS Action field and any Vendor Specific elements tunneled as described in 11.20.1.

9.6.12.2 TDLS Setup Request Action field format

The Action field of a TDLS Setup Request Action field contains the information shown in Table 9-414.

Table 9-414—Information for TDLS Setup Request Action field

Order	Information	Notes
1	Category	The Category field is defined in 9.4.1.11.
2	TDLS Action	The TDLS Action field is defined in 9.6.12.1.
3	Dialog Token	The Dialog Token field contains a unique nonzero value for the conversation between the STAs involved in this request. The dialog token is specified in 9.4.1.12.
4	Capability	The Capability field indicates the capabilities of the STA. The Capability field is defined in 9.4.1.4.
5	Supported Rates and BSS Membership Selectors	The Supported Rates and BSS Membership Selectors element indicates the rates that are supported by the STA. The Supported Rates and BSS Membership Selectors element is defined in 9.4.2.3.
6	Country	The Country element is present when dot11MultiDomainCapabilityActivated is true or dot11SpectrumManagementRequired is true. The Country element is defined in 9.4.2.8.

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Table 9-414—Information for TDLS Setup Request Action field *(continued)*

Order	Information	Notes
7	Extended Supported Rates and BSS Membership Selectors	The Extended Supported Rates and BSS Membership Selectors element is present whenever there are more than eight supported rates, and it is optionally present otherwise. The Extended Supported Rates and BSS Membership Selectors element is defined in 9.4.2.12.
8	Supported Channels	The Supported Channels element is present if the TDLS Channel Switching subfield is equal to 1. The Supported Channels element is defined in 9.4.2.17.
9	RSNE	The RSNE is present if security is required on the TDLS direct link (see 12.7.8.1). The RSNE is defined in 9.4.2.24.
10	Extended Capabilities	The Extended Capabilities element is present if any of the fields in this element are nonzero. The Extended Capabilities element is defined in 9.4.2.26.
11	QoS Capability	The QoS Capability element is present when dot11QosOptionImplemented is true and not present otherwise. The QoS Capability element is defined in 9.4.2.34.
12	FTE	The FTE is present if security is required on the TDLS direct link (see 12.7.8.1). The FTE is defined in 9.4.2.47.
13	Timeout Interval (TPK key lifetime)	The Timeout Interval element contains the TPK key lifetime and is present if security is required on the TDLS direct link (see 12.7.8.1). The Timeout Interval element is defined in 9.4.2.48.
14	Supported Operating Classes	The Supported Operating Classes element is present if the TDLS Channel Switching subfield is equal to 1.
15	HT Capabilities	The HT Capabilities element is defined in 9.4.2.55. The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true.
16	20/40 BSS Coexistence	The 20/40 BSS Coexistence element is defined in 9.4.2.59. The 20/40 BSS Coexistence element is optionally present.
17	Link Identifier	The Link Identifier element is specified in 9.4.2.61.
18	Multi-band	The Multi-band element is optionally present if dot11MultibandImplemented is true.
19	AID	The AID element containing the AID of the STA sending the frame is present if dot11VHTOptionImplemented or dot11S1GOptionImplemented is true.
20	VHT Capabilities	The VHT Capabilities element is present if dot11VHTOptionImplemented is true.
21	S1G Capabilities	S1G Capabilities element is optionally present if dot11S1GOptionImplemented is true.
22	EL Operation	EL Operation element is present if dot11S1GELOperationActivated is true.

The TDLS Setup Request Action field is encapsulated in a Data frame and transmitted to the recipient STA through the AP to request the setup of a TDLS direct link. See 11.20.

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9.6.12.3 TDLS Setup Response Action field format

The Action field of a TDLS Setup Response Action field contains the information shown in Table 9-415.

Table 9-415—Information for TDLS Setup Response Action field

Order	Information	Notes
1	Category	The Category field is defined in 9.4.1.11.
2	TDLS Action	The TDLS Action field is defined in 9.6.12.1.
3	Status Code	The Status Code is defined in 9.4.1.9.
4	Dialog Token	The dialog token is copied from the corresponding TDLS Setup Request. The dialog token is specified in 9.4.1.12.
5	Capability	The Capability field indicates the capabilities of the STA and is present when the Status Code is SUCCESS and is not present otherwise. The Capability field is defined in 9.4.1.4.
6	Supported Rates and BSS Membership Selectors	The Supported Rates and BSS Membership Selectors element indicates the rates that are supported by the STA and is present when the Status Code is SUCCESS and is not present otherwise.The Supported Rates and BSS Membership Selectors element is defined in 9.4.2.3.
7	Country	The Country element is present when Status Code is SUCCESS and either dot11MultiDomainCapabilityActivated is true or dot11SpectrumManagementRequired is true and is not present otherwise. The Country element is defined in 9.4.2.8.
8	Extended Supported Rates and BSS Membership Selectors	The Extended Supported Rates and BSS Membership Selectors element is present when there are more than 8 supported rates and Status Code is SUCCESS. It is optionally present when there are less than 8 supported rates and Status Code is SUCCESS. Otherwise it is not present. The Extended Supported Rates and BSS Membership Selectors element is defined in 9.4.2.12.
9	Supported Channels	The Supported Channels element is defined in 9.4.2.17. It is present if the TDLS Channel Switching subfield is equal to 1 and the Status Code is SUCCESS, and not present otherwise.
10	RSNE	The RSNE is present if security is required on the TDLS direct link (see 12.7.8.1) and the Status Code is SUCCESS, and not present otherwise. The RSNE is defined in 9.4.2.24.
11	Extended Capabilities	The Extended Capabilities element is present if any of the fields in this element are nonzero and the Status Code is SUCCESS, and not present otherwise. The Extended Capabilities element is defined in 9.4.2.26.
12	QoS Capability	The QoS Capability element is present when dot11QosOptionImplemented is true and the Status Code is SUCCESS and not present otherwise. The QoS Capability element is defined in 9.4.2.34.
13	FTE	The FTE is present if security is required on the TDLS direct link (see 12.7.8.1) and the Status Code is SUCCESS, and not present otherwise. The FTE is defined in 9.4.2.47.

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Table 9-415—Information for TDLS Setup Response Action field *(continued)*

Order	Information	Notes
14	Timeout Interval (TPK key lifetime)	The Timeout Interval element, containing the TPK key lifetime, is present if security is required on the TDLS direct link (see 12.7.8.1) and the Status Code is SUCCESS, and not present otherwise. The Timeout Interval element is defined in 9.4.2.48.
15	Supported Operating Classes	The Supported Operating Classes element is present if the TDLS Channel Switching subfield is equal to 1 and the Status Code is SUCCESS and not present otherwise.
16	HT Capabilities	The HT Capabilities element is present if dot11HighThroughputOptionImplemented is true and the Status Code is SUCCESS and is not present otherwise. The HT Capabilities element is defined in 9.4.2.55.
17	20/40 BSS Coexistence	The 20/40 BSS Coexistence element is optionally present if the Status Code is SUCCESS and not present otherwise. The 20/40 BSS Coexistence element is defined in 9.4.2.59.
18	Link Identifier	The Link Identifier element is present if the Status Code is SUCCESS and not present otherwise. The Link Identifier is specified in 9.4.2.61.
19	Multi-band	The Multi-band element is optionally present if dot11MultibandImplemented is true and the Status Code is SUCCESS and not present otherwise.
20	AID	The AID element containing the AID of the STA sending the frame is present if dot11VHTOptionImplemented or dot11S1GOptionImplemented is true and the Status Code is SUCCESS and not present otherwise.
21	VHT Capabilities	The VHT Capabilities element is present if dot11VHTOptionImplemented is true and the Status Code is SUCCESS and not present otherwise.
22	Operating Mode Notification	The Operating Mode Notification element is optionally present if the TDLS Setup Request frame contained an Extended Capabilities element with the Operating Mode Notification field is equal to 1.
23	S1G Capabilities	S1G Capabilities element is optionally present if dot11S1GOptionImplemented is true.
24	EL Operation	EL Operation element is present if dot11S1GELOperationActivated is true.

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The TDLS Setup Response Action field is encapsulated in a Data frame and transmitted to the TDLS initiator STA through the AP in response to a TDLS Setup Request Action field. See 11.20.

9.6.12.4 TDLS Setup Confirm Action field format

The Action field of a TDLS Setup Confirm Action field contains the information shown in Table 9-416.

The TDLS Setup Confirm Action field is encapsulated in a Data frame and transmitted to the TDLS responder STA through the AP in response to a TDLS Setup Response Action field. See 11.20.

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Table 9-416—Information for TDLS Setup Confirm Action field

Order	Information	Notes
1	Category	The Category field is defined in 9.4.1.11.
2	TDLS Action	The TDLS Action field is defined in 9.6.12.1.
3	Status Code	The Status Code is defined in 9.4.1.9.
4	Dialog Token	The dialog token is copied from the corresponding TDLS Setup Response. The dialog token is specified in 9.4.1.12.
5	RSNE	The RSNE is present if security is required on the TDLS direct link (see 12.7.8.1) and the Status Code is SUCCESS, and not present otherwise. The RSNE is defined in 9.4.2.24.
6	EDCA Parameter Set	The EDCA parameter set is present if QoS is supported on the TLDS direct link (see 12.7.8.1) . The EDCA Parameter Set element is specified in 9.4.2.28. It is present for Status Code SUCCESS.
7	FTE	The FTE is defined in 9.4.2.47. The FTE is present if security is required on the TDLS direct link (see 12.7.8.1) and the Status Code is SUCCESS, and not present otherwise.
8	Timeout Interval (TPK Key Lifetime)	The Timeout Interval element is defined in 9.4.2.48. The Timeout Interval containing the TPK Key Lifetime, is present if security is required on the direct link and the Status Code is SUCCESS, and not present otherwise.
9	HT Operation	The HT Operation element is present if dot11HighThroughputOptionImplemented is true, the TDLS Setup Response frame contained an HT Capabilities element, the Status Code is SUCCESS. The HT Operation element is defined in 9.4.2.56.
10	Link Identifier	The Link Identifier is specified in 9.4.2.61. It is present if the Status Code is SUCCESS.
11	VHT Operation	VHT Operation element (optional). The VHT Operation element is present if dot11VHTOptionImplemented is true, the TDLS Setup Response frame contained a VHT Capabilities element, the status code is SUCCESS, and the TDLS direct link is not established in the 2.4 GHz band. The VHT Operation element is defined in 9.4.2.158.
12	Operating Mode Notification	The Operating Mode Notification element is optionally present if the TDLS Setup Request frame contained an Extended Capabilities element with the Operating Mode Notification field is equal to 1.
13	S1G Operation	The S1G Operation element is present if dot11S1GOptionImplemented is true and the status code is 0 (Successful). The S1G Operation element is defined in 9.4.2.212.

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9.6.12.5 TDLS Teardown Action field format

The Action field of a TDLS Teardown Action field contains the information shown in Table 9-417.

Table 9-417—Information for TDLS Teardown Action field

Order	Information	Notes
1	Category	The Category field is defined in 9.4.1.11.
2	TDLS Action	The TDLS Action field is defined in 9.6.12.1.
3	Reason Code	The Reason Code is defined in 9.4.1.7.
4	FTE	The FTE is present if a TPK handshake was successful for this session. The FTE is defined in 9.4.2.47.
5	Link Identifier	The Link Identifier is specified in 9.4.2.61.

The TDLS Teardown Action field is encapsulated in a Data frame and transmitted to the TDLS peer STA directly or through the AP to tear down a TDLS direct link. See 11.20.

9.6.12.6 TDLS Peer Traffic Indication Action field format

The Action field of a TDLS Peer Traffic Indication Action field contains the information shown in Table 9-418.

Table 9-418—Information for TDLS Peer Traffic Indication Action field

Order	Information	Notes
1	Category	The Category field is defined in 9.4.1.11.
2	TDLS Action	The TDLS Action field is defined in 9.6.12.1.
3	Dialog Token	The dialog token is specified in 9.4.1.12.
4	Link Identifier	The Link Identifier is specified in 9.4.2.61.
5	PTI Control	The PTI Control element is optionally present. It is defined in 9.4.2.64.
6	TPU Buffer Status	The TPU Buffer Status element is defined in 9.4.2.65.

The TDLS Peer Traffic Indication Action field indicates the state of the power save buffer at the STA supporting TPU that is buffering data for a TDLS peer STA in power save mode.

The TPU Buffer Status element indicates the status of the AC buffers at the TPU buffer STA.

The PTI Control element is optionally included in the TDLS Peer Traffic Indication Action field (see 11.2.3.13) to identify the latest MPDU transmitted to the TPU sleep STA that is the destination of the TDLS Peer Traffic Indication Action field.

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The TDLS Peer Traffic Indication Action field is encapsulated in a Data frame and transmitted to the TDLS peer STA through the AP. See 11.2.3.13.

9.6.12.7 TDLS Channel Switch Request Action field format

The Action field of the TDLS Channel Switch Request Action field contains the information shown in Table 9-419.

Table 9-419—Information for TDLS Channel Switch Request Action field

Order	Information	Notes
1	Category	The Category field is defined in 9.4.1.11.
2	TDLS Action	The TDLS Action field is defined in 9.6.12.1.
3	Target Channel	1-octet field that specifies the channel number of the target channel. See 9.4.1.35.
4	Operating Class	1-octet field that specifies the operating class for the target channel. The Operating Channel field is defined in 9.4.1.36.
5	Secondary Channel Offset	The secondary channel offset is present if a switch to a 40 MHz direct link is indicated and is absent otherwise. See 9.4.2.19.
6	Link Identifier	The Link Identifier element is specified in 9.4.2.61.
7	Channel Switch Timing	The Channel Switch Timing element is specified in 9.4.2.63.
8	Wide Bandwidth Channel Switch	Wide Bandwidth Channel Switch element (optional). The Wide Bandwidth Channel Switch element is included when a switch to an 80 MHz, 160 MHz, or 80+80 MHz direct link is indicated. See 9.4.2.160.
9	Country	Country element (optional). The Country element is included to change operating classes when a switch to a direct link is indicated. The Country element indicates the same country as the BSS and includes zero Subband Triplet fields.
10	Transmit Power Envelope	Transmit Power Envelope element (zero or more). Each Transmit Power Envelope element that is present includes a distinct value of the Local Maximum Transmit Power Unit Interpretation subfield. If present, the New Transmit Power Envelope element indicates the maximum transmit powers for the direct link for the indicated bandwidths with an indicated unit interpretation after a switch to a direct link (see 11.20.6.5.1).

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The TDLS Channel Switch Request Action field is encapsulated in a Data frame and transmitted directly to the TDLS peer STA to request for the TDLS direct link to be switched to another channel. See 11.20.

9.6.12.8 TDLS Channel Switch Response Action field format

The Action field of the TDLS Channel Switch Response Action field contains the information shown in Table 9-420.

The TDLS Channel Switch Response Action field is encapsulated in a Data frame and transmitted directly to the TDLS peer STA in response to a TDLS Channel Switch Request Action field. See 11.20.

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Table 9-420—Information for TDLS Channel Switch Response Action field

Order	Information	Notes
1	Category	The Category field is defined in 9.4.1.11.
2	TDLS Action	The TDLS Action field is defined in 9.6.12.1.
3	Status Code	The Status Code is defined in 9.4.1.9.
5	Link Identifier	The Link Identifier element is specified in 9.4.2.61. It is present if the Status Code is SUCCESS.
6	Channel Switch Timing	The Channel Switch Timing element is specified in 9.4.2.63.

9.6.12.9 TDLS Peer PSM Request Action field format

The TDLS Peer PSM Request Action field contains the information shown in Table 9-421.

Table 9-421—Information for TDLS Peer PSM Request Action field

Order	Information	Notes
1	Category	The Category field is defined in 9.4.1.11.
2	TDLS Action	The TDLS Action field is defined in 9.6.12.1.
3	Dialog Token	The Dialog Token field contains a value that is unique among TDLS Peer PSM Request Action fields for which a corresponding TDLS Peer PSM Response Action field has not been received. The dialog token is specified in 9.4.1.12.
4	Link Identifier	The Link Identifier element is specified in 9.4.2.61.
5	Wakeup Schedule	The Wakeup Schedule element is specified in 9.4.2.62.

The TDLS Peer PSM Request Action field is encapsulated in a Data frame and transmitted to the TDLS peer STA, directly or through the AP, to set up or change a periodic wakeup schedule on the TDLS direct link. See 11.2.3.12.

9.6.12.10 TDLS Peer PSM Response Action field format

The TDLS Peer PSM Response Action field contains the information shown in Table 9-422.

Table 9-422—Information for TDLS Peer PSM Response Action field

Order	Information	Notes
1	Category	The Category field is defined in 9.4.1.11.
2	TDLS Action	The TDLS Action field is defined in 9.6.12.1.
3	Dialog Token	The dialog token is set to the value contained in the corresponding TDLS Peer PSM Request Action field. The dialog token is specified in 9.4.1.12.

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Table 9-422—Information for TDLS Peer PSM Response Action field *(continued)*

Order	Information	Notes
4	Status Code	The Status Code is specified in 9.4.1.9.
5	Link Identifier	The Link Identifier element is specified in 9.4.2.61. It is present if the Status Code is SUCCESS.
6	Wakeup Schedule	The Wakeup Schedule element is present is present if the status code is set to TDLS_REJECTED_ALTERNATIVE_PROVIDED and is not present otherwise. The Wakeup Schedule element is specified in 9.4.2.62.

The TDLS Peer PSM Response Action field is encapsulated in a Data frame and transmitted to the TDLS peer STA directly in response to a TDLS Peer PSM Request Action field. See 11.2.3.12.

9.6.12.11 TDLS Peer Traffic Response Action field format

The Action field of a TDLS Peer Traffic Response Action field contains the information shown in Table 9-423.

Table 9-423—Information for TDLS Peer Traffic Response Action field

Order	Information	Notes
1	Category	The Category field is defined in 9.4.1.11.
2	TDLS Action	The TDLS Action field is defined in 9.6.12.1.
3	Dialog Token	The dialog token is specified in 9.4.1.12.
4	Link Identifier	The Link Identifier element is specified in 9.4.2.61.

The TDLS Peer Traffic Response Action field indicates the receipt of the corresponding TDLS Peer Traffic Indication Action field.

The Dialog Token field is set to the nonzero value of the corresponding TDLS Peer Traffic Indication Action field.

The Link Identifier field is set to identify the TDLS direct link in relation to which the TDLS Peer Traffic Response Action field is transmitted.

The TDLS Peer Traffic Response Action field is encapsulated in a Data frame and transmitted to the TDLS peer STA directly. See 11.2.3.13.

9.6.12.12 TDLS Discovery Request Action field format

The TDLS Discovery Request Action field contains the information shown in Table 9-424.

The TDLS Discovery Request Action field is encapsulated in a Data frame and transmitted to a TDLS peer STA through the AP, to request TDLS STAs in the same BSS to respond with a TDLS Discovery Response frame. See 11.20.

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Table 9-424—Information for TDLS Discovery Request Action field

Order	Information	Notes
1	Category	The Category field is defined in 9.4.1.11.
2	TDLS Action	The TDLS Action field is defined in 9.6.12.1.
3	Dialog Token	The Dialog Token field can be used to match TDLS Discovery Response frames to the corresponding TDLS Discovery Request frame. The dialog token is specified in 9.4.1.12.
4	Link Identifier	The Link Identifier element is specified in 9.4.2.61.
5	Multi-band	The Multi-band element is optionally present if dot11MultibandImplemented is true.

9.6.13 WNM Action details

9.6.13.1 WNM Action fields

Several Action frame formats are defined for wireless network management (WNM) purposes. A WNM Action field, in the field immediately after the Category field, differentiates the formats. The WNM Action field values associated with each frame format are defined in Table 9-425.

Table 9-425—WNM Action field values

WNM Action field value	Description
0	Event Request
1	Event Report
2	Diagnostic Request
3	Diagnostic Report
4	Location Configuration Request
5	Location Configuration Response
6	BSS Transition Management Query
7	BSS Transition Management Request
8	BSS Transition Management Response
9	FMS Request
10	FMS Response
11	Collocated Interference Request
12	Collocated Interference Report
13	TFS Request
14	TFS Response
15	TFS Notify
16	WNM Sleep Mode Request

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Table 9-425—WNM Action field values *(continued)*

WNM Action field value	Description
17	WNM Sleep Mode Response
18	TIM Broadcast Request
19	TIM Broadcast Response
20	QoS Traffic Capability Update
21	Channel Usage Request
22	Channel Usage Response
23	DMS Request
24	DMS Response
25	Timing Measurement Request
26	WNM Notification Request
27	WNM Notification Response
28–255	Reserved

9.6.13.2 Event Request frame format

The Event Request frame is transmitted to request another STA to report one or more events. The format of the Event Request frame Action field is shown in Figure 9-916.

	Category	WNM Action	Dialog Token	Event Request Elements	Destination URI Element (optional)
Octets:	1	1	1	variable	variable

Figure 9-916—Event Request frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is a nonzero value chosen by the STA sending the event request to identify the request/report transaction.

The Event Request Elements field contains one or more of the Event Request elements described in 9.4.2.66.

The Destination URI element field contains zero or one Destination URI elements described in 9.4.2.89.

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9.6.13.3 Event Report frame format

The Event Report frame is transmitted in response to an Event Request frame, or autonomously. The format of the Event Report frame Action field is shown in Figure 9-917.

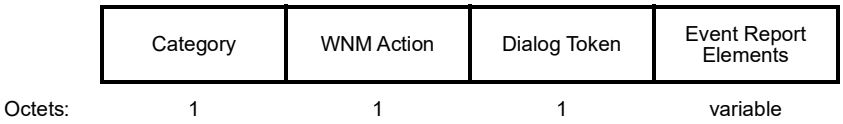

Figure 9-917—Event Report frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is the nonzero value of the corresponding Event Request frame. If the Event Report frame is being transmitted other than in response to an Event Request frame, then the dialog token is 0.

The Event Report Elements field contains one or more of the Event Report elements described in 9.4.2.67.

9.6.13.4 Diagnostic Request frame format

The Diagnostic Request frame is transmitted requesting the receiving STA to execute a diagnostic test. The format of the Diagnostic Request frame Action field is shown in Figure 9-918.

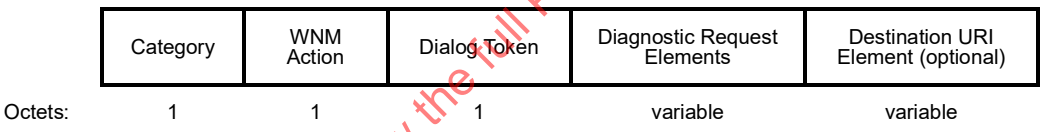

Figure 9-918—Diagnostic Request frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is a nonzero value chosen by the STA sending the Diagnostic Request frame to identify the request/report transaction.

The Diagnostic Request Elements field contains one or more of the Diagnostic Request elements described in 9.4.2.68. The number and length of the Diagnostic Request elements in a Diagnostic Request frame is limited by the maximum MMPDU size (see 9.3.3.1).

The Destination URI element field contains zero or one Destination URI elements described in 9.4.2.89.

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9.6.13.5 Diagnostic Report frame format

The Diagnostic Report frame is transmitted by a STA in response to a Diagnostic Request frame. The format of the Diagnostic Report frame Action field is shown in Figure 9-919.

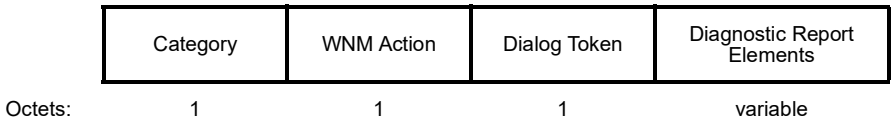

Figure 9-919—Diagnostic Report frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is the nonzero value in any corresponding Diagnostic Request frame.

The Diagnostic Report Elements field contains one or more of the Diagnostic Report elements described in 9.4.2.69. The number and length of the Diagnostic Report elements in a Diagnostic Report frame is limited by the maximum MMPDU size (see 9.3.3.1).

9.6.13.6 Location Configuration Request frame format

The Location Configuration Request frame is transmitted to configure another STA to send a Location Track Notification frame on a set of channels periodically for the purposes of determining location of the STA. The format of the Location Configuration Request frame Action field is shown in Figure 9-920.

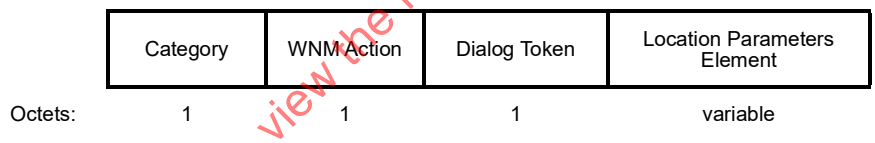

Figure 9-920—Location Configuration Request frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is a nonzero value that is unique among the Location Configuration Request frames sent to each destination MAC address for which a corresponding Location Configuration Response frame has not been received.

The Location Parameters Element field contains the location parameters subelements, described in 9.4.2.70. Table 9-426 defines the allowed Location Parameters subelements for a Location Parameters element that is included in the Location Configuration Request frame.

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Table 9-426—Location Parameters Element field for Location Configuration Request frame

Allowed subelements	Subelement ID	Notes
Location Indication Parameters	1	The Location Indication Parameters subelement is included in the Location Configuration Request frame.
Location Indication Channels	2	The Location Indication Channels subelement is included in the Location Configuration Request frame.
Location Indication Broadcast Data Rate	6	The Location Indication Broadcast Data Rate subelement is included in the Location Configuration Request frame.
Location Indication Options	8	The Location Indication Options subelement is optionally included in the Location Configuration Request frame.
Vendor Specific Information	221	Zero or more Vendor Specific subelements are included in the Location Configuration Request frame.

9.6.13.7 Location Configuration Response frame format

The Location Configuration Response frame is transmitted in response to a Location Configuration Request frame. The format of the Location Configuration Response frame Action field is shown in Figure 9-921.

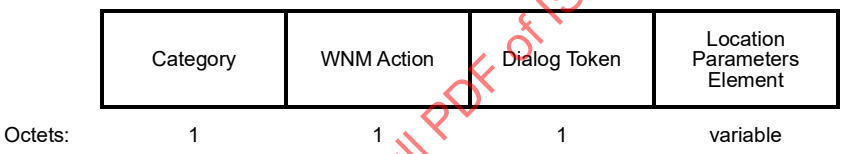

Figure 9-921—Location Configuration Response frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is the nonzero value received in the Location Configuration Request frame to identify the request/response transaction.

The Location Parameters Element field contains the location parameters subelements, described in 9.4.2.70. Table 9-427 defines the allowed Location Parameters subelements for a Location Parameters element that is included in the Location Configuration Response frame.

Table 9-427—Location Parameters Element field for Location Configuration Response frame

Allowed subelements	Subelement ID	Notes
Location Indication Parameters	1	The Location Indication Parameters subelement is optionally included in the Location Configuration Response frame.
Location Indication Channels	2	The Location Indication Channels subelement is optionally included in the Location Configuration Response frame.

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Table 9-427—Location Parameters Element field for Location Configuration Response frame *(continued)*

Allowed subelements	Subelement ID	Notes
Location Indication Broadcast Data Rate	6	The Location Indication Broadcast Data Rate subelement is optionally included in the Location Configuration Response frame.
Location Indication Options	8	The Location Indication Options subelement is optionally included in the Location Configuration Response frame.
Location Status	3	The Location Status subelement is included in the Location Configuration Response frame. If all configuration of the subelements contained in a Location Configuration Request frame was successful, then a single Location Status subelement is included in the Location Configuration Response frame. For each subelement contained in the Location Configuration Request frame that is not successful a Location Status subelement is included in the Location Configuration Response frame that indicates the subelement ID and the unsuccessful status code for that subelement ID.
Vendor Specific Information	221	Zero or more Vendor Specific subelements are included in the Location Configuration Response frame.

9.6.13.8 BSS Transition Management Query frame format

The BSS Transition Management Query frame is transmitted to request or provide information on BSS transition candidate APs. The format of the BSS Transition Management Query frame Action field is shown in Figure 9-922.

	Category	WNM Action	Dialog Token	BSS Transition Query Reason	BSS Transition Candidate List Entries (Optional)
Octets:	1	1	1	1	variable

Figure 9-922—BSS Transition Management Query frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is a nonzero value chosen by the STA sending the BSS Transition Management Query frame to identify the query/request/response transaction.

The BSS Transition Query Reason field contains the reason code for a BSS transition management query as defined in Table 9-198.

The BSS Transition Candidate List Entries field contains zero or more Neighbor Report elements, as described in 9.4.2.36. The Neighbor Report elements are collected by the STA as part of its scanning procedures and provided to the AP as described in 11.21.7.2. The length of the BSS Transition Candidate List Entries field in a BSS Transition Management Query frame is limited by the maximum MMPDU size (see 9.3.3.1).

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9.6.13.9 BSS Transition Management Request frame format

The BSS Transition Management Request frame is transmitted by an AP in response to a BSS Transition Management Query frame, or autonomously. The format of the BSS Transition Management Request frame Action field is shown in Figure 9-923.

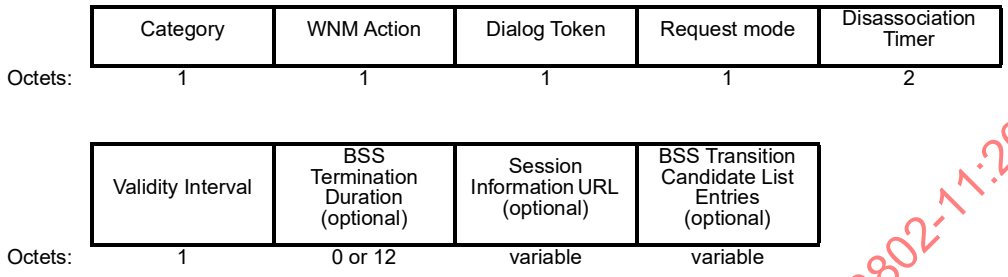

Figure 9-923—BSS Transition Management Request frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is the nonzero value received in the BSS Transition Management Query frame if the BSS Transition Management Request frame is being transmitted in response to a BSS Transition Management Query frame. If the BSS Transition Management Request frame is being transmitted other than in response to a BSS Transition Management Query frame, then the Dialog Token field is a nonzero value chosen by the AP sending the BSS Transition Management Request frame to identify the request/response transaction.

The Request mode field is defined in Figure 9-924.

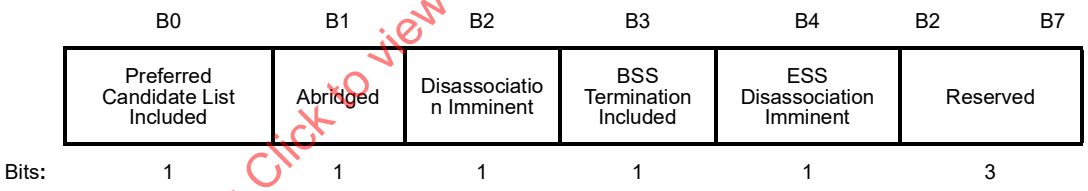

Figure 9-924—Request Mode field format

— The Preferred Candidate List Included (bit 0) field indicates whether the BSS transition candidate list included in this frame is a preferred candidate list or a list of known BSS transition candidates. The Preferred Candidate List Included bit set to 0 indicates that the receiving STA can ignore the BSS Transition Candidate List Entries field (see 11.21.7.3). The Preferred Candidate List Included bit set to 1 indicates that the sender expects the receiving STA to process this frame.

— The Abridged (bit 1) field indicates to the recipient of the frame the intended treatment of all BSSIDs not listed in the BSS Transition Candidate List Entries field. The AP sets the Abridged bit in the Request Mode field to 1 when a preference value of 0 is assigned to all BSSIDs that do NOT appear in the BSS Transition Candidate List. The AP sets the Abridged bit in the Request Mode field to 0 when the AP has no recommendation for or against any BSSID not present in the BSS Transition Candidate List Entries field.

— The Disassociation Imminent (bit 2) field indicates whether the STA will be disassociated from the current AP. The value 1 in the Disassociation Imminent bit in the Request Mode field indicates that

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the STA is to be disassociated from the current AP, while the value 0 indicates that disassociation from the AP is not imminent.

— The BSS Termination Included (bit 3) field indicates that the BSS Termination Duration field is included, the BSS is shutting down and the STA will be disassociated. The AP sets the BSS Termination Included bit in the Request mode field to 1 to indicate that the BSS is shutting down. The BSS Termination Included bit is 0 if no BSS Termination Duration information is included in the BSS Transition Management Request frame.

— The ESS Disassociation Imminent (bit 4) field indicates that the Session Information URL field is included, and that the STA will be disassociated from the ESS. The value 1 in the ESS Disassociation Imminent bit in the Request Mode field indicates that the STA is to be disassociated from the ESS, while the value 0 indicates that disassociation from the ESS is not imminent. When the ESS Disassociation Imminent bit value is 1, a Session Information URL field is included in the BSS Transition Management Request frame.

The Disassociation Timer indicates the time after which the AP issues a Disassociation frame to this STA. The Disassociation Timer field contains the number of beacon transmission times (TBTTs) until the AP sends a Disassociation frame to this STA. Setting the field to 0 indicates that the AP has not determined when it will send a Disassociation frame to this STA. If the Disassociation Imminent field is 0, the Disassociation Timer field is reserved. The format of the Disassociation Timer field is shown in Figure 9-925.

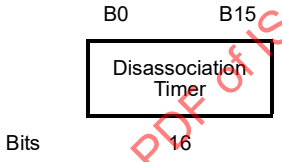

Figure 9-925—Disassociation Timer field format

The Validity Interval field is the number of beacon transmission times (TBTTs) until the BSS transition candidate list is no longer valid. A value of 0 is reserved.

The BSS Termination Duration field contains the BSS Termination Duration subelement (see 9.4.2.36) for the current BSS and is present only when the BSS Termination Included field is 1 in the Request mode field.

The format of the optional Session Information URL field is shown in Figure 9-926. This field is present when the ESS Disassociation Imminent field is 1.

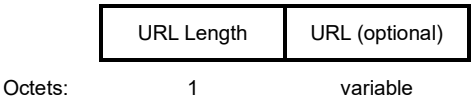

Figure 9-926—Session Information URL field format

The URL Length field is the value of the length of the URL field. The URL Length field is 0 when the URL field is not present.

The URL field is a variable length field formatted in accordance with IETF RFC 3986.

The BSS Transition Candidate List Entries field contains zero or more Neighbor Report elements described in 9.4.2.36. If the STA has no information in response to the BSS Transition Management Query frame or in an unsolicited BSS Transition Management Request frame, the Neighbor Report elements are omitted and

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the Preferred Candidate List Included bit is 0. The length of the BSS Transition Candidate List Entries in a BSS Transition Management Request frame is limited by the maximum MMPDU size (see 9.3.3.1).

9.6.13.10 BSS Transition Management Response frame format

The BSS Transition Management Response frame is optionally transmitted by a STA in response to a BSS Transition Management Request frame. The format of the BSS Transition Management Response frame Action field is shown in Figure 9-927.

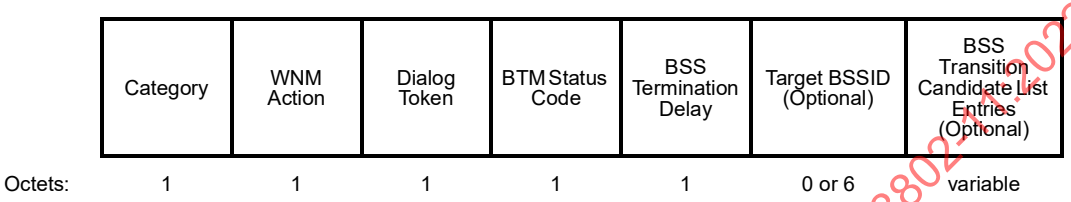

Figure 9-927—BSS Transition Management Response frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is the value in the corresponding BSS Transition Management Request frame. The BSS Transition Management Response frame is transmitted in response to a BSS Transition Management Request frame.

The BTM Status Code field contains the status code in response to a BSS Transition Management Request frame as defined in Table 9-428. If the STA will transition to another BSS, then the status code is 0 (i.e., Accept). If the STA intends to retain the association with the current BSS, the status code is one of the "Reject" status codes.

Table 9-428—BTM status code definitions

Status code	Status code description
0	Accept
1	Reject—Unspecified reject reason.
2	Reject—Insufficient Beacon or Probe Response frames received from all candidates.
3	Reject—Insufficient available capacity from all candidates.
4	Reject—BSS termination undesired.
5	Reject—BSS termination delay requested.
6	Reject—STA BSS Transition Candidate List provided.
7	Reject—No suitable BSS transition candidates.
8	Reject—Leaving ESS.
9–255	Reserved

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The BSS Termination Delay field is the number of minutes that the responding STA requests the BSS to delay termination. This field is reserved if the Status code field value is not set to 5.

The Target BSSID field is the BSSID of the BSS that the non-AP STA transitions to. This field is present if the Status code subfield contains 0, and not present otherwise.

The BSS Transition Candidate List Entries field contains zero or more Neighbor Report elements described in 9.4.2.36. The Neighbor Report elements are collected by the STA as part of its scanning procedures and provided to the AP as described in 11.21.7.4. The length of the BSS Transition Candidate List Entries field in a BSS Transition Management Response frame is limited by the maximum MMPDU size (see 9.3.3.1).

9.6.13.11 FMS Request frame format

The FMS Request frame is sent by a non-AP STA to the AP to request the specified FMS and to propose delivery intervals for a set of group addressed streams. The FMS Request frame is also sent by a non-AP STA to request a modification to a previous FMS Request. The format of the Action field of the FMS Request frame is shown in Figure 9-928.

	Category	WNM Action	Dialog Token	FMS Request Element
Octets:	1	1	1	variable

Figure 9-928—FMS Request frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is a nonzero value that is unique among the FMS Request frame sent to each destination MAC address for which a corresponding FMS Report frame has not been received.

The FMS Request Element field indicates the group addressed traffic streams that are requested by the non-AP STA. The FMS Request Element field contains one FMS Request element described in 9.4.2.75.

9.6.13.12 FMS Response frame format

The FMS Response frame is sent by an AP in response to an FMS Request frame, or sent by the AP to the STA to instruct the non-AP STA to change the delivery interval or data rate. The format of the Action field of the FMS Response frame is shown in Figure 9-929.

	Category	WNM Action	Dialog Token	FMS Response Element
Octets:	1	1	1	variable

Figure 9-929—FMS Response frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

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The Dialog Token field is the nonzero value received in the FMS Request frame to identify the request/response transaction. If an FMS Response frame is being transmitted other than in response to an FMS Request frame, then the Dialog Token field is 0.

The FMS Response Element indicates the group addressed traffic streams that the AP supports and the corresponding delivery intervals. The FMS Response Element field contains one FMS Response elements, described in 9.4.2.76.

9.6.13.13 Collocated Interference Request frame format

The Collocated Interference Request frame is transmitted to request collocated interference reports, sent using Collocated Interference Report frames. The format of the Collocated Interference Request frame Action field is shown in Figure 9-930.

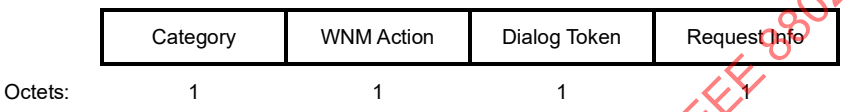

Figure 9-930—Collocated Interference Request frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is any nonzero value to identify the request/response transaction.

The Request Info field is shown in Figure 9-931.

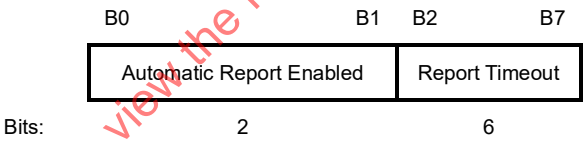

Figure 9-931—Request Info field format

The Automatic Report Enabled subfield contains an unsigned integer value.

The Automatic Report Enabled subfield set to 0 indicates that the requesting STA cancels the previous requests so that the receiving STA stops sending collocated interference reports.

The Automatic Report Enabled subfield set to 1 indicates that the requesting STA requests the receiving STA to send a collocated interference report when the STA knows of a change in the collocated interference, subject to meeting the Report Timeout requirement.

The Automatic Report Enabled subfield set to 2 indicates that the requesting STA requests the receiving STA to send a collocated interference report periodically using the period included in the Report Period field in the Collocated Interference Report element; see 9.4.2.84.

The Automatic Report Enabled subfield set to 3 indicates that the requesting STA requests the receiving STA to send collocated interference reports periodically using the period included in the Report Period field in the Collocated Interference Report element; see 9.4.2.84, or send a collocated interference report when the STA knows of a change in the collocated interference, subject to meeting the Report Timeout requirement.

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The Report Timeout field contains a value in units of 200 TUs and indicates the minimum duration between two consecutive Collocated Interference Report frames from the reporting STA. When the Automatic Report Enabled subfield is 0, the Report Timeout field is reserved.

9.6.13.14 Collocated Interference Report frame format

The Collocated Interference Report frame is transmitted in response to Collocated Interference Request frame. The format of the Collocated Interference Report frame Action field is shown in Figure 9-932.

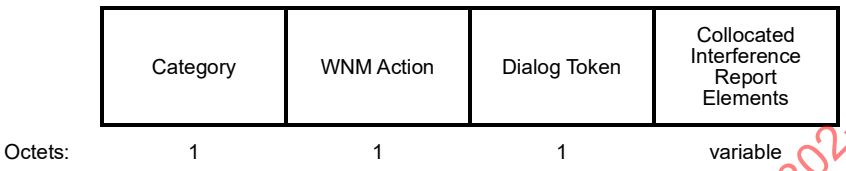

Figure 9-932—Collocated Interference Report frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is the nonzero value received in the corresponding Collocated Interference Request frame to identify the request/response transaction.

The Collocated Interference Report Elements field contains one or more Collocated Interference Report elements to indicate the characteristics of the reported collocated interferences, as defined in 9.4.2.84.

9.6.13.15 TFS Request frame format

The TFS Request frame is sent by a non-AP STA to the AP to request the specified traffic filtering. The format of the TFS Request frame Action field is defined in Figure 9-933.

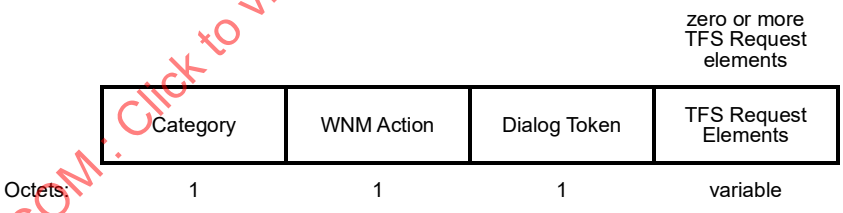

Figure 9-933—TFS Request frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is a value chosen by the STA sending the TFS Request frame to identify the request/response transaction.

The TFS Request Elements field contains one or more TFS Request elements to specify one or more traffic filter sets that are requested by the non-AP STA, as defined in 9.4.2.79, or zero TFS Request elements to cancel all of the existing traffic filter sets (see 11.21.12.2).

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9.6.13.16 TFS Response frame format

The TFS Response frame is sent by an AP in response to a TFS Request frame. The format of the TFS Response frame Action field is defined in Figure 9-934.

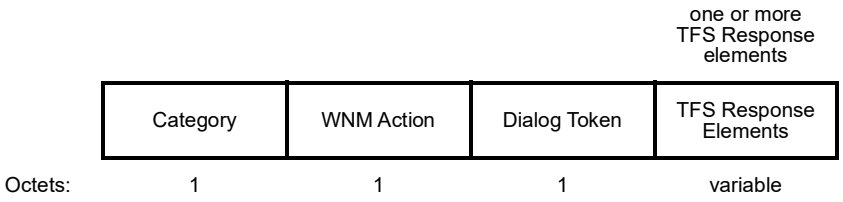

Figure 9-934—TFS Response frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is the value in the corresponding TFS Request frame.

The TFS Response Elements field contains one or more TFS Response elements to indicate the status of the filtering parameters that the AP is requested to support, as defined in 9.4.2.80. The number of TFS Response elements in a TFS Response frame is the same as the number of the TFS Request elements in the TFS Request frame with the same dialog token, where the TFS Response elements appear in the same order as the corresponding TFS Request elements in the TFS Request frame with the same dialog token.

9.6.13.17 TFS Notify frame format

The TFS Notify frame is sent by an AP to a STA when a frame matching a traffic filter is encountered. The format of the TFS Notify frame Action field is defined in Figure 9-935.

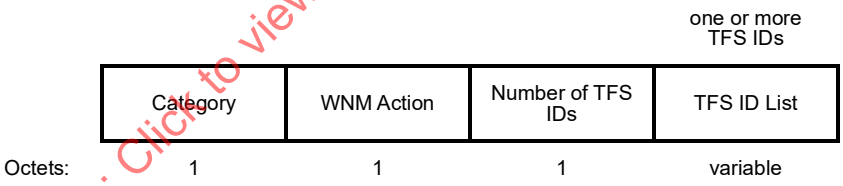

Figure 9-935—TFS Notify frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Number of TFS IDs field indicates the number of 1-octet TFS IDs present in the TFS ID List field.

The TFS ID field indicates the traffic filter set containing the matched TCLAS element.

9.6.13.18 TFS Notify Response frame format

A TFS Notify Response frame is transmitted by a non-AP STA to an AP to request the AP to resume generation of the TFS Notify frame when a frame matches any traffic filter set identified by the TFS ID(s) included in the TFS Notify Response frame. The format of the TFS Notify Response frame Action field is shown in Figure 9-936.

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	Category	WNM Action	Number of TFS IDs	TFS ID List
Octets:	1	1	1	variable

Figure 9-936—TFS Notify Response frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Number of TFS IDs field indicates the number of 1-octet TFS IDs present in the TFS ID List field.

The TFS ID List field indicates the identifiers of the traffic filter sets.

9.6.13.19 WNM Sleep Mode Request frame format

The WNM Sleep Mode Request frame is sent by a non-AP STA to the AP to enter the WNM sleep mode. The format of the WNM Sleep Mode Request frame Action field is defined in Figure 9-937.

	Category	WNM Action	Dialog Token	WNM Sleep Mode Element	TFS Request Elements (one or more TFS Request elements)	OCI Element (optional)
Octets:	1	1	1	6	variable	0 or 6

Figure 9-937—WNM Sleep Mode Request frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is a nonzero value chosen by the non-AP STA sending the WNM Sleep Mode Request frame to identify the request/response transaction.

The WNM Sleep Mode Element field contains a WNM Sleep Mode element that is requested by a non-AP STA, as described in 9.4.2.81.

The TFS Request Elements field contains one or more TFS Request elements to specify the traffic filters that are requested by a non-AP STA, as defined in 9.4.2.79.

The OCI Element field is optionally present, and contains an OCI element as defined in 9.4.2.236.

9.6.13.20 WNM Sleep Mode Response frame format

The WNM Sleep Mode Response frame is sent by an AP in response to a WNM Sleep Mode Request frame or is sent without solicitation by an AP to a non-AP STA upon the AP's deletion of all traffic filter sets established according to the traffic filtering agreement between the AP and the non-AP STA. The format of the WNM Sleep Mode Response frame Action field is defined in Figure 9-938.

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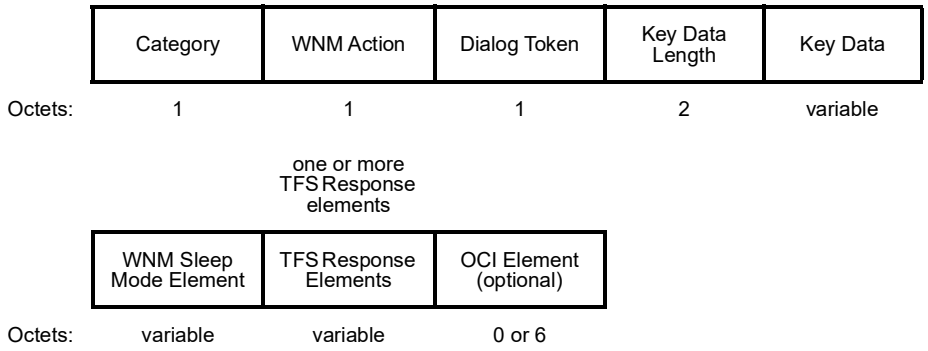

Figure 9-938—WNM Sleep Mode Response frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

When the WNM Sleep Mode Response frame is transmitted as a response to a WNM Sleep Mode Request frame, the Dialog Token field is the value in the corresponding WNM Sleep Mode Request frame. When the WNM Sleep Mode Response frame is transmitted as an unsolicited response, the Dialog Token field is set to 0.

The Key Data Length field is the length of the Key Data field. If the management frame protection is not used, this field is 0.

The Key Data field contains zero or more subelements that provide the current GTK, IGTK and BIGTK to the STA. The format of these subelements is shown in Figure 9-939, Figure 9-940, and Figure 9-940. The subelement IDs for these subelements are defined in Table 9-429. When management frame protection is not used, the Key Data field is not present.

Table 9-429—Optional subelement IDs for WNM Sleep Mode parameters

Value	Contents of subelement
0	GTK
1	IGTK
2	BIGTK
3–255	Reserved

The GTK subelement contains the GTK as shown in Figure 9-939.

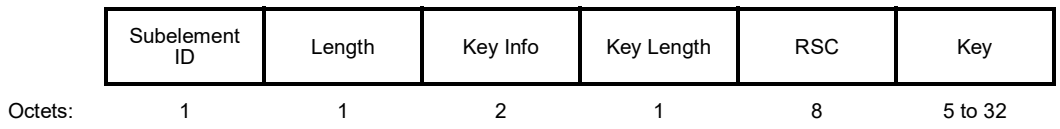

Figure 9-939—WNM Sleep Mode GTK subelement format

The Length field is defined in 9.4.3.

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The Key Info field is defined in Figure 9-360.

The Key Length field is the length of the Key field in octets.

The RSC field contains the current receive sequence counter (RSC) for the GTK being installed, to allow a STA to identify replayed MPDUs. If the RSC is less than 8 octets in length, it is stored in the first octets and the remaining octets are set to 0. The least significant octet of the RSC is in the first octet of the RSC field. The RSC for TKIP is the TKIP sequence counter (TSC); for CCMP and GCMP it is the packet number (PN); see Table 12-8.

The Key field is the GTK being distributed.

The IGTK subelement contains the IGTK as shown in Figure 9-940.

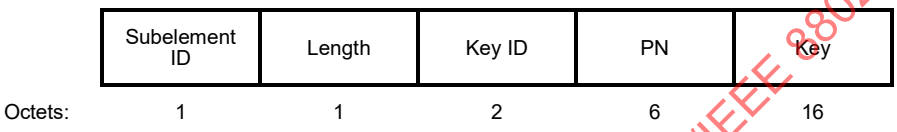

Figure 9-940—WNM Sleep Mode IGTK subelement format

The Length field is defined in 9.4.3.

The Key ID field indicates the value of the BIP key identifier.

The PN field contains the current RSC number for the IGTK being installed, to allow a STA to identify replayed protected group addressed robust Management frames. The RSC for an IGTK is the IGTK packet number (IPN).

The Key field is the IGTK being distributed.

The BIGTK subelement contains the BIGTK as shown in Figure 9-941.

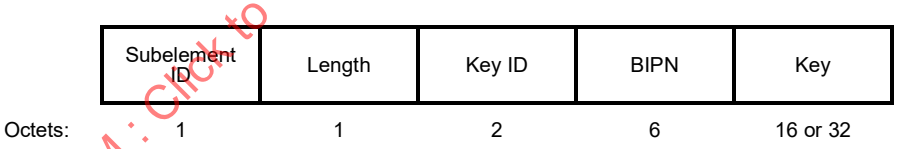

Figure 9-941—WNM Sleep Mode BIGTK subelement format

The Subelement ID field is defined in 9.6.13.20.

The Length field is defined in 9.4.3.

The Key ID field indicates the value of the BIGTK identifier.

The BIPN field contains the current RSC for the BIGTK being installed, to allow a STA to identify replayed Beacon frames. The RSC for a BIGTK is the BIGTK packet number (BIPN).

The Key field is the BIGTK being distributed.

NOTE 1—There might be multiple GTK, multiple IGTK, and multiple BIGTK subelements if a group rekeying is in process when the non-AP STA wakes up from WNM sleep mode.

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NOTE 2—Management frame protection is used to provide confidentiality, replay, and integrity protection for GTK/IGTK/BIGTK update in WNM Sleep Mode Response frames.

The WNM Sleep Mode Element field contains a WNM Sleep Mode element, as described in 9.4.2.81.

The TFS Response Elements field contains one or more TFS Response elements to specify the traffic filters, as defined in 9.4.2.80.

The OCI Element field is optionally present, and contains an OCI element as defined in 9.4.2.236.

9.6.13.21 TIM Broadcast Request frame format

The format of the TIM Broadcast Request frame Action field is shown in Figure 9-942.

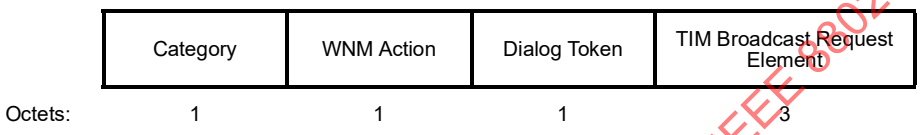

Figure 9-942—TIM Broadcast Request frame Action fieldformat

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is a nonzero value chosen by the STA sending the TIM Broadcast Request frame to identify the request/response transaction.

The TIM Broadcast Request Element field contains a TIM Broadcast Request Element as specified in 9.4.2.82.

9.6.13.22 TIM Broadcast Response frame format

The format of the TIM Broadcast Response frame Action field is shown in Figure 9-943.

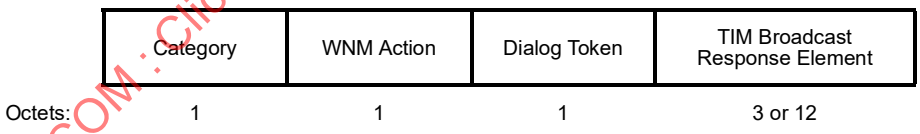

Figure 9-943—TIM Broadcast Response frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is the nonzero value of the corresponding TIM Broadcast Request frame. If the TIM Broadcast Response frame is being transmitted other than in response to a TIM Broadcast Request frame, then the dialog token is 0.

The TIM Broadcast Response Element field contains a TIM Broadcast Response Element as specified in 9.4.2.83.

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9.6.13.23 QoS Traffic Capability Update frame format

The QoS Traffic Capability Update frame is sent by a non-AP STA to the AP to update QoS Traffic Capability information. The format of the Action field of the QoS Traffic Capability Update frame is shown in Figure 9-944.

	Category	WNM Action	QoS Traffic Capability Flags
Octets:	1	1	1

Figure 9-944—QoS Traffic Capability Update frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The QoS Traffic Capability Flags field is defined in Table 9-430. The QoS Traffic Capability Flags field comprises 1 octet, with the bits 4–6 serving as QoS Traffic Capability Flags. Each of the bits 4–6 serves as a flag for one of the three user priorities, UP 4–6. The field is 1 to indicate the expectation of generating traffic belonging to the corresponding user priority (UP). The field is 0 to indicate that such expectation does not exist. The use of the QoS Traffic Capability Update frame is described in 11.21.10.

Table 9-430—QoS Traffic Capability Flags definition

Bit	Description
0–3	Reserved
4	UP 4 Traffic
5	UP 5 Traffic
6	UP 6 Traffic
7	Reserved

9.6.13.24 Channel Usage Request frame format

The Channel Usage Request frame is sent by a non-AP STA to the AP to request the specified Channel Usage information. The format of the Channel Usage Request frame Action field is defined in Figure 9-945.

	Category	WNM Action	Dialog Token	Channel Usage Elements	Supported Operating Classes Element
Octets:	1	1	1	variable	variable

Figure 9-945—Channel Usage Request frame Action field format

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The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is a nonzero value chosen by the non-AP STA sending the Channel Usage Request frame to identify the request/response transaction.

The Channel Usage Element field includes one or more Channel Usage elements described in 9.4.2.85 to identify the request Usage Mode.

The Supported Operating Classes Element field contains a Supported Operating Classes element to indicate the supported operating classes for the requested network type, consistent with the Country element advertised by the AP. The Supported Operating Classes is described in 9.4.2.53.

9.6.13.25 Channel Usage Response frame format

The Channel Usage Response frame is sent by an AP in response to a Channel Usage Request frame, or autonomously. The format of the Channel Usage Response frame Action field is shown in Figure 9-946.

	Category	WNM Action	Dialog Token	Channel Usage Elements	Country String	Power Constraint Element (optional)	EDCA Parameter Set Element (optional)	Transmit Power Envelope element (optional)
Octets:	1	1	1	variable	3	0 or 3	0 or 20	variable

Figure 9-946—Channel Usage Response frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is the nonzero value received in the Channel Usage Request frame if the Channel Usage Response frame is being transmitted in response to a Channel Usage Request frame. The Dialog Token field is 0 if the Channel Usage Response frame is being transmitted other than in response to a Channel Usage Request frame.

The Channel Usage Element field includes zero or more Channel Usage elements described in 9.4.2.85.

The Country String field is the value contained in the dot11CountryString attribute.

The Power Constraint Element field includes zero or one Power Constraint elements described in 9.4.2.13. The use of the Power Constraint element included in the Power Constraint Element field is described in 11.21.15.

The EDCA Parameter Set Element field includes zero or one EDCA Parameter Set elements described in 9.4.2.28. The use of the EDCA Parameter Set element included in the EDCA Parameter Set Element field is described in 11.21.15.

The Transmit Power Envelope element field is defined in 9.4.2.161.

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9.6.13.26 DMS Request frame format

The DMS Request frame is sent by a non-AP STA to the AP to define information about a DMS request to the AP. The format of the DMS Request frame Action field is defined in Figure 9-947.

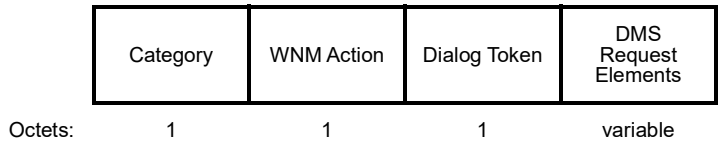

Figure 9-947—DMS Request frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is a nonzero value chosen by the non-AP STA sending the DMS Request frame to identify the request/response transaction.

The DMS Request Elements field contains one or more DMS Request elements as specified in 9.4.2.87.

9.6.13.27 DMS Response frame format

The DMS Response frame is sent by an AP or a mesh STA in response to a DMS Request frame, or autonomously to terminate a requested DMS stream, or to advertise the current parameters for one or more GCR streams. The format of the DMS Response frame Action field is shown in Figure 9-948.

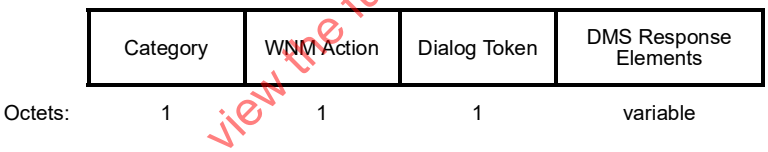

Figure 9-948—DMS Response frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is the nonzero value received in the DMS Request frame if the DMS Response frame is being transmitted in response to a DMS Request frame. The Dialog Token field is 0 if the DMS Response frame is being transmitted autonomously, and not in response to a DMS Request frame.

The DMS Response Elements field contains one or more DMS Response elements as specified in 9.4.2.88.

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9.6.13.28 Timing Measurement Request frame format

The format of the Timing Measurement Request frame Action field is shown in Figure 9-949.

	Category	WNM Action	Trigger
Octets:	1	1	1

Figure 9-949—Timing Measurement Request frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Trigger field set to the value 1 indicates that the sending STA requests a timing measurement procedure at the receiving STA as defined in 11.21.5. The Trigger field set to the value 0 indicates that the sending STA requests that the receiving STA stop sending Timing Measurement frames. Trigger field values 2–255 are reserved.

9.6.13.29 WNM Notification Request frame format

The format of the WNM Notification Request frame Action field is shown in Figure 9-950.

	Category	WNM Action	Dialog Token	Type	Optional Subelements
Octets:	1	1	1	1	variable

Figure 9-950—WNM Notification Request frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is set to a nonzero value chosen by the STA sending the WNM notification request to identify the request/response transaction.

The Type field indicates the type of WNM notification, as defined in Table 9-431.

Table 9-431—WNM notification type

Value	Description
0	Firmware Update Notification
1	Reserved
2	Beacon Protection Failure
3–220	Reserved
221	Vendor Specific
222–255	Reserved

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The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3.

The Subelement ID field values for the defined subelements are shown in Table 9-432.

Table 9-432—Optional subelement IDs for WNM Notification Request

Subelement ID	Name	Extensible
0	AP Descriptor	No
1	Firmware Version—Current	No
2	Firmware Version—New	No
3–220	Reserved	
221	Vendor Specific	Vendor defined
222–255	Reserved	

When the Type field is 0, the AP Descriptor, Firmware Version—Current, and Firmware Version—New optional subelements are included in the WNM Notification Request frame. The AP descriptor field format is defined in Figure 9-417. The Firmware Version—Current subelement contains the current firmware version, in the Firmware Version subelement format defined in Figure 9-423. The Firmware Version—New subelement contains the new firmware version, in the Firmware Version subelement format defined in Figure 9-423.

When the Type field is 2, the AP Descriptor, Firmware Version—Current, and Firmware Version—New optional subelements are not included in the WNM Notification Request frame.

9.6.13.30 WNM Notification Response frame format

The format of the WNM Notification Response frame Action field is shown in Figure 9-951.

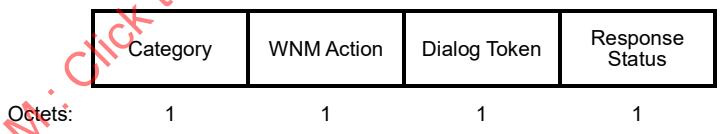

Figure 9-951—WNM Notification Response frame Action field format

The Category field is defined in 9.4.1.11.

The WNM Action field is defined in 9.6.13.1.

The Dialog Token field is set to the nonzero value of the corresponding WNM Notification Request frame.

The Response Status field indicates the Response Status value, as defined in Table 9-433.

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Table 9-433—WNM Notification Response Status

Value	Description
0	Notification Acknowledged
1–255	Reserved

9.6.14 Unprotected WNM Action details

9.6.14.1 Unprotected WNM Action fields

Unprotected WNM Action frames are not encapsulated using mechanisms defined for robust Management frames. An Unprotected WNM Action field, in the field immediately after the Category field, differentiates the formats. The Unprotected WNM Action field values associated with each frame format is defined in Table 9-434.

Table 9-434—Unprotected WNM Action field values

Action field value	Description
0	TIM
1	Timing Measurement
2–255	Reserved

9.6.14.2 TIM frame format

The format of the TIM frame Action field is shown in Figure 9-952.

	Category	Unprotected WNM Action	Check Beacon	Timestamp	TIM Element
Octets:	1	1	1	8	4–256

Figure 9-952—TIM frame Action field format

The Category field is defined in 9.4.1.11.

The Unprotected WNM Action field is defined in 9.6.14.1.

The Check Beacon field is defined as an unsigned integer initialized to 0, that increments when a critical update to the Beacon frame has occurred; see 11.2.3.15.

The Timestamp field is defined in 9.4.1.10. The field contains a TSF timestamp when the TIM Broadcast Response frame contained a Status field set to “Accept, timestamp present in TIM frames” or “Overridden, timestamp present in TIM frames.” The field is reserved otherwise.

The TIM Element field contains a TIM element as specified in 9.4.2.5. The bit corresponding to buffered group addressed frames is reserved for all BSSIDs.

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9.6.14.3 Timing Measurement frame format

The Timing Measurement frame is used to support the timing measurement procedure described in 11.21.5. The format of the Timing Measurement frame Action field is shown in Figure 9-953.

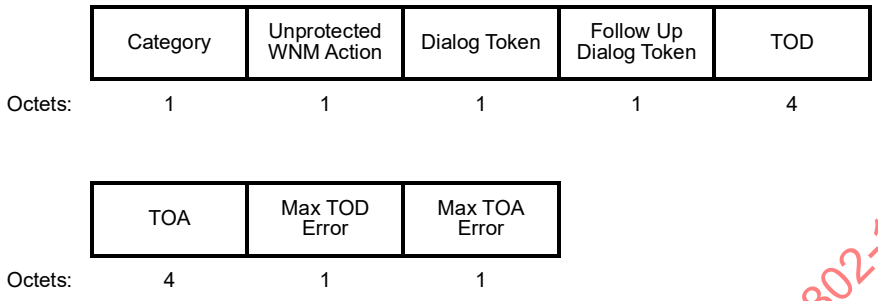

Figure 9-953—Timing Measurement frame Action field format

The Category field is defined in 9.4.1.11.

The Unprotected WNM Action field is defined in 9.6.14.1.

The Dialog Token field is a nonzero value chosen by the sending STA to identify the Timing Measurement frame as the first of a pair, with the second or follow-up Timing Measurement frame to be sent later. The Dialog Token field is set to 0 to indicate that the Timing Measurement frame will not be followed by a subsequent follow-up Timing Measurement frame.

The Follow Up Dialog Token field is the nonzero value of the Dialog Token field of the previously transmitted Timing Measurement frame to indicate that it is the follow up Timing Measurement frame and that the TOD, TOA, Max TOD Error and Max TOA Error fields contain the values of the timestamps captured with the first Timing Measurement frame of the pair. The Follow Up Dialog Token field is 0 to indicate that the Timing Measurement frame is not a follow up to a previously transmitted Timing Measurement frame. The value 0 in this field also indicates that the TOD, TOA, Max TOD Error, and Max TOA Error fields are reserved. See 11.21.5.

The TOD, TOA, Max TOD Error, and Max TOA Error fields are expressed in units of 10 ns.

The TOD field contains a timestamp that represents the time at which the start of the preamble of the previously transmitted Timing Measurement frame appeared at the transmit antenna connector.

The TOA field contains a timestamp that represents the time at which the start of the preamble of the Ack frame to the previously transmitted Timing Measurement frame arrived at the receive antenna connector.

NOTE—The values specified in the TOD and TOA fields are described in 6.3.55.

The Max TOD Error field contains an upper bound for the error in the value specified in the TOD field. For instance, a 2 in the Max TOD Error field indicates that the TOD field has a maximum error of ± 20 ns.

The Max TOA Error field contains an upper bound for the error in the value specified in the TOA field. For instance, a 2 in the Max TOA Error field indicates that the TOA field has a maximum error of ± 20 ns.

Setting the Max TOD Error or the Max TOA Error field to 0 indicates that the upper bound on the error in the corresponding TOD or TOA value is unknown. Setting either field to 255 indicates that the upper bound on the error is greater than or equal to 2.55 μs.

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9.6.15 Self-protected Action frame details

9.6.15.1 Self-protected Action fields

The Self-protected Action frame is defined to allow robust STA-STA communications of the Action frames that are not robust (see 9.4.1.11). The protocols that use these Action frames are responsible for deciding whether to protect these frames and supporting protection mechanisms for these frames as needed.

Self-protected Action frames have a different nature than Public Action frames and robust Action frames. Robust Action frames assume the existence of a completely established security association. Self-protected Action frames typically exist to manage the creation and deletion of security associations, regardless of whether they are completely established.

Public Action frames are defined as public for all STAs, including those that are not in the BSS and MBSS. Self-protected Action frames, however, are used for relationship creation and maintenance between two specific STAs. Their public nature is incidental.

A Self-protected Action field, in the field immediately after the Category field, differentiates the formats. The defined Self-protected Action frames are listed in Table 9-435.

Table 9-435—Self-protected Action field values

Self-protected Action field value	Description
0	Reserved
1	Mesh Peering Open
2	Mesh Peering Confirm
3	Mesh Peering Close
4	Mesh Group Key Inform
5	Mesh Group Key Acknowledge
6–255	Reserved

The Mesh Peering Open frame, the Mesh Peering Confirm frame, and the Mesh Peering Close frame are referred to as *mesh peering Management frames*.

9.6.15.2 Mesh Peering Open frame format

9.6.15.2.1 Mesh Peering Open frame self protection

Protection of this frame is provided when authenticated mesh peering exchange (AMPE) is enabled. AMPE provides integrity protection of Mesh Peering Open frames.

When the Mesh Peering Open frame is used by the mesh peering management (MPM) protocol, integrity protection on the frame is not enabled.

9.6.15.2.2 Mesh Peering Open frame details

The Mesh Peering Open frame is used to open a mesh peering using the procedures defined in 14.3.6 and in 14.5.5. The format of the Mesh Peering Open frame Action field is shown in Table 9-436.

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Table 9-436—Mesh Peering Open frame Action field format

Order	Information	Notes
1	Category	
2	Self-protected Action	
3	Capability	
4	Supported Rates and BSS Membership Selectors	
5	Extended Supported Rates and BSS Membership Selectors	The Extended Supported Rates and BSS Membership Selectors element is present if there are more than eight supported rates and is optionally present otherwise.
6	Power Capability	The Power Capability element is present if dot11SpectrumManagementRequired is true.
7	Supported Channels	The Supported Channels element is present if dot11SpectrumManagementRequired is true and dot11ExtendedChannelSwitchActivated is false.
8	RSN	The RSNE is present if dot11MeshSecurityActivated, dot11ProtectedQLoadReportActivated, or dot11ProtectedTXOPNegotiationActivated is true; otherwise not present.
9	Mesh ID	
10	Mesh Configuration	
11	Mesh Peering Management	The Mesh Peering Management element is set as described in 9.4.2.97.
12	ERP Information	The ERP element is present if ERP mesh STA detects non-ERP STAs in its vicinity and is optionally present otherwise.
13	Supported Operating Classes	The Supported Operating Classes element is present if dot11ExtendedChannelSwitchActivated is true, or for a mesh STA if dot11OperatingClassesImplemented is true and the STA is capable of operation in more than one operating class.
14	HT Capabilities	The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true.
15	HT Operation	The HT Operation element is included when dot11HighThroughputOptionImplemented is true.
16	20/40 BSS Coexistence element	The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true.
17	Extended Capabilities element	The Extended Capabilities element is present if any of the fields in this element are nonzero.
18	Interworking	The Interworking element is present if dot11InterworkingServiceActivated is true.
19	VHT Capabilities	The VHT Capabilities element is present when dot11VHTOptionImplemented is true.
20	VHT Operation	The VHT Operation element is present when dot11VHTOptionImplemented is true.
21	Operating Mode Notification	The Operating Mode Notification element is optionally present if dot11OperatingModeNotificationImplemented is true.

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The Category field is defined in 9.4.1.11.

The Self-protected Action field is defined in 9.6.15.1.

The MIC element appears prior to the Authenticated Mesh Peering Exchange element in the Mesh Peering Open frame. The information following the MIC element through to the end of the Mesh Peering Open frame body is encrypted and authenticated (see 14.5).

The OCI element appears prior to the MIC element in the Mesh Peering Open frame, and as part of the input AAD is authenticated by the MIC element (see 14.5).

9.6.15.3 Mesh Peering Confirm frame format

9.6.15.3.1 Mesh Peering Confirm frame self protection

Protection of this frame is provided when authenticated mesh peering exchange (AMPE) is enabled. AMPE provides integrity protection of Mesh Peering Confirm frames.

When the Mesh Peering Confirm frame is used by the mesh peering management (MPM) protocol, integrity protection on the frame is not enabled.

9.6.15.3.2 Mesh Peering Confirm frame details

The Mesh Peering Confirm frame is used to confirm a mesh peering using the procedures defined in 14.3.7 and 14.5.5. The format of the Mesh Peering Confirm frame Action field is shown in Table 9-437.

Table 9-437—Mesh Peering Confirm frame Action field format

Order	Information	Notes
1	Category	
2	Self-protected Action	
3	Capability	
4	AID	
5	Supported Rates and BSS Membership Selectors	
6	Extended Supported Rates and BSS Membership Selectors	The Extended Supported Rates and BSS Membership Selectors element is present if there are more than eight supported rates and is optionally present otherwise.
7	RSN	The RSNE is present only when dot11MeshSecurityActivated, dot11ProtectedQLoadReportActivated, or dot11ProtectedTXOPNegotiationActivated is true.
8	Mesh ID	
9	Mesh Configuration	The Mesh Configuration element is present when dot11MeshActivated is true.
10	Mesh Peering Management	The Mesh Peering Management element is set as described in 9.4.2.101.

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Table 9-437—Mesh Peering Confirm frame Action field format *(continued)*

Order	Information	Notes
11	HT Capabilities	The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true.
12	HT Operation	The HT Operation element is included when dot11HighThroughputOptionImplemented is true.
13	20/40 BSS Coexistence element	The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true.
14	Extended Capabilities element	The Extended Capabilities element is present if any of the fields in this element are nonzero.
15	VHT Capabilities	The VHT Capabilities element is present when dot11VHTOptionImplemented is true.
16	VHT Operation	The VHT Operation element is present when dot11VHTOptionImplemented is true.
17	Operating Mode Notification	The Operating Mode Notification element is optionally present if dot11OperatingModeNotificationImplemented is true.

The Category field is defined in 9.4.1.11.

The Self-protected Action field is defined in 9.6.15.1.

The MIC element appears prior to the Authenticated Mesh Peering Exchange element in the Mesh Peering Confirm frame. The information following the MIC element through to the end of the Mesh Peering Confirm frame body is encrypted and authenticated (see 14.5).

The OCI element appears prior to the MIC element in the Mesh Peering Open frame, and as part of the input AAD is authenticated by the MIC element (see 14.5).

9.6.15.4 Mesh Peering Close frame format

9.6.15.4.1 Mesh Peering Close frame self protection

Protection of this frame is provided when authenticated mesh peering exchange (AMPE) is enabled. AMPE provides integrity protection of Mesh Peering Close frames.

When the Mesh Peering Close frame is used by the mesh peering management (MPM) protocol, integrity protection on the frame is not enabled.

9.6.15.4.2 Mesh Peering Close frame details

The Mesh Peering Close frame is used to close a mesh peering using the procedures defined in 14.3.8 and in 14.5.5. The format of the Mesh Peering Close frame Action field is shown in Table 9-438.

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Table 9-438—Mesh Peering Close frame Action field format

Order	Information	Notes
1	Category	
2	Self-protected Action	
3	Mesh ID	
4	Mesh Peering Management	

The Category field is defined in 9.4.1.11.

The Self-protected Action field is defined in 9.6.15.1.

The MIC element appears prior to the Authenticated Mesh Peering Exchange element in the Mesh Peering Close frame. The information following the MIC element through to the end of the Mesh Peering Close frame body is encrypted and authenticated (see 14.5).

9.6.15.5 Mesh Group Key Inform frame format

9.6.15.5.1 Mesh Group Key Inform frame self protection

The protection of the frames is provided by the mesh group key handshake protocol (see 14.6) that uses Mesh Group Key Inform frames.

9.6.15.5.2 Mesh Group Key Inform frame details

The Mesh Group Key Inform frame is used to update a mesh GTK (MGTK) with a peer. The format of the Mesh Group Key Inform frame Action field is shown in Table 9-439.

Table 9-439—Mesh Group Key Inform frame Action field format

Order	Information	Notes
1	Category	
2	Self-protected Action	
3	MIC element	
4	Authenticated Mesh Peering Exchange	

The Category field is defined in 9.4.1.11.

The Self-protected Action field is defined in 9.6.15.1.

The MIC element is set as defined in 9.4.2.118.

The Authenticated Mesh Peering Exchange element is set according to 14.6. The information following the MIC element through to the end of the Mesh Group Key Inform frame body is encrypted and authenticated (see 14.6.2).

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9.6.15.6 Mesh Group Key Acknowledge frame format

9.6.15.6.1 Mesh Group Key Acknowledge frame self protection

The protection of the frames is provided by the mesh group key handshake protocol (see 14.6) that uses Mesh Group Key Acknowledge frames.

9.6.15.6.2 Mesh Group Key Acknowledge frame details

The Mesh Group Key Acknowledge frame is used to acknowledge receipt and processing of a Mesh Group Key Inform frame. The format of the Mesh Group Key Acknowledge frame Action field is shown in Table 9-440.

Table 9-440—Mesh Group Key Acknowledge frame Action field format

Order	Information	Notes
1	Category	
2	Self-protected Action	
3	MIC element	
4	Authenticated Mesh Peering Exchange	

The Category field is defined in 9.4.1.11.

The Self-protected Action field is defined in 9.6.15.1.

The MIC element is set as defined in 9.4.2.118.

The Authenticated Mesh Peering Exchange element is set according to 14.6. The information following the MIC element through to the end of the Mesh Group Key Acknowledge frame body is encrypted and authenticated (see 14.6.2).

9.6.16 Mesh Action frame details

9.6.16.1 Mesh Action fields

Several Mesh Action frame formats are defined for mesh BSS operation. A Mesh Action field, in the field immediately after the Category field, differentiates the formats. The Mesh Action field values associated with each frame format are defined in Table 9-441.

Table 9-441—Mesh Action field values

Mesh Action field value	Description
0	Mesh Link Metric Report
1	HWMP Mesh Path Selection
2	Gate Announcement

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Table 9-441—Mesh Action field values *(continued)*

Mesh Action field value	Description
3	Congestion Control Notification
4	MCCA Setup Request
5	MCCA Setup Reply
6	MCCA Advertisement Request
7	MCCA Advertisement
8	MCCA Teardown
9	TBTT Adjustment Request
10	TBTT Adjustment Response
11–255	Reserved

9.6.16.2 Mesh Link Metric Report frame format

The Mesh Link Metric Report frame is transmitted by a mesh STA to a neighbor peer mesh STA to report metric information on the link between the two mesh STAs. It is also transmitted by a mesh STA to a neighbor peer mesh STA to request metric information on the link between the two mesh STAs from the recipient. This frame is transmitted using an individually addressed frame. The format of the Mesh Link Metric Report frame Action field is shown in Table 9-442.

Table 9-442—Mesh Link Metric Report frame Action field format

Order	Information	Notes
1	Category	
2	Mesh Action	
3	Mesh Link Metric Report element	

The Category field is defined in 9.4.1.11.

The Mesh Action field is defined in 9.6.16.1.

The Mesh Link Metric Report element is set as described in 9.4.2.99.

9.6.16.3 HWMP Mesh Path Selection frame format

The HWMP Mesh Path Selection frame is transmitted by a mesh STA to establish, update or delete paths to other mesh STAs using the HWMP defined in 14.10. This frame is transmitted in an individually or group addressed frame depending on the contained elements and as defined in 14.10.7. The format of the HWMP Mesh Path Selection frame Action field is shown in Table 9-443.

The HWMP Mesh Path Selection frame contains one or more of the elements indicated in Table 9-443. Usage of the HWMP Mesh Path Selection frame is described in 14.10.7.

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Table 9-443—HWMP Mesh Path Selection frame Action field format

Order	Information	Notes
1	Category	
2	Mesh Action	
3	PREQ element	A PREQ element is optionally present
4	PREP element	A PREP element is optionally present
5	PERR element	A PERR element is optionally present
6	RANN element	A RANN element is optionally present

The Category field is defined in 9.4.1.11.

The Mesh Action field is defined in 9.6.16.1.

The PREQ element is set as described in 9.4.2.112. It is present in an HWMP Mesh Path Selection frame as described in 14.10.9.

The PREP element is set as described in 9.4.2.113.

The PERR element is set as described in 9.4.2.114.

The RANN element is set as described in 9.4.2.111.

9.6.16.4 Gate Announcement frame format

The Gate Announcement frame is transmitted by a mesh gate to announce its presence in the MBSS. This frame is transmitted using group addresses. The format of the Gate Announcement frame Action field is shown in Table 9-444.

Table 9-444—Gate Announcement frame Action field format

Order	Information	Notes
1	Category	
2	Mesh Action	
3	GANN element	

The Category field is defined in 9.4.1.11.

The Mesh Action field is defined in 9.6.16.1.

The GANN element is set as described in 9.4.2.110.

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9.6.16.5 Congestion Control Notification frame format

A mesh STA uses the Congestion Control Notification frame to indicate its congestion status to its neighbor peer mesh STA(s). This frame is transmitted using individual addresses or group addresses. The format of the Congestion Control Notification frame Action field is shown in Table 9-445.

Table 9-445—Congestion Control Notification frame Action field format

Order	Information	Notes
1	Category	
2	Mesh Action	
3	Congestion Notification element	One or more Congestion Notification elements (9.4.2.100) are present. Repeated *N* times (*N* is the number of Congestion Notification elements contained in the frame).

The Category field is defined in 9.4.1.11.

The Mesh Action field is defined in 9.6.16.1.

The Congestion Notification element is set as described in 9.4.2.100.

9.6.16.6 MCCA Setup Request frame format

The MCCA Setup Request frame is used to set up an MCCAOP reservation. A mesh STA (with dot11MCCAActivated equal to true) transmits the MCCA Setup Request frame to one or more neighbor mesh STAs (with dot11MCCAActivated equal to true too). This frame is transmitted using individual addresses or group addresses. The format of the MCCA Setup Request frame Action field is shown in Table 9-446.

Table 9-446—MCCA Setup Request frame Action field format

Order	Information	Notes
1	Category	
2	Mesh Action	
3	MCCAOP Setup Request element	

The Category field is defined in 9.4.1.11.

The Mesh Action field is defined in 9.6.16.1.

The MCCAOP Setup Request element is described in 9.4.2.105.

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9.6.16.7 MCCA Setup Reply frame format

The MCCA Setup Reply frame is used to reply to an MCCA Setup Request frame. It is transmitted by a mesh STA with dot11MCCAActivated equal to true to a neighbor peer mesh STA with dot11MCCAActivated equal to true. This frame is transmitted using individual addresses. The format of the MCCA Setup Reply frame Action field is shown in Table 9-447.

Table 9-447—MCCA Setup Reply frame Action field format

Order	Information	Notes
1	Category	
2	Mesh Action	
3	MCCAOP Setup Reply element	

The Category field is defined in 9.4.1.11.

The Mesh Action field is defined in 9.6.16.1.

The MCCAOP Setup Reply element is described in 9.4.2.106.

9.6.16.8 MCCA Advertisement Request frame format

The MCCA Advertisement Request frame is transmitted by a mesh STA with dot11MCCAActivated equal to true to a neighbor peer mesh STA with dot11MCCAActivated equal to true in order to request MCCAOP advertisements from the neighbor peer mesh STA. This frame is transmitted using individual addresses. The format of the MCCA Advertisement Request frame Action field is shown in Table 9-448.

Table 9-448—MCCA Advertisement Request frame Action field format

Order	Information	Notes
1	Category	
2	Mesh Action	
3	MCCAOP Advertisement Overview element	An MCCAOP Advertisement Overview element is optionally present.

The Category field is defined in 9.4.1.11.

The Mesh Action field is defined in 9.6.16.1.

The MCCAOP Advertisement Overview element is described in 9.4.2.107.

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9.6.16.9 MCCA Advertisement frame format

The MCCA Advertisement frame is transmitted by a mesh STA with dot11MCCAActivated equal to true to one or more neighbor peer mesh STAs with dot11MCCAActivated equal to true. This frame is transmitted using group addresses or individual addresses. The format of the MCCA Advertisement frame Action field is shown in Table 9-449.

Table 9-449—MCCA Advertisement frame Action field format

Order	Information	Notes
1	Category	
2	Mesh Action	
3	MCCAOP Advertisement Overview element	An MCCAOP Advertisement Overview element is optionally present.
4	MCCAOP Advertisement elements	If an MCCAOP Advertisement Overview element is present, zero or more MCCAOP Advertisement elements are present. If an MCCAOP Advertisement Overview element is not present, one or more MCCAOP Advertisement elements are present.

The Category field is defined in 9.4.1.11.

The Mesh Action field is defined in 9.6.16.1.

The MCCAOP Advertisement Overview element is described in 9.4.2.107.

The MCCAOP Advertisement element is described in 9.4.2.108.

9.6.16.10 MCCA Teardown frame format

The MCCA Teardown frame is transmitted by a mesh STA with dot11MCCAActivated equal to true to one or more neighbor peer mesh STAs with dot11MCCAActivated equal to true. This frame is transmitted using group addresses or individual addresses. The format of the MCCA Teardown frame Action field is shown in Table 9-450.

Table 9-450—MCCA Teardown frame Action field format

Order	Information	Notes
1	Category	
2	Mesh Action	
3	MCCAOP Teardown element	

The Category field is defined in 9.4.1.11.

The Mesh Action field is defined in 9.6.16.1.

The MCCAOP Teardown element is described in 9.4.2.109.

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9.6.16.11 TBTT Adjustment Request frame format

The TBTT Adjustment Request frame is used to request a particular neighbor peer mesh STA to adjust its TBTT. This frame is transmitted using individual addresses. The format of the TBTT Adjustment Request frame Action field is shown in Table 9-451.

Table 9-451—TBTT Adjustment Request frame Action field format

Order	Information	Notes
1	Category	
2	Mesh Action	
3	Beacon Timing element	Repeated *N_Info* times (*N_Info* is a number of beacon timing information tuples as described in 14.13.4.2.5).

The Category field is defined in 9.4.1.11.

The Mesh Action field is defined in 9.6.16.1.

The Beacon Timing element is set as described in 9.4.2.104. When not all beacon timing information is included in a Beacon Timing element due to the maximum element size limit, multiple Beacon Timing elements are present. The elements are present in the order of Beacon Timing Element Number field value in the Report Control field of the Beacon Timing element.

9.6.16.12 TBTT Adjustment Response frame format

The TBTT Adjustment Response frame is used to respond to a TBTT adjustment request. This frame is transmitted using individual addresses. The format of the TBTT Adjustment Response frame Action field is shown in Table 9-452.

Table 9-452—TBTT Adjustment Response frame Action field format

Order	Information	Notes
1	Category	
2	Mesh Action	
3	Status Code	
4	Beacon Timing element (optional)	Repeated *N_Info* times (*N_Info* is a number of beacon timing information tuples as described in 14.13.4.2.5).

The Category field is defined in 9.4.1.11.

The Mesh Action field is defined in 9.6.16.1.

The Status Code field is set as described in 14.13.4.4.2.

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The Beacon Timing element is set as defined in 9.4.2.104. It is present only if the Status Code is set to CANNOT_FIND_ALTERNATIVE_TBTT (i.e., when the request is not successful due to the neighbor constraint). When not all beacon timing information is included in a Beacon Timing element due to the maximum element size limit, multiple Beacon Timing elements are present. The elements are present in the order of Beacon Timing Element Number field value in the Report Control field of the Beacon Timing element.

9.6.17 Multihop Action frame details

9.6.17.1 Multihop Action fields

Several Multihop Action frame formats are defined for mesh BSS operation. A Multihop Action field, in the field immediately after the Category field, differentiates the formats. The Multihop Action field values associated with each frame format are defined in Table 9-453. The Mesh Control field is present immediately after the Multihop Action field in all Multihop Action frames.

Table 9-453—Multihop Action field values

Multihop Action field value	Description
0	Proxy Update
1	Proxy Update Confirmation
2–255	Reserved

9.6.17.2 Proxy Update frame format

The Proxy Update frame is used to inform the recipient about new, updated, or deleted proxy information. This frame is transmitted using individual addresses. The format of the Proxy Update frame Action field is shown in Table 9-454.

Table 9-454—Proxy Update frame Action field format

Order	Information	Notes
1	Category	
2	Multihop Action	
3	Mesh Control	
4	PXU element	Repeated *N* times (*N* is the number of PXU elements contained in the frame).

The Category field is defined in 9.4.1.11.

The Multihop Action field is defined in 9.6.17.1.

The Mesh Control field is set as defined in 9.2.4.7.3.

The PXU element is described in 9.4.2.115. The Proxy Update frame allows the inclusion of multiple PXU elements.

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9.6.17.3 Proxy Update Confirmation frame format

The Proxy Update Confirmation frame is transmitted by a mesh STA in response to a Proxy Update frame. This frame is used to inform that the corresponding PXU element has been properly received and is transmitted using individual addresses. The format of the Proxy Update Confirmation frame Action field is shown in Table 9-455.

Table 9-455—Proxy Update Confirmation frame Action field format

Order	Information	Notes
1	Category	
2	Multihop Action	
3	Mesh Control	
4	PXUC element	Repeated *N* times (*N* is the number of PXUC elements contained in the frame).

The Category field is defined in 9.4.1.11.

The Multihop Action field is defined in 9.6.17.1.

The Mesh Control field is set as defined in 9.2.4.7.3.

The PXUC element is described in 9.4.2.116. The Proxy Update Confirmation frame allows the inclusion of one or more PXUC elements.

9.6.18 Robust AV Streaming Action frame details

9.6.18.1 General

Several Action frame formats are defined to support robust AV streaming. The Robust Action field values associated with each frame format within the robust AV streaming category are defined in Table 9-456. The frame formats are defined in 9.6.18.2 to 9.6.18.7.

Table 9-456—Robust AV streaming Robust Action field values

Robust Action field value	Meaning
0	SCS Request
1	SCS Response
2	Group Membership Request
3	Group Membership Response
4	MSCS Request
5	MSCS Response
6–255	Reserved

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9.6.18.2 SCS Request frame format

SCS Request frames are used to request the creation, modification, or deletion of a stream classification using the procedures defined in 11.25.2.

The Action field of the SCS Request frame contains the information shown in Figure 9-954.

	Category	Robust Action	Dialog Token	SCS Descriptor List
Octets:	1	1	1	variable

Figure 9-954—SCS Request frame Action field format

The Category field is defined in 9.4.1.11.

The Robust Action field is defined in 9.6.18.1.

The Dialog Token field is defined in 9.4.1.12 and set by the requesting STA to a nonzero value that is used for matching action responses with action requests. See 10.28.5.

The SCS Descriptor List field contains one or more SCS Descriptor elements, as defined in 9.4.2.121.

9.6.18.3 SCS Response frame format

The SCS Response frame is sent in response to an SCS Request frame using the procedures defined in 11.25.2. The Action field of an SCS Response frame contains the information shown in Figure 9-955.

	Category	Robust Action	Dialog Token	SCS Status List
Octets:	1	1	1	variable

Figure 9-955—SCS Response frame Action field format

The Category field is defined in 9.4.1.11.

The Robust Action field is defined in 9.6.18.1.

The Dialog Token field is set to the nonzero value of the corresponding SCS Request frame. If the SCS Report frame is being transmitted for a reason other than in response to an SCS Request frame, then the Dialog Token field is set to 0.

The SCS Status List field contains one or more SCS Status duples. The format of the SCS Status duple is defined in Figure 9-956.

	SCSID	Status
Octets:	1	2

Figure 9-956—SCS Status duple format

The SCSID field is set to the value of the SCSID field in the SCS Descriptor element received in the SCS Request frame.

The Status field indicates the status of the requested SCSID, as indicated in Table 9-50.

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9.6.18.4 Group Membership Request frame format

The Group Membership Request frame is sent to a STA to request the contents of its dot11GroupAddressesTable. The Action field of a Group Membership Request frame contains the information shown in Figure 9-957.

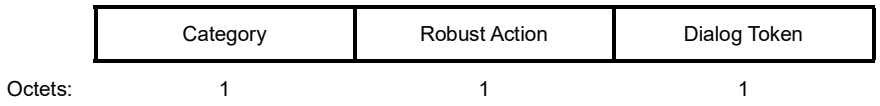

Figure 9-957—Group Membership Request frame Action field format

The Category field is defined in 9.4.1.11.

The Robust Action field is defined in 9.6.18.1.

The Dialog Token field is defined in 9.4.1.12 and set by the requesting STA to a nonzero value that is used for matching action responses with action requests. See 10.28.5.

Usage of the Group Membership Request frame is described in 11.21.16.3.2.

9.6.18.5 Group Membership Response frame format

The Group Membership Response frame is sent in response to a Group Membership Request frame or upon a change in the dot11GroupAddressesTable object, using the procedures defined in 11.21.16.3.2. The Action field of a Group Membership Response frame contains the information shown in Figure 9-958.

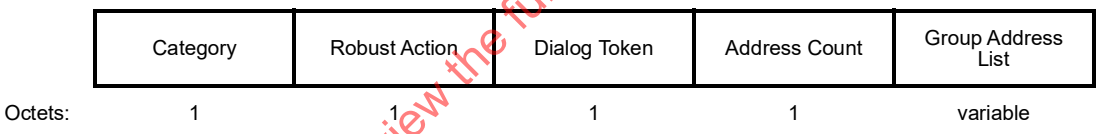

Figure 9-958—Group Membership Response frame Action field format

The Category field is defined in 9.4.1.11.

The Robust Action field is defined in 9.6.18.1.

The Dialog Token field is set to the nonzero value of the corresponding Group Membership Request frame. If the Group Membership Report frame is being transmitted for a reason other than in response to a Group Membership Request frame, the Dialog Token field is set to 0.

The Address Count field specifies the number of MAC addresses that are in the Group Address List field.

The Group Address List field contains zero or more MAC addresses to indicate the set of group addressed MAC addresses for which the STA receives frames. Each MAC address is 6 octets in length, as described in 9.2.4.3.2.

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9.6.18.6 MSCS Request frame format

MSCS Request frames are used to request the creation, modification, or deletion of mirrored stream classification using the procedures defined in 11.25.3.

The Action field of the MSCS Request frame contains the information shown in Figure 9-959.

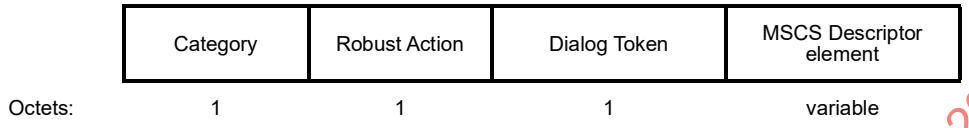

Figure 9-959—MSCS Request frame Action field format

The Category field is defined in 9.4.1.11.

The Robust Action field is defined in 9.6.18.1.

The Dialog Token field is defined in 9.4.1.12 and set by the requesting STA to a nonzero value that is used for matching action responses with action requests. See 10.28.5.

The MSCS Descriptor element is defined in 9.4.2.243.

9.6.18.7 MSCS Response frame format

The MSCS Response frame is sent in response to an MSCS Request frame using the procedures defined in 11.25.3. The Action field of an MSCS Response frame contains the information shown in Figure 9-960.

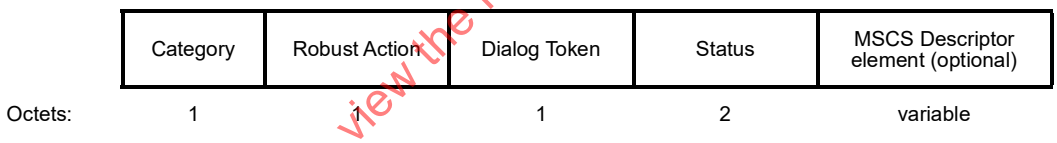

Figure 9-960—MSCS Response frame Action field format

The Category field is defined in 9.4.1.11.

The Robust Action field is defined in 9.6.18.1

The Dialog Token field is set to the nonzero value of the corresponding MSCS Request frame. If the MSCS Report frame is being transmitted for a reason other than in response to an MSCS Request frame, then the Dialog Token field is set to 0.

The Status field indicates the status of the request, as indicated in Table 9-50.

The MSCS Descriptor element is defined in 9.4.2.243. When the Status field is SUCCESS the element is not present; otherwise it is optionally present as described in 11.25.3.

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9.6.19 DMG Action frame details

9.6.19.1 DMG Action field

Several Action frame formats are defined to support DMG features. A DMG Action field, in the octet immediately after the Category field, differentiates the DMG Action frame formats. The DMG Action field values associated with each frame format within the DMG category are defined in Table 9-457.

Table 9-457—DMG Action field values

DMG Action field value	Meaning
0	Power Save Configuration Request
1	Power Save Configuration Response
2	Information Request
3	Information Response
4	Handover Request
5	Handover Response
6	Reserved
7	Reserved
8	Relay Search Request
9	Relay Search Response
10	Multi-Relay Channel Measurement Request
11	Multi-Relay Channel Measurement Report
12	RLS Request
13	RLS Response
14	RLS Announcement
15	RLS Teardown
16	Relay Ack Request
17	Relay Ack Response
18	TPA Request
19	TPA Response
20	TPA Report
21	ROC Request
22	ROC Response

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9.6.19.2 Power Save Configuration Request frame format

The format of the Power Save Configuration Request (PSC-REQ) frame Action field is shown in Table 9-458.

Table 9-458—Power Save Configuration Request frame Action field format

Order	Information
1	Category
2	DMG Action
3	Dialog Token
4	DMG Power Management
5	DMG Wakeup Schedule element (optional)

The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Dialog Token field is set to a value chosen by the STA sending the frame to uniquely identify the transaction.

The length of the DMG Power Management (DPM) field is 1 octet. Setting the DPM field to 0 indicates a transition from power save mode to active mode. Setting the DPM field to 1 indicates a transition from active mode to power save mode. All other values are reserved.

The DMG Wakeup Schedule element is defined in 9.4.2.130 (11.2.7.2).

9.6.19.3 Power Save Configuration Response frame format

The format of the Power Save Configuration Response (PSC-RSP) frame Action field is shown in Table 9-459.

Table 9-459—Power Save Configuration Response frame Action field format

Order	Information
1	Category
2	DMG Action
3	Dialog Token
4	Status Code
5	DMG Wakeup Schedule element (optional)
6	Antenna Sector ID Pattern element (optional)

The Category field is defined in 9.4.1.11.

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The DMG Action field is defined in 9.6.19.1.

The Dialog Token field is set to the value of the Dialog Token field in the corresponding PSC-REQ frame.

The Status Code field is defined in 9.4.1.9.

The DMG Wakeup Schedule element is defined in 9.4.2.130.

The Antenna Sector ID Pattern element is defined in 9.4.2.156.

9.6.19.4 Information Request frame format

The format of an Information Request frame Action field is shown in Table 9-460.

Table 9-460—Information Request frame Action field format

Order	Information
1	Category
2	DMG Action
3	Subject Address
4	Request element
5	Zero or more DMG Capabilities elements
6	Zero or more provided elements
7	Zero or more Extended Request elements
8	Zero or more Vendor Specific Request elements

The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Subject Address field contains the MAC address of the STA whose information is being requested. If this frame is sent to the PCP and the Subject Address field is the broadcast address, then the STA is requesting information regarding all associated STAs.

The Request element field is described in 9.4.2.9.

The DMG Capabilities element carries information about the transmitter STA and other STAs known to the transmitter STA. The format of this element is defined in 9.4.2.127.

Each provided element is an element as specified in 9.4.2, that the transmitter of this frame is providing to the destination of the frame.

The Extended Request element is described in 9.4.2.10.

The Vendor Specific Request element is described in 9.4.2.218.

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9.6.19.5 Information Response frame format

The format of an Information Response frame Action field is shown in Table 9-461.

This frame is individually addressed to a STA in response to an Information Request frame or it is sent unsolicited and individually addressed to a STA or broadcast to all STAs in the PBSS/infrastructure BSS. If this frame is sent as a broadcast, then this frame is an Action No Ack frame.

Table 9-461—Information Response frame Action field format

Order	Information
1	Category
2	DMG Action
3	Subject Address
4	One or more DMG Capabilities elements
5	Zero or more requested elements
6	Zero or more provided elements

The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Subject Address field contains the MAC address of the STA whose information is being provided. If this field is set to the broadcast address, then the STA is providing information regarding all associated STAs.

The DMG Capabilities element carries information about the transmitter STA and other STAs known to the transmitter STA. The DMG Capabilities element is described in 9.4.2.127.

The requested elements are those returned in response to an Information Request frame, as described in 11.28.1.

The provided elements are elements, as described in 9.4.2, that the transmitter of this frame provides to the destination of the frame, either in addition to the requested elements, or in an unsolicited Information Response frame.

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9.6.19.6 Handover Request frame format

The format of the Handover Request frame Action field is shown in Table 9-462.

Table 9-462—Handover Request frame Action field format

Order	Information
1	Category
2	DMG Action
3	Handover Reason
4	Handover Remaining BI

The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Handover Reason field is 1 octet in length and indicates the reason that the current PCP intends to do the PCP handover. The Handover Reason field is set to 0 to indicate the PCP is leaving the PBSS, it is set to 1 to indicate low power in the PCP, is set to 2 to indicate that a more qualified PCP handover capable STA is available, and is set to 3 to indicate that the PCP handover capable STA wishes to become a PCP. The other values are reserved.

The Handover Remaining BI field is 1 octet in length and indicates the number of beacon intervals, excluding the beacon interval in which this frame is transmitted, remaining until the handover takes effect.

9.6.19.7 Handover Response frame format

The format of the Handover Response frame Action field is shown in Table 9-463.

Table 9-463—Handover Response frame Action field format

Order	Information
1	Category
2	DMG Action
3	Handover Result
4	Handover Reject Reason

The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Handover Result field is 1 octet in length and indicates whether the STA accepted the handover request. Setting this field to 0 indicates that the STA accepts the handover request. Setting this field to 1 indicates that the STA does not accept the handover request.

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If the Handover Result field is set to 0, the Handover Reject Reason field is reserved and set to 0. If the Handover Result field is set to 1, the Handover Reject Reason field indicates the reason the STA rejected the handover request and can be one of the following: 0 for low power, 1 for handover in progress with another STA, 2 for invalid value for Handover Remaining BI field, and 3 for unspecified reason. The length of Handover Reject Reason field is 1 octet.

9.6.19.8 Relay Search Request frame format

The Relay Search Request frame is transmitted by a non-AP and non-PCP STA to the AP or PCP to request a list of RDSs in the BSS. The format of the Relay Search Request frame Action field is shown in Table 9-464.

Table 9-464—Relay Search Request frame Action field format

Order	Information
1	Category
2	DMG Action
3	Dialog Token
4	Destination REDS AID

The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Dialog Token field is set to a nonzero value chosen by the STA sending the Relay Search Request frame to identify the request/response transaction.

The Destination REDS AID field is set to the AID of the target destination REDS. The structure of the field is defined in 9.4.1.8.

9.6.19.9 Relay Search Response frame format

The Relay Search Response frame is sent by an AP or PCP in response to a Relay Search Request frame. The format of a Relay Search Response frame Action field is shown in Table 9-465.

Table 9-465—Relay Search Response frame Action field format

Order	Information
1	Category
2	DMG Action
3	Dialog Token
4	Status Code
5	Number of Relay Capable STAs
6	Zero or more Relay Capable STA Info fields

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The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Dialog Token field is set to the value in the corresponding Relay Search Request frame that generated this response.

The Status Code field is defined in 9.4.1.9.

The Number of Relay Capable STAs field is 1 octet in length and indicates the number of STAs in the BSS that are relay capable. This field is set to 0 if the Status Code does not indicate success.

The Relay Capable STA Info field is defined in 9.4.1.44. This information is included only if the status code indicates successful. The number of Relay Capable STA Info fields that appear in the frame is indicated by the value of the Number of Relay Capable STAs field.

9.6.19.10 Multi-relay Channel Measurement Request frame format

The Multi-Relay Channel Measurement Request frame is transmitted by a STA initiating relay operation to the recipient STA in order to obtain Channel Measurements between the recipient STA and the other STA participating in the relay operation. The format of the Multi-Relay Channel Measurement Request frame Action field is shown in Table 9-466.

Table 9-466—Multi-relay Channel Measurement Request frame Action field format

Order	Information
1	Category
2	DMG Action
3	Dialog Token

The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Dialog Token field is set to a nonzero value chosen by the STA sending the Multi-Relay Channel Measurement Request frame to identify the request/report transaction.

9.6.19.11 Multi-relay Channel Measurement Report frame format

The Multi-Relay Channel Measurement Report frame is sent in response to a Multi-Relay Channel Measurement Request. The format of the Multi-Relay Channel Measurement Report frame Action field is shown in Table 9-467.

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Table 9-467—Multi-relay Channel Measurement Report frame Action field format

Order	Information
1	Category
2	DMG Action
3	Dialog Token
4	Number of Channel Measurement Info
5	One or more Channel Measurement Info fields

The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Dialog Token field is set to the value in any corresponding Multi-Relay Channel Measurement Request frame. If the Multi-Relay Channel Measurement Report frame is not being transmitted in response to a Multi-Relay Channel Measurement Request frame, then the dialog token is set to 0.

The Number of Channel Measurement Info field is 1 octet in length and indicates the number of Channel Measurements Info fields included in the frame.

The format of the Channel Measurement Info field is defined in Figure 9-961. The number of Channel Measurement Info fields included in the frame is indicated by the Number of Channel Measurement Info field. More than one Multiple Channel Measurement Info field is included if the reporting STA measures the channel for multiple RDSs.

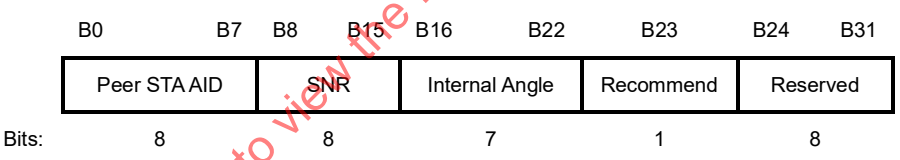

Figure 9-961—Channel Measurement Info field format

The Peer STA AID subfield contains the AID of the STA toward which the reporting STA measures link.

The SNR subfield indicates the SNR measured in the link toward the STA corresponding to Peer STA AID. This subfield is encoded as 8-bit 2s complement value of 4x(SNR-19), where SNR is measured in dB. This covers from -13 dB to 50.75 dB in 0.25 dB steps.

The Internal Angle subfield indicates the angle between directions toward the other STAs involved in the relay operation. This covers from 0° to 180° in 2° steps. This subfield uses the degree of the direction from the sector that the feedbacks indicates has highest quality during TXSS if SLS phase of BF is performed and RXSS is not included.

The Recommend subfield indicates whether the responding STA recommends relay operation based on the channel measurement with the Peer STA. This subfield is set to 1 when the relay operation is recommended and otherwise is set to 0.

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9.6.19.12 RLS Request frame format

The RLS Request frame is used to set up a relay link. The format of the RLS Request frame Action field is shown in Table 9-468.

Table 9-468—RLS Request frame Action field format

Order	Information
1	Category
2	DMG Action
3	Dialog Token
4	Destination AID
5	Relay AID
6	Source AID
7	Destination Capability Information
8	Relay Capability Information
9	Source Capability Information
10	Relay Transfer Parameter Set

The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Dialog Token field is set to a nonzero value chosen by the STA sending the RLS Request frame to identify the request/response transaction.

The Destination AID field value is the AID of the target destination formatted per 9.4.1.8.

The Relay AID field value is the AID of the selected RDS formatted per 9.4.1.8.

The Source AID field value is the AID of the initiating STA formatted per 9.4.1.8.

The Destination Capability Information field indicates the Relay Capability Information field within the Relay Capabilities element of the target destination REDS as defined in 9.4.2.147.

The Relay Capability Information field indicates the Relay Capability Information field within the Relay Capabilities element of the selected RDS as defined in 9.4.2.147.

The Source Capability Information field indicates the Relay Capability Information field within the Relay Capabilities element of the originator of the request as defined in 9.4.2.147.

The Relay Transfer Parameter Set element is defined in 9.4.2.148.

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9.6.19.13 RLS Response frame format

The RLS Response frame is sent in response to an RLS Request frame. The format of an RLS Response frame Action field is shown in Table 9-469.

Table 9-469—RLS Response frame Action field format

Order	Information
1	Category
2	DMG Action
3	Dialog Token
4	Destination Status Code
5	Relay Status Code (optional)

The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Dialog Token field is set to the value in any corresponding RLS Request frame.

The Destination Status Code field is included when the destination REDS transmits an RLS Response frame as a result of RLS Request. It is defined in 9.4.1.9.

The Relay Status Code field is included when the relay REDS transmits an RLS Response frame as a result of RLS Request. It is defined in 9.4.1.9.

9.6.19.14 RLS Announcement frame format

The RLS Announcement frame is sent to announce the successful RLS. The format of an RLS Announcement frame Action field is shown in Table 9-470.

Table 9-470—RLS Announcement frame Action field format

Order	Information
1	Category
2	DMG Action
3	Status Code
4	Destination AID
5	Relay AID
6	Source AID

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The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Status Code field is defined in 9.4.1.9.

The Destination AID field value is the AID of the target destination formatted per 9.4.1.8.

The Relay AID field value is the AID of the RDS formatted per 9.4.1.8.

The Source AID field value is the AID of the initiating STA formatted per 9.4.1.8.

9.6.19.15 RLS Teardown frame format

The RLS Teardown frame is sent to terminate a relay operation. The format of the RLS Teardown frame Action field is shown in Table 9-471.

Table 9-471—RLS Teardown frame Action field format

Order	Information
1	Category
2	DMG Action
3	Destination AID
4	Relay AID
5	Source AID
6	Reason Code

The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Destination AID field value is the AID of the destination REDS formatted per 9.4.1.8.

The Relay AID field value is the AID of the RDS formatted per 9.4.1.8.

The Source AID field value is the AID of the source REDS formatted per 9.4.1.8.

The Reason Code field is defined in 9.4.1.7.

9.6.19.16 Relay Ack Request frame format

The Relay Ack Request frame is sent by a source REDS to an RDS participating in a relay operation in order to determine whether all frames forwarded through the RDS were received by the destination REDS also participating in the relay operation. This frame is used only when the RDS is operated in HD-DF mode and relay operation is link switching. The format of the Relay Ack Request frame Action field is shown in Table 9-472.

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Table 9-472—Relay Ack Request frame Action field format

Order	Information
1	Category
2	DMG Action
3	BAR Control
4	BlockAck Starting Sequence Control

The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The BAR Control field and BlockAck Starting Sequence Control fields are defined in 9.3.1.7.

9.6.19.17 Relay Ack Response frame format

The Relay Ack Response frame is sent by an RDS to a source REDS participating in a relay operation in order to report the frames received by the destination REDS also participating in the relay operation. This frame is used only when the RDS is operated in HD-DF mode and relay operation is link switching. The format of the Relay Ack Response frame Action field is shown in Table 9-473.

Table 9-473—Relay Ack Response frame Action field format

Order	Information
1	Category
2	DMG Action
3	BA Control
4	BlockAck Starting Sequence Control
5	BlockAck Bitmap

The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The BA Control field is defined in 9.3.1.8.

The BlockAck Starting Sequence Control field is defined in 9.3.1.8 and is set to the corresponding value within the immediately previously received Relay Ack Request frame.

The BlockAck Bitmap field is defined in 9.3.1.8.

9.6.19.18 TPA Request frame format

The TPA Request frame is sent by a destination REDS participating in operation based on link cooperation to both the RDS and source REDS that belong to the same group as the destination REDS in order for them

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to send back their own TPA Response frames at the separately predefined times. Also, a source REDS sends a TPA Request frame to the RDS that is selected by the source REDS in order for the RDS to feedback its own TPA Response frame at the predefined time.

The format of the TPA Request frame Action field is shown in Table 9-474.

Table 9-474—TPA Request frame Action field format

Order	Information
1	Category
2	DMG Action
3	Dialog Token
4	Timing Offset
5	Sampling Frequency Offset

The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Dialog Token field is set to a nonzero value chosen by the STA sending the TPA Request frame to identify the request/response transaction.

The Timing Offset field is 2 octets in length and indicates the amount of time, in nanoseconds, that the STA identified in the RA of the frame is required to change the timing offset of its transmissions so that they arrive at the expected time at the transmitting STA.

The Sampling Frequency Offset field is 2 octets in length and indicates the amount by which to change the sampling frequency offset of the burst transmission so that bursts arrive at the destination DMG STA with no sampling frequency offset. The unit is 0.01 ppm.

9.6.19.19 TPA Response frame format

The TPA Response frame is sent by an RDS or a source REDS participating in relay operation in response to a TPA Request frame from a destination REDS or a source REDS. The RDS or the source REDS that receives a TPA Request frame responds to the destination REDS or the source REDS, as appropriate, with a TPA Response frame at a predetermined time from the end of the TPA Request frame (see 11.34). The format of the TPA Response frame Action field is shown in Table 9-475.

Table 9-475—TPA Response frame Action field format

Order	Information
1	Category
2	DMG Action
3	Dialog Token

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The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Dialog Token field is set to the value of the Dialog Token field of the TPA Request frame that generated this response.

9.6.19.20 TPA Report frame format

The TPA Report frame is sent to announce whether a TPA procedure is successful. The format of the TPA Report frame Action field is shown in Table 9-476.

Table 9-476—TPA Report frame Action field format

Order	Information
1	Category
2	DMG Action
3	Status code

The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Status Code field indicates the result of the current TPA procedure and is defined in 9.4.1.9.

9.6.19.21 ROC Request frame format

The ROC Request frame is sent by the source REDS participating in a relay operation in order to request a change in the current relay operation type. The format of the ROC Request frame Action field is shown in Table 9-477.

Table 9-477—ROC Request frame Action field format

Order	Information
1	Category
2	DMG Action
3	Dialog Token
4	Relay Operation Type

The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Dialog Token field is set to a nonzero value chosen by the STA sending the ROC Request frame to identify the request/response transaction.

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The format of the Relay Operation Type field is defined in Figure 9-962.

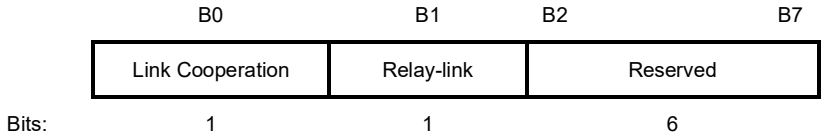

Figure 9-962—Relay Operation Type field format

The Link Cooperation subfield is set to 0 to request the operation to be changed to link switching and is set to 1 to request the operation to be changed to link cooperation.

The Relay-link subfield is set to 0 to indicate that the link switching operation starts at the direct link between the source REDS and destination REDS and set to 1 to indicate that the link switching operation starts with the RDS. If the Link Cooperation subfield is set to 1, the Relay-link subfield is reserved.

9.6.19.22 ROC Response frame format

The ROC Response frame is sent by the RDS or the destination DMG STA participating in a relay operation in response to a ROC Request frame from the source DMG STA. The format of the ROC Response frame Action field is shown in Table 9-478.

Table 9-478—ROC Response frame Action field format

Order	Information
1	Category
2	DMG Action
3	Dialog Token
4	Status Code

The Category field is defined in 9.4.1.11.

The DMG Action field is defined in 9.6.19.1.

The Dialog Token field is set to the value received in the corresponding ROC Request frame that generated this response.

The Status Code field is defined in 9.4.1.9.

9.6.20 FST Action frame details

9.6.20.1 FST Action field

The FST Action field values are defined in Table 9-479.

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Table 9-479—FST Action field values

FST Action field value	Meaning
0	FST Setup Request
1	FST Setup Response
2	FST Teardown
3	FST Ack Request
4	FST Ack Response
5	On-channel Tunnel Request

9.6.20.2 FST Setup Request frame format

The FST Setup Request frame allows an initiating STA to announce to a peer STA whether the initiating STA intends to enable FST for the session between the initiating STA and the peer STA (11.31). The format of the FST Setup Request frame Action field is shown in Table 9-480.

Table 9-480—FST Setup Request frame Action field format

Order	Information
1	Category
2	FST Action
3	Dialog Token
4	LLT
5	Session Transition
6	Multi-band (optional)
7	DMG Wakeup Schedule (optional)
8	Awake Window (optional)
9	Switching Stream (optional)
10	Zero or more additional elements are present, as defined in 11.31.1. Each of these elements is not present more than once in the frame.

The Category field is defined in 9.4.1.11.

The FST Action field is defined in 9.6.20.1.

The Dialog Token field is set to a nonzero value chosen by the STA.

The Link loss timeout (LLT) field is 32 bits and indicates the compressed maximum duration counted from the last time an MPDU was received by the initiating STA from the peer STA until the initiating STA decides to initiate FST. The use of this field is described in 11.31.

The Session Transition field contains the Session Transition element as defined in 9.4.2.145.

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The Multi-band field contains the Multi-Band element as defined in 9.4.2.138. The regulatory information contained in the Multi-band element is applicable to all of the fields and elements contained in the frame.

The DMG Wakeup Schedule element is defined in 9.4.2.130.

The Awake Window element is defined in 9.4.2.137.

The Switching Stream element is defined in 9.4.2.144.

9.6.20.3 FST Setup Response frame format

The FST Setup Response frame is transmitted in response to an FST Setup Request frame. The format of the frame Action field is shown in Table 9-481.

Table 9-481—FST Setup Response frame Action field format

Order	Information
1	Category
2	FST Action
3	Dialog Token
4	Status Code
5	Session Transition
6	Multi-band (optional)
7	DMG Wakeup Schedule (optional)
8	Awake Window (optional)
9	Switching Stream (optional)
10	Timeout Interval (optional)
11	Zero or more additional elements are present, as defined in 11.31.1. Each of these elements is not present more than once in the frame.

The Category field is defined in 9.4.1.11.

The FST Action field is defined in 9.6.20.1.

The Dialog Token field value is copied from the corresponding received FST Setup Request frame.

The Status Code field is defined in 9.4.1.9.

The Session Transition field contains the Session Transition element as defined in 9.4.2.145.

The Multi-band element is defined in 9.4.2.138.

The DMG Wakeup Schedule element is defined in 9.4.2.130.

The Awake Window element is defined in 9.4.2.137

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The Switching Stream element is defined in 9.4.2.144.

The Timeout Interval element is defined in 9.4.2.48.

9.6.20.4 FST Teardown frame format

The FST Teardown frame is transmitted to delete an established FST session between STAs. The format of the frame Action field is shown in Table 9-482.

Table 9-482—FST Teardown frame Action field format

Order	Information
1	Category
2	FST Action
3	FSTS ID

The Category field is defined in 9.4.1.11.

The FST Action field is defined in 9.6.20.1.

The FSTS ID field contains the identification of the FST session established between the STAs identified by the TA and RA fields of this frame. The format of the FSTS ID field is as specified 9.4.2.145.

9.6.20.5 FST Ack Request frame format

The FST Ack Request frame is transmitted in the frequency band an FST session is transferred to and confirms the FST. The format of the frame Action field is shown in Table 9-483.

Table 9-483—FST Ack Request frame Action field format

Order	Information
1	Category
2	FST Action
3	Dialog Token
4	FSTS ID

The Category field is defined in 9.4.1.11.

The FST Action field is defined in 9.6.20.1.

The Dialog Token field is set to a nonzero value chosen by the STA sending the FST Ack request to identify the request/report transaction.

The FSTS ID field contains the identification of the FST session established between the STAs identified by the TA and RA fields of this frame. The format of the FSTS ID field is as specified in 9.4.2.145.

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9.6.20.6 FST Ack Response frame format

The FST Ack Response frame is transmitted in response to an FST Ack Request frame. The format of the frame Action field is shown in Table 9-484.

Table 9-484—FST Ack Response frame Action field format

Order	Information
1	Category
2	FST Action
3	Dialog Token
4	FSTS ID

The Category field is defined in 9.4.1.11.

The FST Action field is defined in 9.6.20.1.

The Dialog Token field is set to the value in any corresponding FST Ack Request frame. If the FST Ack Response frame is not being transmitted in response to an FST Ack Request frame, then the dialog token is set to 0.

The FSTS ID field contains the identification of the FST session established between the STAs identified in the TA and RA fields of this frame. The format of the FSTS ID field is as specified in 9.4.2.145.

9.6.20.7 On-channel Tunnel Request frame format

The On-channel Tunnel Request frame allows a STA of a multi-band device to encapsulate an MMPDU for transmission to an MLME of a peer STA within the same multi-band device (11.31), which can be used to perform multi-band association and multi-band authentication.

The format of the On-channel Tunnel Request frame Action field is shown in Table 9-485.

Table 9-485—On-channel Tunnel Request frame Action field format

Order	Information
1	Category
2	FST Action
3	OCT MMPDU Descriptor
4	Multi-band
5	OCT Source

The Category field is defined in 9.4.1.11.

The FST Action field is defined in 9.6.20.1.

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The OCT MMPDU Descriptor field is defined in Figure 9-963.

	MMPDU Length	MMPDU Frame Control	MMPDU Frame Body
Octets:	2	2	Variable

Figure 9-963—Definition of the OCT MMPDU Descriptor field

The MMPDU Length subfield contains the length in octets of the MMPDU Frame Body subfield.

The MMPDU Frame Control subfield carries the content of the Frame Control field of an MMPDU that would be constructed if the MMPDU for the corresponding management frame type were transmitted over the air.

The MMPDU Frame Body subfield carries the content of the Frame Body field of an MPDU carrying the MMPDU that would be constructed if the MMPDU for the corresponding management frame type were transmitted unencrypted over the air (i.e., all of the octets after the MAC header and up to, but not including, the FCS).

The Multi-band field contains the Multi-band element (see 9.4.2.138) of the peer MLME to which the OCT MMPDU is destined to. The values of the Band ID, Channel Number and BSSID fields contained in this element are used to deliver the OCT MMPDU to the correct MLME within the peer STA.

The OCT Source field contains an OCT Source element that identifies the MLME that is the source of an OCT MMPDU.

9.6.21 Unprotected DMG Action frame details

9.6.21.1 Unprotected DMG Action field

Unprotected DMG Action frames are not encapsulated using mechanisms defined for robust Management frames. An Unprotected DMG Action field, in the field immediately after the Category field, differentiates the formats. The Action field values associated with each frame format are defined in Table 9-486.

Table 9-486—Unprotected DMG Action field values

Unprotected DMG Action field value	Meaning
0	Announce
1	BRP

9.6.21.2 Announce frame format

The Announce frame is an Action or an Action No Ack frame of category Unprotected DMG. The format of an Announce frame Action field is shown in Table 9-487.

Announce frames can be transmitted during the ATI of a beacon interval and can perform functions including of a DMG Beacon frame, but since this frame does not have to be transmitted as a sector sweep to a STA, it can provide much more spectrally efficient access than using a DMG Beacon frame.

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Table 9-487—Announce frame Action field format

Order	Information	Notes
1	Category	The Category field is defined in 9.4.1.11.
2	Unprotected DMG Action	The Unprotected DMG Action field is defined in 9.6.21.1.
3	Timestamp	The Timestamp field is defined in 9.4.1.10.
4	Beacon Interval	The Beacon Interval field is defined in 9.4.1.3 and specifies the duration of the beacon interval of the BSS.
5	SSID	The SSID element is defined in 9.4.2.2. The SSID element is optionally present. If present, the SSID element specifies the SSID of the BSS.
6	Extended Schedule	The Extended Schedule element is defined in 9.4.2.131. The Extended Schedule element is optionally present. If present, the Extended Schedule element specifies the schedule of the BSS.
7	DMG Capabilities	The DMG Capabilities element is defined in 9.4.2.127. The DMG Capabilities element is optionally present. If present, the DMG Capabilities element specifies capabilities of the transmitting STA.
8	RSN	The RSNE is defined in 9.4.2.24. The RSNE is optionally present. If present, the RSNE indicates that security is required in the BSS.
9	Multiple BSSID	The Multiple BSSID element is defined in 9.4.2.45. The Multiple BSSID element is optionally present. If present, the Multiple BSSID element signals all the BSSIDs in use by the BSS.
10	DMG Operation	The DMG Operation element is defined in 9.4.2.128. The DMG Operation element is optionally present. If present, the DMG Operation element specifies the operational parameters of the BSS.
11	Next DMG ATI	The Next DMG ATI element is defined in 9.4.2.135. The Next DMG ATI element is optionally present. If present, the Next DMG ATI element specifies the start time of the next ATI at a subsequent beacon interval.
12	Multi-band	The Multi-band element is defined in 9.4.2.138. The Multi-band element is optionally present.
13	Awake Window	The Awake Window element is defined in 9.4.2.137. The Awake Window element is optionally present.
14	DMG BSS Parameter Change	The DMG BSS Parameter Change element is defined in 9.4.2.126. The DMG BSS Parameter Change element is optionally present.
15	BeamLink Maintenance	The BeamLink Maintenance element is defined in 9.4.2.151. The BeamLink Maintenance element is optionally present.
16	Multiple MAC Sublayers	The Multiple MAC Sublayers element is defined in 9.4.2.152. The Multiple MAC Sublayers element is optionally present.
17	ECAPC Policy	The ECAPC Policy element is defined in 9.4.2.154. The ECAPC Policy element is optionally present.
18	Cluster Report	The Cluster Report element is defined in 9.4.2.146. The Cluster Report element is optionally present.
19	Next PCP List	The Next PCP List element is defined in 9.4.2.140. The Next PCP List element is optionally present.

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Table 9-487—Announce frame Action field format *(continued)*

Order	Information	Notes
20	PCP Handover	The PCP Handover element is defined in 9.4.2.141. The PCP Handover element is optionally present.
21	STA Availability	The STA Availability element is defined in 9.4.2.132. The STA Availability element is optionally present.
22	UPSIM	The UPSIM element is defined in 9.4.2.166. The UPSIM element is optionally present.
23	Extended Channel Switch Announcement	The Extended Channel Switch Announcement element is defined in 9.4.2.52. The Extended Channel Switch Announcement element is optionally present if dot11ExtendedChannelSwitchActivated is true.
24	Cluster Probe	The Cluster Probe element is defined in 9.4.2.223. The Cluster Probe element is optionally present.
25	Extended Cluster Report	The Extended Cluster Report element is defined in 9.4.2.224. The Extended Cluster Report element is optionally present.
26	Cluster Switch Announcement	The Cluster Switch Announcement element is defined in 9.4.2.225. The Cluster Switch Announcement element is optionally present.
27	CDMG Extended Schedule	The Extended Schedule element is optionally present if dot11OpportunisticTransmissionsImplemented is true; otherwise not present.
28	Service Hash	The Service Hash element is optionally present if dot11UnsolicitedPADActivated is true; otherwise not present.
29	Service Hint	The Service Hint element is optionally present if dot11UnsolicitedPADActivated is true; otherwise not present.

9.6.21.3 BRP frame format

The BRP frame is an Action No Ack frame. The format of a BRP frame Action field is shown in Table 9-488.

Table 9-488—BRP frame Action field format

Order	Information
1	Category
2	Unprotected DMG Action
3	Dialog Token
4	BRP Request field
5	DMG Beam Refinement element
6	Zero or more Channel Measurement Feedback elements
7	Enhanced Beam Tracking element
8	SSW Report element

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The Category field is defined in 9.4.1.11.

The Unprotected DMG Action field is defined in 9.6.21.1.

The Dialog Token field is set to a value chosen by the STA sending the frame to uniquely identify the transaction.

The BRP Request field is defined in 9.5.4.

The DMG Beam Refinement element is defined in 9.4.2.129.

The Channel Measurement Feedback element is defined in 9.4.2.136.

The BRP frame contains more than one Channel Measurement Feedback element if the measurement information exceeds 255 octets. The content of each Channel Measurement Feedback element that follows the first one in a single BRP frame is a continuation of the content in the previous element. The Channel Measurement, Tap Delay, and Sector ID Order subfields can be split between several elements. Each Channel Measurement Feedback element that is not the last Channel Measurement Feedback element in the frame is 257 octets long. Channel measurement information for a single channel measurement is always contained within a single BRP frame.

NOTE—The length of a BRP frame can limit the choice of channel measurement parameters such as the number of measurements and the number of taps.

The Enhanced Beam Tracking element is defined in 9.4.2.226.

The SSW Report element is defined in 9.4.2.222.

9.6.22 VHT Action frame details

9.6.22.1 VHT Action field

Several Action frame formats are defined to support VHT functionality and S1G functionality. A VHT Action field, in the octet immediately after the Category field, differentiates the VHT Action frame formats. The VHT Action field values associated with each frame format within the VHT category are defined in Table 9-489.

Table 9-489—VHT Action field values

Value	Meaning	Time priority
0	VHT Compressed Beamforming	Yes
1	Group ID Management	No
2	Operating Mode Notification	No
3–255	Reserved	

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9.6.22.2 VHT Compressed Beamforming frame format

The VHT Compressed Beamforming frame is an Action No Ack frame of category VHT. The Action field of a VHT Compressed Beamforming frame contains the information shown in Table 9-490.

Table 9-490—VHT Compressed Beamforming frame Action field format

Order	Information
1	Category
2	VHT Action
3	VHT MIMO Control (see 9.4.1.48)
4	VHT Compressed Beamforming Report (see 9.4.1.49)
5	MU Exclusive Beamforming Report (see 9.4.1.51)

The Category field is defined in 9.4.1.11.

The VHT Action field is defined in 9.6.22.1.

The VHT MIMO Control field is always present in the frame. The presence and contents of the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field are dependent on the values of the Feedback Type, Remaining Feedback Segments, and First Feedback Segment subfields of the VHT MIMO Control field (see 9.4.1.48, 9.4.1.49, 9.4.1.51, and 10.36.5).

No Vendor Specific elements are present in a VHT Compressed Beamforming frame.

When carried in an S1G PPDU, a VHT Compressed Beamforming frame is referred to as an S1G Compressed Beamforming frame, and a VHT MIMO Control field is referred to as an S1G MIMO Control field.

When carried in an S1G PPDU, a VHT NDP Announcement frame is referred to as an S1G NDP Announcement frame.

9.6.22.3 Group ID Management frame format

The Group ID Management frame is transmitted by the AP to assign or change the user position of a STA for one or more group IDs. The Action field of a Group ID Management frame contains the information shown in Table 9-491.

Table 9-491—Group ID Management frame Action field format

Order	Information
1	Category
2	VHT Action
3	Membership Status Array (see 9.4.1.54)
4	User Position Array (see 9.4.1.55)

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The Category field is defined in 9.4.1.11.

The VHT Action field is defined in 9.6.22.1.

9.6.22.4 Operating Mode Notification frame format

The Operating Mode Notification frame is used to notify STAs that the transmitting STA is changing one or more of its operating channel width, the maximum number of spatial streams it can receive, and its LDPC receive preference.

The Action field of the Operating Mode Notification frame contains the information shown in Table 9-492.

Table 9-492—Operating Mode Notification frame Action field format

Order	Information
1	Category
2	VHT Action
3	Operating Mode (see 9.4.1.53)

The Category field is defined in 9.4.1.11.

The VHT Action field is defined in 9.6.22.1.

9.6.23 FILS Action frame details

9.6.23.1 General

The FILS Action frame is used for FILS operation after the non-AP STA has associated with the AP. The defined FILS Action frames are listed in Table 9-493.

Table 9-493—FILS Action frame values

Action field value	Description
0	FILS Container frame
1–255	Reserved

9.6.23.2 FILS Container frame

The FILS Container frame is used to exchange FILS IP Address Assignment elements (see 9.4.2.184). The format of the Action field of the FILS Container frame is shown in Figure 9-964.

	Category	FILS Action	FILS IP Address Assignment Elements
Octets:	1	1	variable

Figure 9-964—FILS Container frame Action field format

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The Category field is set to the value for FILS defined in Table 9-51.

The FILS Action field is set to the value given in Table 9-493 for FILS Container frame.

The FILS IP Address Assignment Elements field contains one or more FILS IP Address Assignment elements as defined in 9.4.2.184.

9.6.24 Unprotected S1G Action frame details

9.6.24.1 Unprotected S1G Action field

Several Action frame formats are defined to support S1G functionality. An Unprotected S1G Action field, in the octet immediately after the Category field, differentiates the Unprotected S1G Action frame formats. The Unprotected S1G Action field values associated with each frame format within the Unprotected S1G category are defined in Table 9-494.

Table 9-494—Unprotected S1G Action field values

Value	Meaning	Time Priority
0	AID Switch Request	No
1	AID Switch Response	No
2	Sync Control	No
3	STA Information Announcement	No
4	EDCA Parameter Set	No
5	EL Operation	No
6	TWT Setup	No
7	TWT Teardown	No
8	Sectorized Group ID List	No
9	Sector ID Feedback	No
10	Reserved	
11	TWT Information	No
12–255	Reserved	

9.6.24.2 AID Switch Request frame format

A STA that is changing its device characteristic as defined in 9.4.2.193 uses the AID Switch Request frame to request the frame's recipient to change its AID or to request a group AID from an AP. The Action field of the AID Switch Request frame contains the information shown in Table 9-495.

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Table 9-495—AID Switch Request frame Action field format

Order	Information
1	Category
2	Unprotected S1G Action
3	Dialog Token
4	AID Request (see 9.4.2.193)

The Category field is defined in 9.4.1.11.

The Unprotected S1G Action field is defined in 9.6.24.1.

The Dialog Token field is a value chosen by the non-AP STA sending the AID Switch Request frame to identify the request/response transaction.

The AID Request field contains an AID Request element as specified in 9.4.2.193.

9.6.24.3 AID Switch Response frame format

The AID Switch Response frame is sent by an AP in response to an AID Switch Request frame, or sent by an AP to a non-AP STA to instruct the STA to change its AID or wakeup interval and it is sent by an AP to assign a group AID to a requesting STA. The Action field of the AID Switch Response frame contains the information shown in Table 9-496.

Table 9-496—AID Switch Response frame Action field format

Order	Information
1	Category
2	Unprotected S1G Action
3	Dialog Token
4	AID Response (see 9.4.2.194)

The Category field is defined in 9.4.1.11.

The Unprotected S1G Action field is defined in 9.6.24.1.

The Dialog Token field is the value in the corresponding AID Switch Request frame. If the AID Switch Response frame is not being transmitted in response to an AID Switch Request frame, then the Dialog token is set to 0.

The AID Response field contains an AID Response element as specified in 9.4.2.194.

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9.6.24.4 Sync Control frame format

The Sync Control frame is transmitted by a non-AP STA to a UL-Sync capable AP to enable or disable sync frame transmission for uplink traffic (see 10.49). The Action field of a Sync Control frame contains the information shown in Table 9-497.

Table 9-497—Sync Control frame Action field format

Order	Information
1	Category
2	Unprotected S1G Action
3	Sync Control (see 9.4.1.58)

The Category field is defined in 9.4.1.11.

The Unprotected S1G Action field is defined in 9.6.24.1.

The Sync Control field is defined in 9.4.1.58.

9.6.24.5 STA Information Announcement frame format

The STA Information Announcement frame is either used by a non-AP STA to inform the peer STAs of the updated AID when a STA's AID is changed or used by a relay STA to inform the AP of a newly associated STA's AID or the updated AID when a STA's AID is changed. The Action field of the STA Information Announcement frame contains the information shown in Table 9-498.

Table 9-498—STA Information Announcement frame Action field format

Order	Information
1	Category
2	Unprotected S1G Action
3	AID Announcement (9.4.2.208)

The Category field is defined in 9.4.1.11.

The Unprotected S1G Action field is defined in 9.6.24.1.

The AID Announcement field contains an AID Announcement element as specified in 9.4.2.208.

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9.6.24.6 EDCA Parameter Set frame format

The EDCA Parameter Set frame is used to update the EDCA Parameter Set at the recipient STA, as defined in 10.2.3.2). The Action field of the EDCA Parameter Set frame contains the information shown in Table 9-499.

Table 9-499—EDCA Parameter Set frame Action field format

Order	Information
1	Category
2	Unprotected S1G Action
3	EDCA Parameter Set (9.4.2.28)

The Category field is defined in 9.4.1.11.

The Unprotected S1G Action field is defined in 9.6.24.1.

The EDCA Parameter Set field contains an EDCA Parameter Set element as specified in 9.4.2.28.

9.6.24.7 EL Operation frame format

The EL Operation frame is used to carry the EL Operation element (9.4.2.210). The Action field of the EL Operation frame contains the information shown in Table 9-500

Table 9-500—EL Operation Action field format

Order	Information
1	Category
2	Unprotected S1G Action
3	EL Operation (9.4.2.210)

The Category field is defined in 9.4.1.11.

The Unprotected S1G Action field is defined in 9.6.24.1.

The EL Operation field contains an EL Operation element as specified in 9.4.2.210.

9.6.24.8 TWT Setup frame format

The TWT Setup frame is sent by a STA to request the setup of a TWT SP and it is sent by a responding STA to indicate the status of a requested TWT SP. The Action field of the TWT Setup frame contains the information shown in Table 9-501.

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Table 9-501—TWT Setup frame Action field format

Order	Information
1	Category
2	Unprotected S1G Action
3	Dialog Token
4	TWT (9.4.2.199)

The Category field is defined in 9.4.1.11.

The Unprotected S1G Action field is defined in 9.6.24.1.

In a TWT Setup frame with a TWT Request field that is equal to 1, the Dialog Token field is set to a value chosen by the transmitting STA to identify the request/response transaction. In a TWT Setup frame with a TWT Request field equal to 0, the Dialog Token field is set to the value copied from the corresponding received TWT Setup frame with a TWT Request field equal to 1.

9.6.24.9 TWT Teardown frame format

The TWT Teardown frame is sent by a STA to request the teardown of a TWT agreement and is transmitted by either STA of an existing TWT agreement. The Action field of the TWT Teardown frame contains the information shown in Table 9-502.

Table 9-502—TWT Teardown frame Action field format

Order	Information
1	Category
2	Unprotected S1G Action
3	TWT Flow

The Category field is defined in 9.4.1.11.

The Unprotected S1G Action field is defined in 9.6.24.1.

The TWT Flow field contains the TWT Flow Identifier field and 5 reserved bits as shown in Figure 9-965:

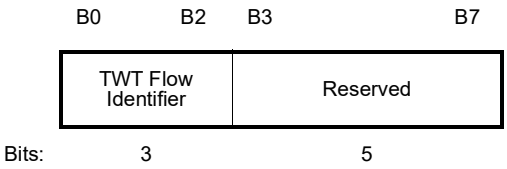

Figure 9-965—TWT Flow field format

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The TWT Flow Identifier field is defined in 9.4.2.199. In a TWT Teardown frame, the TWT Flow Identifier field is set to the value of the TWT Flow Identifier field of the TWT element in the frame that successfully concluded the setup of the TWT that is the subject of the teardown request.

9.6.24.10 Sectorized Group ID List frame format

The Sectorized Group ID List frame is an Action or Action No Ack frame of category Unprotected S1G Action. The frame is used to allocate/change sectorized group IDs to a STA. The format of its Action field is defined in Table 9-503.

Table 9-503—Sectorized Group ID List frame Action field format

Order	Information
1	Category
2	Unprotected S1G Action
3	Sectorized Group ID List (9.4.2.211)

The Category field is defined in 9.4.1.11.

The Unprotected S1G Action field is defined in 9.6.24.1.

The Sectorized Group ID List field contains a Sectorized Group ID List as specified in 9.4.2.211.

9.6.24.11 Sector ID Feedback frame format

The Sector ID Feedback frame is an Action or Action No Ack frame of category Unprotected S1G. The format of its Action field is defined in Table 9-504.

Table 9-504—Sector ID Feedback frame Action field format

Order	Information
1	Category
2	Unprotected S1G Action
3	Sector ID Index

The Category field is defined in 9.4.1.11.

The Unprotected S1G Action field is defined in 9.6.24.1.

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The Sector ID index field is shown in Figure 9-966.

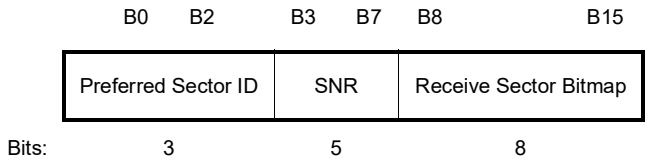

Figure 9-966—Sector ID Index format

The Preferred Sector ID field indicates the sector selected by the STA. The method in which a STA selects the Sector ID is out of the scope of this standard.

The SNR field indicates the received SNR at the preferred Sector, 0 to 30 represents SNR values from –3 to 27 dB, respectively. If the SNR value is less than –3 dB, set to 0. If the SNR value is greater than 27 dB, set to 30. 31 indicates no feedback.

The Receive Sector Bitmap field indicates a bit map. A bit position equal to 0 within the bit map indicates that the STA does not receive the AP signal in the corresponding Sector ID. A bit position equal to 1 within the bit map indicates that the STA does receive the AP signal in the corresponding Sector ID. The position of the bit map (0 to 7) corresponding to the sector ID (see Figure 9-967).

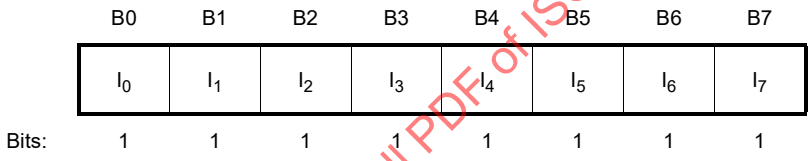

Figure 9-967—Receive Sector Bitmap format

9.6.24.12 TWT Information frame format

The TWT Information frame is sent by a STA to request or deliver information about a TWT agreement and is transmitted by either STA of an existing TWT agreement. The Action field of the TWT Information frame contains the information shown in Table 9-505.

Table 9-505—TWT Information frame Action field format

Order	Information
1	Category
2	Unprotected S1G Action
3	TWT Information (9.4.1.60)

The Category field is defined in 9.4.1.11.

The Unprotected S1G Action field is defined in 9.6.24.1.

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9.6.25 S1G Action frame details

9.6.25.1 S1G Action field

The S1G Action field values are specified in Table 9-506.

Table 9-506—S1G Action field values

S1G Action field value	Description
0	Reachable Address Update
1	Relay Activation Request
2	Relay Activation Response
3	Header Compression Update
4	Protected TWT Setup
5	Protected TWT Teardown
6	Protected TWT Information
7–255	Reserved

9.6.25.2 Reachable Address Update frame format

The Reachable Address Update frame is used to update the addresses that can be reached through a relay STA. The format of the Reachable Address Update frame Action field is shown in Table 9-507.

Table 9-507—Reachable Address Update frame Action field format

Order	Information
1	Category
2	S1G Action
3	Reachable Address

The Category field is defined in 9.4.1.11.

The S1G Action field is defined in 9.6.25.1.

The Reachable Address element (as specified by 9.4.2.205) contains the addresses whose reachability through the S1G relay STA is being updated.

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9.6.25.3 Relay Activation Request frame format

The Relay Activation Request frame is used by the STA or AP to Request start or terminate a relay function. The format of the Relay Activation Request frame Action field is shown in Table 9-508.

Table 9-508—Relay Activation Request frame Action field format

Order	Information
1	Category
2	S1G Action
3	Relay Activation

The Category field is defined in 9.4.1.11.

The S1G Action field is defined in 9.6.25.1.

The Relay Activation Mode subfield of the S1G Relay Activation element (as specified by 9.4.2.206) included in the Relay Activation Request frame is set to 1.

9.6.25.4 Relay Activation Response frame format

The Relay Activation Response frame is used by the STA or AP to confirm or reject the start or the termination of the relay function. The format of the Relay Activation Response frame Action field is shown in Table 9-509.

Table 9-509—Relay Activation Response frame Action field format

Order	Information
1	Category
2	S1G Action
3	Relay Activation

The Category field is defined in 9.4.1.11.

The S1G Action field is defined in 9.6.25.1.

The Relay Activation Mode subfield of the S1G Relay Activation element (as specified by 9.4.2.206) included in the Relay Activation Response frame is set to 0.

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9.6.25.5 Header Compression frame format

The Header Compression frame is used to update information at the recipient STA, as defined in 10.58. The Header Compression frame Action field contains the information shown in Table 9-510.

Table 9-510—Header Compression frame Action field format

Order	Information
1	Category
2	S1G Action
3	Dialog Token
4	Header Compression (see 9.4.2.213)

The Category field is defined in 9.4.1.11.

The S1G Action field is defined in 9.6.25.1.

The Dialog Token field is a value chosen by the STA sending the Header Compression frame to identify the request/response transaction.

The Header Compression field contains a Header Compression element as specified in 9.4.2.213.

9.6.25.6 Protected TWT Setup frame format

The Protected TWT Setup frame allows robust STA-STA communication of the same information that is conveyed in the TWT Setup frame that is not robust (see 9.6.24.1).

The Action field of the Protected TWT Setup frame has the same format as the Action field of the unprotected TWT Setup frame (see 9.6.24.8), except that the Order 2 item is the S1G Action field, which is defined in 9.6.25.1, instead of the Unprotected S1G Action field.

9.6.25.7 Protected TWT Teardown frame format

The Protected TWT Teardown frame allows robust STA-STA communication of the same information that is conveyed in the TWT Teardown frame that is not robust (see 9.6.24.1).

The Action field of the Protected TWT Teardown frame has the same format as the Action field of the unprotected TWT Teardown frame (see 9.6.24.9), except that the Order 2 item is the S1G Action field, which is defined in 9.6.25.1, instead of the Unprotected S1G Action field.

9.6.25.8 Protected TWT Information frame format

The Protected TWT Information frame allows robust STA-STA communication of the same information that is conveyed in the TWT Information frame that is not robust (see 9.6.24.1).

The Action field of the Protected TWT Information frame has the same format as the Action field of the unprotected TWT Information frame (see 9.6.24.12), except that the Order 2 item is the S1G Action field, which is defined in 9.6.25.1, instead of the Unprotected S1G Action field.

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9.6.26 Flow Control Action frame details

9.6.26.1 Flow Control Action field

The Flow Control Action field values are specified in Table 9-511.

Table 9-511—Flow Control Action field format

Flow Control Action field value	Description	Time priority
0	Flow suspension	Yes when transmitted as an Action no Ack frame
1	Flow resumption	Yes when transmitted as an Action no Ack frame
2–255	Reserved	

9.6.26.2 Flow Suspension frame format

The Flow Suspension frame is an Action or an Action No Ack frame of category Flow Control Action used by a STA to suspend incoming transmissions for an amount of time indicated in the Suspend Duration field. The format of the Flow Suspension frame Action field is shown in Table 9-512.

Table 9-512—Flow Suspension frame Action field format

Order	Information
1	Category
2	Flow Control Action
3	Suspend Duration

The Category field is defined in 9.4.1.11.

The Flow Control Action field is defined in 9.6.26.1.

The Suspend Duration field is 2 octets and denotes the amount of time, in microseconds, during which the intended recipient STAs are not allowed to transmit Data frames to the STA identified by the TA field of the Flow Suspension frame.

9.6.26.3 Flow Resumption frame format

The Flow Resumption frame is an Action or an Action No Ack frame of category Flow Control Action used by the STA identified by the TA field of the frame to cancel any outstanding flow suspension time the STA had previously invoked through the transmission of a Flow Suspension, BAT, TACK, STACK, or NDP Ack frame as described in 10.61. The format of the Flow Resumption frame Action field is shown in Table 9-513.

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Table 9-513—Flow Resumption frame Action field format

Order	Information
1	Category
2	Flow Control Action

The Category field is defined in 9.4.1.11.

The Flow Control Action field is defined in 9.6.26.1.

9.6.27 Control Response MCS Negotiation frame details

9.6.27.1 Control Response MCS Negotiation Action field

The Control Response MCS Negotiation Action field values are specified in Table 9-514.

Table 9-514—Control Response MCS Negotiation Action field values

MCS Negotiation Action field value	Description
0	Control Response MCS Negotiation Request
1	Control Response MCS Negotiation Response
2–255	Reserved

9.6.27.2 Control Response MCS Negotiation Request frame format

The Control Response MCS Negotiation Request frame is used by a STA to negotiate with its peer STA the requested MCS for transmitting control response frame as defined in 10.6.6.5.3. The format of the Action field of the Control Response MCS Negotiation Request frame is shown Table 9-515.

Table 9-515—Control Response Negotiation Request frame Action field format

Order	Information
1	Category
2	Control Response MCS Negotiation Action
3	MCS Difference

The Category field is defined in 9.4.1.11.

The Control Response MCS Negotiation Action field is defined in 9.6.27.1.

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The MCS Difference field is 1 octet and is set to an unsigned value that represents the MCS difference between the index of the primary MCS and the index of the MCS that is preferred for use by the STA to transmit control response frame as described in 10.6.6.5.6.

9.6.27.3 Control Response MCS Negotiation Response frame format

The Control Response MCS Negotiation Response frame is used to indicate a response to a Control Response MCS Negotiation Request frame, which is either Accept or Reject, and the MCS Difference proposed by the Requesting STA. The format of the Action field of the Control Response MCS Negotiation Response frame is shown in Table 9-516.

Table 9-516—Control Response MCS Negotiation Response frame Action field format

Order	Information
1	Category
2	Control Response MCS Negotiation Action
3	Command

The Category field is defined in 9.4.1.11.

The Control Response MCS Negotiation Action field is defined in 9.6.27.1.

The Command field is 1 octet and is set to a value from the Table 9-517 to represent accepting or rejecting the proposed MCS Difference by the Control Response MCS Negotiation Request frame as described in 10.6.6.5.6.

Table 9-517—Command values

Values	Description
0	Reject
1	Accept
2–255	Reserved

9.6.28 CDMG Action frame details

9.6.28.1 CDMG Action field

Several Action frame formats are defined to support CDMG features. A CDMG Action field, in the octet immediately after the Category field, differentiates the CDMG Action frame formats. The CDMG Action field values associated with each frame format within the CDMG category are defined in Table 9-518.

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Table 9-518—CDMG Action field values

CDMG Action field value	Meaning
0	Notification Period Request frame
1	Notification Period Response frame
2	Channel Splitting Request frame
3	Channel Splitting Response frame
4	CDMG Allocation Request frame
5	CDMG Allocation Response frame

9.6.28.2 Notification Period Request frame format

The format of the Notification Period Request frame Action field is shown in Figure 9-968.

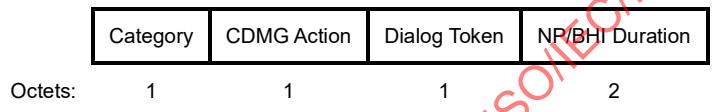

Figure 9-968—Notification Period Request frame Action field format

The Category field is defined in 9.4.1.11.

The CDMG Action field is defined in 9.6.28.1.

The Dialog Token field is defined in 9.4.1.12 and set by the requesting STA.

The NP/BHI Duration field is set to the length of the NP/BHI duration requested by the STA intending to establish its BSS on a free 1.08 GHz channel to the peer STA operating on the adjacent 1.08 GHz channel.

9.6.28.3 Notification Period Response frame format

The format of the Notification Period Response frame Action field is shown in Table 9-519.

Table 9-519—Notification Period Response frame Action field format

Order	Information
0	Category
1	CDMG Action
2	Dialog Token
3	Status Code
4	Dynamic Bandwidth Control

The Category field is defined in 9.4.1.11.

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The CDMG Action field is defined in 9.6.28.1.

The Dialog Token field is copied from the corresponding Notification Period Request frame.

The Status Code field indicates the result of the notification period allocation request and is defined in 9.4.1.9.

The Dynamic Bandwidth Control element is defined in 9.4.2.220. This element is present if the Status Code field indicates successful; otherwise, it is not present.

9.6.28.4 Channel Splitting Request frame format

The format of the Channel Splitting Request frame Action field is shown in Figure 9-969.

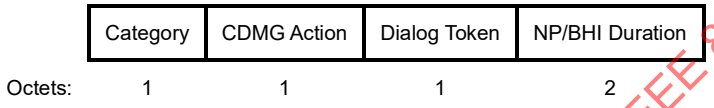

Figure 9-969—Channel Splitting Request frame Action field format

The Category field is defined in 9.4.1.11.

The CDMG Action field is defined in 9.6.28.1.

The Dialog Token field is defined in 9.4.1.12 and set by the requesting STA.

The NP/BHI Duration field is set to the length of the NP/BHI duration requested by the STA intending to establish its BSS on a free 1.08 GHz channel to the peer STA operating on the adjacent 1.08 GHz channel.

9.6.28.5 Channel Splitting Response frame format

The format of the Channel Splitting Response frame Action field is shown in Table 9-520.

Table 9-520—Channel Splitting Response frame Action field format

Order	Information
0	Category
1	CDMG Action
2	Dialog Token
3	Status Code
4	Channel Switch Announcement
5	Beacon Interval
6	Dynamic Bandwidth Control

The Category field is defined in 9.4.1.11.

The CDMG Action field is defined in 9.6.28.1.

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The Dialog Token field is copied from the corresponding Channel Splitting Request frame.

The Status Code field indicates the result of the channel splitting request and is defined in 9.4.1.11.

The Channel Switch Announcement element is defined in 9.4.2.18. This element is present if the Status Code field indicates successful; otherwise, it is not present.

The Beacon Interval field specifies the beacon interval length on a 2.16 GHz channel set by the STA operating on one of the 1.08 GHz channel after channel splitting and is defined in 9.4.1.3. This element is present if the Status Code field indicates successful; otherwise, it is not present.

The Dynamic Bandwidth Control element specifies the information of the STA operating on a 1.08 GHz channel after channel splitting and is defined in 9.4.2.220. This element is present if the Status Code field indicates successful; otherwise, it is not present.

9.6.28.6 CDMG Allocation Request frame format

The format of the CDMG Allocation Request frame Action field is shown in Figure 9-970.

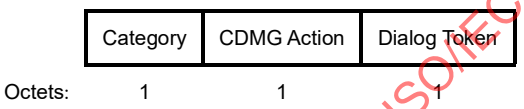

Figure 9-970—CDMG Allocation Request frame Action field format

The Category field is defined in 9.4.1.11.

The CDMG Action field is defined in 9.6.28.1.

The Dialog Token field is defined in 9.4.1.12 and set by the requesting STA.

9.6.28.7 CDMG Allocation Response frame format

The format of the CDMG Allocation Response frame Action field is shown in Table 9-521.

Table 9-521—CDMG Allocation Response frame Action field format

Order	Information
0	Category
1	CDMG Action
2	Dialog Token
3	Status Code
4	Extended Schedule

The Category field is defined in 9.4.1.11.

The CDMG Action field is defined in 9.6.29.1.

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The Dialog Token field is copied from the corresponding CDMG Allocation Request frame.

The Status Code field indicates the result of the Allocation request and is defined in 9.4.1.9.

The Extended Schedule element indicates all the available time that can be allocated to the DMG STAs on a 2.16 GHz channel by the STA operating on the adjacent 1.08 GHz channel of the STA sending this response and is defined in 9.4.2.131. This element is present if the Status Code field indicates successful; otherwise, it is not present.

9.6.29 CMMG Action frame details

9.6.29.1 CMMG Action field

Several Action frame formats are defined to support CMMG functionality. A CMMG Action field, in the octet immediately after the Category field, differentiates the CMMG Action frame formats. The CMMG Action field values associated with each frame format within the CMMG category are defined in Table 9-522.

Table 9-522—CMMG Action field values

Value	Meaning	Time priority
0	CMMG CSI	Yes
1	CMMG Compressed Beamforming	Yes
2	CMMG Operating Mode Notification	Yes
3–255	Reserved	

9.6.29.2 CMMG Compressed Beamforming frame format

The CMMG Compressed Beamforming frame is an Action or an Action No Ack frame of category CMMG. The format of its Action field is defined in Table 9-523.

Table 9-523—CMMG Compressed Beamforming frame Action field format

Order	Information
1	Category
2	CMMG Action
3	CMMG MIMO Control (see 9.4.1.61)
4	CMMG Compressed Beamforming Report (see 9.4.1.62)

The Category field is defined in 9.4.1.11.

The CMMG Action field is defined in 9.6.29.1.

The CMMG MIMO Control field (see 9.4.1.61) are used as described in Table 9-85.

The CMMG Compressed Beamforming Report field is defined in 9.4.1.62.

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9.6.29.3 CMMG Operating Mode Notification frame format

The CMMG Operating Mode Notification frame is used to notify STAs that the transmitting STA is changing its operating channel width, the maximum number of spatial streams it can receive, or both.

In the context of CMMG STAs, references to an Operating Mode Notification frame or element should be understood as referring to a CMMG Operating Mode Notification frame or element, respectively.

The Action field of the CMMG Operating Mode Notification frame contains the information shown in Table 9-524.

Table 9-524—CMMG Operating Mode Notification frame Action field format

Order	Information
1	Category
2	CMMG Action
3	CMMG Operating Mode (see 9.4.1.63)

The Category field is defined in 9.4.1.11.

The CMMG Action field is defined in 9.6.29.1.

The CMMG Operating Mode field is defined in 9.4.1.63.

9.6.30 GLK Action frame details

9.6.30.1 GLK Action field

A GLK Action field, in the octet immediately after the Category field, differentiates the GLK Action frame formats. The GLK Action field values associated with each frame format within the GLK category are defined in Table 9-525.

Table 9-525—GLK Action field values

Value	Meaning	Time priority
0	GLK Groupcast Mode Change Notification	No
1–255	Reserved	—

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9.6.30.2 GLK Groupcast Mode Change Notification

The GLK Groupcast Mode Change Notification frame is used to indicate a change to the GLK groupcast transmission policy. See Table 9-526.

Table 9-526—GLK Groupcast Mode Change Notification frame format

Order	Information
1	Category
2	GLK Action
3	GLK-GCR Parameter Set

The Category field is defined in 9.4.1.11. The GLK Action field is defined in 9.6.30.1. The GLK-GCR Parameter Set element is defined in 9.4.2.234.

9.7 Aggregate MPDU (A-MPDU)

9.7.1 A-MPDU format

An A-MPDU consists of a sequence of one or more A-MPDU subframes and a variable amount of EOF padding as shown in Figure 9-971.

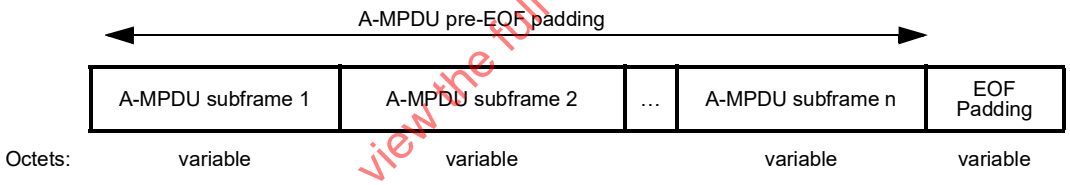

Figure 9-971—A-MPDU format

The structure of the A-MPDU subframe is shown in Figure 9-973. Each A-MPDU subframe consists of an MPDU delimiter optionally followed by an MPDU. Each nonfinal A-MPDU subframe in an A-MPDU has padding octets appended to make the subframe a multiple of 4 octets in length. The content of these octets is unspecified.

In an HT or DMG PPDU, the final A-MPDU subframe is not padded. In a VHT or S1G PPDU, padding is added as described below.

The EOF Padding field is shown in Figure 9-972. This is present only in a VHT or S1G PPDU.

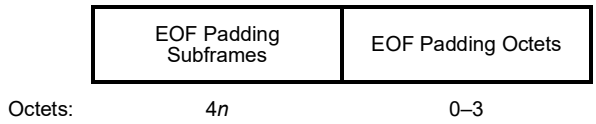

Figure 9-972—EOF Padding field format

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The EOF Padding Subframes subfield contains zero or more EOF padding subframes. An EOF padding subframe is an A-MPDU subframe with 0 in the MPDU Length field and 1 in the EOF field.

In a VHT or S1G PPDU, the following padding is present, as determined by the rules in 10.12.6:

— 0–3 octets in the Padding subfield of the final A-MPDU subframe (see Figure 9-973) before any EOF padding subframes. The content of these octets is unspecified.
— Zero or more EOF padding subframes in the EOF Padding Subframes subfield.
— 0–3 octets in the EOF Padding Octets subfield. The content of these octets is unspecified.

An A-MPDU pre-EOF padding refers to the contents of the A-MPDU up to, but not including, the EOF Padding field.

NOTE 1—A-MPDU pre-EOF padding includes any A-MPDU subframes with 0 in the MPDU Length field and 0 in the EOF field inserted in order to meet the minimum MPDU start spacing requirement.

The maximum length of an A-MPDU in an HT PPDU is 65 535 octets. The maximum length of an A-MPDU in a DMG PPDU is 262 143 octets. The maximum length of an A-MPDU pre-EOF padding in a VHT PPDU is 1 048 575 octets. The length of an A-MPDU addressed to a particular STA can be further constrained as described in 10.12.2.

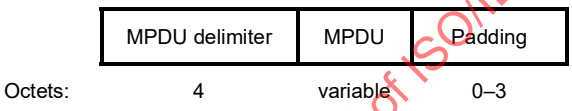

Figure 9-973—A-MPDU subframe format

The structure of the MPDU delimiter when transmitted by a non-DMG STA is defined in Figure 9-974. The structure of the MPDU Delimiter field when transmitted by a DMG STA is shown in Figure 9-975.

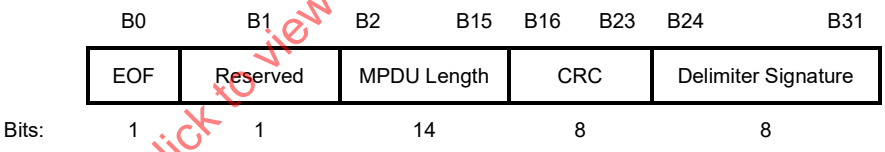

Figure 9-974—MPDU delimiter (non-DMG)

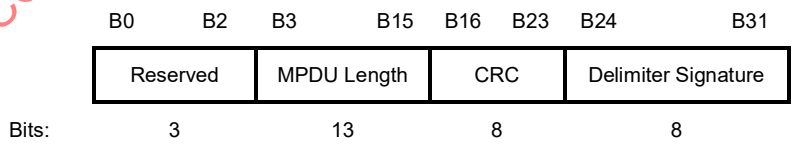

Figure 9-975—MPDU delimiter (DMG)

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The fields of the MPDU delimiter when transmitted by a non-DMG STA are defined in Table 9-527. The fields of the MPDU delimiter when transmitted by a DMG STA are defined in Table 9-528.

Table 9-527—MPDU delimiter fields (non-DMG)

Field	Size (bits)	Description
EOF	1	End of frame indication. Set to 1 in an A-MPDU subframe that has 0 in the MPDU Length field and that is used to pad the A-MPDU in a VHT PPDU as described in 10.12.6. Set to 1 in the MPDU delimiter of an S-MPDU as described in 10.12.7. Set to 0 otherwise.
Reserved	1	
MPDU Length	14	Length of the MPDU in octets. Set to 0 if no MPDU is present. An A-MPDU subframe with 0 in the MPDU Length field is used as defined in 10.12.3 to meet the minimum MPDU start spacing requirement and also to pad the A-MPDU to fill the available octets in a VHT PPDU as defined in 10.12.6.
CRC	8	8-bit CRC of the preceding 16 bits (see 9.7.2).
Delimiter Signature	8	Pattern that can be used to detect an MPDU delimiter when scanning for an MPDU delimiter. The unique pattern is 0x4E (see NOTE).
NOTE—The ASCII value of the character 'N' was chosen as the unique pattern for the value in the Delimiter Signature field.		

Table 9-528—MPDU delimiter fields (DMG)

MPDU Delimiter field	Size (bits)	Description
Reserved	3	
MPDU Length	13	Length of MPDU in octets
CRC	8	8-bit CRC on preceding 16 bits (see 9.7.2).
Delimiter Signature	8	Pattern that can be used to detect an MPDU delimiter when scanning for a delimiter. The unique pattern is 0x4E.

The format of the MPDU Length field when transmitted by a non-DMG STA is shown in Figure 9-976. The MPDU Length Low subfield contains the 12 low order bits of the MPDU length. In a VHT PPDU, the MPDU Length High subfield contains the two high order bits of the MPDU length. In an HT PPDU, the MPDU Length High subfield is reserved.

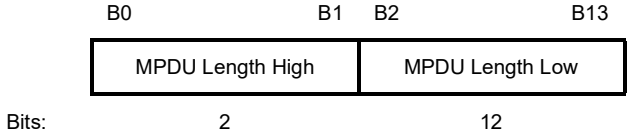

Figure 9-976—MPDU Length field format (non-DMG)

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The MPDU length value is derived from the MPDU Length field subfields as follows:

$$L_{MPDU} = \begin{cases} L_{low} + L_{high} \times 4096, & \text{VHT PPDU} \\ L_{low}, & \text{HT PPDU} \\ L, & \text{DMG PPDU} \end{cases} \quad (9\text{-}5)$$

where

L_{low} is the value of the MPDU Length Low subfield
L_{high} is the value of the MPDU Length High subfield
L is the value of the MPDU Length field

NOTE 2—The format of the MPDU Length field maintains a common encoding structure for both VHT and HT PPDUs. For HT PPDUs, only the MPDU Length Low subfield is used, while for VHT PPDUs, both subfields are used.

The purpose of the MPDU delimiter is to locate the MPDUs within the A-MPDU so that the structure of the A-MPDU can usually be recovered when one or more MPDU delimiters are received with errors. See O.2 for a description of a deaggregation algorithm.

9.7.2 MPDU delimiter CRC field

The MPDU delimiter CRC field is an 8-bit CRC value. It is used as a check sequence to protect the fields that precede it in the MPDU delimiter. The CRC field is the 1s complement of the remainder generated by the modulo 2 division of the protected bits by the polynomial $x^8 + x^2 + x^1 + 1$, where the shift-register state is preset to all 1s.

NOTE—The order of transmission of bits within the CRC field is defined in 9.2.2.

Figure 9-977 illustrates the CRC calculation for the MPDU delimiter.

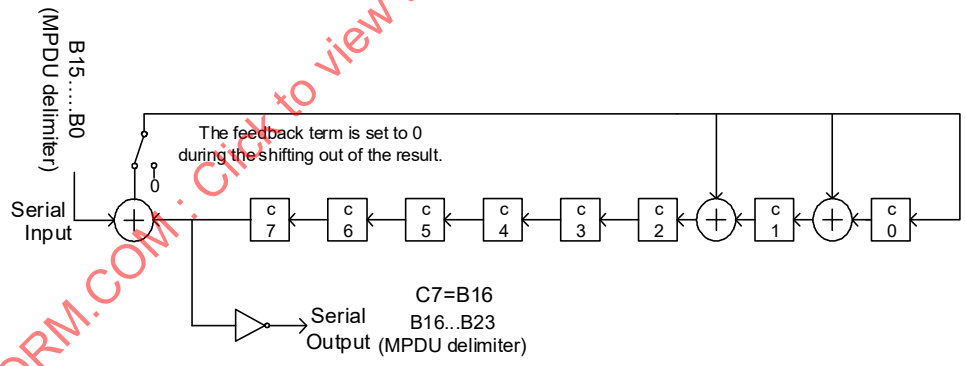

Figure 9-977—MPDU delimiter CRC calculation

9.7.3 A-MPDU contents

In a non-DMG PPDU, an A-MPDU is a sequence of A-MPDU subframes carried in a single PPDU with one of the following combinations of RXVECTOR or TXVECTOR parameter values:

— The FORMAT parameter set to VHT
— The FORMAT parameter set to HT_MF or HT_GF and the AGGREGATION parameter set to 1
— The FORMAT parameter set to S1G, S1G_DUP_1M, or S1G_DUP_2M and the AGGREGATION parameter set to 1

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In a DMG PPDU, an A-MPDU is a sequence of MPDUs carried in a single PPDU with the TXVECTOR/RXVECTOR AGGREGATION parameter set to 1.

All of the MPDUs within an A-MPDU are addressed to the same RA. All QoS Data frames within an A-MPDU that have a TID for which an HT-immediate block ack agreement exists have the same value for the Ack Policy Indicator subfield of the QoS Control field.

All protected MPDUs within an A-MPDU have the same Key ID.

The Duration/ID fields in the MAC headers of all MPDUs in an A-MPDU carry the same value. The Duration/ID fields in the MAC headers of MPDUs in A-MPDUs carried in the same VHT MU PPDU all carry the same value.

NOTE 1—The reference point for the Duration/ID field is the end of the PPDU carrying the MPDU. Setting the Duration/ID field to the same value in the case of A-MPDU aggregation means that each MPDU consistently specifies the same NAV setting.

An A-MPDU is transmitted in one of the contexts specified in Table 9-529 as defined by the description in the Definition of context column, independently of whether the A-MPDU is contained in a VHT MU PPDU or an SU PPDU. Ordering of MPDUs within an A-MPDU is not constrained, except where noted in these tables. See 10.12.1.

A VHT MU PPDU or S1G MU PPDU does not carry more than one A-MPDU that contains one or more MPDUs soliciting an immediate response.

NOTE 2—The TIDs present in a data enabled A-MPDU context are also constrained by the channel access rules (for a TXOP holder; see 10.23.2 and 10.23.3) and the RD response rules (for an RD responder, see 10.29.4). This is not shown in these tables.

NOTE 3—If a STA supports A-MSDUs of 7935 octets (indicated by the Maximum A-MSDU Length field in the HT Capabilities element), A-MSDUs transmitted by that TA within an A-MPDU carried in a PPDU with FORMAT HT_MF or HT_GF or within an MPDU carried in a non-HT PPDU are constrained so that the length of the QoS Data frame carrying the A-MSDU is no more than 4095 octets. The 4095-octet MPDU length limit does not apply to A-MPDUs carried in VHT or DMG PPDUs. The use of A-MSDU within A-MPDU might be further constrained as described in 9.4.1.13 through the operation of the A-MSDU Supported field.

Table 9-529—A-MPDU contexts

Name of Context	Definition of Context	Table defining permitted contents
Data Enabled Immediate Response	The A-MPDU is transmitted outside a PSMP sequence by a TXOP holder or an RD responder including potential immediate responses.	Table 9-530
Data Enabled No Immediate Response	The A-MPDU is transmitted outside a PSMP sequence by a TXOP holder that does not include or solicit an immediate response. See NOTE.	Table 9-531
PSMP	The A-MPDU is transmitted within a PSMP sequence.	Table 9-532

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Table 9-529—A-MPDU contexts *(continued)*

Name of Context	Definition of Context	Table defining permitted contents
Control Response	The A-MPDU is transmitted by a STA that is neither a TXOP holder nor an RD responder that also needs to transmit one of the following immediate response frames: Ack frame BlockAck frame with a TID for which an HT-immediate block ack agreement exists	Table 9-533
S-MPDU context	The A-MPDU is transmitted within a VHT PPDU and contains an S-MPDU.	Table 9-534
NOTE—This context includes cases when no response is generated.		

Table 9-530—A-MPDU contents in the data enabled immediate response context

MPDU Description	Conditions	
Ack	If the preceding PPDU contains an MPDU that requires an Ack frame response, a single Ack frame at the start of the A-MPDU.	Of these, in a non-DMG STA: at most one MPDU is present. Of these, in a DMG STA: at most one Ack frame is present, and zero or more HT-immediate BlockAck frames are present.
HT-immediate BlockAck	In a non-DMG STA: if the preceding PPDU contains an implicit or explicit block ack request for a TID for which an HT-immediate block ack agreement exists, at most one BlockAck frame for this TID, in which case it occurs at the start of the A-MPDU. In a DMG STA: if the preceding PPDU contains an implicit or explicit block ack request for a TID for which an HT-immediate block ack agreement exists, one or more copies of the same BlockAck for this TID.	
Action No Ack	Action No Ack frames.	
Data frames sent under an HT-immediate block ack agreement	QoS Data frames with the same TID, which corresponds to an HT-immediate block ack agreement. See NOTE.	Of these, at most one of the following is present in a non-DMG BSS: — One or more QoS Data frames with Implicit BAR ack policy — A BlockAckReq frame Of these, at most one of the following is present in a DMG BSS: — One or more QoS Data frames with Implicit BAR ack policy — QoS Null frame with the No Ack ack policy — A BlockAckReq frame with an optional QoS Null frame with No Ack ack policy
QoS Null frames with the No Ack ack policy	In a DMG BSS, QoS Null frames with the No Ack ack policy.	
Immediate BlockAckReq	At most one BlockAckReq frame with a TID that corresponds to an HT-immediate block ack agreement. This is the last MPDU in the A-MPDU. It is not present if any QoS Data frames for that TID are present.	
NOTE—These MPDUs all have the same ack policy, which is either Implicit BAR or Block Ack.		

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Table 9-531—A-MPDU contents in the data enabled no immediate response context

MPDU Description	Conditions
Data without a block ack agreement	QoS Data frames with a TID that does not correspond to a block ack agreement. These have No Ack ack policy and the A-MSDU Present subfield equal to 0.
Action No Ack	Action No Ack frames.

Table 9-532—A-MPDU contents in the PSMP context

MPDU Description	Conditions	
Acknowledgment for PSMP data	At most one Multi-TID BlockAck frame. Acknowledgment in response to data received with the PSMP Ack ack policy and/or a Multi-TID BlockAckReq frame in the previous PSMP-UTT or PSMP-DTT.	
HT-immediate Data	QoS Data frames with the PSMP Ack or Block Ack ack policy and with a TID that corresponds to an HT-immediate block ack agreement.	An A-MPDU containing MPDUs with a block ack agreement does not also contain MPDUs without a block ack agreement.
Data without a block ack agreement	QoS Data frames with a TID that does not correspond to a block ack agreement. These have No Ack ack policy and the A-MSDU Present subfield is equal to 0.	
Action No Ack	Action No Ack frames.	
Multi-TID BlockAckReq	At most one Multi-TID BlockAckReq frame with the BAR Ack Policy subfield equal to No Acknowledgment.	

Table 9-533—A-MPDU contents in the control response context

MPDU	Conditions	
Ack	Ack frame transmitted in response to an MPDU that requires an Ack frame.	One of these is present at the start of the A-MPDU; these are not present other than at the start of the A-MPDU.
BlockAck	BlockAck frame with a TID that corresponds to an HT-immediate block ack agreement.	
Action No Ack	BRP +HTC frames. Action No Ack +HTC frames containing an explicit feedback response. Action No Ack frames that are Flow Suspension frames or Flow Resumption frames.	

Table 9-534—A-MPDU contents in the S-MPDUcontext

MPDU	Conditions
Any MPDU	An S-MPDU.

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9.8 MAC frame format for PV1 frames

9.8.1 Basic components

Each PV1 frame consists of the following basic components:

a) A PV1 MAC header, which comprises frame control, address, optional sequence control information;

b) A variable-length frame body, which contains information specific to the frame type;

c) An FCS, which contains a 32-bit CRC based on ITU-T Recommendation V.42 [B55] (see 9.2.4.8).

9.8.2 General PV1 frame format

Figure 9-978 depicts the general PV1 MAC frame format. The first three fields (Frame Control, A1 and A2) and the last field FCS are always present in PV1 frames. The Sequence Control, A3, A4 and Frame body fields are optionally present. Each field is defined in 9.8.3.

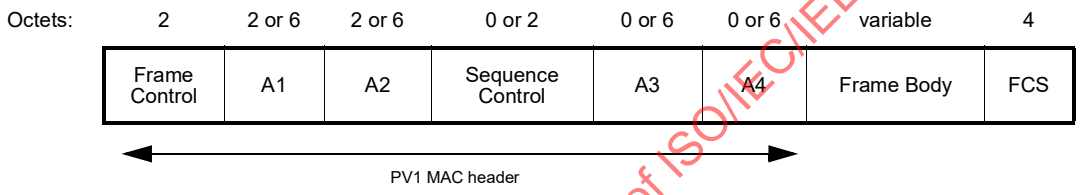

Figure 9-978—PV1 frame format)

NOTE—In Figure 9-978, the total number of octets in the A1 and A2 fields is either 8 or 12.

The Frame Body field is of variable size, constrained as defined in 9.2.4.7.1.

9.8.3 PV1 frame fields

9.8.3.1 Frame Control field

The Frame Control field of the PV1 MAC header for PV1 frames except the PV1 Probe Request frame, PV1 Resource Allocation frame, and PV1 Control frames, is defined in Figure 9-979.

The Frame Control field of the PV1 MAC header for the PV1 Probe Response frame, PV1 Resource Allocation frame and PV1 Control frames is defined in 9.8.5.3, 9.8.5.4, and 9.8.4, respectively.

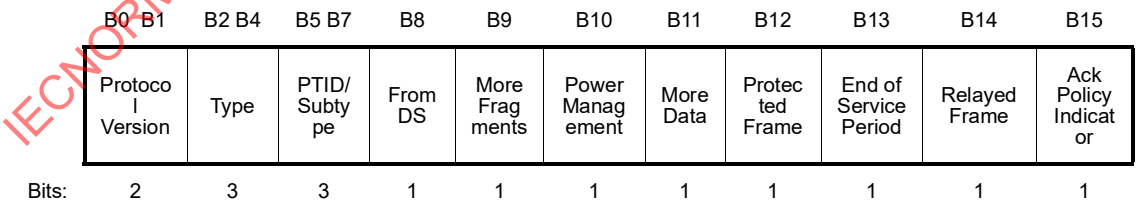

Figure 9-979—Frame Control field format

The Protocol Version subfield is defined in 9.2.4.1.2. For PV1 frames the Protocol Version subfield is 1.

The Type subfield identifies the type of the frame, as defined in Table 9-535.

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Table 9-535—PV1 frame types

Type Value	Type	Description
0	QoS Data	Either the A1 field or the A2 field is an SID (defined in 9.8.3.2), as determined by the From DS subfield in the Frame Control field.
1	Management	Both A1 and A2 fields contain MAC addresses for PV1 Probe Response frames, or Either the A1 field or the A2 field is an SID (defined in 9.8.3.2), as determined by the From DS subfield in the Frame Control field.
2	Control	The A1 field is an SID and the A2 field is either an SID or contains a MAC address.
3	QoS Data	Both A1 and A2 fields contain MAC addresses.
4–6	Reserved	
7	Reserved for extension	

PV1 frames with Type subfield value equal to 0 define a PV1 QoS Data frame where either A1 or A2 field is an SID as indicated in Table 9-536 and the other A1 or A2 field contains a MAC address. PV1 frames with Type subfield value equal to 1 define a PV1 Management frame where either A1 or A2 field is an SID as indicated in Table 9-536 and the other A1 or A2 field contains a MAC address. PV1 frames with Type subfield value equal to 2 define PV1 Control frames. PV1 frames with Type subfield value equal to 3 define a PV1 QoS Data frame where both A1 and A2 fields contain MAC addresses. All other values of the Type subfield are reserved.

The PTID/Subtype subfield, depending on the type of the PV1 frame, indicates:

— The 3 LSBs of the TID as defined in 9.2.4.5.2 for PV1 QoS Data frames (Type field equal to 0 and 3) transmitted by a QoS STA.
— The Subtype for PV1 Control frames (Type subfield equal to 2) as described in 9.8.4.
— The Subtype for PV1 Management frames (Type subfield equal to 1) as described in 9.8.5.

The From DS subfield, if present, defines the addressing of PV1 frames with values of the Type field less than 2, as defined in Table 9-536.

Table 9-536—From DS values in PV1 frames

From DS field	Meaning	Use
0	A1 contains the MAC address of the receiver A2 is an SID, which contains the AID of the transmitter — A2 contains the MAC address of the transmitter for PV1 QoS Data frames with Type subfield equal to 3 A3 (if present) contains the MAC address of the destination A4 (if present) contains the MAC address of the source	For frames transmitted by a non-AP STA to an AP For frames transmitted from a non-AP STA to non-AP STA (direct link)
1	A1 is an SID, which contains the AID of the receiver — A1 contains the MAC address of the receiver for PV1 QoS Data frames with Type subfield equal to 3 A2 is the MAC address of the transmitter A3 (if present) contains the MAC address of the destination A4 (if present) contains the MAC address of the source	AP to non-AP STA

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The More Fragments subfield is described in 9.2.4.1.5.

The Power Management subfield is described in 9.2.4.1.7.

The EOSP subfield is described in 9.2.4.5.3.

The Protected Frame subfield is described in 9.2.4.1.9.

The More Data subfield is described in 9.2.4.1.8.

The Relayed Frame subfield indicates that the current TXOP is shared with the relay STA using the TXOP sharing procedures for relays described in 10.54.5.

The Ack Policy Indicator subfield identifies the ack policy that is followed upon the delivery of the MPDU, as defined in Table 9-537.

Table 9-537—Ack Policy Indicator subfield in the Frame Control field for PV1 frames

Ack policy	Ack Policy Indicator subfield	Other conditions	Meaning
Normal Ack	0	MPDU is a non-A-MPDU frame	Where the frame contains a fragment and both the originator and the addressed recipient support fragment BA: The addressed recipient returns an NDP BlockAck or BAT frame after a SIFS, according to the procedures defined in 10.3.2.12 and 10.47.2. Otherwise: The addressed recipient returns an Ack, TACK or STACK frame after a short interframe space (SIFS) period, according to the procedures defined in 10.3.2.11 and 10.47.2.
Implicit BAR	0	MPDU is not a non-A-MPDU frame	The addressed recipient returns a BlockAck or BAT frame, either individually or as part of an A-MPDU starting a SIFS after the PPDU carrying the frame, according to the procedures defined in 10.3.2.11 and 10.47.2.
No Ack	1	MPDU is a non-A-MPDU frame	The addressed recipient takes no action upon receipt of the frame. More details are provided in 10.26. This ack policy is used in all individually addressed frames in which the sender does not require acknowledgment. It is also used in all group addressed frames. It is not used for PV1 Data frames with a TID for which a block ack agreement exists.
Block Ack	1	MPDU is not a non-A-MPDU frame	The addressed recipient takes no action upon the receipt of the frame except for recording the state. The recipient can expect a BlockAckReq frame in the future to which it responds using the procedure described in 10.25.

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9.8.3.2 Address fields

There are up to four address fields in the PV1 MAC frame format. These fields are used to indicate the recipient of the frame (A1), the transmitter of the frame (A2), and optionally the MAC address of the source and/or the MAC address of the destination of the frame (A3 and/or A4).

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The recipient of the frame (A1) or the transmitter of the frame (A2) can be identified by the AID subfield located in the Short ID (SID) field depending on the value of the From DS subfield of the Frame Control field as described in 9.8.3.1. A group of receiving non-AP STAs of the frame can be identified by the AID subfield with a group AID value, as described in 10.55, located in the Short ID (SID) field. The length of the SID field is 2 octets and is shown in Figure 9-980.

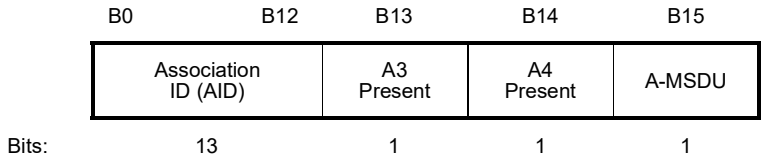

Figure 9-980—SID field format

The AID subfield contains an AID as specified in Table 9-536 in PV1 frames of Type 0, 1, and 2.

The A3 Present subfield is 1 if the A3 is present in the PV1 MAC header, otherwise it is 0.

The A4 Present subfield is 1 if the A4 is present in the PV1 MAC header, otherwise it is 0.

The A-MSDU subfield is 1 if the MPDU contains a Dynamic A-MSDU as described in 9.3.2.2.4.

NOTE—PV1 frames without an SID field do not contain A3 and A4 fields and do not carry A-MSDUs.

The A3 field is present if A3 is not equal to the address identified by A1 and an A3 is not stored at the receiver, or when A3 is not equal to an A3 stored at the receiver (as described in 10.58). When the A3 field is not present, A3 is either stored at the recipient of the frame or, if an A3 is not stored at the recipient of the frame then A3 is equal to the address identified by A1.

The A4 field is present if A4 is not equal to the address identified by A2 and an A4 is not stored at the receiver, or when A4 is not equal to an A4 stored at the receiver (as described in 10.58). When the A4 field is not present, A4 is either stored at the recipient of the frame or, if an A4 is not stored at the recipient of the frame then A4 is equal to the address identified by A2.

9.8.3.3 Sequence Control field

The Sequence Control field is present in all PV1 Data frames and PV1 Management frames other than PV1 Probe Response frames, and is described in 9.2.4.4. The Sequence Control field is not present in PV1 Control frames and in PV1 Probe Response frames.

9.8.3.4 Frame Body field

The Frame Body field is a variable-length field and is described in 9.2.4.7.

9.8.3.5 Overhead for encryption

The overhead for encryption is described in Clause 12.

9.8.3.6 FCS field

The FCS field is described in 9.2.4.8.

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9.8.4 PV1 Control frames

9.8.4.1 General

The subfields within the Frame Control field of PV1 Control frames are set as shown in Figure 9-981.

	B0 B1	B2 B4	B5 B7	B8 B10	B11	B12	B13	B14	B15
	Protocol Version (1)	Type (Control)	PTID/ Subtype	Bandwidth Indication	Dynamic Indication	Power Management	More Data	Flow Control	Next TWT Info Present
Bits:	2	3	3	3	1	1	1	1	1

Figure 9-981—Frame Control field subfield values within PV1 Control frames

Table 9-538 defines the different PV1 Control frame subtypes.

Table 9-538—PV1 Control frame subtypes

PTID/Subtype value b8 b7 b6	Subtype description
000	STACK
001	BAT
010–111	Reserved

The Bandwidth Indication subfield and the Dynamic Indication subfield are described in 9.2.4.1.11.

The Next TWT Info Present subfield is set to 1 if the Next TWT Info field is present in PV1 Control frames. Otherwise, it is set to 0.

The More Data subfield is described in 9.2.4.1.8.

The Flow Control subfield is used for flow suspension signaling as described in 10.61.

9.8.4.2 STACK frame format

The frame format of the short TWT acknowledgment (STACK) frame is defined in Figure 9-982. The A1 field is an SID field that contains the AID of the intended recipient of the frame in the AID subfield when the intended recipient is not an AP and the value 0 when the intended recipient is an AP. A3 Present, A4 Present, and A-MSDU subfields (B13, B14, and B15) of the SID field are reserved.

The A2 field is an SID field that contains the bit sequence Scrambler Initialization[0:6] || FCS[23:31] obtained from the scrambler initialization value in the Service field (as defined in 23.3.9.2), prior to descrambling, and the FCS field of the PSDU that carries the soliciting frame. The scrambler initialization value is obtained from the RXVECTOR parameter SCRAMBLER_OR_CRC.

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	Frame Control	A1	A2	Tetrapartial Timestamp/ Next TWT Info/ Suspend Duration	FCS
Octets:	2	2	2	4	4

Figure 9-982—STACK frame format

If the Next TWT Info Present subfield in the Frame Control field is equal to 0, the Tetrapartial Timestamp/Next TWT Info/Suspend Duration field contains the value of the 4 least significant octets of the STA's TSF timer at the time that the start of the data symbol containing the first bit of the Tetrapartial Timestamp field appears at the transmit antenna connector.

If the Next TWT Info Present subfield in the Frame Control field is equal to 1 and the Flow Control subfield of the Frame Control field is equal to 0, then the Tetrapartial Timestamp/Next TWT Info/Suspend Duration field contains the value of the 4 least significant octets of the TSF timer for the next TWT logically ANDed with the value 0xFFFFFFF8 and then added to the value of the TWT flow identifier that corresponds to that next TWT value.

If the Next TWT Info Present subfield in the Frame Control field is equal to 1 and the Flow Control subfield of the Frame Control field is equal to 0 and the 29 MSBs of the Next TWT Info subfield is equal to all 0s, the transmitter does not currently have a next TWT value available for transmission for the TWT indicated by the TWT flow identifier corresponding to the value of the 3 LSBs of the Next TWT Info field.

If the Next TWT Info Present subfield in the Frame Control field is equal to 1 and the Flow Control subfield of the Frame Control field is equal to 1, then the Tetrapartial Timestamp/Next TWT Info/Suspend Duration field contains a flow suspension duration, in microseconds, during which the intended recipient TWT STAs are not allowed to transmit Data frames to the STA identified by the RA field of the frame that elicited the STACK frame.

9.8.4.3 BAT frame format

The frame format of the Block Acknowledgment TWT (BAT) frame is defined in Figure 9-983:

	Frame Control	A1	A2	Beacon Sequence	Pentapartial Timestamp	Next TWT Info /Suspend Duration	Starting Sequence Control	BAT Bitmap	FCS
Octets:	2	2	6	1	5	6	2	4	4

Figure 9-983—BAT frame format

The A1 field is an SID field that contains the AID of the intended recipient of the frame in the AID subfield when the intended recipient is not an AP and the value 0 when the intended recipient is an AP. A3 Present, A4 Present, and A-MSDU subfields (B13, B14, and B15) of the SID field are reserved.

The A2 field contains the MAC address of the transmitter sending the frame.

The Beacon Sequence field contains the value of the Change Sequence field from the most recently transmitted Beacon frame.

The Pentapartial Timestamp field contains the value of the 5 least significant octets of the STA's TSF timer at the time that the start of the data symbol containing the first bit of the Pentapartial Timestamp field appears at the transmit antenna connector.

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If the Next TWT Info Present subfield in the Frame Control field is equal to 1 and the Flow Control subfield of the Frame Control field is equal to 0, then the Next TWT Info/Suspend Duration field contains a next TWT value for the intended recipient of the frame corresponding to the value of the 6 least significant octets of the TSF timer for the next TWT logically ANDed with the value 0xFFFFFFFFFFF8 and then added to the value of the TWT flow identifier that corresponds to that next TWT value.

If the Next TWT Info Present subfield in the Frame Control field is equal to 1 and the Flow Control subfield of the Frame Control field is equal to 0 and the 45 MSBs of the Next TWT Info/Suspend Duration subfield is equal to all 0s, the transmitter does not currently have a next TWT value available for transmission for the TWT indicated by the TWT flow identifier corresponding to the value of the 3 LSBs of the Next TWT Info/Suspend Duration field.

If the Next TWT Info Present subfield in the Frame Control field is equal to 1 and the Flow Control subfield of the Frame Control field is equal to 1, then the Next TWT Info/Suspend Duration field contains a flow suspension duration, in microseconds, during which the intended recipient TWT STAs are not allowed to transmit Data frames to the STA identified by the A2 field of the BAT frame.

If the Next TWT Info Present subfield in the Frame Control field is equal to 0, then the Next TWT Info/Suspend Duration field is reserved.

The Starting Sequence Control field contains the sequence number of the first MSDU and the TID for which this BAT frame is sent and is defined in Figure 9-984:

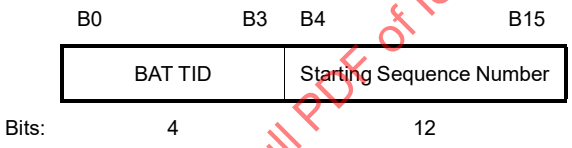

Figure 9-984—Starting Sequence Control field format

The BAT Bitmap field is used to indicate the received status of up to 32 MSDUs and A-MSDUs. Each bit that is equal to 1 in the BAT Bitmap field acknowledges the reception of a single MSDU or A-MSDU in sequentially increasing sequence number order, with the first bit of the BAT Bitmap field corresponding to the MSDU or A-MSDU with the sequence number that matches the value of the Starting Sequence Number subfield of the BAT frame.

9.8.5 PV1 Management frames

9.8.5.1 Format of PV1 Management frames

The format of a PV1 Management frame is defined in Figure 9-985.

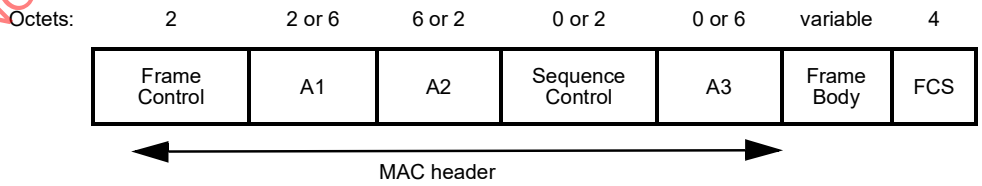

Figure 9-985—PV1 Management frame format

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The Frame Control, A1, and A2 fields are present in all PV1 Management frame subtypes.

The address fields A1 and A2 contain the receiver and transmitter addresses either of which can be an SID field as described in 9.8.3.2.

The Sequence Control field is described in 9.2.4.4 and is present in PV1 Management frames of subtype Action and Action No Ack.

The address field A3 (if present, as described in 9.8.3.2) is set to the BSSID.

The frame body consists of the fields followed by the elements defined for each PV1 Management frame subtype. All fields and elements are mandatory unless stated otherwise and appear in the specified, relative order. STAs that encounter an element ID they do not recognize in the frame body of a received PV1 Management frame ignore that element and continue to parse the remainder of the PV1 Management frame body (if any) for additional elements with recognizable element IDs. See 10.28.7.

Table 9-539 defines the different PV1 Management frame subtypes.

Table 9-539—PV1 Management frame subtypes

PTID/Subtype value b8 b7 b6	Subtype description
000	Action
001	Action No Ack
010	PV1 Probe Response
011	Resource Allocation
100–111	Reserved

PV1 Management frames are Management frames.

9.8.5.2 Action and Action No Ack frames

The frame body of a PV1 Management frame of subtype Action is described in 9.3.3.13 and the format of the Action field formats allowed is described in 9.6.

The frame body of a PV1 Management frame of subtype Action No Ack is described in 9.3.3.14 and the format of the Action field formats allowed is described in 9.6.

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9.8.5.3 PV1 Probe Response frame format

The format of the PV1 Probe Response frame is shown in Figure 9-986.

	Frame Control	A1	A2	Times tamp	Change Sequence	Next TBTT (optional)	Compressed SSID (optional)	Access Network Options (optional)	Optional Elements	FCS
Octets:	2	6	6	4	1	0 or 3	0 or 4	0 or 1	variable	4

Figure 9-986—PV1 Probe Response frame format

The A1 field contains the MAC address of the intended recipient of the frame.

The A2 field contains the MAC address of the transmitter sending the frame.

The Timestamp field contains the value of the 4 least significant octets of the STA's TSF timer at the time that the start of the data symbol containing the first bit of the Timestamp field appears at the transmit antenna connector.

The Change Sequence field is defined as an unsigned integer, initialized to 0, that increments when a critical update to the Beacon frame has occurred (see 10.46.2).

The Next TBTT field is present if the Next TBTT Present subfield in the Frame Control field is 1 and indicates the most significant 3 octets of the 4 least significant octets of the next TBTT. Otherwise, it is not present.

Either a Compressed SSID field or an SSID element is included in the PV1 Probe Response frame.

The Compressed SSID field is present if the Full SSID Present subfield in the Frame Control field is 0 and it contains a 32-bit CRC calculated over the SSID contained in the Probe Response or S1G Beacon frame (calculation is performed as defined in 9.2.4.8 where the SSID is the calculation fields). An SSID element is not present if the Full SSID Present subfield in the Frame Control field is 0.

An SSID element as defined in 9.4.2.2 is present in the Optional Elements field of the PV1 Probe Response frame if the Full SSID Present subfield in the Frame Control field is 1. The Compressed SSID field is not present if the Full SSID Present subfield in the Frame Control field is 1.

The Access Network Options field is present if the ANO Present subfield in the Frame Control field is 1 and is defined in 9.4.2.91. Otherwise, it is not present.

The Optional Elements field contains optional elements requested to be included in the PV1 Probe Response frame such as S1G Beacon Compatibility element. If the S1G Beacon Compatibility element is requested to be included, the PV1 Probe Response frame includes it as the first optional element.

The Frame Control field of the PV1 Probe Response frame is shown in Figure 9-987.

The Next TBTT present subfield is set to 1 if the Next TBTT field is included in the PV1 Probe Response frame and otherwise set to 0.

The Full SSID Present field indicates whether a Full SSID or a Compressed SSID is included in the PV1 Probe Response frame. Setting the field to 1 indicates that an SSID element is included and the Compressed

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SSID field is not included in the PV1 Probe Response frame. Setting the field to 0 indicates that the Compressed SSID field is included and the SSID element is not included in the PV1 Probe Response frame.

	B0 B1	B2 B4	B5 B7	B8	B9	B10	B11 B13	B14	B15
	Protocol Version	Type	PTID/ Subtype	Next TBTT Present	Full SSID Present	ANO Present	BSS BW	Security	1 MHz Primary Channel Location
Bits:	2	3	3	1	1	1	3	1	1

Figure 9-987—Frame Control field of PV1 Probe Response frame format

The ANO Present subfield equals 1 if the Access Network Options field is present; otherwise, it equals 0.

The BSS BW subfield indicates the minimum and the maximum operating bandwidths of the BSS and is defined in Table 9-8.

The Security subfield equals 1 if the transmitting STA is an RSNA STA.

The 1 MHz Primary Channel Location subfield indicates the location of the 1 MHz primary channel. If it is equal to 0, it indicates that the 1 MHz primary channel is located at lower side of 2 MHz primary channel. If it is equal to 1, it indicates that the 1 MHz primary channel is located at upper side of 2 MHz primary channel.

9.8.5.4 Resource Allocation frame format

The Resource Allocation (RA) frame is broadcasted to all non-AP STAs that belong to the RAW group identified by the RAW Group field of a previously transmitted RPS element with the RAW Type subfield indicating a generic RAW and the RAW Type Options subfield indicating an RA frame (see 9.4.2.191). The RA frame signals the presence of downlink buffered data for paged STAs and their assigned RAW slots for both uplink and downlink service periods. The Resource Allocation frame has two kinds of format depending on the slot assignment mode indicated in the Frame Control field. The Resource Allocation frame formats are shown in Figure 9-988 and Figure 9-989.

	Frame Control	A1	BSSID	RAW Group	RAW Duration	Slot Assignment 1	...	Slot Assignment N	FCS
Octets:	2	2	6	3	2	3 or 4		3 or 4	4

Figure 9-988—Resource Allocation frame format when Slot Assignment Mode field is 0

	Frame Control	A1	BSSID	RAW Group	RAW Duration	Slot Assignment Indication	FCS
Octets:	2	2	6	3	2	variable	4

Figure 9-989—Resource Allocation frame format when Slot Assignment Mode field is 1

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The Slot Assignment Indication field formats are shown in Figure 9-990, Figure 9-991, and Figure 9-992.

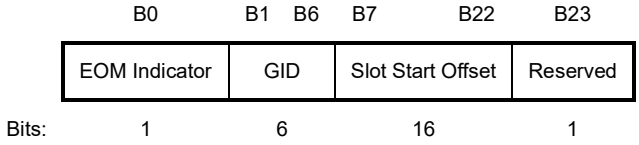

Figure 9-990—Slot Assignment Indication field for MU group when Slot Assignment Mode field is 0 and the Group Indicator field is 1

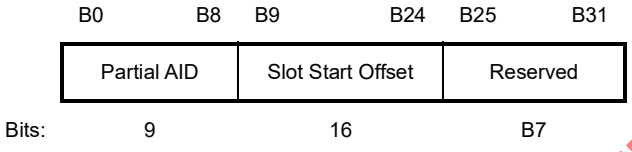

Figure 9-991—Slot Assignment Indication field for a STA when Slot Assignment Mode is 0 and the Group Indicator field is 0

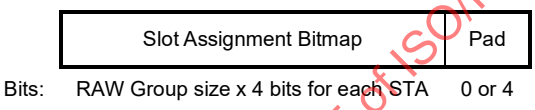

Figure 9-992—Slot Assignment Indication field when Slot Assignment Mode field is 1

The Frame Control field of the Resource Allocation frame is shown in Figure 9-993.

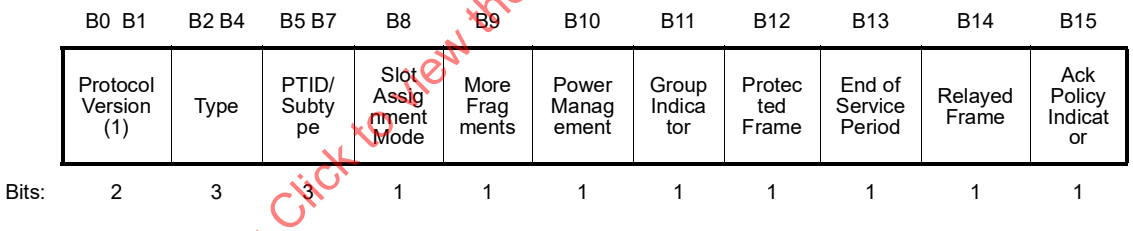

Figure 9-993—Frame Control field format for Resource Allocation frame

The subfields of the Frame Control field, except for the Slot Assignment Mode and the Group Indicator subfields, are defined in 9.8.3.1. The Slot Assignment Mode and the Group Indicator subfields are defined as follows:

— The Slot Assignment Mode subfield indicates the format of the Resource Allocation frame:
  — If the Slot Assignment Mode subfield is equal to 0, the Resource Allocation frame format is as shown in Figure 9-988.
  — If the Slot Assignment Mode subfield is equal to 1, the Resource Allocation frame format is as shown in Figure 9-989.
— The Group Indicator subfield indicates whether any subfield of MU group is included or no subfield of MU group exists in the Slot Assignment field if Slot Assignment mode field is equal to 0. Otherwise, it is reserved.

The A1 field is an SID field that contains the value 0 in the AID subfield. A3 Present, A4 Present, and A-MSDU subfields (B13, B14, and B15) of the SID field are reserved.

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The BSSID field indicates the address of the AP transmitting the Resource Allocation frame.

The RAW Group field indicates the STA AIDs that are assigned the RAW as defined in 9.4.2.191. The AIDs in this RAW Group are identical to the AIDs in the RAW Group subfield with the value in the RAW Type subfield set to 0 and the value in the RAW Type Options subfield set to 1 in the RAW Control subfield within the RPS element. STAs that wake up and receive the Resource Allocation frame use this field to determine whether their AIDs are included within the RAW Group.

The RAW Duration field is an unsigned integer expressed in TUs that indicates the duration of the current RAW where the Resource Allocation frame is broadcasted. The field is either set to the value of the RAW duration deduced from the value in the RAW Slot Definition subfield (9.4.2.191) or is modified from the value indicated in the RAW Slot Definition subfield of the RPS element (9.4.2.191).

The Slot Assignment field indicates a partial AID for a STA or a GID for STAs in the corresponding MU Group and their corresponding slot(s) of medium access within the current RAW. Since MU MIMO is used for DL traffic, the first bit, as called end of multi-user (EOM) Indicator, for the MU group block indicates whether the following subfields are used for the last MU group when this bit is 1 or more MU groups exist after subfields for this MU group when the bit is 0. This field is of length 3 octets for each MU Group and 4 octets for each STA and the length is determined based on the value in the EOM subfield.

If Slot Assignment Mode field is 0 and the Group Indicator field is 1, the Slot Assignment field is used for either MU group of STAs or an assigned STA as shown in Figure 9-990 and Figure 9-991. If Slot Assignment Mode field is 0 and the Group Indicator field is 0, the Slot Assignment field is not used for MU group of STAs. The Slot Assignment field for MU group of STAs is located first at the beginning of the Slot Assignment fields, if exists.

The Partial AID subfield indicates a partial AID for an assigned STA.

The Slot Start Offset subfield indicates the start time of a RAW slot, in TU, for a STA's or MU MIMO group of STAs' medium access, relative to the RAW Start Time field as defined in 9.4.2.191 and is of length 2 octets.

The RA frame contains Slot Assignment Indication field to indicate to each of the STAs in the RAW group the number of UL/DL slot allocations within the current RAW.

The Slot Assignment Bitmap subfield indicates the number of RAW slots allocated for all STAs in the RAW group in ascending order with each 4 bits corresponding to one STA. The decimal number represented by the 4 bits indicates the number of allocation units for a STA. For example, setting this subfield to 0 indicates no allocation for a STA. Setting this subfield to 1 indicates one RAW slot for a STA. All RAW slots have equal duration, in TUs, which is calculated by dividing the value of the RAW Duration field with the number of RAW slots allocated to all STAs in the RAW group. The first RAW slot starts at the end of the Resource Allocation frame while the start times of the remaining RAW slots are equal to the end times of their immediately preceding RAW slots as indicated in the Slot Assignment Bitmap subfield.

The Slot Assignment Bitmap subfield has a length in bits, SAB_{length}, which is determined as:

SAB_{length} = (RAW End AID – RAW Start AID + 1) × 4

where
RAW End AID and RAW Start AID for the RAW group are defined in 9.4.2.191

The Pad subfield contains 0 or 4 bits of 0s to make the total number of bits in the Slot Assignment Indication field equal to an integer number of octets.

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10. MAC sublayer functional description

10.1 Introduction

The MAC functional description is presented in this clause. The architecture of the MAC sublayer, including the distributed coordination function (DCF), the hybrid coordination function (HCF), the mesh coordination function (MCF), and their coexistence in an IEEE 802.11 LAN are introduced in 10.2. These functions are expanded on in 10.3, 10.23, and 10.24. Fragmentation and defragmentation are defined in 10.4 and 10.5. Multirate support is addressed in 10.6. A number of additional restrictions to limit the cases in which MSDUs are reordered or discarded are described in 10.7. Operation across regulatory domains is defined in 10.22. The block ack mechanism is described in 10.25. The No Ack mechanism is described in 10.26. The protection mechanism is described in 10.27. Rules for processing MAC frames are described in 10.28.

10.2 MAC architecture

10.2.1 General

The MAC architecture is shown in Figure 10-1, Figure 10-2, and Figure 10-3.

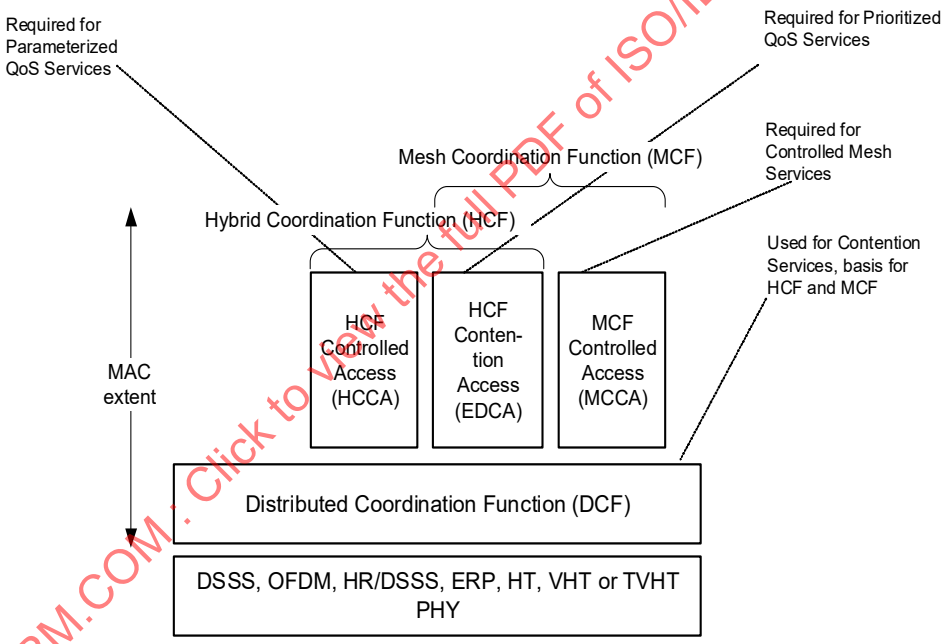

Figure 10-1—Non-DMG non-CMMG non-S1G STA MAC architecture

In a non-DMG non-CMMG non-S1G STA:

— The MAC provides the HCF and MCF service using the services of the DCF. The MAC also provides direct access to the DCF service.

— The HCF is present in QoS STAs and absent otherwise.

— The MCF is present in mesh STAs and absent otherwise.

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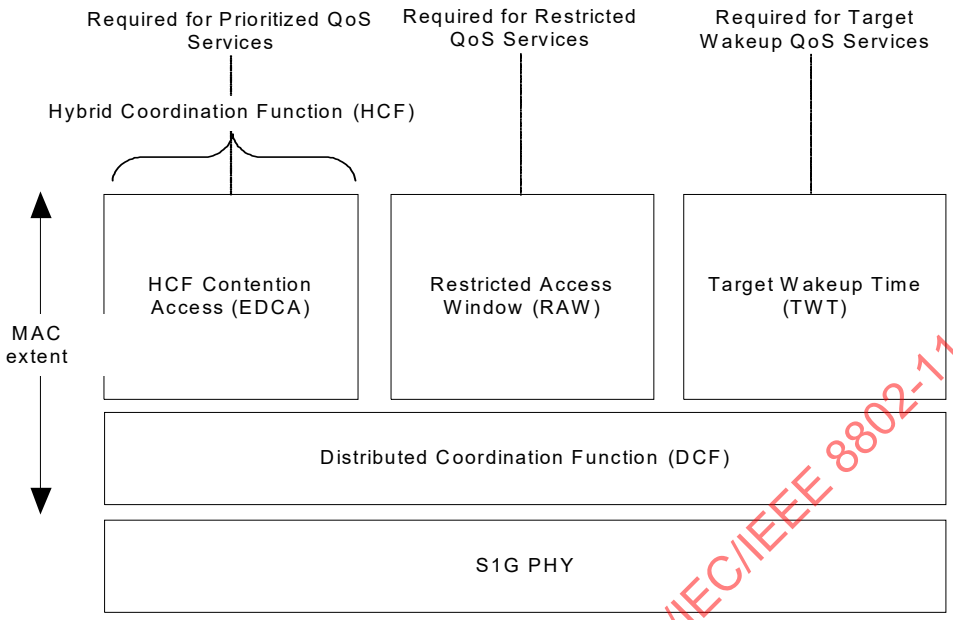

Figure 10-2—S1G STA MAC architecture

In an S1G STA:

— The MAC provides EDCA service using the services of the DCF.
— The RAW is optionally present.
— The TWT is optionally present.

In a DMG STA:

— The MAC provides services using the DMG channel access mechanisms.

In a CMMG STA:

— The MAC provides services using the CMMG channel access mechanisms.

In either a DMG or CMMG STA:

— Specific rules apply for access during scheduled periods, which include the association beamforming training (A-BFT) period, announcement transmission interval (ATI), contention based access period (CBAP), and service period (SP).
— The DCF is used during contention based access periods.
— Dynamic allocation (10.39.7) is built on service period and contention based access period.

The MAC maintains information in local variables called *MAC variables*. MAC variables that hold state information are also called *state variables*.

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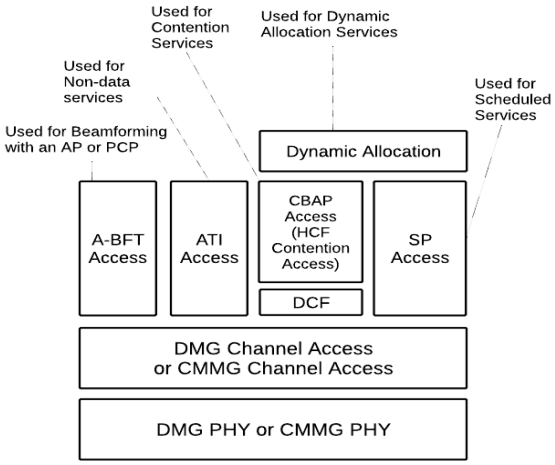

Figure 10-3—DMG STA and CMMG STA architecture

10.2.2 DCF

The fundamental access method of the MAC used by non-DMG STAs is a DCF known as *carrier sense multiple access with collision avoidance* (CSMA/CA). The DCF shall be implemented in all STAs.

For a STA to transmit, it shall sense the medium to determine if another STA is transmitting. If the medium is not determined to be busy (see 10.3.2.1), the transmission may proceed. The CSMA/CA distributed algorithm mandates that a gap of a minimum specified duration exists between frame exchange sequences. A transmitting STA shall verify that the medium is idle for this required duration before attempting to transmit. If the medium is determined to be busy, a non-DMG STA shall defer until the end of the current transmission, and a DMG STA may defer until the end of the current transmission. After deferral, or prior to attempting to transmit again immediately after a successful transmission, the STA shall initialize a backoff counter to a random backoff count [see Equation (10-1)] and shall decrement the backoff counter once per interval of aSlotTime (a backoff slot) while the medium is idle. A refinement of the method may be used under various circumstances to further minimize collisions—here the transmitting and receiving STA exchange short Control frames (RTS and CTS frames for non-DMG STAs, and RTS and DMG CTS frames for DMG STAs) after determining that the medium is idle and after any deferrals or backoffs, prior to data transmission. The details of CSMA/CA, deferrals, and backoffs are described in 10.3. RTS/CTS and RTS/DMG CTS exchanges are also presented in 10.3.

10.2.3 Hybrid coordination function (HCF)

10.2.3.1 General

The QoS facility includes an additional coordination function called *HCF* that is usable only in QoS network configurations. The HCF shall be implemented in all QoS STAs except mesh STAs. Instead, mesh STAs implement the MCF. The HCF combines functions from the DCF with some enhanced, QoS-specific mechanisms and frame subtypes to allow a uniform set of frame exchange sequences to be used for QoS data transfers . The HCF uses both a contention based channel access method, called the *enhanced distributed channel access (EDCA)* mechanism for contention based transfer and a controlled channel access, referred to as the *HCF controlled channel access (HCCA)* mechanism, for contention free transfer.

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A STA may obtain a TXOP using one or both of the channel access mechanisms specified in 10.23. If a TXOP is obtained using the contention based channel access, it is defined as *EDCA TXOP*. If a TXOP is obtained using the controlled channel access, it is defined as *HCCA TXOP*. If an HCCA TXOP is obtained due to a QoS (+)CF-Poll frame from the HC, the TXOP is defined as a *polled TXOP*.

Time priority Management frames are transmitted outside of the normal MAC queuing process as per individually described transmission rules. Time priority Management frames are defined to be those that have a value of Yes in the Time priority column in Table 9-405, Table 9-489, Table 9-494, and Table 9-511. No other frames are time priority Management frames.

10.2.3.2 HCF contention based channel access (EDCA)

The EDCA mechanism provides differentiated, distributed access to the WM for STAs using eight different UPs. The EDCA mechanism defines four access categories (ACs) that provide support for the delivery of traffic with UPs at the STAs. Six transmit queues are defined when dot11AlternateEDCAActivated is true, and four transmit queues otherwise. The transmit queue and AC are derived from the UPs as shown in Table 10-1.

Table 10-1—UP-to-AC mappings

Priority	UP (Same as IEEE 802.1D user priority)	IEEE 802.1D designation	AC	Transmit queue (dot11Alternate-EDCAActivated false or not present)	Transmit queue (dot11Alternate EDCAActivated true)	Designation
Lowest	1	BK	AC_BK	BK	BK	Background
	2	—	AC_BK	BK	BK	Background
	0	BE	AC_BE	BE	BE	Best Effort
	3	EE	AC_BE	BE	BE	Best Effort
	4	CL	AC_VI	VI	A_VI	Video (alternate)
	5	VI	AC_VI	VI	VI	Video (primary)
	6	VO	AC_VO	VO	VO	Voice (primary)
Highest	7	NC	AC_VO	VO	A_VO	Voice (alternate)

NOTE—The Designation column is an indication of general usage and guidance. Actual uses of each UP are implementation specific.

NOTE 1—A DMG or S1G STA that implements a single AC (see 10.23.2.1) has all of its UP values in Table 10-1 mapped to AC_BE.

For each AC an enhanced variant of the DCF, called an *enhanced distributed channel access function (EDCAF)*, contends for TXOPs using a set of EDCA parameters. When communicating Data frames outside the context of a BSS (dot11OCBActivated is true), the EDCA parameters are the corresponding default values or are as set by the SME in dot11EDCATable (except for TXOP limits, which shall be set to 0 for each AC). For a non-AP STA communicating within a non-mesh QoS BSS, the EDCA parameters used are from the EDCA Parameter Set element or (for a non-AP STA prior to associating with an AP of an infrastructure BSS, a mesh STA, or a STA that operates OCB) from the default values for the parameters. The parameters used by the EDCAF to control its operation are defined by dot11QAPEDCATable at the AP and by dot11EDCATable at the non-AP STA.

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The following rules apply for HCF contention based channel access:

a) The minimum specified idle duration is not the constant value (DIFS) defined for DCF, but is a distinct value. This value is specified in table dot11QAPEDCATableAIFSN for an AP and in table dot11EDCATableAIFSN for a non-AP STA; see 10.23.2. The minimum idle duration is assigned either by a management entity or by an AP.

b) The contention window limits aCWmin and aCWmax, from which the random backoff is computed, are not fixed per PHY, as with DCF, but are variable (contained in tables dot11QAPEDCATableCWmin and dot11QAPEDCATableCWmax for an AP and in tables dot11EDCATableCWmin and dot11EDCATableCWmax for a non-AP STA) and assigned by a management entity or by an AP.

c) Collisions between contending EDCAFs in a STA are resolved within the STA, so that the Data frames from the higher priority AC receive the TXOP and the Data frames from the lower priority colliding AC(s) behave as if there were an external collision on the WM except that the Retry subfield in the MAC headers of MPDUs at the head of the lower priority ACs is not affected.

d) During an EDCA TXOP won by an EDCAF a STA may initiate multiple frame exchange sequences to transmit MMPDUs and/or MSDUs within the same AC. The duration of this EDCA TXOP is bounded, for an AC, by the value dot11QAPEDCATableTXOPLimit for an AP and by dot11EDCATableTXOPLimit for a non-AP STA. A value of 0 for this duration means that the EDCA TXOP is limited as defined by the rule for TXOP limit of 0 found in 10.23.2.9.

The QoS AP shall announce the EDCA parameters in selected Beacon frames and in all Probe Response and (Re)Association Response frames by the inclusion of the EDCA Parameter Set element using the information from the MIB entries in dot11EDCATable. If no such element has been received (e.g., prior to association in an infrastructure BSS), a non-AP QoS STA shall use the default values for the parameters. The EDCA Parameter Set element shall be included in all Beacon frames occurring within two delivery traffic indication map (DTIM) periods following a change in announced EDCA parameters, which provides all STAs an opportunity to receive the updated EDCA parameters; it may optionally be included in more Beacon frames. If any associated STAs are in WNM sleep mode or using FMS, these fields should be included by the AP for as many DTIM periods as needed to exceed the longest interval any STA is expected to not receive Beacon frames.

A QoS STA, on receiving an updated EDCA Parameter Set element, should update the dot11EDCATable as soon as practical in the implementation and shall update the dot11EDCATable within an interval of time equal to one beacon interval. QoS STAs update the dot11EDCATable and store the EDCA Parameter Set update count value in the QoS Info field. An S1G STA shall update its dot11EDCATable if its STA type is indicated by the STA Type subfield contained in the received EDCA Parameter Set element (see 10.61). An AP may change the EDCA access parameters by changing the EDCA Parameter Set element in the Beacon frame, Probe Response frame, and (Re)Association Response frame. However, the AP should change them only rarely. A QoS STA shall use the EDCA Parameter Set Update Count Value subfield in the QoS Capability element of all Beacon frames to determine whether the STA is using the current EDCA Parameter Values. If the EDCA Parameter Set update count value in the QoS Capability element is different from the value that has been stored, the QoS STA shall query the updated EDCA parameter values by sending a Probe Request frame to the AP.

The S1G AP shall set the STA Type subfield of EDCA Parameter Set elements it transmits as follows:

— 1 if it indicates support for sensor STAs but no support for non-sensor STAs
— 2 if it indicates support for non-sensor STAs but no support for sensor STAs

The S1G AP may set the STA Type subfield of EDCA Parameter Set elements to any value that is less than 3 if it indicates support for both sensor STAs and non-sensor STAs as described in 10.61.

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An S1G AP may assign to an S1G STA EDCA parameters different from the ones in dot11EDCATable, by sending to the STA an EDCA Parameter Set frame with an EDCA Parameter Set element with the Override field equal to 1. An S1G STA receiving an EDCA Parameter Set element with the Override field equal to 1 shall update its MIB values of the EDCA parameters based on the values indicated by the EDCA Parameter Set element.

An S1G STA that receives an EDCA Parameter Set frame with an EDCA Parameter Set element with the Override field equal to 1 shall disregard any EDCA Parameter Set elements with the Override field equal to 0 received afterward during the current association until it receives the EDCA Parameter Set element with the Override field equal to 1 carried in an EDCA Parameter Set frame.

In the Beacon frame the EDCA Parameter Set Update Count subfield is initially set by the AP to 0 and is incremented every time any of the announced EDCA parameters change.

An AP or PCP may use a different set of EDCA parameter values than it advertises to the STAs in its BSS.

A QoS STA that transmits a Management frame determines access category used for medium access in transmission of the Management frame as follows:

- If dot11QMFActivated is false or not present and
  - If the Management frame is individually addressed to a non-QoS STA, category AC_BE should be selected.

    NOTE 2—Category AC_BE might not be selected when no prior Data frames have been transmitted to the non-QoS STA.
  - If category AC_BE was not selected by the previous step, category AC_VO shall be selected.

    NOTE 3—Selection of AC_VO above is independent of whether the STA is associated with a BSS, or whether there is a QoS facility in the BSS.
- If dot11QMFActivated is true, the STA determines the access category as described in 11.24.

BlockAckReq and BlockAck frames shall be sent using the same access category for medium access as the corresponding QoS Data frames.

A non-S1G STA shall send PS-Poll frames using the access category AC_BE. This reduces the likelihood of collisions following a Beacon frame.

If an S1G STA receives an EDCA Parameter Set element from its associated AP and its STA type is indicated in the STA Type subfield in the received EDCA Parameter Set element, an S1G STA shall transmit PS-Poll frames, PS-Poll+BDT frames and NDP PS-Poll frames using the access category indicated in the PS-Poll ACI subfield. Otherwise, an S1G STA shall transmit PS-Poll frames, PS-Poll+BDT frames and NDP PS-Poll frames either using access category AC_VO when the S1G STA is a non-sensor STA or using access category AC_BE when the S1G STA is a sensor STA (see 10.61).

When the first frame in a frame exchange sequence intended to carry a QoS Data, QoS Null or Management frame is an RTS or CTS frame, the RTS or CTS frame shall be transmitted using the access category of the corresponding QoS Data or QoS Null frame or the access category used for medium access of the Management frame.

Control Wrapper frames shall be sent using the access category that would apply to the carried Control frame.

A beamformer may send a VHT NDP Announcement frame or Beamforming Report Poll frame using any access category and without being restricted by admission control procedures.

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PS-Poll frames and Management frames are exempted from any and all restrictions on transmissions arising from admission control procedures.

The operation rules of HCF contention based channel access are defined in 10.23.2.

The alternate video (A_VI) and alternate voice (A_VO) transmit queues share the same EDCAF as VI and VO transmit queues, respectively, as shown in Figure 10-24. When dot11AlternateEDCAActivated is true, a scheduling function above the VO EDCAF selects from the primary or alternate transmit queue an MSDU, an A-MSDU, an MMPDU, or set of MSDUs to be the next to be passed to the VO EDCAF (as shown in Figure 10-24) so that the MSDU(s), A-MSDU(s), or MMPDU(s) from the queue with the higher UP are selected with a higher probability than from the queue with the lower UP. When dot11AlternateEDCAActivated is true, a scheduling function above the VI EDCAF selects from the primary or alternate transmit queue an MSDU, an A-MSDU, an MMPDU, or set of MSDUs to be the next to be passed to the VI EDCAF so that the MSDU(s), A-MSDU(s), or MMPDU(s) from the queue with the higher UP are selected with a higher probability than from the queue with the lower UP. The default algorithm to select an MSDU, A-MSDU, or MMPDU from either the A_VI or VI queue and to select an MSDU, A-MSDU, or MMPDU from either the A_VO or VO queue is as follows:

— For each EDCAF, an MSDU, A-MSDU, or MMPDU is selected for transmission using the transmission selection procedures defined in 8.6.8 of IEEE Std 802.1Q using two queues, the primary and alternate.
— For a given AC, the order in which frames are selected for transmission shall maintain the requirements specified in 10.7 of this standard.

Alternative prioritization algorithms that meet the requirements of 10.7 may be used.

All MSDUs, A-MSDUs, and MMPDUs passed to the VO EDCAF are transmitted according to AC_VO EDCAF parameters and rules. All MSDUs, A-MSDUs, and MMPDUs passed to the VI EDCAF are transmitted according to AC_VI EDCAF parameters and rules.

10.2.3.3 HCF controlled channel access (HCCA)

The HCCA mechanism uses a QoS-aware centralized coordinator, called a *hybrid coordinator (HC)*. The HC is collocated with the AP of the BSS and uses the HC's higher priority of access to the WM to initiate frame exchange sequences and to allocate TXOPs to itself and other STAs in order to provide limited-duration CAPs for contention free transfer of QoS data.

The HC traffic delivery and TXOP allocation may be scheduled to meet the QoS requirements of a particular TC or TS. TXOP allocations and contention free transfers of QoS traffic might be based on the HC's BSS-wide knowledge of the amounts of pending traffic belonging to different TS and/or TCs and are subject to BSS-specific QoS policies.

Implementers are cautioned that QoS STAs are not required to interpret data subtypes that include QoS +CF-Ack in frames not addressed to themselves unless they set the Q-Ack subfield in the QoS Capability element to 1.

The HCF protects the transmissions during each CAP using the virtual CS mechanism.

A STA may initiate multiple frame exchange sequences during a polled TXOP of sufficient duration to perform more than one such sequence.

The operation rules of the HCCA are defined in 10.23.3.

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10.2.4 Mesh coordination function (MCF)

The mesh facility includes an additional coordination function called *MCF* that is usable only in an MBSS. A mesh STA shall implement the MCF only. MCF has both a contention based channel access and contention free channel access mechanism. The contention based mechanism is EDCA and the contention free mechanism is called the *MCF controlled channel access (MCCA)*. MCF uses the default values for the PTKSA, and GTKSA Replay Counters. The operation rules of the EDCA are defined in 10.23.2. The operation rules of the MCCA are defined in 10.24.3.

10.2.5 Combined use of DCF and HCF

The DCF and the hybrid coordination function are defined so they may operate within the same BSS. The HCF access methods (controlled and contention based) operate sequentially. Sequential operation allows the polled and contention based access methods to alternate, within intervals as short as the time to transmit a frame exchange sequence, under rules defined in 10.23.

10.2.6 Fragmentation/defragmentation overview

The process of partitioning an MSDU or an MMPDU into smaller MAC-level frames, MPDUs, is called *fragmentation*. Fragmentation creates MPDUs smaller than the original MSDU or MMPDU length to increase reliability, by increasing the probability of successful transmission as defined in 10.2.2 of the MSDU or MMPDU when channel characteristics limit reception reliability for longer frames. A STA may use fragmentation to use the medium efficiently in consideration of the duration available in granted TXOPs, as long as the rules in 10.4 are followed. Fragmentation is accomplished at each immediate transmitter. The process of recombining MPDUs into a single MSDU or MMPDU is defined as *defragmentation*. Defragmentation is accomplished at each immediate recipient.

An MSDU transmitted under an HT-immediate block ack agreement shall not be fragmented even if its length exceeds dot11FragmentationThreshold. An MSDU or MMPDU transmitted within an A-MPDU that does not contain an S-MPDU (see 10.12.8) shall not be fragmented even if its length exceeds dot11FragmentationThreshold. MSDUs or MMPDUs carried in a group addressed MPDU shall not be fragmented even if their length exceeds dot11FragmentationThreshold.

NOTE 1—A fragmented MSDU or MMPDU transmitted by an HT STA to another HT STA can be acknowledged only using immediate acknowledgment (i.e., transmission of an Ack frame after a SIFS).

NOTE 2—As specified in 10.11, A-MSDUs are never fragmented.

NOTE 3—A fragmented MSDU or MMPDU transmitted by an S1G STA to another S1G STA can be acknowledged either using immediate acknowledgment (i.e., transmission of an (NDP) Ack frame after a SIFS) or using fragment BA described in 10.3.2.12.

Except as described below, when an individually addressed MSDU is received from the LLC or an individually addressed MMPDU is received from the MLME that would result in an MPDU of length greater than dot11FragmentationThreshold, the MSDU or MMPDU shall be fragmented. An exception applies when an MSDU is transmitted using an HT-immediate block ack agreement or when the MSDU or MMPDU is carried in an A-MPDU that does not contain an S-MPDU, in which case the MSDU or MMPDU is transmitted without fragmentation. Each fragment is a frame no longer than dot11FragmentationThreshold, if security encapsulation is not invoked for the MPDU. If security encapsulation is active for the MPDU, then the fragments shall be expanded by the encapsulation overhead and this may result in a fragment larger than dot11FragmentationThreshold. It is possible that any fragment may be a frame smaller than dot11FragmentationThreshold. An illustration of fragmentation is shown in Figure 10-4.

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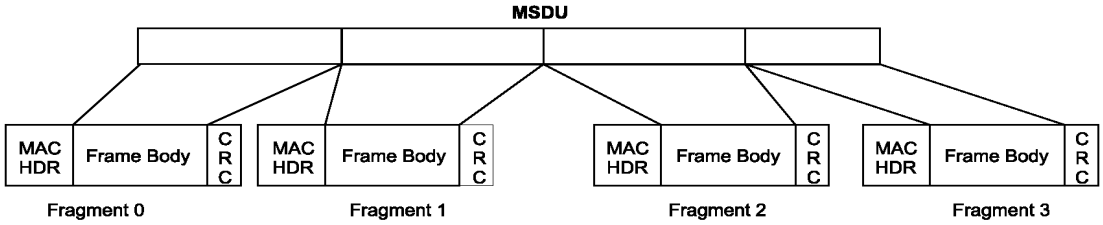

Figure 10-4—Fragmentation

The MPDUs resulting from the fragmentation of an MSDU or MMPDU are sent as independent transmissions, each of which is separately acknowledged. This permits transmission retries to occur per fragment, rather than per MSDU or MMPDU. The fragments of a single MSDU or MMPDU are either

— Sent as individual frames using the DCF, or
— Sent as a burst in an EDCA or HCCA TXOP, subject to TXOP limits and medium occupancy limits for the attached PHY.

A QoS Data frame with a TID matching a block ack agreement may be transmitted in a non-A-MPDU with Normal Ack ack policy.

Transmission of fragmented MPDUs by a DMG STA outside of an A-MPDU depends on setting of the No-Fragmentation field in the ADDBA Extension element within the ADDBA Response frame transmitted during the block ack agreement handshake. The MSDU shall not be fragmented if the No-Fragmentation field in the ADDBA Extension element within the ADDBA Response frame transmitted during the block ack agreement handshake is 1. If the No-Fragmentation field in the ADDBA Extension element within the ADDBA Response frame is 0, the originator may fragment an MSDU sent under the block ack agreement, with Normal Ack ack policy for the corresponding MPDUs.

10.2.7 MAC data service

The MAC data service provides the transport of MSDUs between MAC peer entities as characterized in 5.1.1.

The transmission process is started by the MAC's receipt of an MA-UNITDATA.request primitive containing an MSDU and the associated parameters. This might cause one or more Data frames containing the MSDU to be transmitted following A-MSDU aggregation, fragmentation, and security encapsulation, as appropriate.

The MAC generates the MA-UNITDATA.indication primitive in response to one or more received Data frames containing an MSDU following validation, address filtering, decryption, decapsulation, defragmentation, and A-MSDU deaggregation, as appropriate.

When dot11SSPNInterfaceActivated is true, an AP shall distribute the group addressed message into the BSS only if dot11NonAPStationAuthSourceMulticast in the dot11InterworkingEntry identified by the source MAC address in the received message is true. When dot11SSPNInterfaceActivated is false, an AP shall distribute the group addressed message into the BSS, except when dot11RelayAPOperationActivated is true and the group addressed message is received from a STA. In that case, the group addressed message shall not be distributed into the BSS, and it shall be forwarded to the S1G relay STA in the same relay. The S1G relay STA shall send the group addressed message to the associated AP as an individually addressed frame using either a four address frame format (PV0 or PV1) or an A-MSDU format as specified in 10.54.4.

Unless the MPDU is delivered via DMS, the STA originating the message receives the message as a group addressed message (prior to any filtering). Therefore, a STA shall filter out group addressed messages that contain their address as the source address; the point at which such filtering occurs in the processing of

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received frames is an implementation choice. When dot11SSPNInterfaceActivated is false, group addressed MSDUs shall be propagated throughout the ESS. When dot11SSPNInterfaceActivated is true, group addressed MSDUs shall be propagated throughout the ESS only if dot11NonAPStationAuthSourceMulticast in the dot11InterworkingEntry identified by the source MAC address in the received message is true.

A STA transmitting on a general link also uses the addressing rules described in 10.65.

A MAC not contained within an S1G relay performs address filtering on the Address 1 field in each MPDU contained in a PPDU and, for non-GLK non-AP STAs, on the DA of each MSDU within an A-MSDU. In the case of a non-GLK STA receiver, when the Address 1 field or DA field contains a group address, address filtering is performed by comparing the value in the Address 1 field or DA field to all values in the dot11GroupAddressesTable, and the STA also validates the BSSID to verify either that the group addressed frame originated from a STA in the BSS of which the receiving STA is a member, or that it contains the wildcard BSSID value, indicating a Data frame sent outside the context of a BSS (dot11OCBActivated is true in the transmitting STA). Address 1 filtering is as specified in 10.65 when Address 1 is a SYNRA. A GLK AP does not perform any DA filtering for MPDUs received over a non-general link; all MSDUs so received are passed to the DS for further processing. A GLK STA does not perform DA filtering for MPDUs received over a general link; all MSDUs so received are passed to the GLK convergence function and from there to the bridge for further processing.

A mesh STA also uses the address matching rules described in 10.38.3, when it receives an individually addressed frame. When a mesh STA receives a frame with the Address 1 field equal to a group address, the mesh STA also checks the TA to determine whether the group addressed frame originated from one of its peer mesh STAs; if there is no match, the STA shall discard the frame. A mesh STA also uses the address matching rules described in 10.38.4.

If the Address 1 field of an MPDU carrying an A-MSDU does not match any address at a receiving STA, then the entire A-MSDU is discarded.

In a QoS STA, the TID parameter of the MA-UNITDATA.request primitive results in a TID being specified for the transmitted MSDU. This TID associates the MSDU with the AC or TS queue for the indicated traffic.

10.3 DCF

10.3.1 General

The basic medium access protocol is a DCF that allows for automatic medium sharing between compatible PHYs through the use of CSMA/CA and a random backoff count following a busy medium condition. In addition, all individually addressed traffic uses immediate positive acknowledgment (Ack frame), in which retransmission is scheduled by the sender if no Ack frame is received.

The CSMA/CA protocol is designed to reduce the collision probability between multiple STAs accessing a medium, at the point where collisions would most likely occur. Just after the medium becomes idle following a busy medium (as indicated by the CS function) is when the highest probability of a collision exists. This is because multiple STAs could have been waiting for the medium to become available again. This is the situation that necessitates a random backoff procedure to resolve medium contention conflicts.

The DCF is modified for use by DMG STAs to allow sharing of the medium between compatible DMG PHYs (see 10.3.4). A DMG STA has no direct knowledge of when it might interfere (collide with the transmission of) another STA.

The CS function of a DMG STA might not indicate the medium busy condition due to the predominant nature of directional transmissions and receptions. The transmission of a STA might interfere (collide) with

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the transmission of another STA even though the CS function at the first STA does not indicate medium busy. The interference (collision) is identified when the expected response frame is not received. SPSH is achieved by the proper combination of the STA antenna configuration during the media access and data transfer phases.

CS shall be performed both through physical and virtual mechanisms.

The virtual CS mechanism is achieved by distributing reservation information announcing the impending use of the medium. The exchange of RTS and CTS frames prior to the actual Data frame is one means of distribution of this medium reservation information. The RTS and CTS frames contain a Duration field that defines the period of time that the medium is to be reserved to transmit the actual Data frame and the returning Ack frame. A STA receiving either the RTS frame (sent by the originating STA) or the CTS frame (sent by the destination STA) shall process the medium reservation. Thus, a STA might be unable to receive from the originating STA and yet still know about the impending use of the medium to transmit a Data frame.

Another means of distributing the medium reservation information is the Duration/ID field in individually addressed frames. This field gives the time that the medium is reserved, either to the end of the immediately following Ack frame, or in the case of a fragment sequence, to the end of the Ack frame following the next fragment.

The RTS/CTS exchange also performs both a type of fast collision inference and a transmission path check. If the return CTS frame is not detected by the STA originating the RTS, the originating STA may repeat the process (after observing the other medium-use rules) more quickly than if the long Data frame had been transmitted and a return Ack frame had not been detected. An RTS/CTS exchange by VHT STAs also performs fast collision inference on the secondary 20 MHz channel, secondary 40 MHz channel, and secondary 80 MHz channel and helps the VHT STA transmitting the RTS to determine the available bandwidth at the responder.

Another advantage of the RTS/CTS mechanism occurs where multiple BSSs utilizing the same channel overlap. The medium reservation mechanism works across the BSS boundaries. The RTS/CTS mechanism might also improve operation in a typical situation in which all STAs are able to receive from the AP, but might not be able to receive from all other STAs in the BSA.

Except for MPDUs transmitted via the GCR service, the RTS/CTS mechanism cannot be used for MPDUs with a group addressed immediate destination because there are multiple recipients for the RTS frame, and thus potentially multiple concurrent senders of the CTS frame in response. For MPDUs transmitted via the GCR service, an RTS frame may be used if it is directed to a STA within the GCR group (see 10.23.2.12.2 and 10.25.8). The RTS/CTS mechanism is not used for every Data frame transmission. Because the additional RTS and CTS frames add overhead inefficiency, the mechanism is not always justified, especially for short Data frames.

The use of the RTS/CTS mechanism under control of dot11RTSThreshold is described in 10.3.5.

All non-DMG STAs that are members of a BSS are able to receive and transmit at all of the data rates in the BSSBasicRateSet parameter of the MLME-START.request primitive or BSSBasicRateSet parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive; see 6.3.4.2.4 and 6.3.11.2.4.

NOTE—The operational rate or MCS set that a STA advertises does not necessarily contain all the mandatory rates or MCSs, respectively. The basic rate or MCS set that a STA starting a BSS advertises does not necessarily contain all the mandatory rates or MCSs, respectively. However, a STA has to be capable of receiving using a mandatory rate or MCS (when required by the rules in 10.6) even if it is not present in the operational rate or MCS set, respectively, that the STA advertises, and similarly has to be capable of transmitting using a mandatory rate or MCS (when required by the rules in 10.6) even if it is not present in the basic rate or MCS set, respectively. In this context, “mandatory” describes rates or MCSs that are so described, or described using “shall support”, in reference to the STA type, in the PHY clause applicable to the STA.

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All HT STAs that are members of a BSS are able to receive and transmit using all of the MCSs in the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive; see 6.3.4.2.4 and 6.3.11.2.4.

All VHT STAs that are members of a BSS are able to receive and transmit using all of the <VHT-MCS, NSS> tuples in the basic VHT-MCS and NSS set (see 11.38.7) except as constrained by the rules of 10.6.13.

All DMG STAs that are members of a BSS are able to receive and transmit using all of the MCSs in the OperationalRateSet parameter of the MLME-START.request primitive or OperationalRateSet parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive; see 6.3.4.2.4 and 6.3.11.2.4.

To support the proper operation of the RTS/CTS by non-DMG STAs, RTS/DMG CTS by DMG STAs, and the virtual CS mechanism, a non-DMG STA shall be able to interpret Control frames with the Subtype subfield equal to RTS or CTS, and a DMG STA shall be able to interpret Control frames with the Subtype subfield equal to RTS or DMG CTS.

A Data frame sent under the DCF shall have the Type subfield set to Data and the Subtype subfield set to Data or Null. A STA receiving a frame with the Type subfield equal to Data shall not indicate the frame to the LLC when the Subtype subfield is equal to Null, but shall indicate the frame to the LLC when the Subtype subfield is equal to Data, even if the frame body contains zero octets.

While in the awake state and operating under DCF but not transmitting, a DMG STA can configure its receive antenna to a quasi-omni pattern in order to receive frames transmitted by any STA that is covered by this antenna pattern.

10.3.2 Procedures common to the DCF and EDCAF

10.3.2.1 CS mechanism

Physical and virtual CS functions are used to determine the state of the medium. When either function indicates a busy medium, the medium shall be considered busy; otherwise, it shall be considered idle.

A physical CS mechanism shall be provided by the PHY. See Clause 8 for how this information is conveyed to the MAC. The details of physical CS are provided in the individual PHY specifications.

A virtual CS mechanism, referred to as the NAV, shall be provided by all MACs. An additional virtual CS mechanism, referred to as response indication deferral (RID), shall be provided by S1G MACs.

The NAV maintains a prediction of future traffic on the medium based on duration information that is announced in RTS/CTS frames by non-DMG STAs and RTS/DMG CTS frames by DMG STAs prior to the actual exchange of data. The duration information is also available in the MAC headers of all frames other than PV1 MAC frames and PS-Poll frames, and during the BTI, the A-BFT, the ATI, the CBAP, and the SP. The duration information in a frame transmitted by an S1G STA is also available in PS-Poll+BDT frames, in NDP CTS frames, in NDP Ack frames whose Idle Indication field value is 0, and in NDP_2M PS-Poll-Ack frames whose Idle Indication field is 0.

The mechanism for setting the NAV using RTS/CTS or RTS/DMG CTS in the DCF is described in 10.3.2.4, and use of the NAV in HCF is described in 10.23.2.2 and 10.23.3.4. Additional details regarding NAV use appear in 10.3.2.6, 10.3.2.15, 10.39.10, and 10.27.

The mechanism for setting the RID is described in 10.3.2.5.

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The CS mechanism combines the NAV state, and in S1G STAs also the RID state, and the STA's transmitter status with physical CS to determine the busy/idle state of the medium. The NAV and RID might be thought of as counters that count down to 0 at a uniform rate. In non-S1G STAs, when the NAV counter is 0, the virtual CS indication is that the medium is idle; when the counter is nonzero, the indication is busy. In S1G STAs, when both NAV and RID counters are 0, the virtual CS indication is that the medium is idle; when either the NAV counter or the RID counter is nonzero the indication is that the medium is busy. If a DMG STA supports multiple NAVs as defined in 10.39.10 and all counters are 0, the virtual CS indication is that the medium is idle; when at least one of the counters is nonzero, the indication is busy. The medium shall be determined to be busy when the STA is transmitting.

At aRxTxTurnaroundTime + aAirPropagationTime + aRxPHYDelay + 10% × (aSlotTime − aAirPropagationTime) after each MAC slot boundary as defined in 10.3.7 and 10.23.2.4, the MAC shall issue a PHY-CCARESET.request primitive to the PHY, where aAirPropagationTime determined as described in 10.22.5.

10.3.2.2 MAC-level acknowledgments

The reception of some frames, as described in 10.3.2.11, requires the receiving STA to respond with an acknowledgment if the FCS of the received frame is correct. This technique is known as positive acknowledgment.

Lack of reception of an expected frame containing an acknowledgment indicates to the STA initiating the frame exchange that an error has occurred. Note, however, that the destination STA may have received the frame correctly, and that the error may have occurred in the transfer or reception of the frame containing an acknowledgment. When a frame containing an acknowledgment is lost, the MAC that initiated the frame exchange does not receive a protocol indication of whether the initial frame was correctly received.

A correctly received frame is one for which the PHY-RXEND.indication primitive does not indicate an error and the FCS indicates the frame is error free.

10.3.2.3 IFS

10.3.2.3.1 General

The time interval between frames is called the *IFS*. A STA shall determine that the medium is idle through the use of the CS function for the interval specified. Ten different IFSs are defined to provide priority levels for access to the wireless medium. Figure 10-5 shows some of these relationships. All timings are referenced from occurrence of the PHY interface primitives PHY-TXEND.confirm, PHY-TXSTART.confirm, PHY-RXSTART.indication, and PHY-RXEND.indication.

The IFSs are as follows:

a) RIFS reduced interframe space
b) SIFS short interframe space
c) PIFS priority interframe space
d) DIFS DCF interframe space
e) AIFS[AC] AIFS arbitration interframe space (for the AC used by the QoS facility)
f) EIFS extended interframe space
g) SBIFS short beamforming interframe space
h) BRPIFS beam refinement protocol interframe space
i) MBIFS medium beamforming interframe space
j) LBIFS long beamforming interframe space

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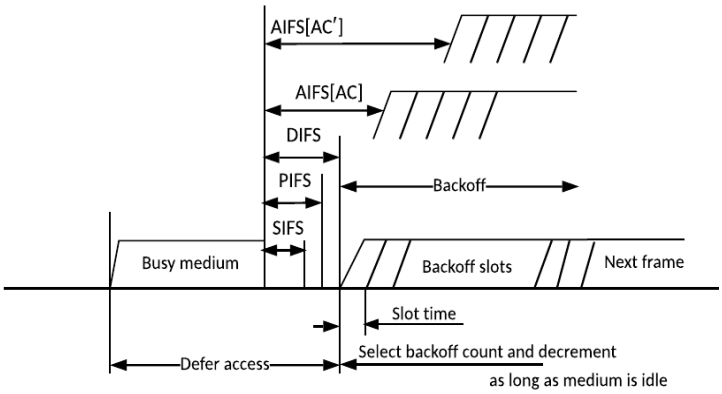

Figure 10-5—Some IFS relationships

The different IFSs shall be independent of the STA bit rate. The IFS timings are defined as time gaps on the medium, and the IFS timings except AIFS are fixed for each PHY (even in multirate-capable PHYs). The IFSs are determined from attributes specified by the PHY.

10.3.2.3.2 RIFS

The use of RIFS for a non-DMG STA is obsolete, and support for such use might be subject to removal in a future revision of the standard. A VHT or S1G STA shall not transmit frames separated by a RIFS.

RIFS is a means of reducing overhead and thereby increasing network efficiency.

RIFS may be used in place of SIFS to separate multiple transmissions from a single transmitter, when no SIFS-separated response transmission is expected and either of the following is true:

— The transmitter is not a DMG STA.
— The transmitter is a DMG STA, and each transmission occurs with the same transmit antenna configuration.

RIFS shall not be used between frames with different RA values. The duration of RIFS is defined by the aRIFS PHY characteristic (see Table 19-25 and Table 20-30). The RIFS is the time from the end of the last symbol of the previous frame to the beginning of the first symbol of the preamble of the subsequent frame as seen on the WM. A STA shall not allow the space between frames that are defined to be separated by a RIFS, as measured on the medium, to vary from the nominal RIFS (aRIFSTime) by more than ± 10% of aRIFSTime. Two frames separated by a RIFS shall both be HT PPDUs or shall both be DMG PPDUs.

An HT STA shall not transmit PPDUs separated by a RIFS unless the beacon or probe response most recently received from the BSS's AP contains an HT Operation element with RIFS Mode field equal to 1.

There are additional restrictions regarding when RIFS may be employed as defined in 10.29 and 10.30. See also 10.27.3.3.

10.3.2.3.3 SIFS

The SIFS is the time from the end of the last symbol, or signal extension if present, of the previous frame to the beginning of the first symbol of the preamble of the subsequent frame as seen on the WM.

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The SIFS shall be used prior to transmission of each of the following frames:

- An (NDP) Ack frame, a TACK frame, a STACK frame, NDP PS-Poll-Ack frame, a (NDP) CTS frame;
- A PPDU containing a BlockAck frame, NDP BlockAck frame, or BAT frame that is an immediate response to either a BlockAckReq frame or an A-MPDU;
- A DMG CTS frame, a DMG DTS frame, a Grant Ack frame;
- A response frame transmitted in the ATI, and the second or subsequent MPDU of a fragment burst;
- A frame within a series of NDP sector training frames transmitted by an S1G AP after a sector training announcement;
- An RTS frame that is sent as an immediate response to a PS-Poll(+BDT) frame.

The SIFS may also be used, and by an S1G STA for an (NDP) PS Poll frame or uplink trigger frame that is a response to an NDP Paging frame (see 10.47.6).

An IEEE 802.11 implementation of a non-DMG STA shall not allow the space between frames that are defined to be separated by a SIFS, as measured on the medium, to vary from the nominal SIFS by more than ± 10% × (aSlotTime – aAirPropagationTime) for the PHY in use. An implementation of a DMG STA shall not allow the space between frames that are defined to be separated by a SIFS, as measured on the medium, to vary from the nominal SIFS by more than –0% or +10% × (aSlotTime – aAirPropagationTime).

SIFS is the shortest of the IFSs between transmissions from different STAs. SIFS shall be used when STAs have seized the medium and need to keep it for the duration of the frame exchange sequence to be performed. Using the smallest gap between transmissions within the frame exchange sequence prevents other STAs, which are required to wait for the medium to be idle for a longer gap, from attempting to use the medium, thus giving priority to completion of the frame exchange sequence in progress.

When transmitting a response frame immediately following a SIFS, a DMG STA shall set the TXVECTOR parameter LAST_RSSI of the response frame to the power that was measured on the received PPDU, as reported in the RCPI field of the frame that elicited the response frame. The encoding of the value is as follows:

- Power values less than or equal to –68 dBm are represented as the value of 1.
- Power values between –68 dBm and –42 dBm are represented as $\left\lfloor \frac{p-(-71)+0.5}{2} \right\rfloor$, where p is the power in dBm.
- Power values greater than or equal to –42 dBm are represented as the value 15.
- For all other cases, the STA shall set the TXVECTOR parameter LAST_RSSI of the transmitted frame to 0.

A DMG STA that transmits a PPDU containing at least one individually addressed MPDU shall set the TXVECTOR parameter TURNAROUND to 1 if the STA is required to listen for an incoming PPDU immediately following the transmission of the PPDU; otherwise, the STA shall set the TXVECTOR parameter TURNAROUND to 0. The STA shall set the TXVECTOR parameter TURNAROUND to 0 when it transmits an RTS frame.

10.3.2.3.4 PIFS

The PIFS is used to gain priority access to the medium.

The PIFS may be used as described in the following list and shall not be used otherwise:

- A STA transmitting a Channel Switch Announcement frame, as described in 11.8 or transmitting an Extended Channel Switch Announcement frame, as described in 11.9
- A STA transmitting a TIM frame, as described in 11.2.3.15
- An HC starting an HCCA TXOP, as described in 10.23.3.2.2

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- A non-AP QoS STA that is a polled TXOP holder recovering from the absence of an expected reception in a CAP, as described in 10.23.3.2.3
- An HT STA using dual CTS protection before transmission of the CTS2, as described in 10.3.2.10
- A TXOP holder continuing to transmit after a transmission failure, as described in 10.23.2.8
- A TXOP holder transmitting an RTS with a bandwidth signaling TA within a multiple frame transmission sequence, as specified in 10.23.2.8
- An RD initiator continuing to transmit using error recovery, as described in 10.29.3
- An HT AP during a PSMP sequence transmitting a PSMP recovery frame, as described in 10.30.2.3
- An HT STA performing clear channel assessment (CCA) in the secondary channel before transmitting a 40 MHz mask PPDU using EDCA channel access, as described in 11.15.9
- An AP continuing to transmit in a GCR block ack TXOP after the failure to receive a BlockAck frame, as described in 10.25.8
- A VHT STA performing CCA in the secondary 20 MHz, 40 MHz, and 80 MHz channels before transmitting a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz mask PPDU using EDCA channel access, as described in 10.23.3
- An AP or PCP continuing to transmit in the ATI after a transmission failure during the ATI (10.39.3)
- A source DMG STA of an SP continuing to transmit after a transmission failure, as described in 10.39.6.2
- A DMG STA performing EDCA access during an allocated CBAP, as described in 10.39.5
- A TVHT STA performing CCA in the secondary TVHT_W and TVHT_2W channels before transmitting a TVHT_2W or TVHT_W+W mask PPDU and TVHT_4W or TVHT_2W+2W mask PPDU, respectively, using EDCA channel access, as defined in 10.23.3
- An S1G STA performing clear channel assessment (CCA) in the secondary 2 MHz, 4 MHz, and 8 MHz channels before transmitting a 4 MHz, 8 MHz, or 16 MHz mask PPDU using EDCA channel access, as described in 10.23.2.6
- An S1G AP transmitting sounding NDP(s) within an SST sounding RAW

With the exception of performing CCA in the secondary channel (where the timing is defined in 11.15.9), a STA using PIFS starts its transmission after its CS mechanism (see 10.3.2.1) determines that the medium is idle at the TxPIFS slot boundary, as defined in 10.3.7 and 10.23.2.4.

10.3.2.3.5 DIFS

The DIFS shall be used by STAs operating under the DCF to transmit Data frames (MPDUs) and Management frames (MMPDUs). A STA using the DCF may transmit if both:

- After it has correctly received a frame, its CS mechanism (see 10.3.2.1) determines that the medium is idle at the TxDIFS slot boundary as defined in 10.3.7.
- The STA's backoff counter has a value of zero.

10.3.2.3.6 AIFS

The AIFS shall be used by QoS STAs that access the medium using the EDCAF to transmit: all Data frames (MPDUs) except during the ATI or an SP, all Management frames (MMPDUs) except during the ATI or an SP, all Extension frames except for the DMG Beacon frame, and the following Control frames:

- PS-Poll(+BDT)
- SSW (if first transmission by an initiator in a CBAP)
- Poll (if first transmission and when in a CBAP)
- Grant (if first transmission and when in a CBAP and not transmitted in response to an SPR frame)

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— SPR (when in a CBAP and not transmitted as a response to a Poll)
— RTS (when not transmitted as a response to a PS-Poll(+BDT) frame by an S1G STA)
— CTS (when not transmitted as a response to an RTS frame)
— DMG CTS (when not transmitted as a response to an RTS frame)
— BlockAckReq
— BlockAck (when not transmitted as a response to a BlockAckReq frame)
— NDP PS-Poll

A STA using the EDCAF shall obtain a TXOP for an AC if the STA's CS mechanism (see 10.3.2.1) determines that the medium is idle at the AIFS[AC] slot boundary (see 10.23.2.4), after a correctly received frame, and the backoff counter for that AC has a value of zero.

A non-AP and non-PCP QoS STA computes the time periods for each AIFS[AC] from dot11EDCATableAIFSN. In an infrastructure BSS, QoS STAs update their dot11EDCATableAIFSN values using information in the most recent EDCA Parameter Set element of Beacon frames received from the AP of the BSS (see 9.4.2.28) if the STA is a non-DMG STA or the most recent EDCA Parameter Set element of DMG Beacon and Announce frames received from the AP or PCP of the BSS if the STA is a DMG STA. A QoS AP or PCP computes the time periods for each AIFS[AC] from dot11QAPEDCATableAIFSN.

10.3.2.3.7 EIFS

A DCF shall use EIFS before transmission, when it determines that the medium is idle immediately following reception of a frame for which the PHY-RXEND.indication primitive contained an error or a frame for which the FCS value was not correct. Similarly, a STA's EDCA mechanism under HCF shall use the EIFS–DIFS+AIFS[AC] interval. The duration of an EIFS is defined in 10.3.7. The EIFS or EIFS–DIFS+AIFS[AC] interval shall begin following indication by the PHY that the medium is idle after detection of the erroneous frame, without regard to the virtual CS mechanism. The STA shall not begin a transmission until the expiration of the later of the NAV and EIFS or EIFS–DIFS+AIFS[AC]. The EIFS and EIFS–DIFS+AIFS[AC] are defined to provide enough time for another STA to acknowledge what was, to this STA, an incorrectly received frame before this STA commences transmission. Reception of an error-free frame during the EIFS or EIFS–DIFS+AIFS[AC] resynchronizes the STA to the actual busy/idle state of the medium, so the EIFS or EIFS–DIFS+AIFS[AC] is terminated and medium access (using DIFS or AIFS as appropriate and, if necessary, backoff) continues following reception of that frame. At the expiration or termination of the EIFS or EIFS–DIFS+AIFS[AC], the STA reverts to the NAV and physical CS to control access to the medium.

EIFS shall not be invoked for an A-MPDU if one or more of its frames are received correctly.

10.3.2.3.8 SBIFS

The SBIFS shall be used to separate multiple transmissions from a single transmitter during a receive sector sweep or when each transmission occurs with a different transmit antenna configuration and no SIFS-separated response transmission is expected. The duration of SBIFS is determined by the aSBIFSTime PHY characteristic. The SBIFS is the time from the end of the last symbol of the previous frame to the beginning of the first symbol of the preamble of the subsequent frame as seen on the WM. A STA shall not allow the space between frames that are defined to be separated by an SBIFS, as measured on the medium, to be less than aSBIFSTime or to be more than aSBIFSTime + aSBIFSAccuracy. Two frames separated by an SBIFS shall both be DMG PPDUs.

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10.3.2.3.9 BRPIFS

The BRPIFS shall be used by STAs between transmissions of BRP frames. The BRPIFS is the maximum time from the end of the last symbol of the previous PPDU, or training field if present in the PPDU, to the beginning of the first symbol of the preamble of the subsequent PPDU as seen on the WM. The corresponding minimum time is SIFS. BRPIFS is defined to be equal to aBRPIFS+10%.

10.3.2.3.10 MBIFS

The MBIFS shall be used between the BTI and the A-BFT and between the ISS, RSS, SSW-Feedback, and SSW-Ack. MBIFS is equal to 3×aSIFSTime. An implementation of a DMG STA shall not allow the space between frames that are defined to be separated by an MBIFS, as measured on the medium, to vary from the nominal MBIFS by more than –0% or +10% × (aSlotTime – aAirPropagationTime).

10.3.2.3.11 LBIFS

The LBIFS shall be used between transmissions employing different DMG antennas and when the recipient STA is expected to switch DMG antennas. LBIFS is equal to TXTIME(SSW) + 2×SBIFS. An implementation of a DMG STA shall not allow the space between frames that are defined to be separated by an LBIFS, as measured on the medium, to vary from the nominal LBIFS by more than –0% or +10% × (aSlotTime – aAirPropagationTime).

10.3.2.4 Setting and resetting the NAV

This subclause describes the setting and resetting of the NAV for non-DMG STAs and DMG STAs that support a single NAV. DMG STAs that support multiple NAVs shall update their NAVs according to the procedures described in 10.39.10.

A STA that receives at least one valid frame in a PSDU can update its NAV with the information from any valid Duration field in the PSDU. When the received frame's RA is equal to the STA's own MAC address, the STA shall not update its NAV. Further, when the received frame is a DMG CTS frame and its TA is equal to the STA's own MAC address, the STA shall not update its NAV. For all other received frames the STA shall update its NAV when the received Duration is greater than the STA's current NAV value. Upon receipt of a PS-Poll frame, a STA, except for an S1G STA for which the RXVECTOR parameter RESPONSE_INDICATION of the received PS-Poll frame is NDP Response, shall update its NAV settings as appropriate under the data rate selection rules using a duration value equal to the time, in microseconds, required to transmit one Ack frame plus one SIFS, but only when the new NAV value is greater than the current NAV value. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer. When the NAV is reset, a PHY-CCARESET.request primitive shall be issued. This NAV update operation is performed when the PHY-RXEND.indication primitive is received.

NOTE 1—An S1G STA that receives a valid frame that does not include a valid Duration field does not update its NAV. However, it updates its RID as described in 10.3.2.5.

An S1G STA that receives a PS-Poll frame with the RXVECTOR parameter RESPONSE_INDICATION equal to NDP Response shall update its NAV using a duration value equal to NDPTxTime (10.3.2.5.2) plus one SIFS, but only when the new NAV value is greater than the current NAV value. The NDPTxTime is calculated according to additional RXVECTOR parameters as described in 10.3.2.5.2.

In addition to the NAV update rules described in this subclause, an S1G STA shall also update its NAV to a new NAV value if it receives information that the NAV is greater than the STA's current NAV value. This information shall be received in the Duration field of the following frames: NDP CTS, NDP Ack, NDP_2M PS-Poll-Ack, and S1G Beacon, except when the received frame is one of the following:

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— NDP CTS frame that is either addressed to the S1G STA as a response to an RTS frame, or that is an NDP CTS frame whose value of the Duration field can be disregarded as defined in 10.3.2.9.
— NDP Ack frame that is either addressed to the S1G STA, or that has the Idle Indication field equal to 1 (see 10.3.2.11).
— NDP_2M PS-Poll-Ack frame that is either addressed to that S1G STA, or that has the Idle Indication field equal to 1 (see 10.3.2.11).
— S1G Beacon frame that includes at least one TIM element in which there is an indication of available BUs for the receiving STA in at least one of the TIM elements.
— S1G Beacon frame that includes at least one TIM element and at least one RPS element that indicate both of the following:
  — There is no indication of available BUs for the receiving STA in any of the TIM elements.
  — The receiving S1G STA is allowed to access the first RAW immediately following the S1G Beacon frame as specified in at least one of the RPS elements.

Figure 10-6 indicates the NAV for STAs that might receive the RTS frame, while other STAs might receive only the CTS frame, resulting in the lower NAV bar as shown (with the exception of the STA to which the RTS frame was addressed).

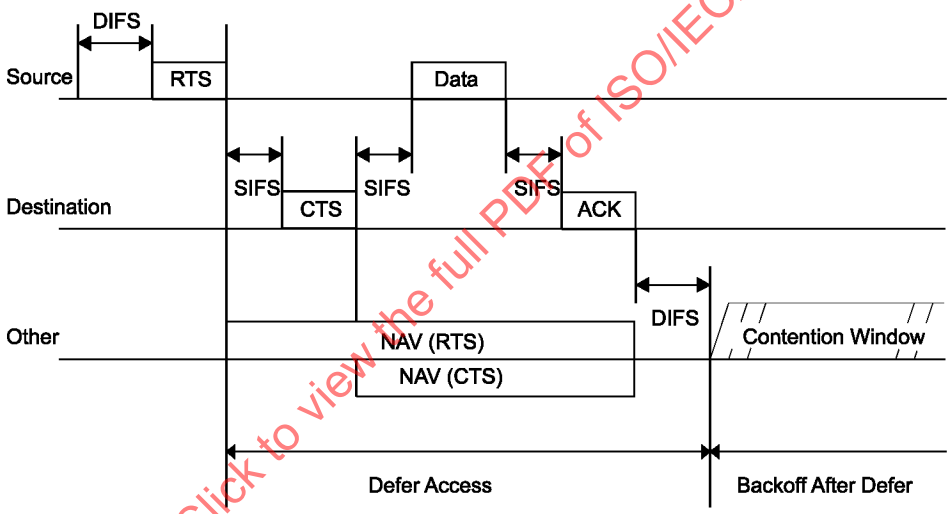

Figure 10-6—RTS/CTS/data/Ack and NAV setting

A STA that used information from an RTS frame as the most recent basis to update its NAV setting is permitted to reset its NAV if no PHY-RXSTART.indication primitive is received from the PHY during a NAVTimeout period starting when the MAC receives a PHY-RXEND.indication primitive corresponding to the detection of the RTS frame.

In non-DMG BSS, NAVTimeout period is equal to (2 × aSIFSTime) + (CTS_Time) + aRxPHYStartDelay + (2 × aSlotTime). In a non-S1G STA, the CTS_Time shall be calculated using the length of the CTS frame and the data rate at which the RTS frame used for the most recent NAV update was received. In an S1G STA, the CTS_Time shall be calculated using the time required to transmit an NDP CTS frame that is equal to NDPTxTime, which is specified in 10.3.2.5.2.

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In DMG BSS, NAVTimeout period is equal to (2 × aSIFSTime) + $T_{DMG\text{-}CTS}$ + StartDelayCompensation + (2 × aSlotTime), where $T_{DMG\text{-}CTS}$ is the duration of a DMG CTS frame calculated using the TXVECTOR TRN_LEN parameter equal to the RXVECTOR TRN_LEN parameter of the received RTS frame and StartDelayCompensation is equal to aSlotTime.

NOTE 2—This value of StartDelayCompensation is a compromise over the possible values of aRxPHYStartDelay, which are dependent on both the implementation and the DMG PHY mode.

10.3.2.5 Setting and resetting the RID

10.3.2.5.1 General

This subclause describes the setting and resetting of the RID for S1G STAs.

An S1G STA that receives a frame that is not an NDP CMAC PPDU shall update its RID counter based on the values of the received frame's RXVECTOR parameters FORMAT, PREAMBLE_TYPE, RESPONSE_INDICATION, AGGREGATION, MCS, PARTIAL_AID, COLOR, UPLINK_INDICATION, and CH_BANDWITH, as described in this subclause. An S1G STA that receives an NDP CMAC PPDU shall update its RID counter based on the values of the RXVECTOR parameter FORMAT, PREAMBLE_TYPE and the RESPONSE_INDICATION value, which is defined per type of NDP CMAC PPDU in Table 10-2.

Table 10-2—RESPONSE_INDICATION value for NDP CMAC PPDUs

NDP CMAC PPDU type	RESPONSE_INDICATION value
NDP Ack or NDP PS-Poll-Ack (NDP (PS-Poll-)Ack)	No Response if either Idle Indication field value is 0 or the Duration field value is not 0 Long Response if Idle Indication field value is 1 and Duration field value is 0
NDP Block Ack	No Response
NDP CTS	No Response
NDP PS-Poll	NDP Response
NDP Beamforming Report Poll	Long Response
NDP Paging	No Response
NDP Probe Request	No Response
NDP CF-End	No Response

A member PPDU is a PPDU transmitted by a STA that is a member of the same BSS of the receiving STA. A PPDU that is not a member PPDU is a nonmember PPDU.

An S1G STA that receives a member PPDU shall reset and update its RID counter, as defined in 10.3.2.5.2, when the PHY-RXSTART.indication primitive corresponding to that PPDU is received. An S1G STA that receives a nonmember PPDU shall not reset the RID counter and shall update the RID counter, i.e., set it to a new value (as defined in 10.3.2.5.2) that is not less than the value that the RID counter will have at the instant of time that corresponds to the end of the received PPDU.

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The S1G STA shall classify a received PPDU as a member PPDU if it is an NDP CMAC PPDU, or an S1G_1M PPDU. The S1G STA shall classify a received PPDU as a member PPDU if its PREAMBLE_TYPE is either S1G_LONG_PREAMBLE or S1G_SHORT_PREAMBLE and either of the conditions below is satisfied:

— UPLINK_INDICATION is 1 and the PARTIAL_AID indicates that the PPDU is addressed to the AP with which the non-AP STA is associated.

— UPLINK_INDICATION is 0 and the COLOR indicates that the PPDU is generated by the AP with which the STA is associated.

Because the PARTIAL_AID and COLOR values obtained from received PPDUs are not globally unique, an S1G STA that has classified a PPDU as a member PPDU based on PARTIAL_AID and/or COLOR may additionally use the information contained in a valid MAC header (i.e., neither A1 nor A2 field contain a MAC address that corresponds to a STA that is a member of the same BSS as known at the STA) from an MPDU carried in the received PPDU to change the classification of the PPDU to a nonmember PPDU. If the classification of a PPDU is changed from member to nonmember PPDU, then the STA shall:

— Reload the RID counter to the value that the RID counter had at the time of the receipt of the PHY-RXSTART.indication primitive corresponding to this PPDU minus the difference between the current time and that time; and

— Update the RID counter according to the rules for a nonmember PPDU.

NOTE 1—If the PHY-RXEND.indication primitive for the received S1G PPDU contains an ERROR or FormatViolation then the S1G STA sets the EIFS as described in 10.3.7.

If the RID counter is updated then it shall start counting down the RID counter at the end of the received S1G PPDU, except when the PPDU either contains a valid nonzero Duration field that is used for setting the NAV, as described in 10.3.2.4, or it is intended to the S1G STA. In both of these cases the RID shall be reset.

The received PPDU has an expected duration, in microseconds, of PSDU_RXTIME, starting from the moment the PHY-RXSTART.indication primitive is received. If the PPDU is an NDP CMAC PPDU, the PSDU_RXTIME is equal to 0. If the PPDU is not an NDP CMAC PPDU, the PSDU_RXTIME is calculated based on multiple RXVECTOR parameters and is equal to

— The RXTIME defined in Equation (23-69) for S1G_SHORT/S1G_1M formats.

— The RXTIME defined in Equation (23-69) if the PPDU has S1G_LONG format and is an SU PPDU.

— The RXTIME defined in Equation (23-70) minus ($T_{DSTF} + N_{LTF}\, D_{DLTF} + T_{SIG\text{-}B}$) if the PPDU has S1G_LONG format and is an MU PPDU.

NOTE 2—T_{DSTF}, T_{DLTF}, and $T_{SIG\text{-}B}$ are defined in Table 23-4 while N_{LTF} is defined in Table 23-10.

Figure 10-7 indicates the RID for STAs that receive the PHY header of the Data frame whose MAC portion does not contain a valid Duration field that updates the NAV. The RID for STAs that receive the PHY header of the Ack frame but not that of the Data frame is 0 (i.e., no response is expected to the Ack frame in this example). The RID is reset for the STA to which the Data was addressed.

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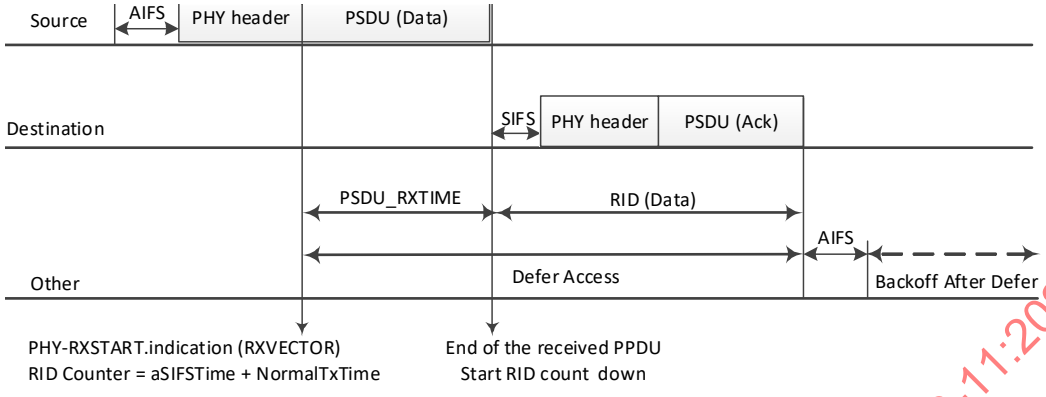

Figure 10-7—Data/Ack with RID setting

10.3.2.5.2 RID update

An S1G STA updates the value of the RID counter by setting it as described below.

If the value of the RESPONSE_INDICATION parameter is Long Response, the RID counter shall be set to LongTxTime + aSIFSTime, where LongTxTime is obtained as follows:

— If FORMAT is S1G and CH_BANDWIDTH is CBW1 or FORMAT is S1G_DUP_1M, then LongTxTime is equal to the S1G PPDU duration as defined in Table 9-25.

— If FORMAT is S1G and PREAMBLE_TYPE is S1G_SHORT_PREAMBLE or S1G_LONG_PREAMBLE, then LongTxTime is equal to the largest value in the dot11EDCATableTXOPLimit.

— If FORMAT is S1G_DUP_2M and PREAMBLE_TYPE is S1G_SHORT_PREAMBLE or S1G_LONG_PREAMBLE, then LongTxTime is equal to the largest value in the dot11EDCATableTXOPLimit.

If the value of the RESPONSE_INDICATION parameter is Normal Response, the RID counter shall be set to NormalTxTime + aSIFSTime. NormalTxTime is calculated based on the RXVECTOR parameters PREAMBLE_TYPE, AGGREGATION, MCS and CH_BANDWIDTH following the rules listed in Table 10-3.

Table 10-3—NormalTXTime duration based on RXVECTOR parameters

PPDU format (see 23.1.4)	AGGREGATION	Expected Response Length (Type)	NormalTxTime
S1G_1M	0	14-octet MPDU (Ack)	The time, in microseconds, required to transmit one Ack frame, where the duration of the frame is calculated according to the rate selection rules described in 10.6.6.5 using its BSSBasicMCSSet parameter and with CH_BANDWIDTH RXVECTOR value equal to CBW1.
	1	32-octet MPDU (BlockAck)	The time, in microseconds, required to transmit one BlockAck frame, where the duration of the frame is calculated according to the rate selection rules described in 10.6.6.5 using its BSSBasicMCSSet parameter and with CH_BANDWIDTH RXVECTOR value equal to CBW1

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Table 10-3—NormalTXTime duration based on RXVECTOR parameters *(continued)*

PPDU format (see 23.1.4)	AGGREGATION	Expected Response Length (Type)	NormalTxTime
S1G_SHORT or S1G LONG PREAMBLE	0	14-octet MPDU (Ack)	The time, in microseconds, required to transmit one Ack frame, where the duration of the frame is calculated according to the rate selection rules described in 10.6.6.5 using its BSSBasicMCSSet parameter and channel width selection rules for Control frames described in 10.6.6.6.
	1	32-octet MPDU (BlockAck)	The time, in microseconds, required to transmit one BlockAck frame, where the duration of the frame is calculated according to the rate selection rules described in 10.6.6.5 using its BSSBasicMCSSet parameter and channel width selection rules for Control frames described in 10.6.6.6.

If the value of RESPONSE_INDICATION parameter is NDP Response, the RID counter shall be set to NDPTxTime + aSIFSTime. NDPTxTime is calculated based on the RXVECTOR parameter PREAMBLE_TYPE and is equal to the time, in microseconds, required to transmit either an NDP_1M CMAC PPDU if the PPDU format is S1G_1M or an NDP_2M CMAC PPDU if the PPDU format is either S1G_SHORT or S1G_LONG (see 23.1.4).

If the value of the RESPONSE_INDICATION parameter is No Response, the RID counter shall be set to 0.

10.3.2.6 RTS/CTS with fragmentation

The following is a description of using RTS/CTS for a fragmented MSDU or MMPDU. The RTS/CTS frames define the duration of the following frame and acknowledgment. The Duration/ID field in the Data and Ack frames specifies the total duration of the next fragment and acknowledgment. This is illustrated in Figure 10-8.

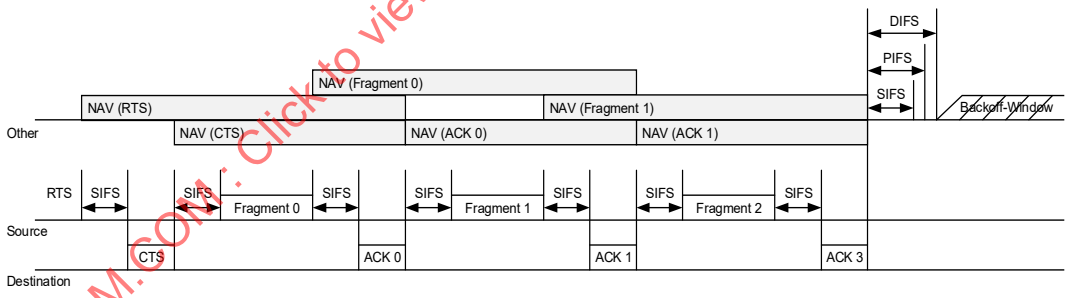

Figure 10-8—RTS/CTS with fragmented MSDU

Each frame contains information that defines the duration of the next transmission. The duration information from RTS frames shall be used to update the NAV to indicate busy until the end of Ack frame 0. The duration information from the CTS frame shall also be used to update the NAV to indicate busy until the end of Ack frame 0. Both Fragment 0 and Ack frame 0 shall contain duration information to update the NAV to indicate busy until the end of Ack frame 1. This shall be done by using the Duration/ID field in the Data and Ack frames. This shall continue until the last fragment, which shall have a duration of one Ack time plus one SIFS, and its Ack frame, which shall have its Duration/ID field set to 0. Each fragment and Ack frame acts as a virtual RTS frame and CTS frame; therefore no further RTS/CTS frames need to be generated after the RTS/CTS that began the frame exchange sequence even though the PSDUs carrying subsequent fragments may be larger than dot11RTSThreshold.

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In the case where an acknowledgment is sent but not received by the source STA, STAs that heard the fragment, or Ack frame, mark the channel busy for the next frame exchange due to the NAV having been updated from these frames. This is the worst-case situation, and it is shown in Figure 10-9. If an acknowledgment is not sent by the destination STA, STAs that can only hear the destination STA do not update their NAV and may attempt to access the channel when their NAV updated from the previously received frame reaches 0. All STAs that hear the source are free to access the channel after their NAV updated from the transmitted fragment has expired.

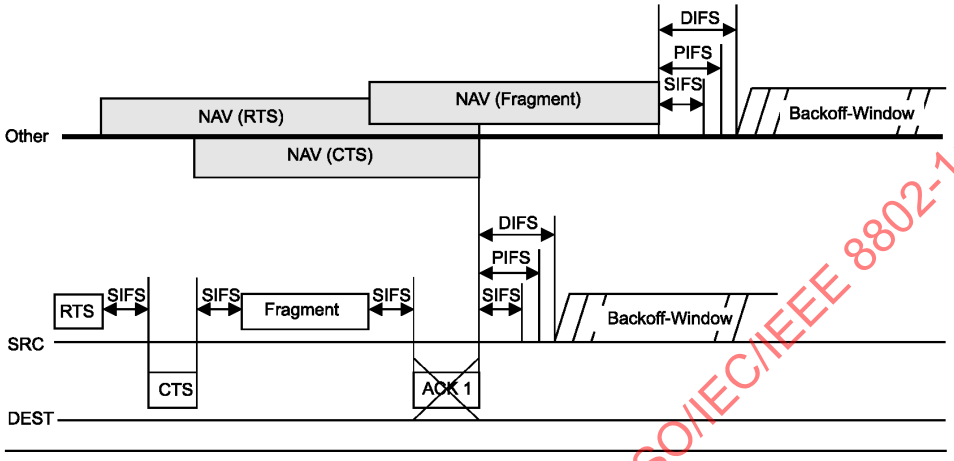

Figure 10-9—RTS/CTS with transmitter priority and missed acknowledgment

10.3.2.7 VHT and S1G RTS procedure

A VHT STA transmitting an RTS frame carried in non-HT or non-HT duplicate format and addressed to a VHT STA shall set the TA field to a bandwidth signaling TA and shall set the TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and CH_BANDWIDTH to the same value. If the STA sending the RTS frame is capable of dynamic bandwidth operation (see 10.3.2.9), the STA shall set the TXVECTOR parameter DYN_BANDWIDTH_IN_NON_HT to Dynamic. Otherwise, the STA shall set the TXVECTOR parameter DYN_BANDWIDTH_IN_NON_HT to Static.

A VHT STA that initiates a TXOP by transmitting an RTS frame with the TA field set to a bandwidth signaling TA shall not send an RTS frame to a non-VHT STA for the duration of the TXOP.

NOTE—A non-VHT STA considers the bandwidth signaling TA as the address of the TXOP holder. If an RTS frame is sent to a non-VHT STA during a TXOP that is initiated by an RTS frame with a bandwidth signaling TA, the non-VHT STA does not recognize the RTS sender as the TXOP holder.

An S1G STA using dynamic bandwidth operation (see 10.3.2.9) that transmits an RTS carried in a greater than 2 MHz PPDU with the TXVECTOR parameter FORMAT set to S1G_DUP_2M shall set the Dynamic Indication field in the Frame Control field of the RTS frame to 1. Otherwise, the S1G STA shall set the Dynamic Indication field in the Frame Control field of the RTS carried in any other PPDU to 0 to indicate that it shall not use dynamic bandwidth operation (see 10.3.2.9).

An S1G STA that transmits an RTS frame to another STA shall set the TXVECTOR parameter RESPONSE_INDICATION to NDP_RESPONSE unless the Link Adaptation Without NDP CMAC PPDU Capable field of the S1G Capabilities element received from that STA contained a value of 1 in which case the S1G STA may set the RESPONSE_INDICATION to NORMAL_RESPONSE as described in 10.32.3.

An S1G STA that initiates a TXOP with a PV1 frame or an NDP CMAC PPDU shall not send an RTS frame to an S1G STA for the duration of the TXOP.

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10.3.2.8 CMMG RTS procedure

A CMMG STA shall transmit an RTS frame carried in CMMG or CMMG duplicate format (see 25.3.10). If the STA sending the RTS frame is capable of dynamic bandwidth operation (see 10.3.2.9), the CMMG STA shall set the TXVECTOR parameter DYN_BANDWIDTH to Dynamic. Otherwise, the STA shall set the TXVECTOR parameter DYN_BANDWIDTH to Static.

10.3.2.9 CTS and DMG CTS procedure

A STA that receives an RTS frame addressed to it considers the NAV in determining whether to respond with CTS, unless the NAV was set by a frame originating from the STA sending the RTS frame (see 10.23.2.2). In this subclause for a non-S1G STA, "NAV indicates idle" means that the NAV count is 0 or that the NAV count is nonzero but the nonbandwidth signaling TA obtained from the TA field of the RTS frame matches the saved TXOP holder address. In an S1G STA, "NAV indicates idle" means that both NAV and RID counters are 0 or that either NAV or RID counter is nonzero but the TA field of the RTS frame matches the saved TXOP holder address.

A VHT STA that is addressed by an RTS frame in a non-HT or non-HT duplicate PPDU that has a bandwidth signaling TA and that has the RXVECTOR parameter DYN_BANDWIDTH_IN_NON_HT equal to Static behaves as follows:

— If the NAV indicates idle and CCA has been idle for all secondary channels (secondary 20 MHz channel, secondary 40 MHz channel, and secondary 80 MHz channel) in the channel width indicated by the RTS frame's RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT for a PIFS prior to the start of the RTS frame, then the STA shall respond with a CTS frame carried in a non-HT or non-HT duplicate PPDU after a SIFS. The CTS frame's TXVECTOR parameters CH_BANDWIDTH and CH_BANDWIDTH_IN_NON_HT shall be set to the same value as the RTS frame's RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT.

— Otherwise, the STA shall not respond with a CTS frame.

A VHT STA that is addressed by an RTS frame in a non-HT or non-HT duplicate PPDU that has a bandwidth signaling TA and that has the RXVECTOR parameter DYN_BANDWIDTH_IN_NON_HT equal to Dynamic behaves as follows:

— If the NAV indicates idle, then the STA shall respond with a CTS frame in a non-HT or non-HT duplicate PPDU after a SIFS. The CTS frame's TXVECTOR parameters CH_BANDWIDTH and CH_BANDWIDTH_IN_NON_HT shall be set to any channel width for which CCA on all secondary channels has been idle for a PIFS prior to the start of the RTS frame and that is less than or equal to the channel width indicated in the RTS frame's RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT.

— Otherwise, the STA shall not respond with a CTS frame.

An S1G STA that is addressed by an RTS frame that has the Dynamic Indication field in the Frame Control field equal to 0 (Static) behaves as follows:

— If the NAV indicates idle and the CCA has been idle for all secondary channels within the channel width indicated in the Bandwidth Indication field of the Frame Control field of the RTS frame for a PIFS period prior to the start of the RTS frame, then the STA shall respond with an (NDP) CTS frame after a SIFS. The STA shall set the TXVECTOR parameter CH_BANDWIDTH to a value that is equivalent to the value of the Bandwidth Indication field of the Frame Control field in the received RTS frame. The (NDP_2M) CTS frame shall have the Bandwidth Indication field set to the value of the Bandwidth Indication field of the received RTS frame.

— Otherwise the STA shall not respond with an (NDP) CTS frame.

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An S1G STA that is addressed by an RTS carried in a 2 MHz duplicate frame that has the Dynamic Indication field in the Frame Control field equal to 1 (Dynamic) behaves as follows:

— If the NAV indicates idle, then the STA shall respond with an (NDP_2M) CTS frame after a SIFS. The (NDP) CTS frame's TXVECTOR parameter CH_BANDWIDTH may be set to any channel width for which the CCA on all secondary channels has been idle for a PIFS prior to the start of the RTS frame and that is equal to or less than the channel width indicated in the Bandwidth Indication field of the Frame Control field of the RTS frame. The (NDP_2M) CTS frame shall have the Bandwidth Indication field set to a value that is equivalent to the value of the TXVECTOR parameter's CH_BANDWIDTH.
— Otherwise the STA shall not respond with an (NDP) CTS frame.

NOTE—The NDP_1M CTS frame is not used for dynamic bandwidth indication.

A non-VHT and non-S1G STA that is addressed by an RTS frame or a VHT STA that is addressed by an RTS frame carried in a non-HT or non-HT duplicate PPDU that has a nonbandwidth signaling TA or a VHT STA that is addressed by an RTS frame in a format other than non-HT or non-HT duplicate behaves as follows:

— If the NAV indicates idle, the STA shall respond with a CTS frame after a SIFS.
— Otherwise, the STA shall not respond with a CTS frame.

The RA field of the CTS frame shall be set to the nonbandwidth signaling TA obtained from the TA field of the RTS frame to which this CTS frame is a response. The Duration field in the CTS frame shall be the duration field from the received RTS frame, adjusted by subtraction of aSIFSTime and the number of microseconds required to transmit the CTS frame at a data rate determined by the rules in 10.6.

After transmitting an RTS frame, the STA shall wait for a CTSTimeout interval with a value of aSIFSTime + aSlotTime + aRxPHYStartDelay. This interval begins when the MAC receives a PHY-TXEND.confirm primitive. If a PHY-RXSTART.indication primitive does not occur during the CTSTimeout interval, the STA shall conclude that the transmission of the RTS frame has failed, and this STA shall invoke its backoff procedure upon expiration of the CTSTimeout interval. If a PHY-RXSTART.indication primitive does occur during the CTSTimeout interval, the STA shall wait for the corresponding PHY-RXEND.indication primitive to determine whether the RTS frame transmission was successful. The recognition of a valid CTS frame sent by the recipient of the RTS frame, corresponding to this PHY-RXEND.indication primitive, shall be interpreted as successful response, permitting the frame exchange sequence to continue (see Annex G). The recognition of anything else, including any other valid frame, shall be interpreted as failure of the RTS frame transmission. In this instance, the STA shall invoke its backoff procedure at the PHY-RXEND.indication primitive and may process the received frame.

A DMG STA follows the procedure defined in this subclause, except that it uses a DMG CTS frame instead of a CTS frame. A non-DMG STA does not transmit DMG CTS frames.

An S1G STA shall transmit NDP CTS frames instead of CTS frames with the following exception: transmission of an CTS frame is required if the link adaptation procedure is negotiated as described in 10.32.

The RA/Partial BSSID field of the NDP CTS shall be generated as described in 23.3.12.2.1. The Duration field in the NDP CTS frame shall be set to the same value as the Duration field from the received RTS frame, adjusted by subtracting the value of aSIFSTime and the NDPTxTime required to transmit the NDP CTS frame, where NDPTxTime is calculated according to 10.3.2.5.2.

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An S1G STA that receives an NDP CTS frame should disregard the value of the Duration field of the NDP CTS frame if any of the following conditions are satisfied:

— The Address Indicator field is equal to 1, and the Early Sector Indicator field is equal to 0, and the RA/PBSSID field is equal to the PBSSID of the BSS of which the non-AP STA is a member (see 10.53.4).

— The Address Indicator field is equal to 0, and the RA/PBSSID indicates that the STA is the intended receiver of this frame, and the frame is received during the intervals of time negotiated with the UL-Sync capable AP (see 10.49).

A CMMG STA that receives an RTS frame in a CMMG or CMMG duplicate PPDU that has the RXVECTOR parameter DYN_BANDWIDTH equal to Static behaves as follows:

— If the NAV indicates idle and CCA has been idle for the secondary channel (secondary 540 MHz channel) in the channel width indicated by the RTS frame's RXVECTOR parameter CH_BANDWIDTH for a PIFS period prior to the start of the RTS frame, then the STA shall respond with a CTS frame carried in a CMMG or CMMG duplicate PPDU after a SIFS. The CTS frame's TXVECTOR parameters CH_BANDWIDTH shall be set to the same value as the RTS frame's RXVECTOR parameter CH_BANDWIDTH.

— Otherwise, the STA shall not respond with a CTS frame.

A CMMG STA that is addressed by an RTS frame in a CMMG or CMMG duplicate PPDU that has the RXVECTOR parameter DYN_BANDWIDTH equal to Dynamic behaves as follows:

— If the NAV indicates idle, then the STA shall respond with a CTS frame in a CMMG or CMMG duplicate PPDU after a SIFS. The CTS frame's TXVECTOR parameters CH_BANDWIDTH may be set to any channel width for which CCA has been idle for a PIFS prior to the start of the RTS frame and that is equal to or less than the channel width indicated in the RTS frame's RXVECTOR parameter indicated in the RTS frame's RXVECTOR parameter CH_BANDWIDTH.

— Otherwise, the STA shall not respond with a CTS frame.

10.3.2.10 Dual CTS protection

10.3.2.10.1 Dual CTS protection procedure

The dual CTS mechanism is obsolete. Support for this mechanism might be removed in a later revision of the standard.

A VHT STA shall not transmit VHT PPDUs in a TXOP protected by dual CTS protection.

A VHT AP shall not transmit an HT Operation element with the Dual CTS Protection field set to 1.

If the Dual CTS Protection field of the HT Operation element has value 1 in the Beacon frames transmitted by its AP, a non-AP HT STA shall start every TXOP with an RTS frame addressed to the AP. The RTS frame shall be an STBC frame if the STBC transmit and receive capabilities of the non-AP HT STA allow it to receive and transmit STBC frames using a single spatial stream; otherwise, the RTS frame shall be a non-STBC frame. The AP shall respond with a dual CTS (CTS1 followed by CTS2) separated by PIFS or SIFS. Table 10-4 describes the sequence of CTS frame transmissions and the required timing.

The dual CTS response applies only to the AP; a non-AP STA shall respond to an RTS frame with a single CTS frame.

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Table 10-4—Dual CTS rules

Type of RTS	CTS description	Timing
RTS (non-STBC frame)	CTS1: Same rate or MCS as the RTS frame (non-STBC frame) CTS2: Basic STBC MCS (STBC frame)	PIFS shall be used as the interval between CTS1 and CTS2. If the CS mechanism (see 10.3.2.1) indicates that the medium is busy at the TxPIFS slot boundary (see Figure 10-25) following CTS1, CTS2 shall not be transmitted as part of this frame exchange.
RTS (STBC frame)	CTS1: Basic STBC MCS (STBC frame) CTS2: Lowest basic rate (non-STBC frame)	SIFS shall be used as the interval between CTS1 and CTS2. The STA resumes transmission a SIFS+CTS2+SIFS after receiving CTS1, instead of after SIFS.

If dual CTS Protection is enabled, the AP shall begin each EDCA TXOP with a CTS frame. This CTS frame uses STBC when the immediately following frame uses non-STBC and vice versa. The RA of this CTS frame shall be identical to the RA of the immediately following frame. The AP may continue a PIFS after the CTS frame, only if the CS mechanism (see 10.3.2.1) indicates that the medium is IDLE at the TxPIFS slot boundary (see Figure 10-25) following the transmission of the CTS frame.

To avoid the resetting of NAV by STAs that have set their NAV due to the reception of a non-STBC RTS frame that is part of a dual CTS exchange, but then do not hear the CTS2, a non-AP HT STA may create a NAV that is not resettable according to the RTS NAV reset rule defined in 10.3.2.4 at the receiving STAs by initiating the TXOP with a non-STBC CTS addressed to the AP (known as *CTS-to-AP*).

NOTE 1—Sending a CTS-to-AP allows NAV protection to be established without causing the AP to update its NAV, as opposed to, for example, the sending of a CTS-to-self frame, which would potentially have caused the AP NAV to become set and then prevented it from responding to the subsequent RTS frame. The AP does not set a NAV in the CTS-to-AP case and is able to respond to the following RTS frame. The NAV at receiving STAs is not updated by the RTS frame because its duration does not exceed the duration of the preceding CTS frame, and subsequently, the NAV cannot be reset during CTS2.

An STBC CTS addressed to the AP may be transmitted prior to an STBC RTS frame to set a NAV that is not resettable according to the RTS NAV reset rule defined in 10.3.2.4 at receiving STAs.

NOTE 2—When an HT STA sends an RTS frame to the AP that is a non-STBC frame, the AP returns a CTS frame that is a non-STBC frame to the STA and then immediately transmits a CTS frame that is an STBC frame. The original non-AP STA is now free to transmit. But a non-HT STA that has set its NAV based on the original RTS frame might reset its NAV and then decrement its backoff counter, given that a SIFS + the duration of CTS2 is longer than a DIFS (i.e., the STA does not detect PHY-RXSTART.indication primitive within the period specified in 10.3.2.4). Thus, without sending a CTS-to-AP, the NAV reservation might not always work.

If dual CTS protection is enabled and a STA obtains a TXOP and does not have any frames to transmit before the expiration of the TXOP duration, the STA may indicate truncation of the TXOP provided that the remaining duration of the TXOP after the transmission of the last frame can accommodate the CF-End frame, a CF-End frame that is an STBC frame duration at the basic STBC MCS, a CF-End frame that is a non-STBC frame at the lowest basic rate, and three SIFSs. The STA indicates truncation of the TXOP by transmitting a CF-End frame with TXVECTOR parameter restrictions as specified in 10.6.6.3.

On receiving a CF-End frame from a STA with a matching BSSID, an AP whose last transmitted HT Operation element contained the Dual CTS Protection field equal to 1 shall respond with dual CF-End frames, one CF-End frame that is an STBC frame at the basic STBC MCS and one CF-End frame that is a non-STBC frame at the lowest basic rate, after a SIFS. Dual CF-End frames eliminate unfairness toward STAs that are not of the same mode as the one that owns the TXOP being truncated.

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If the TXOP is owned by the AP and dual CTS protection is enabled in the system, the AP may send dual CF-End frames if it runs out of frames to transmit, provided that the remaining TXOP duration after the transmission of the last frame can accommodate an STBC CF-End frame duration at the lowest STBC basic rate, a CF-End frame that is a non-STBC frame at the lowest basic rate, and two SIFSs.

The spacing between the dual CF-End frames sent by the AP shall be SIFS. The first CF-End frame shall use the same encoding (STBC frame versus non-STBC frame) used for transmissions in the TXOP being truncated, and the second CF-End frame shall use the other encoding.

An STBC-capable STA shall choose between control frame operation using either STBC frames or non-STBC frames. In the non-STBC frame case, it discards Control frames that are STBC frames it receives. In the STBC frame case, it discards Control frames that are non-STBC frames received from its own BSS. This choice is a matter of policy local at the STA.

An S1G STA shall not support the Dual CTS Protection procedure defined in 10.3.2.10.

10.3.2.10.2 Dual CTS protection examples

Figure 10-10 shows an example of the operation of the dual CTS protection mechanism. In this example, the initiating STA is an STBC non-AP STA.

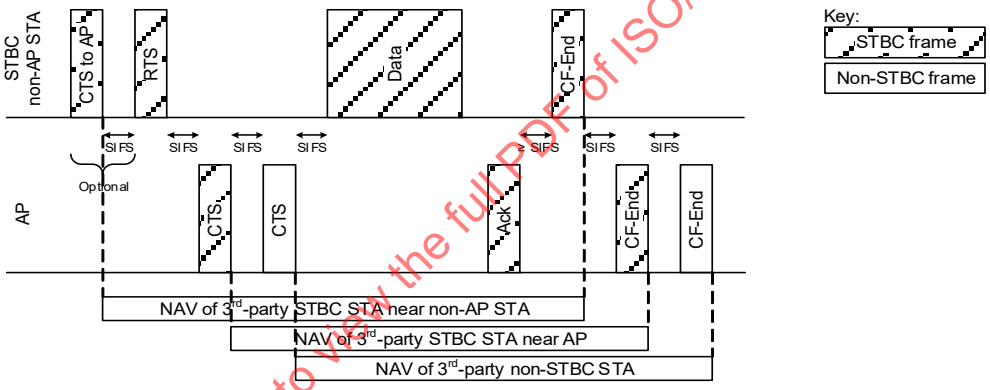

Figure 10-10—Example of dual CTS mechanism (STBC initiator)

Figure 10-11 shows an example of the operation of the dual CTS protection mechanism. In this example, the initiating STA is a non-STBC non-AP HT STA.

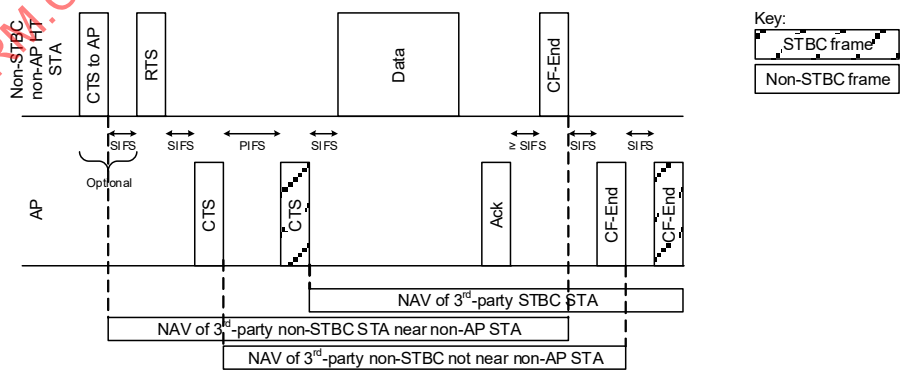

Figure 10-11—Example of dual CTS mechanism (non-STBC initiator)

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10.3.2.11 Acknowledgment procedure

The following frames require immediate acknowledgment:

- Individually addressed Management frames other than Action No Ack frames
- Individually addressed non-QoS Data frames
- Individually addressed QoS Data frames with Normal Ack or Implicit BAR ack policy
- BlockAck frames not sent in immediate response to A-MPDU
- BlockAckReq frames
- PS-Poll frames, which can be acknowledged by generating a Data frame

During a TWT SP, either the STACK frame or TACK frame can be used in place of the (NDP) Ack frame according to the procedure described in 10.47 and otherwise shall not be used.

A STA shall not transmit an Ack frame in response to a Management frame of subtype Action No Ack. A STA shall not transmit an Ack or BlockAck frame in response to a group addressed frame. An MPDU that does not require immediate acknowledgment is implicitly considered acknowledged, as if an explicit acknowledgment had been sent.

NOTE 1—Group addressed MSDUs are sent to an AP in individually addressed frames.

Otherwise, upon reception of a frame that requires immediate acknowledgment and, for an AP, with the To DS subfield equal to 1, a STA shall transmit an Ack or BlockAck frame after a SIFS, without regard to the busy/idle state of the medium. (See Figure 10-12.)

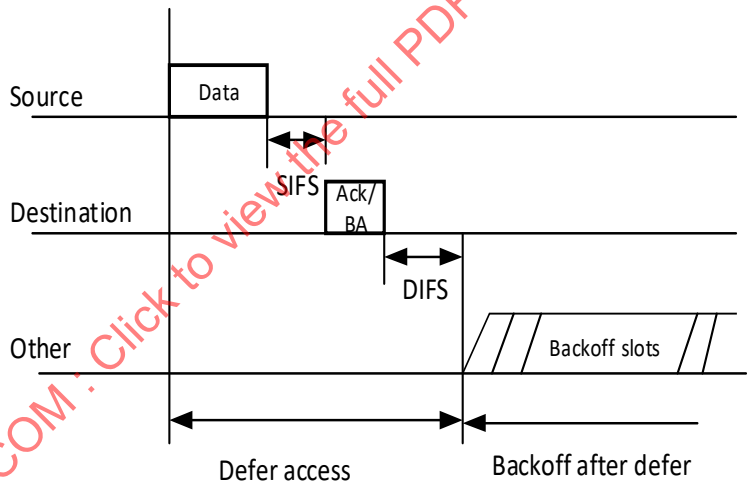

Figure 10-12—Individually addressed data/Ack/BlockAck frame

After transmitting an MPDU that requires an Ack or BlockAck frame as a response (see Annex G), the STA shall wait for an AckTimeout interval, with a value of aSIFSTime + aSlotTime + aRxPHYStartDelay, starting at the PHY-TXEND.confirm primitive. If a PHY-RXSTART.indication primitive does not occur during the AckTimeout interval, the STA concludes that the transmission of the MPDU has failed, and this STA shall invoke its backoff procedure upon expiration of the AckTimeout interval.

If a PHY-RXSTART.indication primitive does occur during the AckTimeout interval, the STA shall wait for the corresponding PHY-RXEND.indication primitive to determine whether the MPDU transmission was successful. If the STA recognizes a valid Ack frame addressed to the STA and corresponding to this PHY-RXEND.indication primitive, this recognition shall be interpreted as successful acknowledgment.

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If the STA does not recognize a valid Ack frame addressed to the STA, this condition shall be interpreted as failure of its MPDU transmission, except as defined below. In this instance, the STA shall invoke its backoff procedure at the PHY-RXEND.indication primitive and may process the received frame. If the STA has transmitted a PS-Poll frame, then the STA's receipt and recognition of a valid Data or Management frame transmitted by the recipient of the PS-Poll frame shall also be accepted as successful acknowledgment of the PS-Poll frame.

NOTE 2—The backoff procedure in the specific case of reception of a corrupted Ack or BlockAck frame results in EIFS rather than DIFS or AIFS being used after the AckTimeout interval and subsequent reception of the corrupted Ack or BlockAck frame (see 10.3.4.3 and 10.23.2.4 respectively).

NOTE 3—The receiver STA performs the acknowledgment procedure on all received frames requiring immediate acknowledgment, even if an MSDU or A-MSDU is carried partly or wholly within the frame and is subsequently discarded due to drop eligibility (see DEI subfield in 9.2.4.6.2).

NOTE 4—The rules that specify the contents of BlockAck frames are defined in 10.25.

Additional exceptions exist for S1G STAs for accepting a valid frame as successful acknowledgment as described in the following three paragraphs:

1) A STA that has enabled the implicit Ack procedure (see 10.54.5.3) shall consider a received S1G_SHORT/S1G_LONG PPDU as successful acknowledgment of a previously transmitted MPDU that was carried in an S1G_SHORT/S1G_LONG PPDU only in the following two cases:
   a) The STA is a non-AP STA associated to an S1G relay AP and all the conditions below are satisfied:
      — A PHY-RXSTART.indication primitive that corresponds to the received PPDU is detected within the AckTimeout interval that started as a result of the previously transmitted MPDU.
      — The RXVECTOR parameter PARTIAL_AID is equal to the PARTIAL_AID that corresponds to the BSSID of the parent AP's BSS, or the RXVECTOR parameter PARTIAL_AID is equal to 0 and the PPDU contains an RTS frame with RA equal to the BSSID of the parent AP's BSS.
      — The RXVECTOR parameter UPLINK_INDICATION is equal to 1.
   b) The STA is an AP that has an S1G relay STA associated to it and all the conditions below are satisfied:
      — A PHY-RXSTART.indication primitive that corresponds to the received PPDU is detected within the AckTimeout interval that started as a result of the previously transmitted MPDU.
      — The RXVECTOR parameter PARTIAL_AID is equal to the 6 LSBs of the PARTIAL_AID that corresponds to the DA of the non-AP STA or the RXVECTOR parameter PARTIAL_AID is equal to 0 and the received PPDU contains an RTS frame with RA equal to the DA of the non-AP STA.
      — The RXVECTOR parameter UPLINK_INDICATION is equal to 0 and the RXVECTOR parameter COLOR is equal to the COLOR value of the S1G relay AP.
2) Under BDT operation as described in 10.50: If a Data frame is sent as an immediate response to an MPDU requiring immediate acknowledgment, the reception of the Data frame shall be accepted as successful acknowledgment of the eliciting MPDU.
3) The recognition of a valid S1G RTS frame, sent by the recipient of a PS-Poll frame or of a PS-Poll+BDT frame shall be accepted as successful acknowledgment of the PS-Poll or of the PS-Poll+BDT frame.

An S1G STA shall transmit NDP Ack frames for acknowledgment with the following exceptions:

1) Transmission of an Ack frame is required if link adaptation procedure is negotiated as described in 10.32.
2) Transmission of a TACK frame or a STACK frame is required if target wake time is negotiated as described in 10.47.

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3) Transmission of a TACK frame is required as a response to a PS-Poll frame with the Poll Type subfield equal to 1 as described in 10.48.2.

4) Transmission of an NDP PS-Poll-Ack frame is required as a response to an NDP PS-Poll frame.

An S1G STA that satisfies any of the first three exceptions above shall transmit an Ack frame, TACK frame, or STACK frame instead of an NDP Ack frame as a response to an eliciting PPDU for which the RXVECTOR parameter RESPONSE_INDICATION is equal to Normal Response. The control response frame shall have a duration that is equal to NormalTXTime value for a 32-octet MPDU (see Table 10-3) if the eliciting PPDU contains an S-MPDU.

A non-S1G STA shall not transmit NDP Ack and NDP PS-Poll-Ack frames.

An S1G STA that transmits or receives an NDP Ack or NDP PS-Poll-Ack frame shall follow the same rules described above for Ack frames with the following exceptions that apply only to NDP Ack and NDP PS-Poll-Ack frames:

1) An S1G STA that transmits an NDP Ack frame for acknowledgment shall generate the Ack ID field of the NDP Ack frame as described in 23.3.12.2.4.

2) An S1G AP that transmits an NDP PS-Poll-Ack frame for acknowledgment of an NDP PS-Poll frame shall generate the Ack ID field of the NDP PS-Poll-Ack frame as described in 23.3.12.2.5. In addition, if the eliciting NDP PS-Poll is an NDP_1M PS-Poll frame the Duration field of the NDP_1M PS-Poll-Ack is set as follows:
   a) If the eliciting NDP_1M PS-Poll frame has a value of the Preferred MCS field equal to “No Preference” the Duration field should indicate an idle period (i.e., the Idle Indication field should be set to 1 as described in 23.3.12.2.5).
   b) Otherwise, the Duration field should indicate an Ack ID extension (i.e., the Idle Indication field should be set to 0 as described in 23.3.12.2.5).

3) An S1G STA that expects an NDP Ack frame as a response, shall consider a received NDP Ack frame as a successful response if the Ack ID field of the NDP Ack frame equals the bit sequence generated from the Scrambler Initialization value and the FCS field of its immediately previously transmitted PSDU as described in 23.3.12.2.4.

4) An S1G STA that expects an NDP PS-Poll-Ack frame as a response to an NDP PS-Poll, shall consider a received NDP PS-Poll-Ack frame as a successful response if the Ack ID field, together with the extension of the Ack ID if present in the Duration field, of the frame equals the bit sequence generated from the RA, TA and CRC fields of its immediately previously transmitted NDP PS-Poll frame as described in 23.3.12.2.5.

Upon reception of a PV1 frame that requires acknowledgment with the From DS field equal to 1, an S1G STA shall generate an acknowledgment frame in response if the AID subfield of A1 field is equal to the AID of the S1G STA and the A2 field is equal to the MAC address of its associated AP. Upon reception of a PV1 frame that requires acknowledgment with the From DS field equal to 0, an S1G STA shall generate an acknowledgment frame in response if A1 field is equal to the MAC address of the S1G STA.

In an S1G BSS, the AckTimeout interval depends on the TXVECTOR parameter PREAMBLE_TYPE. When the TXVECTOR parameter PREAMBLE_TYPE is equal to S1G_SHORT_PREAMBLE or S1G_LONG PREAMBLE, the AckTimeout interval is calculated with aRxPHYStartDelay value for ≥ 2 MHz short/long preamble except when the receiving STA has indicated use of 1 MHz control responses as described in 10.6.6.6 in which case the AckTimeout interval is calculated with aRxPHYStartDelay value for S1G_1M preamble. When the TXVECTOR parameter PREAMBLE_TYPE is equal to S1G_1M preamble, the AckTimeout interval is calculated with aRxPHYStartDelay value for S1G_1M preamble.

During a TWT SP, the BAT frame can be used in place of the (NDP) BlockAck frame, as described in 10.25 and otherwise, is not used.

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10.3.2.12 Fragment BA procedure

An S1G STA can partition an MSDU or an MMPDU into multiple fragments as described in 10.4 and send the frames containing the fragments of the MSDU or of the MMPDU as independent transmissions.

An S1G STA indicates support for fragment BA using the Fragment BA Support subfield of the S1G Capabilities Information field in the S1G Capabilities element. An S1G STA shall set the Fragment BA Support subfield to 1 in S1G Capabilities element if dot11FragmentBAOptionImplemented is true. Otherwise, the S1G STA shall set the Fragment BA Support subfield to 0. An S1G STA (known as the originator STA) with dot11FragmentBAOptionImplemented equal to true sending an MSDU or MMPDU (whether fragmented or not) to another S1G STA shall use the fragment BA procedure as described in this subclause if it has received from the STA (known as the recipient STA) a frame that included an S1G Capabilities element with the Fragment BA Support subfield equal to 1. Otherwise an S1G STA shall not use the fragment BA procedure. Non-S1G STAs shall not use the fragment BA procedure.

An originator STA may send fragments with Block Ack ack policy.

The receiving STA that is the intended receiver of either a fragment with Implicit BAR ack policy or a BlockAckReq frame shall send an NDP BlockAck frame after a SIFS, without regard of the idle/busy state of the medium, that is:

— An NDP_1M BlockAck frame if the eliciting fragment is either carried in an S1G_1M PPDU or the receiving STA has indicated use of 1 MHz control response frames as described in 10.6.6.6.
— An NDP_2M BlockAck frame if the eliciting fragment is carried in an S1G_SHORT/S1G_LONG PPDU and the receiving STA has not indicated use of 1 MHz control response frames as described in 10.6.6.6.

The receiving STA shall generate the BlockAck ID and the Starting Sequence Control field of the NDP BlockAck as described in 23.3.12.2.6.

The receiving STA shall include the receipt status of a set of the fragments in the BlockAck Bitmap field of the NDP BlockAck frame as follows:

1) If the originator STA elicits an NDP_1M BlockAck frame as a response, the BlockAck Bitmap field of the NDP BlockAck frame indicates the receipt status of a set of fragments which depends on the value of the Fragment Number subfield in the Sequence Control field of the fragment that elicited the response:
    a) If the Fragment Number subfield is not greater than 7 then the BlockAck Bitmap field shall indicate the receipt status of fragments with fragment numbers from 0 to 7.
    b) If the Fragment Number subfield is greater than 7 then the BlockAck Bitmap field shall indicate the receipt status of fragments with fragment numbers from 8 to 15.
2) If the originator STA elicits an NDP_2M BlockAck frame as a response, the BlockAck Bitmap field of the NDP BlockAck frame shall indicate the receipt status of the fragments with fragment numbers from 0 to 15.

NOTE—An NDP_1M BlockAck frame can acknowledge only a limited number of consecutive fragments because its BlockAck Bitmap field size is 8. Instead, an NDP_2M BlockAck frame can acknowledge up to the maximum number of fragments because its BlockAck Bitmap field size is 16.

The bitmap of the NDP BlockAck frame is protected using the encoding procedure described in 10.57.

An originator STA that elicits an NDP_1M BlockAck frame as a response shall not transmit a fragment that has a Fragment Number subfield greater than 7 if it has not previously received an NDP_1M BlockAck frame that indicates reception of all fragments with fragment numbers from 0 to 7.

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The originator STA shall consider an NDP_1M BlockAck frame (or an NDP_2M BlockAck frame) as received if the BlockAck ID field value equals the 2 LSBs (or 6 LSBs) of the Scrambler Initialization value in the Service field and the Starting Sequence Control field value equals the Sequence Number of the fragment that elicited the response. The Scrambler Initialization value shall be obtained from the PHY-TXEND.confirm parameter SCRAMBLER_OR_CRC.

The values of the BlockAck ID and Starting Sequence Number are obtained after decoding the NDP BlockAck frame as described in 10.57.

If the originator STA does not receive an NDP BlockAck frame as an immediate response, it may retransmit the last transmitted fragment to resolicit an immediate NDP BlockAck response.

10.3.2.13 MU acknowledgment procedure

The acknowledgment procedure performed by a STA that receives MPDUs that were transmitted within a VHT MU PPDU is the same as the acknowledgment procedure for MPDUs that were not transmitted within a VHT MU PPDU.

NOTE 1—All MPDUs transmitted within a VHT MU PPDU are contained within A-MPDUs, and the rules specified in 9.7.3 prevent an immediate response to more than one of the A-MPDUs.

Responses to A-MPDUs within a VHT MU PPDU that are not immediate responses to the VHT MU PPDU are transmitted in response to explicit BlockAckReq frames by the AP. Examples of VHT MU PPDU frame exchange sequences are shown in Figure 10-13 and Figure 10-14.

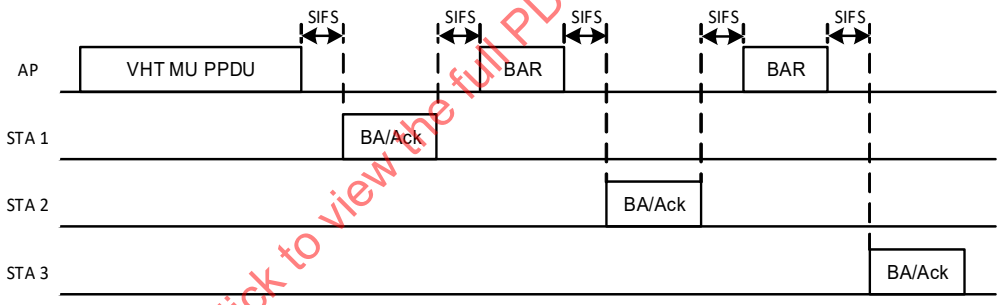

Figure 10-13—Example of TXOP containing VHT MU PPDU transmission with immediate acknowledgment to VHT MU PPDU

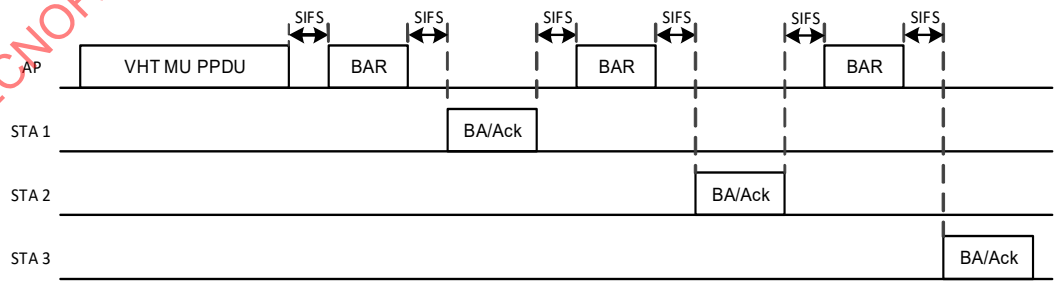

Figure 10-14—Example of TXOP containing VHT MU PPDU transmission with no immediate acknowledgment to VHT MU PPDU

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Recovery within the TXOP that contains a VHT MU PPDU can be performed according to the rules of 10.23.2.8. BlockAckRequest frames related to A-MPDUs within a VHT MU PPDU can be transmitted in a TXOP separate from the one that contained the VHT MU PPDU.

NOTE 2—A BlockAck frame is sent in immediate response to the BlockAckReq frame for HT-immediate block ack. An Ack frame might be sent in immediate response to an S-MPDU in the VHT MU PPDU.

NOTE 3—A BlockAckRequest frame would typically not be sent to a STA in the case where the A-MPDU to the STA contained no MPDUs requiring immediate acknowledgment. It could be sent if MPDUs in a previous A-MPDU remain unacknowledged.

10.3.2.14 Duplicate detection and recovery

10.3.2.14.1 General

Because MAC-level acknowledgments and retransmissions are incorporated into the protocol, there is the possibility that a frame may be received more than once. The procedures defined in this subclause attempt to filter out these duplicates. Additional duplicate filtering is performed during Receive Buffer Operation for frames that are part of a block ack agreement as described in 10.25.6.

Duplicate frame filtering is facilitated through the inclusion of a Sequence Control field (consisting of a sequence number and fragment number) within Data, Management, and Extension frames, a TID subfield in the QoS Control field within QoS Data frames, and an ACI subfield in the Sequence Number field within QMFs, and a PTID/Subtype subfield in the Frame Control field within PV1 Data frames.

NOTE—In 10.3.2.14, Data frames with a value of 1 in the QoS subfield of the Subtype subfield are collectively referred to as *QoS Data frames*.

10.3.2.14.2 Transmitter requirements

A STA maintains one or more sequence number spaces that are used when transmitting a frame to determine the sequence number for the frame. When multiple sequence number spaces are supported, the appropriate sequence number space is determined by information from the MAC control fields of the frame to be transmitted. Except as noted below, each sequence number space is represented by a modulo 4096 counter, starting at 0 and incrementing by 1 for each MSDU or MMPDU transmitted using that sequence number space. If dot11MACPrivacyActivated is true, the counter in each sequence number space shall be set to a random number modulo 4096 when the STA's MAC address is changed.

NOTE—Group addressed retransmissions of BUs use the same sequence number as the initial group addressed transmission of the BU. Individually addressed retransmissions of a group addressed BU delivered via DMS use the same sequence number as the initial individually addressed transmission of the BU. When a BU is delivered both using group addressing and individual addressing (e.g., when DMS is active but there are other associated STAs not using DMS), the sequence number might differ between the group addressed and individually addressed transmissions of the same BU.

MPDUs that are part of the same MSDU or A-MSDU shall have the same sequence number. Different MSDUs or A-MSDUs have (with a high probability) a different sequence number.

A transmitting STA shall support the applicable sequence number spaces defined in Table 10-5. Applicability is defined by the Applies to column. The Status column indicates the level of support that is required if the Applies to column matches the transmission. The Multiplicity column indicates whether the sequence number space contains a single counter, or multiple counters and in the latter case identifies any indexes. The Transmitter requirements column identifies requirements for the operation of this sequence number space. The referenced requirements are defined at the end of the table.

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Table 10-5—Transmitter sequence number spaces

Sequence number space identifier	Sequence number space	Applies to	Status	Multiplicity	Transmitter requirements
SNS1	Baseline	A STA transmitting a frame that is not covered by any of the other sequence number spaces.	Mandatory	Single Instance	TR1
SNS2	Individually addressed QoS Data	A STA transmitting an individually addressed QoS Data frame, excluding SNS5	Mandatory	Indexed by <Address 1, TID>	
SNS3	Time Priority Management	A QoS STA transmitting a Time Priority Management frame	Optional	Indexed by <Address 1, TID>	
SNS4	QMF	A QMF STA transmitting a QMF	Mandatory	Indexed by <Address 1, AC>	TR2
SNS5	QoS (+)Null	A STA transmitting a QoS (+)Null frame	Mandatory	None	TR3
SNS6	Individually addressed PV1 Data frame	A STA operating as an S1G STA transmitting a PV1 Data frame	Mandatory	Indexed by <STA MAC Address identified by Address 1, PTID>	
SNS7	Individually addressed PV1 Management frame	A STA operating as an S1G STA transmitting a PV1 Management frame	Mandatory	Indexed by <STA MAC Address identified by Address 1>	

TR1: A transmitting STA should cache the last used sequence number per RA for frames that are assigned sequence numbers from this sequence number space. The STA should check that the successively assigned sequence numbers for frames transmitted to a single RA do not have the same value as is found in the cache for that RA. If the check fails the STA should increment the counter by 2, rather than 1.

TR2: The STA shall assign the sequence number from one modulo 1024 counter per <Address 1, AC> tuple starting at 0 and incrementing by 1 for each MMPDU carried in one or more QMFs with Address 1 and ACI fields matching the <Address 1, AC> tuple values corresponding to that counter.

TR3: Sequence numbers for transmitted QoS (+)Null frames may be set to any value.

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10.3.2.14.3 Receiver requirements

A STA maintains one or more duplicate detection caches. Table 10-6 defines the conditions under which a duplication detection cache is supported and the rules followed by the receiver for the cache. When a Data, Management or Extension frame is received, a record of that frame is inserted in an appropriate cache. That record is identified by a sequence number and possibly other information from the MAC control fields of the frame. When a Data, Management or Extension frame is received in which the Retry subfield of the Frame Control field is equal to 1, the appropriate cache, if any, is searched for a matching frame. In DMG, when a group addressed frame is received the appropriate cache is searched for a matching frame. When a PV1 Data frame or PV1 Management frame is received, the appropriate cache is searched for a matching frame,

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regardless of the presence of the Retry subfield of the Frame Control field. If the search is successful, the frame is considered to be a duplicate. Duplicate frames are discarded.

NOTE—The receiver STA performs the Ack and (for an AP) PS procedures on all received frames requiring immediate acknowledgment, even if the frame is discarded due to duplicate filtering.

There is a small possibility that a frame may be improperly rejected due to such a match; however, this occurrence is rare and simply results in a lost frame (similar to an FCS error in other LAN protocols).

A receiving STA shall implement the applicable receiver requirements defined in Table 10-6 with Status indicated as Mandatory. A receiving STA should implement the applicable receiver requirements defined in Table 10-6 with Status indicated as Recommended. A receiving STA may implement the applicable receiver requirements defined in Table 10-6 with Status indicated as Optional. Applicability is defined by the Applies to column. The Status column indicates the level of support that is required if the Applies to column matches the received frame. The Multiplicity/Cache size column indicates the indexes that identify a cache entry and the number of entries that shall be supported. The Receiver requirements column identifies requirements for the operation of this cache. The referenced requirements are defined at the end of the table. The requirements relate to caching information that identifies a cache entry and discarding duplicate MPDUs.

Table 10-6—Receiver caches

Receiver cache identifier	Cache name	Applies to	Status	Multiplicity/Cache size	Receiver requirements
RC1	Not QoS Data	A STA receiving frames (individually or group addressed) that are not QoS Data, excluding if supported: RC4 RC5 RC6 RC7 RC8 RC10	Mandatory	Indexed by: <Address 2, sequence number, fragment number>. At least the most recent cache entry per <Address 2>.	RR1 RR2 RR5
RC2	QoS Data	A STA receiving an (individually or group addressed) QoS Data frame, excluding RC3, and if supported: RC7, RC8, RC9, and RC10	Mandatory	Indexed by: <Address 2, TID, sequence number, fragment number>. At least the most recent cache entry per <Address 2, TID> pair in this cache.	RR1 RR5
RC3	QoS (+)Null	A QoS STA receiving a QoS (+)Null frame	Mandatory	None	RR4
RC4	Non-time priority Management	A STA receiving an individually addressed non-time priority Management frame, excluding RC6 if RC6 is supported	Recommended	Indexed by: <Address 2, sequence number, fragment number> At least the most recent cache entry per <Address 2> value.	RR1 RR2 RR5

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Table 10-6—Receiver caches *(continued)*

Receiver cache identifier	Cache name	Applies to	Status	Multiplicity/Cache size	Receiver requirements
RC5	Time priority Management	A STA receiving an individually addressed time priority Management frame	Supported if RC4 is supported; otherwise not supported	Indexed by: <Address 2, sequence number, fragment number>. At least the most recent cache entry per <Address 2> value.	RR5
RC6	QMFs	A STA receiving an individually addressed QMF	Mandatory	Indexed by: <Address 2, AC, sequence number, fragment number> The most recent cache entry per <Address 2, AC, sequence-number, fragment-number>.	RR2 RR3 RR5
RC7	Nonmesh GCR	A nonmesh STA receiving a group addressed frame subject to a GCR agreement.	Mandatory	Indexed by: <DA, sequence number> One cache entry per <DA, sequence-number> tuple for each group address subject to a GCR agreement.	RR5
RC8	Mesh GCR	A mesh STA receiving a group addressed frame subject to a GCR agreement.	Mandatory	Indexed by: <DA, Address 2, sequence number>. One cache entry per <DA, Address 2, sequence-number> tuple for each group address subject to a GCR agreement.	RR5
RC9	QoS Data under BA	A non-DMG QoS STA receiving a QoS Data frame sent under a block ack agreement	Recommended	None	RR4
RC10	DMG Group Addressed	A DMG STA receiving a group addressed frame.	Mandatory	Indexed by: <Address 1, Address 2, sequence number, fragment number> The most recent cache entry per <Address 1, Address 2, sequence-number>.	RR6

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Table 10-6—Receiver caches *(continued)*

Receiver cache identifier	Cache name	Applies to	Status	Multiplicity/Cache size	Receiver requirements
RC11	Individually addressed PV1 Data frame	An S1G STA receiving an individually addressed PV1 Data frame	Mandatory	Indexed by <STA MAC Address identified by Address 2, PTID, sequence number, fragment number>. At least the most recent cache entry per <STA MAC Address identified by Address 2, PTID> pair in this cache.	RR1
RC12	Individually addressed PV1 Management frame	An S1G STA receiving an individually addressed PV1 Management frame	Mandatory	Indexed by <STA MAC Address identified by Address 2, sequence number, fragment number>. At least the most recent cache entry per <STA MAC Address identified by Address 2> pair in this cache.	RR1 RR2

RR1: A receiving non-DMG STA with dot11QMFActivated false or not present and with dot11RobustAVStreamingImplemented false or not present should omit tuples obtained from group addressed frames from this cache.

RR2: A receiving STA should omit tuples obtained from ATIM frames from this cache.

RR3: A receiving QMF STA that is a non-DMG STA with dot11RobustAVStreamingImplemented false or not present shall omit from the cache all tuples obtained from group addressed Data frames.

RR4: For the purposes of duplicate detection using receiver caches, QoS (+)Null frames and, in a non-DMG BSS, QoS Data frames under a block ack agreement, shall be ignored.

RR5: The STA shall discard the frame if the Retry subfield of the Frame Control field is 1 and it matches an entry in the cache.

RR6: The STA shall discard the frame if it matches an entry in the cache.

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10.3.2.15 NAV distribution

When a node needs to distribute NAV information, for instance, to reserve the medium for a transmission of a nonbasic rate frame (that might not be heard by other nodes in the BSS), the node may first transmit a CTS frame with the RA field equal to its own MAC address (CTS-to-self) if the node is a non-DMG STA, or it may transmit a DMG CTS frame with the RA field equal to its own MAC address and the TA field equal to the MAC address of the peer STA for which the forthcoming transmission of the node is intended (DMG CTS-to-self) if the node is a DMG STA. A duration value in the frame protects the pending transmission, plus possibly an Ack frame.

The CTS-to-self and DMG CTS-to-self NAV distribution mechanisms are lower in network overhead cost than are the RTS/CTS and RTS/DMG CTS NAV distribution mechanisms, respectively, but CTS-to-self and DMG CTS-to-self are less robust against hidden nodes and collisions than RTS/CTS and RTS/DMG CTS-to-self, respectively. STAs employing a NAV distribution mechanism should choose a mechanism that is

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appropriate for the given network conditions. If errors occur when employing the CTS-to-self or DMG CTS-to-self mechanism, STAs should switch to a more robust mechanism.

When the NDP CTS frame is a CTS-to-self, the value in the Duration field of the NDP CTS frame shall protect the pending transmission, plus any expected (NDP) Ack frame in response.

10.3.2.16 Operation of aSlotTime

A STA in which dot11ShortSlotTimeOptionImplemented is true shall set the MAC variable aSlotTime to the short slot value upon transmission or reception of Beacon, Probe Response, Association Response, and Reassociation Response frames from the BSS that the STA has joined or started and that have the Short Slot Time subfield equal to 1. The STA shall set the MAC variable aSlotTime to the long slot value upon transmission or reception of Beacon, Probe Response, Association Response, and Reassociation Response frames from the BSS that the STA has joined or started and that have the Short Slot Time subfield equal to 0.

A STA in which dot11ShortSlotTimeOptionImplemented is false shall set the MAC variable aSlotTime to the long slot value at all times. A STA in which dot11ShortSlotTimeOptionImplemented is not present, or whose PHY supports only a single slot time value shall set the MAC variable aSlotTime to the PHY characteristic aSlotTime.

NOTE—The MAC variable aSlotTime is distinct from the PHY characteristic aSlotTime. Outside this subclause, the MAC uses the MAC variable aSlotTime whenever the value of aSlotTime is required.

10.3.2.17 Response Indication procedure

An S1G STA distributes RID information in order to protect the response frame expected SIFS after the frame that elicits that response. The TXVECTOR parameter RESPONSE_INDICATION for S1G non-NDPs shall be set based on the expected response type, as described in Table 10-7. The TXVECTOR parameter RESPONSE_INDICATION for S1G NDPs other than NDP CMAC PPDUs is set as described in 10.36.7.

NOTE—The TXVECTOR parameter RESPONSE_INDICATION is not present for NDP CMAC PPDUs.

Table 10-7—Setting the TXVECTOR parameter RESPONSE_INDICATION

RESPONSE_INDICATION	Solicited Immediate Response
0 (No Response)	No immediate response. None of the MPDUs in the PPDU solicit an immediate acknowledgment (e.g., a QoS Data frame whose ack policy is neither Normal Ack nor Implicit BAR (see 9.2.4.5.4 and 9.8.3.1), Action No Ack frame).
1 (NDP Response)	The addressed recipient returns an individual NDP CMAC PPDU: — NDP Ack frame, as described in 10.3.2.11, — NDP CTS frame, as described in 10.3.2.9, — NDP BlockAck frame, as described in 10.25.6 and 10.3.2.12. At least one of the MPDUs in the PPDU solicits an immediate acknowledgment, (e.g., a QoS Data frame whose ack policy is either Normal Ack or Implicit BAR, Action frame).

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Table 10-7—Setting the TXVECTOR parameter RESPONSE_INDICATION *(continued)*

RESPONSE_INDICATION	Solicited Immediate Response
2 (Normal Response)	The addressed recipient returns an individual control response frame: — Ack frame, as described in 10.3.2.11, — CTS frame, as described in 10.3.2.9, — BlockAck frame or BAT frame, as described in 10.3.2.11 and 10.47, — TACK frame or STACK frame as described in 10.47. At least one of the MPDUs in the PPDU solicits an immediate acknowledgment (e.g., a QoS Data frame whose ack policy is Normal Ack or Implicit BAR; or an Action frame).
3 (Long Response)	The addressed recipient may return a response frame, which is not an individual control response frame. More details are provided in 10.50, 10.29, 10.34.3, and 10.54.5.2.

An S1G STA shall not cause its intended receiver to generate a control response frame that is not an NDP CMAC PPDU except as specified below:

a) If the intended receiver has indicated that it supports generating +HTC Control frames then the S1G STA can solicit +HTC Control frames of the types described in 10.32.

b) If the intended receiver has negotiated with the S1G STA the generation of TACK frame or STACK frames then the S1G STA can solicit TACK frames or STACK frames as described in 10.47.

c) If the intended receiver has indicated that it supports generating TACK frames then the S1G STA can solicit a TACK frame as described in 10.48.2.

d) If the intended receiver has negotiated with the S1G STA the use of either BlockAck or BAT frames then the S1G STA can solicit either BlockAck or BAT frames as described in 10.25.5.

e) If the intended receiver has negotiated with the S1G STA the generation of control response frames with different MCSs than the primary MCS as described in 10.6.6.5.6.

An S1G STA transmitting a PPDU that expects an NDP Response shall calculate the Duration/ID field of the transmitted PPDU as described in 9.2.5.2 where the estimated duration of "CTS frame," "Ack frame," or "BlockAck frame" is equal to NDPTxTime. NDPTxTime depends on the TXVECTOR parameter PREAMBLE_TYPE and is equal to the time in microseconds, required to transmit:

— An NDP_1M MAC frame if PREAMBLE_TYPE is an S1G_1M preamble or the intended receiver has indicated the use of 1 MHz control response frames (see 10.6.6.6).

— An NDP_2M MAC frame if PREAMBLE_TYPE is a ≥ 2 MHz short/long preamble and the intended receiver has not indicated the use of 1 MHz control response frames.

An S1G STA that expects a Normal Response that is a BAT frame or TACK frame shall calculate the Duration/ID field of the PPDU as described in 9.2.5.2 using the same estimated duration of a BlockAck frame. An S1G STA that expects a Normal Response that is a STACK frame shall use the estimated duration of an Ack frame.

An S1G STA that expects a Long Response shall calculate the Duration/ID field of the PPDU as described in 9.2.5.2 for multiple protection settings.

An S1G STA transmitting an eliciting frame for which it expects a response that is a BAT frame or BlockAck frame as described in 10.25.6 or a TACK frame as described in 10.47 and 10.48.2 shall carry the eliciting frame in an A-MPDU or in an S-MPDU (i.e., sets the TXVECTOR parameter AGGREGATION

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to 1). The intended recipient selects the type of control response frame based on the type of the eliciting frame and other information available in the PSDU such as Ack Policy Indicator field, EOF field, etc.

An S1G STA transmitting an eliciting frame for which it expects a response that is an Ack frame as described in 10.32 or a STACK frame as described in 10.47 shall carry the eliciting frame in an MPDU (i.e., sets the TXVECTOR parameter AGGREGATION to 0) except when the intended receiver has set the A-MPDU Supported field in the most recently transmitted S1G Capabilities element to 1, in which case the S1G STA may transmit the eliciting frame as an S-MPDU.

An S1G STA transmitting a CF-End frame shall set the TXVECTOR parameter RESPONSE_INDICATION to No Response.

An S1G AP sending an NDP Ack frame with the More Data field equal to 1 as a response to an eliciting PS-Poll frame may set the Duration field of the NDP Ack frame to the estimated duration of the BU frame that the S1G AP has buffered for the polling STA, plus SIFS, plus the duration of the response from the S1G non-AP STA, if required.

An S1G AP that sends an NDP_2M PS-Poll-Ack frame with the Idle Indication field equal to 0 and the More Data field equal to 1 as a response to an eliciting NDP PS-Poll frame may set the Duration field of the NDP_2M PS-Poll-Ack frame to the estimated duration of the BU frame that the S1G AP has buffered for the polling STA, plus SIFS, plus the duration of the response from the S1G non-AP STA, if required. An S1G AP that sends an NDP_2M PS-Poll-Ack frame with the Idle Indication field equal to 0 and the More Data field equal to 0 as a response to an eliciting NDP PS-Poll frame shall set the Duration field of the NDP_2M PS-Poll-Ack frame to 0.

An S1G STA that intends to transmit two or more SIFS-separated PV1 frames for which it does not follow the BDT rules defined in 10.50 should protect the sequence with a protective mechanism that uses multiple protection as described in 9.2.5.2.

10.3.3 Random backoff procedure

A STA desiring to initiate transfer of Data frames and/or Management frames using the DCF shall invoke the CS mechanism (see 10.3.2.1) to determine the busy/idle state of the medium. If the medium is busy, the STA shall defer until the medium is determined to be idle without interruption for a period of time equal to EIFS when the last transition to idle medium was a result of a frame detected on the medium that was not received correctly, or equal to DIFS otherwise. After this DIFS or EIFS medium idle time, the STA shall then generate a random backoff count [defined by Equation (10-1)] for an additional deferral time before transmitting, unless the backoff counter already contains a nonzero value, in which case the selection of a random number is not needed and not performed. This process minimizes collisions during contention between multiple STAs that have been deferring to the same event.

$$\text{Backoff Count} = \text{Random}() \tag{10-1}$$

where

Random() = Pseudorandom integer drawn from a uniform distribution over the interval [0,CW], where CW is an integer within the range of values of the PHY characteristics aCWmin and aCWmax, aCWmin ≤ CW ≤ aCWmax.

NOTE—It is important that designers recognize the need for statistical independence of the random number streams between STAs.

The contention window (CW) parameter shall take an initial value of aCWmin. Every STA shall maintain a STA short retry count (SSRC) as well as a STA long retry count (SLRC), both of which shall take an initial value of 0. The SSRC shall be incremented when any short retry count (SRC) associated with any MPDU with

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the Type subfield equal to Data or Management is incremented. The SLRC shall be incremented when any long retry count (LRC) associated with any MPDU with the Type subfield equal to Data or Management is incremented. The CW shall take the next value in the series every time an unsuccessful attempt to transmit an MPDU causes either STA retry count to increment, until the CW reaches the value of aCWmax. A retry is defined as the entire sequence of frames sent, separated by SIFSs, in an attempt to deliver an MPDU, as described in Annex G. Once it reaches aCWmax, the CW shall remain at the value of aCWmax until the CW is reset. This improves the stability of the access protocol under high-load conditions. See Figure 10-15.

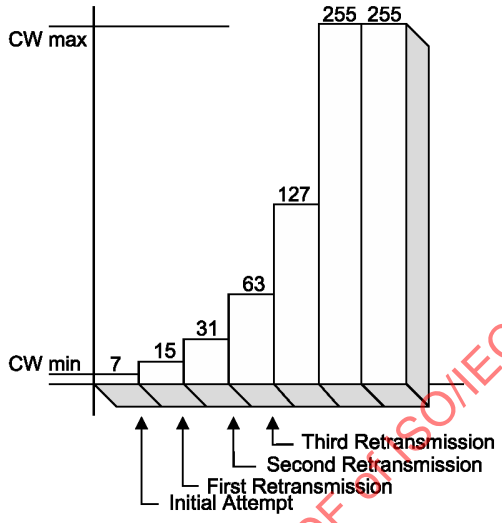

Figure 10-15—Example of exponential increase of CW

The CW shall be reset to aCWmin after every successful attempt to transmit a Data or Management frame, or when SSRC reaches dot11ShortRetryLimit.

The SSRC shall be reset to 0 when a CTS frame is received in response to an RTS frame, when a BlockAck frame is received in response to a BlockAckReq frame, when an Ack frame is received in response to the transmission of a frame containing all or part of an MSDU or MMPDU that is contained in a PSDU of length less than or equal to dot11RTSThreshold, or when a frame with a group address in the Address 1 field is transmitted.

The SLRC shall be reset to 0 when an Ack frame is received in response to transmission of a frame containing all or part of an MSDU or MMPDU that is contained in a PSDU of length greater than dot11RTSThreshold, or when a frame with a group address in the Address 1 field is transmitted.

The set of CW values shall be sequentially ascending integer powers of 2, minus 1, beginning with a PHY-specific aCWmin value, and continuing up to a PHY-specific aCWmax value.

10.3.4 DCF access procedure

10.3.4.1 Introduction

The CSMA/CA access method is the foundation of the DCF.

10.3.4.2 Basic access

Basic access refers to the core mechanism a STA uses to determine whether it may transmit using the DCF.

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A STA may transmit an MPDU when it is operating under the DCF access method, when the STA determines that the medium is idle when a frame is queued for transmission, and remains idle for a period of a DIFS, or an EIFS (10.3.2.3.7) from the end of the immediately preceding medium-busy event, whichever is the greater, and the backoff counter has a value of zero. Otherwise the random backoff procedure described in 10.3.4.3 shall be followed.

A DMG STA operating under the DCF access method should transmit frames with its transmit antenna pattern directed toward the intended receiver.

A DMG STA operating under the DCF access method that does not operate in a TXOP exchange may configure its receiving antenna array to a quasi-omni antenna pattern to be ready to receive frames from any DMG STA.

NOTE—The steady state of the antenna configuration might depend on the actual applications in which a DMG STA is involved. For example, a DMG STA that expects transactions with several STAs during a CBAP configures the receiving antenna to a quasi-omni pattern to be ready to receive transmission from any of the STAs. A DMG STA that expects transactions with a single STA (e.g., AP or PCP) might keep its receiving antenna directed to the peer STA.

A DMG STA operating under the DCF access method that is participating in a TXOP exchange should configure its receiving antenna array to be directed toward the other transmitter involved in the TXOP.

The basic access mechanism is illustrated in Figure 10-16.

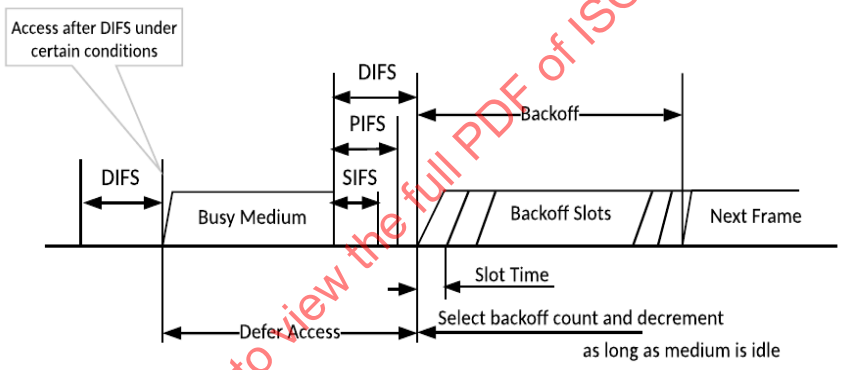

Figure 10-16—Basic access method

10.3.4.3 Backoff procedure for DCF

This subclause describes backoff procedure that is to be invoked when DCF is used. For the backoff procedure when EDCA is used, see 10.23.2.2.

A STA shall invoke the backoff procedure to transfer a frame when finding the medium busy as indicated by either the physical or virtual CS mechanism (see Figure 10-17). A transmitting STA shall invoke the backoff procedure when the STA infers a failed transmission as defined in 10.3.2.9 or 10.3.2.11.

To begin the backoff procedure, the STA shall set its backoff counter to a random value using the equation in 10.3.3. All backoff slots occur following a DIFS or EIFS as appropriate (see 10.3.3 and 10.3.2.3.7) except that no backoff slots for DCF occur during the BTI, the A-BFT, the ATI, and non-CBAP portions of the DTI.

A STA performing the backoff procedure shall use the CS mechanism (see 10.3.2.1) to determine whether there is activity during each backoff slot. If no medium activity is indicated for the duration of a particular backoff slot, then the backoff procedure shall decrement its backoff counter.

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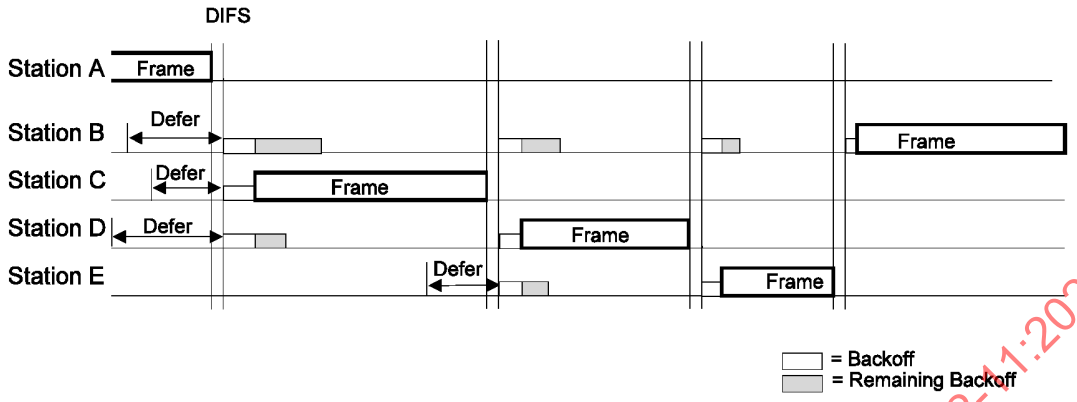

Figure 10-17—Backoff procedure

If the medium is determined to be busy at any time during a backoff slot, then the backoff counter shall not be decremented for that slot. The backoff counter is next decremented after the medium has been determined to be idle for the duration of a DIFS or EIFS, as appropriate (see 10.3.3 and 10.3.2.3.7), plus aSlotTime.

Transmission shall commence when the backoff counter equals 0.

A backoff procedure shall be performed immediately after the end of every transmission with the More Fragments bit equal to 0 of an MPDU with the Type subfield equal to Data, Management, or Control with subtype PS-Poll, even if no additional transmissions are currently queued. In the case of successful acknowledged transmissions, this backoff procedure shall begin at the end of the received Ack frame. In the case of unsuccessful transmissions requiring an immediate response, this backoff procedure shall begin at the end of the AckTimeout interval (as defined in 10.3.2.11) or CTSTimeout interval (as defined in 10.3.2.9). An unsuccessful transmission is one where a control response frame is not received from the STA addressed by the RA field of the transmitted frame and the value of the RA field is an individual address. If the transmission is successful, the CW value reverts to aCWmin before the random backoff count is chosen, and the SSRC and/or SLRC are updated as described in 10.3.3. The result of this procedure is that transmitted frames from a STA are always separated by at least DIFS.

The effect of this procedure is that when multiple STAs are deferring and go into random backoff, then the STA selecting the smallest backoff count using the random function wins the contention (assuming all of the contending STAs detect the same instances of WM activity at their respective receivers, a situation that is not always true, due to hidden node effects and interference events). The number of DMG STAs that are able to detect each WM transmission is reduced even further due to SPSH.

In an IBSS the backoff counter for a pending non-Beacon or non-ATIM transmission shall not decrement in the period from the TBTT until the expiration of the ATIM window, and the backoff counter for a pending ATIM frame shall decrement only within the ATIM window. (See Clause 11.) Within an IBSS a separate backoff count shall be generated to precede the transmission of a Beacon frame, as described in 11.1.3.5.

At the start of an awake window, a DMG STA shall suspend decrementing its backoff counter(s) for any transmission of non-ATIM frames for the duration of the awake window as indicated in the most recently received Awake Window element. At the end of the awake window, the DMG STA shall resume decrementing the backoff counter(s) for non-ATIM frames. A DMG STA shall not decrement the backoff counter for a pending ATIM frame outside the awake window.

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Figure 10-19 describes the backoff procedure for DMG STAs for the example topology shown in Figure 10-18.

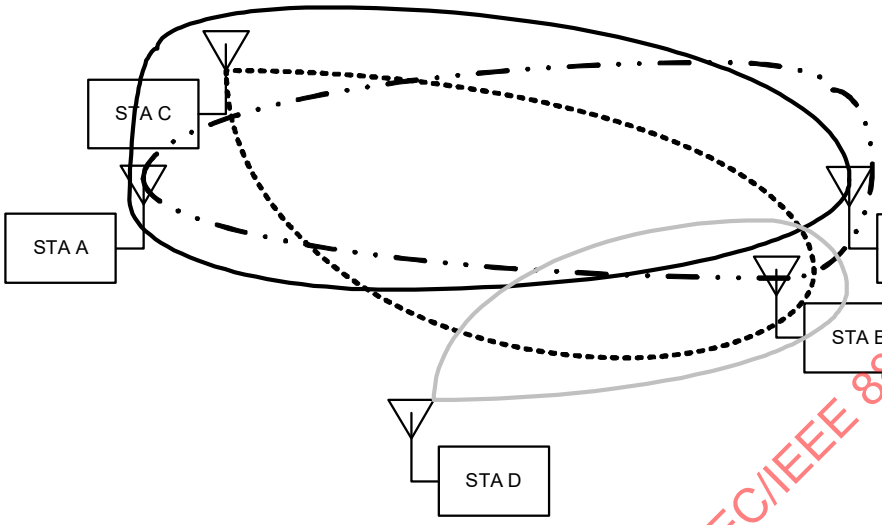

Figure 10-18—Example topology of NAV setting in DMG STAs

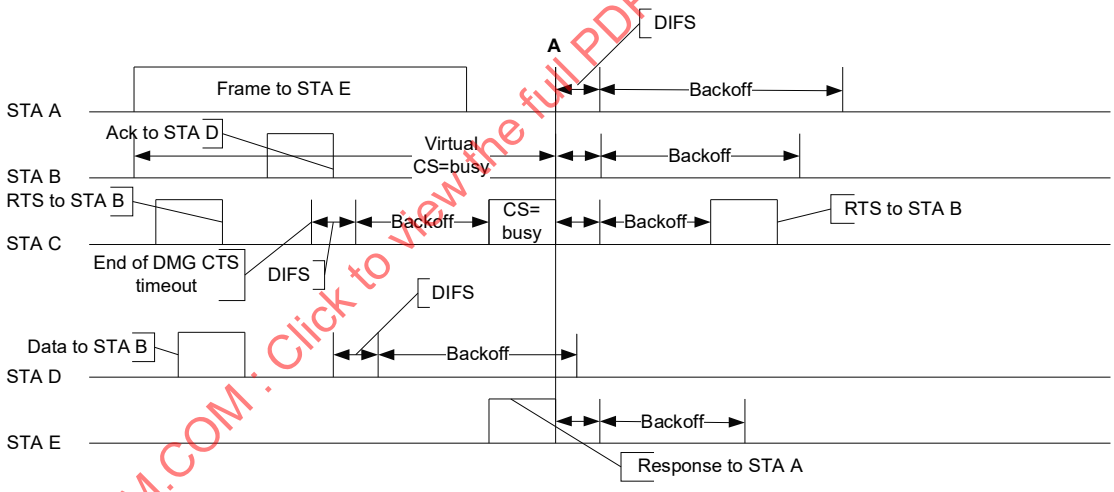

Figure 10-19—Backoff procedure for DMG STAs

At the time that STA A starts transmitting a frame to STA E and STA E starts receiving the frame, the antennas of both stations are directed to the peer, i.e., the transmitting antennas of STA A are directed to STA E and the receiving antennas of STA E are directed to STA A. At this point, STA B, STA C, and STA D are not involved in any frame exchange; therefore, they are in receiving state and happen to have the configuration of their receiving antenna arrays set to a quasi-omni antenna pattern to be ready to receive frames from any STA.

STA B receives the frame transmitted by STA A (to STA E), and CS (physical and virtual) in STA B indicates a busy medium during the exchange between STA A and STA E.

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STA D is not able to receive the frame transmitted by STA A or the response transmitted by STA E; hence CS in STA D indicates IDLE for the duration of the exchange between STA A and STA E.

The physical CS function of STA C indicates a medium busy condition when it receives the response sent by STA E, but indicates an idle medium condition during the transmission from STA A.

STA A and STA E (which are directly involved in the frame exchange), STA B (which received the frame sent by STA A), and STA C (which received the response sent by STA E) are synchronized at point A, where the transaction between STA A and STA E completes.

Since STA D cannot hear the directional transmissions from either STA A or STA C, its physical CS indicates an idle medium condition for the duration of the frame exchange, enabling a frame exchange with STA B at the same time as the frame exchange between STA A and STA E. This is an example of SPSH.

Because STA C is unaware of the transmission of the frame from STA A to STA E, STA C transmits an RTS to STA B. But STA C does not receive a DMG CTS from STA B since the CS at STA B is busy when STA B receives the RTS from the STA C. This causes STA C to retry the RTS transmission following the expiration of a backoff count, which occurs after the completion of the exchange between STA A and STA E.

10.3.4.4 Recovery procedures and retransmit limits

Under DCF, error recovery is always the responsibility of the STA that initiates a frame exchange sequence (described in Annex G). Many circumstances might cause an error to occur that requires recovery. For example, the CTS frame might not be returned after an RTS frame is transmitted. This may happen due to a collision with another transmission, due to interference in the channel during the RTS or CTS frame, or because the STA receiving the RTS frame has an active virtual CS condition (indicating a busy medium time period).

Error recovery shall be attempted by retrying transmissions for frame exchange sequences that the initiating STA infers have failed. Retries shall continue, for each failing frame exchange sequence, until the transmission is successful, or until the relevant retry limit or lifetime is reached, whichever occurs first. A STA shall maintain an SRC and an LRC for each MSDU or MMPDU awaiting transmission. These counts are incremented and reset independently of each other.

After an RTS frame is transmitted, the STA shall perform the CTS procedure, as defined in 10.3.2.9. If the RTS frame transmission fails, the SRC for the MSDU or MMPDU and the SSRC are incremented. This process shall continue until the number of attempts to transmit that MSDU or MMPDU reaches dot11ShortRetryLimit.

After transmitting a frame that requires immediate acknowledgment, the STA shall perform the acknowledgment procedure, as defined in 10.3.2.11. The SRC for an MPDU with the Type subfield equal to Data or Management and of length less than or equal to dot11RTSThreshold and the SSRC shall be incremented every time transmission of that MPDU fails. This SRC and the SSRC shall be reset when transmission of that MPDU succeeds. The LRC for an MPDU with the Type subfield equal to Data or Management and of length greater than dot11RTSThreshold and the SLRC shall be incremented every time transmission of that MPDU fails. This LRC and the SLRC shall be reset when transmission of that MPDU succeeds. All retransmission attempts for an MPDU with the Type subfield equal to Data or Management that has failed the acknowledgment procedure one or more times shall be made with the Retry subfield set to 1. These rules do not apply for frames sent by a non-DMG STA under a block agreement.

Retries for failed transmission attempts shall continue until the SRC for the MPDU with the Type subfield equal to Data or Management is equal to dot11ShortRetryLimit or until the transmit MSDU timer for the MSDU or any undelivered fragments of that MSDU exceeds dot11MaxTransmitMSDULifetime (see 10.4). When any of these limits is reached, retry attempts shall cease, and the MPDU with the Type subfield Data

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(and any MSDU of which it is a part) or Management shall be discarded. A DMG STA, in addition to using random access within a CBAP, may transmit retries in available scheduled SPs.

A STA in PS mode, in an infrastructure BSS, initiates a frame exchange sequence by transmitting a PS-Poll frame to request data from an AP. If no Ack, Data, or Management frame is received from the AP in response to a PS-Poll frame, then the STA shall retry the sequence, by transmitting another PS-Poll frame. If the AP sends a Data or Management frame in response to a PS-Poll frame, but fails to receive the Ack frame acknowledging this Data or Management frame, the next PS-Poll frame from the same STA might cause a retransmission of the last MSDU [28]. If the AP responds to a PS-Poll frame by transmitting an Ack frame, then responsibility for the Data or Management frame delivery error recovery shifts to the AP because the data are transferred in a subsequent frame exchange sequence, which is initiated by the AP. The AP shall attempt to deliver one buffered BU to the STA that transmitted the PS-Poll frame, using any frame exchange sequence valid for an individually addressed BU. If the PS STA that transmitted the PS-Poll frame returns to doze state after transmitting the Ack frame in response to receipt of this BU, but the AP fails to receive this Ack frame, then the AP retries transmission of this BU until the relevant retry limit is reached. See 11.2.3.7 for details on filtering of extra PS-Poll frames.

An AP that fails to receive an acknowledgment after the AP transmits a frame with the More Data subfield set to 0 to a non-AP VHT STA that is in TXOP power save mode retransmits the frame within the current TXOP under certain conditions as described in 11.2.3.17.

A CMMG AP that fails to receive an acknowledgment after the AP transmits a frame with the More Data field set to 0 to a non-AP CMMG STA in CMMG TXOP power save mode may retransmit the frame within the current TXOP under certain conditions as described in 11.2.3.19.

10.3.4.5 Control of the channel

The SIFS is used to provide an efficient MSDU delivery mechanism. Once the STA has contended for the channel, that STA shall continue to send fragments until either all fragments of a single MSDU or MMPDU have been sent or an acknowledgment is not received. Should the sending of the fragments be interrupted due to one of these reasons, when the next opportunity for transmission occurs the STA shall resume transmission. The algorithm by which the STA decides which of the outstanding MSDUs shall next be attempted after an unsuccessful transmission (as defined in 10.3.4.3) attempt is beyond the scope of this standard, but any such algorithm shall comply with the restrictions listed in 10.7.

Figure 10-20 illustrates the transmission of a fragmented MSDU using the SIFS.

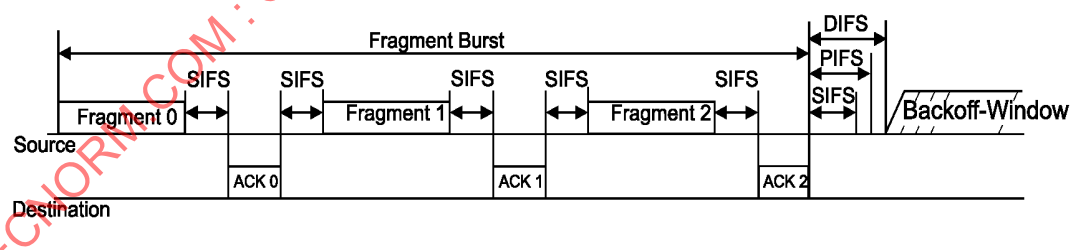

Figure 10-20—Transmission of a fragmented MSDU using SIFS

When the source STA transmits a fragment, it shall release the channel, then immediately monitor the channel for an acknowledgment as described in 10.3.2.11.

[28] This duplicate MSDU is filtered at the receiving STA using the duplicate frame filtering mechanism.

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When the destination STA has finished sending the acknowledgment, the SIFS following the acknowledgment shall be reserved for the source STA to continue (if necessary) with another fragment. The STA sending the acknowledgment shall not transmit on the channel immediately following the acknowledgment.

The process of sending multiple fragments after contending for the channel is defined as a fragment burst.

If the source STA does not receive an acknowledgment frame, it shall attempt to retransmit the failed MPDU or another eligible MPDU, as defined in 10.7, after performing the backoff procedure and the contention process.

After a STA contends for the channel to retransmit a fragment of an MSDU, it shall start with the last fragment that was not acknowledged. The destination STA shall receive the fragments in order (because the source sends them in order and they are individually acknowledged). It is possible, however, that the destination STA may receive duplicate fragments. It shall be the responsibility of the receiving STA to detect and discard duplicate fragments.

A STA shall transmit after the SIFS only under the following conditions during a fragment burst:

— The STA has just received a fragment that requires immediate acknowledgment.
— The source STA has received an acknowledgment for a previous fragment and has more fragment(s) for the same MSDU to transmit.

The following rules shall also apply:

— When a STA has transmitted a frame other than an initial or intermediate fragment, that STA shall not transmit on the channel following the acknowledgment for that frame, without performing the backoff procedure.
— When an MSDU has been successfully delivered or all retransmission attempts have been exhausted, and the STA has a subsequent MSDU to transmit, then that STA shall perform a backoff procedure.

10.3.5 Individually addressed MPDU transfer procedure

A STA shall use an RTS/CTS preceding a frame exchange including an individually addressed Data or Management frame when the length of the PSDU is greater than the length threshold indicated by dot11RTSThreshold. A STA may also use an RTS/CTS exchange for individually addressed frames when it is necessary to distribute the NAV, or when it is necessary to establish protection (see 10.27), or for other purposes.

NOTE 1—If dot11RTSThreshold is 0, an RTS/CTS exchange precedes all frame exchanges including an individually addressed Data or Management frame.

When an RTS/CTS exchange is used, the PPDU containing the PSDU shall be transmitted starting one SIFS after the end of the CTS frame.

NOTE 2—No regard is given to the busy or idle status of the medium when transmitting this PSDU.

When an RTS/CTS exchange is not used, the PSDU shall be transmitted following the success of the basic access procedure. With or without the use of the RTS/CTS exchange procedure, the STA that is the destination of a Data frame shall follow the acknowledgment procedure.

10.3.6 Group addressed MPDU transfer procedure

When a STA transmits group addressed MPDUs in which the To DS subfield is 0, the STA shall use the basic access procedure, unless these MPDUs are delivered using the group addressed transmission service (GATS). When GATS is not used to deliver group addressed MPDUs, the STA shall not use an RTS/(NDP) CTS or

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RTS/DMG CTS exchange, regardless of the length of the frame. In addition, no recipient of the frame shall transmit an Ack frame. A STA that transmits a group addressed MPDU in which the To DS subfield is 1 shall, in addition to complying with the basic access procedure of CSMA/CA, obey the rules for RTS/CTS exchange and the acknowledgment procedure because the MPDU is directed to the AP. For DMG STAs, the MPDU transmission shall also comply with the access procedures defined in 10.39.

There is no MAC-level recovery on group addressed frames, except for the following:

— Frames in which the To DS subfield is 1
— Group addressed frames transmitted via the GATS

As a result, the reliability of this traffic is reduced, relative to the reliability of individually addressed traffic, due to the increased probability of lost frames from interference, collisions, or time-varying channel properties.

A DMG STA may transmit a copy of the same group addressed MPDU using different antenna configurations. This might be needed to provide a quasi-omni coverage or to enable transmission by an MCS that is higher than MCS 0. If multiple copies of a group addressed MPDU with a To DS subfield equal to 0 are transmitted, the STA shall not transmit a different frame before the completion of the transmission of all copies of the group addressed MPDU.

NOTE—The following paragraph addresses the Dual CTS protection mechanism. The use of the Dual CTS protection mechanism is obsolete.

An STBC-capable STA shall discard either all received group addressed Data frames that are STBC frames or all received group addressed Data frames that are non-STBC frames. How it makes this decision is outside the scope of this standard.

A STA that is not an S1G relay STA shall discard an MPDU with a group address in the Address 1 field unless one of the following cases applies: (1) the value in the Address 1 field matches any value in the dot11GroupAddressesTable or matches the broadcast address value, or (2) the STA is a GLK STA and the address in the Address 1 field is a SYNRA. A GLK STA shall process an MPDU with a SYNRA in the Address 1 field as described in 10.66. If an MPDU originates from an S1G relay STA's associated AP and if the MPDU has any group address in its Address 1 field, then the STA shall forward that MPDU to the S1G relay AP.

10.3.7 DCF timing relations

The IFSs are periods of time on the medium. The attributes of the IFSs are determined by the specific PHY (see Figure 10-21). The IFSs apply to transmission under EDCA, too (see Figure 10-25).

All medium timings that are referenced from the end of the transmission are referenced from the end of the last symbol, or signal extension if present, of the PPDU. The beginning of transmission refers to the first symbol of the preamble of the next PPDU. All MAC timings are referenced from the PHY-TXEND.confirm, PHY-TXSTART.confirm, PHY-RXSTART.indication, and PHY-RXEND.indication primitives.

aSIFSTime and aSlotTime are determined per PHY, aSIFSTime is fixed, and aSlotTime can change dynamically as aAirPropagationTime changes (see 10.22.5).

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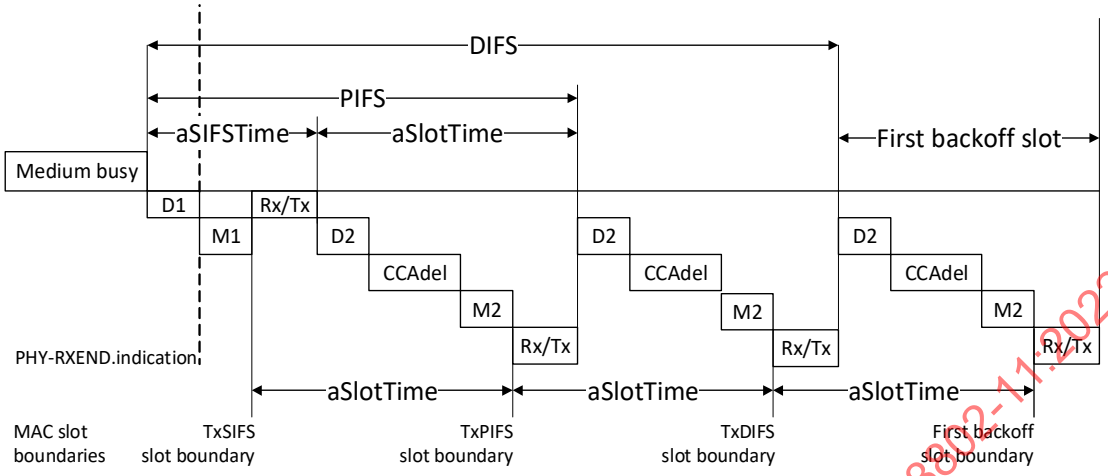

D1 = aRxPHYDelay (referenced from the end of the last symbol of a PPDU on the medium)
D2 = D1 + aAirPropagationTime
Rx/Tx = aRxTxTurnaroundTime (begins with a PHY-TXSTART.request)
M1 = M2 = aMACProcessingDelay
CCAdel = aCCATime – D1

Figure 10-21—DCF timing relationships

The STA may employ any non-negative value for each of the parameters:

- aRxPHYDelay
- aMACProcessingDelay
- aTxPHYDelay
- aTxRampOnTime
- aCCATime
- aRxTxSwitchTime

provided that the constraints in Equation (10-2), Equation (10-3), and Equation (10-4) are met, and provided that the CCA sensitivity specification for the attached PHY is met (see 15.4.6.5, 16.3.8.5, 17.3.10.6, 18.4.6, 19.3.19.5, 20.4.4.2.2, 20.5.4.2.2, 21.3.18.5, and 22.3.18.6).

$$aSIFSTime = aRxPHYDelay + aMACProcessingDelay + aRxTxTurnaroundTime \quad (10\text{-}2)$$

$$aSlotTime = aCCATime + aMACProcessingDelay + aRxTxTurnaroundTime + aAirPropagationTime \quad (10\text{-}3)$$

$$aRxTxTurnaroundTime = aTxPHYDelay + aRxTxSwitchTime + aTxRampOnTime \quad (10\text{-}4)$$

where

aAirPropagationTime is determined as described in 10.22.5

aSlotTime, aSIFSTime, and aRxTxTurnaroundTime
are the values indicated in the PLME-CHARACTERISTICS.confirm primitive

the other attribute values are the values implemented

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The PIFS and DIFS are derived by the Equation (10-5) and Equation (10-6), as illustrated in Figure 10-21.

$$PIFS = aSIFSTime + aSlotTime \quad (10\text{-}5)$$

$$DIFS = aSIFSTime + 2 \times aSlotTime \quad (10\text{-}6)$$

In a non-S1G STA, when dot11DynamicEIFSActivated is false or not defined, the EIFS is derived from the SIFS and the DIFS and the length of time it takes to transmit an Ack frame at the lowest PHY mandatory rate or MCS by Equation (10-7).

$$EIFS = aSIFSTime + AckTxTime + DIFS \quad (10\text{-}7)$$

where AckTxTime is the time expressed in microseconds required to transmit an Ack frame, including preamble, PHY header and any additional PHY dependent information, at the lowest PHY mandatory rate or MCS.

In an S1G STA, the EIFS is equal to DIFS if the PPDU that causes the EIFS does not generate a PHY-RXEND.indication(FormatViolation) primitive. Otherwise, the EIFS for the S1G STA is derived by Equation (10-7), where ACKTxTime is equal to NDPTxTime as defined in 10.3.2.5.2.

When dot11DynamicEIFSActivated is true, EIFS is based on an estimated duration of the PPDU that is the possible response to the PPDU that causes the EIFS. The estimation is based on properties of the PHY header of the PPDU that causes the EIFS, such as modulation, rate/MCS, or length.

NOTE 1—If the L-SIG field is used, as it does not have CRC protection, this information might not always be correct.

In a non-DMG and non-S1G STA, when dot11DynamicEIFSActivated is true, if the PPDU that causes the EIFS does not contain a single MPDU with a length equal to 14 or 32 octets, and the modulation of the PPDU that causes the EIFS is included in Table 10-8, then EIFS is determined as shown in Equation (10-8).

$$EIFS = aSIFSTime + EstimatedAckTxTime + DIFS \quad (10\text{-}8)$$

where EstimatedAckTxTime is based on an estimated duration of the PPDU that is the possible response to the PPDU that causes the EIFS, as specified in Table 10-8.

Table 10-8—Determination of the EstimatedAckTxTime based on properties of the PPDU causing the EIFS

Modulation of PPDU causing EIFS	Rate/MCS of PPDU causing EIFS	Other properties of PPDU causing EIFS	Presumed response	Presumed response rate	EstimatedAckTxTime (μs)
(HR-)DSSS	1 Mb/s		Ack	1 Mb/s	304
(HR-)DSSS	≥ 2 Mb/s (long preamble)		Ack	2 Mb/s	248
(HR-)DSSS	≥ 2 Mb/s (short preamble)		Ack	2 Mb/s	152
(ERP-)OFDM	BPSK		Ack	6 Mb/s	44
(ERP-)OFDM	QPSK		Ack	12 Mb/s	32
(ERP-)OFDM	≥16-QAM		Ack	24 Mb/s	28
HT	BPSK	Aggregation = 0	Ack	6 Mb/s	44

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Table 10-8—Determination of the EstimatedAckTxTime based on properties of the PPDU causing the EIFS *(continued)*

Modulation of PPDU causing EIFS	Rate/MCS of PPDU causing EIFS	Other properties of PPDU causing EIFS	Presumed response	Presumed response rate	EstimatedAck TxTime (μs)
HT	QPSK	Aggregation = 0	Ack	12 Mb/s	32
HT	≥16-QAM	Aggregation = 0	Ack	24 Mb/s	28
HT	BPSK	Aggregation = 1	BlockAck	6 Mb/s	68
HT	QPSK	Aggregation = 1	BlockAck	12 Mb/s	44
HT	≥16-QAM	Aggregation = 1	BlockAck	24 Mb/s	32
VHT	BPSK		BlockAck		68
VHT	QPSK		BlockAck		44
VHT	≥16-QAM		BlockAck		32

When dot11DynamicEIFSActivated is true and the PPDU that causes the EIFS contains a single MPDU with a length equal to 14 or 32 octets, EIFS is equal to DIFS. This reflects the fact that a 14-octet or 32-octet MPDU is very likely an Ack or a BlockAck frame, which does not cause a response PPDU to be transmitted.

When dot11DynamicEIFSActivated is true and the modulation of the PPDU that causes the EIFS does not occur in Table 10-8, then EIFS is determined as shown in Equation (10-7).

Figure 10-21 illustrates the relation between the SIFS, PIFS, and DIFS as they are measured on the medium and the different MAC slot boundaries TxSIFS, TxPIFS, and TxDIFS. These slot boundaries define when the transmitter shall be turned on by the MAC to meet the different IFS timings on the medium, after subsequent detection of the CCA result of the previous slot time.

Equation (10-9), Equation (10-10), and Equation (10-11) define the MAC slot boundaries using attributes provided by the PHY, which are such that they compensate for implementation timing variations. The starting reference of these slot boundaries is again the end of the last symbol of the previous PPDU.

$$\text{TxSIFS} = \text{SIFS} - \text{aRxTxTurnaroundTime} \quad (10\text{-}9)$$

$$\text{TxPIFS} = \text{TxSIFS} + \text{aSlotTime} \quad (10\text{-}10)$$

$$\text{TxDIFS} = \text{TxSIFS} + 2 \times \text{aSlotTime} \quad (10\text{-}11)$$

NOTE 2—The tolerance for SIFS is defined in 10.3.2.3.3.

10.3.8 Signal extension

Transmissions of PSDUs with the TXVECTOR parameter FORMAT of type NON_HT with NON_HT_MODULATION values of ERP-OFDM and NON_HT_DUP_OFDM and transmissions of frames with the TXVECTOR parameter FORMAT with values of HT_MF and HT_GF include a period of no transmission of duration aSignalExtension, except for RIFS transmissions. The purpose of this signal extension is to enable the NAV value of Clause 16 STAs to be set correctly.

When an HT STA transmits a PPDU using a RIFS and with the TXVECTOR parameter FORMAT equal to NON_HT with the NON_HT_MODULATION parameter equal to one of ERP-OFDM and

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NON_HT_DUP_OFDM or a PPDU using a RIFS and with the TXVECTOR parameter FORMAT equal to HT_MF or HT_GF, it shall set the TXVECTOR parameter NO_SIG_EXTN to true. Otherwise, it shall set the TXVECTOR parameter NO_SIG_EXTN to false.

10.3.9 Determination of PLME aCWmin characteristics

In the case of the Clause 18 ERP, the aCWmin value is dependent on the requester's characteristic rate set. The characteristic rate set is equal to the IBSS's basic rate set when the STA is an IBSS STA. It is equal to the AP's operational rate set when the STA is associated with an AP. At all other times, it is equal to the STA's mandatory rate set.

If the PHY characteristic aCWmin is a vector, then the MAC variable aCWmin is set to the PHY characteristic aCWmin(0) if the characteristic rate set includes only rates in the set 1, 2, 5.5, 11 and to aCWmin(1) otherwise. If the PHY characteristic aCWmin is a scalar, then the MAC variable aCWmin is set to the PHY characteristic aCWmin.

NOTE—The MAC variable aCWmin is distinct from the PHY characteristic aCWmin. Outside this subclause, the MAC uses the MAC variable aCWmin whenever the value of aCWmin is required.

10.4 MSDU and MMPDU fragmentation

The MAC may fragment and reassemble MSDUs or MMPDUs that are carried in individually addressed MPDUs. The fragmentation and defragmentation mechanisms allow for fragment retransmission.

The length of each fragment shall be an equal number of octets for all fragments except the last, which may be smaller. The length of each fragment shall be an even number of octets, except for the last fragment of an MSDU or MMPDU, which may be either an even or an odd number of octets. The length of a fragment shall never be larger than dot11FragmentationThreshold unless security encapsulation is invoked for the MPDU. If security encapsulation is active for the MPDU, then the MPDU shall be expanded by the encapsulation overhead and this may result in a fragment larger than dot11FragmentationThreshold.

A fragment is an MPDU, the Frame Body field of which carries only a portion of an MSDU or MMPDU. When data are to be transmitted, the number of octets in the fragment (before processing by the security mechanism) shall be limited by dot11FragmentationThreshold and the number of octets in the MPDU that have yet to be assigned to a fragment at the instant the fragment is constructed for the first time. Once a fragment is transmitted for the first time, its frame body content and length shall be fixed until it is successfully delivered to the immediate receiving STA.

A STA shall be capable of receiving MPDUs, containing all or part of an MSDU, of arbitrary length that is less than or equal to the maximum MSDU size as defined in 9.2.4.7, plus any security encapsulation overhead, plus MAC header and FCS.

A STA shall be capable of receiving MPDUs, containing all or part of an MMPDU, of arbitrary length that is less than or equal to the minimum of

- The maximum MMPDU size as defined in 9.3.3.1, plus any security encapsulation overhead, plus MAC header and FCS
- Any maximum MPDU length advertised by the STA

If a fragment requires retransmission, its frame body content and length shall remain fixed for the lifetime of the MSDU or MMPDU at that STA. Each fragment contains a Sequence Control field, which comprises a sequence number and fragment number. When a STA is transmitting a fragmented MSDU or MMPDU, the sequence number shall remain the same for all fragments of that MSDU or MMPDU. The fragments shall be sent in order of lowest fragment number to highest fragment number, where the fragment number value starts

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at 0, and increases by 1 for each successive fragment. The Frame Control field also contains a bit, the More Fragments bit, that is equal to 0 to indicate the last fragment of the MSDU or MMPDU (or that the MSDU or MMPDU was not fragmented, if the Fragment Number subfield is also equal to 0).

The source STA shall maintain a transmit MSDU/MMPDU timer for each MSDU/MMPDU being transmitted. The attribute dot11MaxTransmitMSDULifetime specifies the maximum amount of time allowed to transmit an MSDU/MMPDU. The timer starts on the initial attempt to transmit the MSDU/MMPDU, or first fragment of the MSDU/MMPDU if the MSDU/MMPDU is fragmented. If the timer exceeds dot11MaxTransmitMSDULifetime, then any remaining fragments are discarded by the source STA and no attempt is made to complete transmission of the MSDU/MMPDU.

NOTE—A STA might interleave fragments of MSDUs with different TIDs sent to the same receiver, subject to any constraint caused by the number of replay counters.

10.5 MSDU and MMPDU defragmentation

Each fragment contains information to allow the complete MSDU or MMPDU to be reassembled from its constituent fragments. The header of each fragment contains the following information that is used by the destination STA to reassemble the MSDU or MMPDU:

- Frame type
- Address of the sender, obtained from the Address 2 field
- Destination address
- *Sequence Control field:* This field allows the destination STA to check that all incoming fragments belong to the same MSDU or MMPDU, and the sequence in which the fragments should be reassembled. The sequence number within the Sequence Control field remains the same for all fragments of an MSDU or MMPDU, while the fragment number within the Sequence Control field increments for each fragment.
- Traffic identifier, for frames with a QoS Control field.
- *More Fragments indicator:* Indicates to the destination STA that this is not the last fragment of a fragmented MSDU or MMPDU. Only the last fragment of a fragmented MSDU or MMPDU shall have this bit set to 0. All other fragments of a fragmented MSDU or MMPDU shall have this bit set to 1.

The destination STA shall reconstruct the MSDU or MMPDU by combining the fragments in order of fragment number subfield of the Sequence Control field. If security encapsulation has been applied to the fragment, it shall be decapsulated and decrypted before the fragment is used for defragmentation of the MSDU or MMPDU. If the fragment with the More Fragments bit equal to 0 has not yet been received, then the destination STA knows that the MSDU or MMPDU is not yet complete. As soon as the STA receives the fragment with the More Fragments bit equal to 0, the STA knows that no more fragments will be received for the MSDU or MMPDU.

A STA shall support the concurrent reception of fragments of at least three MSDUs or MMPDUs. A STA should support the concurrent reception of fragments of at least one MSDU per access category. An AP should support the concurrent reception of at least one MSDU per access category per associated STA. Note that a STA receiving more than three fragmented MSDUs or MMPDUs concurrently might experience a significant increase in the number of frames discarded.

NOTE—The three MSDUs or MMPDUs might be from different peers (e.g., in an IBSS or MBSS).

The destination STA shall maintain a Receive Timer for each MSDU or MMPDU being received, for a minimum of three MSDUs or MMPDUs. The STA may implement additional timers to be able to receive additional concurrent MSDUs or MMPDUs. The receiving STA shall discard all fragments that are part of an

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MSDU or MMPDU for which a timer is not maintained. There is also dot11MaxReceiveLifetime, that specifies the maximum amount of time allowed to receive an MSDU. The receive timer starts on the reception of the first fragment of a fragmented MSDU or MMPDU. If the receive timer exceeds dot11MaxReceiveLifetime, then all received fragments of this MSDU or MMPDU shall be discarded by the destination STA. If additional fragments of this MSDU or MMPDU are subsequently received, those fragments shall be acknowledged and discarded.

To properly reassemble MPDUs into an MSDU or MMPDU, a destination STA shall discard any duplicated fragments received. A STA shall discard duplicate fragments as described in 10.3.2.14. However, a duplicate fragment of an individually addressed MSDU or MMPDU shall be acknowledged.

10.6 Multirate support

10.6.1 Overview

Some PHYs have multiple data transfer rate capabilities that allow implementations to perform dynamic rate switching with the objective of improving performance. The algorithm for performing rate switching is beyond the scope of this standard, but in order to provide coexistence and interoperability of multirate-capable PHYs, this standard defines a set of rules to be followed by all STAs.

Only the data transfer rates of the mandatory rate set of the attached PHY are guaranteed to be supported when a STA for which dot11OCBActivated is true transmits a Management or Data frame. A higher layer protocol entity within a STA in which dot11OCBActivated is true might negotiate a rate outside the mandatory rate set.

A STA that transmits a frame shall select a rate defined by the rules for determining the rates of transmission of protection frames in 10.27 when the following conditions apply:

— The STA's protection mechanism for non-ERP receivers is enabled.
— The frame is a protection mechanism frame.
— The frame initiates an exchange.

Otherwise, a non-DMG and non-CMMG STA shall transmit the frame using a rate that is in accordance with rules defined in 10.6.5 and 10.6.6. A DMG STA shall transmit the frame using a rate that is in accordance with rules defined in 10.6.7. A CMMG STA shall transmit the frame using a rate that is in accordance with rules defined in 10.6.8.

For specific PHYs, the value of the Duration/ID field is determined using the PLME-TXTIME.request primitive and the PLME-TXTIME.confirm primitive. These specific PHYs are defined in:

— Clause 16 for HR/DSSS
— Clause 17 for OFDM
— Clause 18 for ERP
— Clause 19 for HT
— Clause 20 for DMG
— Clause 21 for VHT
— Clause 22 for TVHT
— Clause 24 for CDMG
— Clause 25 for CMMG

The two PLME-TXTIME primitives are defined in the respective PHY specifications:

— 16.3.4 for HR TXTIME calculation
— 17.4.3 for OFDM TXTIME calculation

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— 18.5.3.2 for ERP-OFDM TXTIME calculation
— 19.4.3 for HT TXTIME calculation
— 20.11.3 for DMG PLME TXTIME calculation
— 21.4.3 for VHT PLME TXTIME calculation
— 22.4.3 for TVHT PLME TXTIME calculation
— 25.14.3 for CMMG PLME TXTIME calculation

The Duration/ID field in a frame transmitted by a QoS STA may cover multiple frames and might involve using the PLME-TXTIME.request primitive several times.

10.6.2 Basic HT-MCS Set field

An AP that transmits a frame containing an HT Operation element with either the Dual Beacon field or the Dual CTS Protection field equal to 1 shall include at least one MCS that has only one spatial stream in the Basic HT-MCS Set field of the HT Operation element of that frame.

10.6.3 Basic STBC MCS

The basic STBC MCS has the value null when any of the following conditions is true:

— The Dual Beacon field in the HT Operation element is equal to 0, and the Dual CTS Protection field in the HT Operation element is equal to 0.
— No HT Operation element is present in the Association Response frame received from the current AP.
— The Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive is empty or does not exist.
— The lowest MCS of the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive has NSS value greater than 1 (the mapping of MCS to NSS is PHY dependent, for the HT PHY see 19.5).

If none of the above conditions is true, then the basic STBC MCS is the lowest MCS index of the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive.

When an MCS from the basic STBC MCS is required in 10.6.5 and 10.6.6 but the basic STBC MCS has the value null, the STA shall select a mandatory MCS of the attached PHY.

10.6.4 Basic rate set, basic HT-MCS set, and basic VHT-MCS and NSS set for mesh STA

A mesh STA shall not establish a mesh peering with a mesh STA using a different BSSBasicRateSet (see 14.2.7 and 14.2.8).

The SME of a Mesh STA should use the mandatory PHY rates as the default BSSBasicRateSet in the MLME-START.request primitive to reduce the risk that a candidate peer mesh STA utilizes a different BSSBasicRateSet. If the mesh STA is also an HT STA, it should adopt the mandatory HT-MCSs as the default basic HT-MCS set. If the mesh STA is also a VHT STA, it should adopt <VHT-MCS, NSS> tuples formed from the mandatory VHT-MCSs and NSS = 1 as the default basic VHT-MCS and NSS set (see 11.38.7).

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10.6.5 Rate selection for Data and Management frames

10.6.5.1 Rate selection for non-STBC Beacon and non-STBC PSMP frames

In an S1G STA, non-STBC S1G Beacon frames shall be transmitted in an S1G 1 MHz PPDU, an S1G 2 MHz PPDU with short preamble, an S1G 1 MHz duplicate PPDU, or an S1G 2 MHz duplicate PPDU with short preamble using one of the mandatory PHY rates.

If the BSSBasicRateSet parameter is not empty, a non-STBC PSMP frame or a non-STBC Beacon frame shall be transmitted in a non-HT PPDU using one of the rates included in the BSSBasicRateSet parameter.

If the BSSBasicRateSet parameter is empty, the frame shall be transmitted in a non-HT PPDU using one of the mandatory PHY rates.

10.6.5.2 Rate selection for STBC group addressed Data and Management frames

When a STA has dot11TxSTBCOptionActivated true, it shall use the basic STBC MCS when it transmits an STBC Beacon frame or when it transmits a group addressed Data or Management frame that is an STBC frame.

10.6.5.3 Rate selection for other group addressed Data and Management frames

This subclause describes the rate selection rules for group addressed Data and Management frames, excluding the following:

— Non-STBC Beacon and non-STBC PSMP frames
— STBC group addressed Data and Management frames
— Data frames located in an FMS stream (see 11.21.8)
— Group addressed frames transmitted to the GCR concealment address (see 11.21.16.3.5)

If the BSSBasicRateSet parameter is not empty, a Data or Management frame (excluding the frames listed above) with a group address in the Address 1 field shall be transmitted in a non-HT PPDU using one of the rates included in the BSSBasicRateSet parameter or the rate chosen by the AP, described in 11.21.8, if the Data frames are part of an FMS stream.

If the BSSBasicRateSet parameter is empty and the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive is not empty, the frame shall be transmitted in an HT PPDU using one of the MCSs included in the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive.

If the BSSBasicRateSet parameter is empty and the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive is empty and the basic VHT-MCS and NSS set is not empty, the frame shall be transmitted in a VHT PPDU using one of the <VHT-MCS. NSS> tuples included in the basic VHT-MCS and NSS set.

In a non-S1G STA, if the BSSBasicRateSet parameter, the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive, and the basic VHT-MCS and NSS set are empty (e.g., a scanning STA that is not yet associated with a BSS), the frame shall be transmitted in a non-HT PPDU using one of the mandatory PHY rates.

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In an S1G STA, if the BSSBasicS1GMCS_NSSSet parameter is empty (e.g., a scanning STA that is not yet associated with a BSS), the frame shall be transmitted in an S1G PPDU using one of the mandatory PHY rates.

If the BSSBasicS1GMCS_NSSSet is not empty, the frame shall be transmitted in an S1G PPDU using an MCS and NSS from one of the <S1G-MCS, NSS> tuples included in the BSSBasicS1GMCS_NSSSet parameter.

10.6.5.4 Rate selection for polling frames

A Data frame of a subtype that includes CF-Poll that does not also include CF-Ack shall be transmitted at a rate selected as follows:

a) If an initial exchange has already established protection and the Duration/ID field in the frame establishing protection covers the entire TXOP, the rate or MCS is selected according to the rules in 10.6.5.7.

b) Otherwise, the Data frame shall be transmitted at a rate or MCS as defined in 10.6.5.3, treating the frame as though it has a group address in the Address 1 field, solely for the purpose of determining the appropriate rate or MCS.

10.6.5.5 Rate selection for +CF-Ack frames

For a frame of type Data +CF-Ack, Data +CF-Poll+CF-Ack, or CF-Poll +CF-Ack, the rate or MCS and TXVECTOR parameter CH_BANDWIDTH used to transmit the frame shall be chosen from among those supported by both the addressed recipient STA and the STA to which the Ack frame is intended.

10.6.5.6 Rate selection for Data frames sent within an FMS stream

Data frames sent within an FMS stream are sent at a rate negotiated during the establishment of the FMS stream. See 11.21.8.

10.6.5.7 Rate selection for other individually addressed Data and Management frames

A Data or Management frame not identified in 10.6.5.1 to 10.6.5.6 shall be sent using any data rate, MCS, <VHT-MCS, NSS> tuple, or <S1G-MCS, NSS> tuple subject to the following constraints:

— A STA shall not transmit a frame using a rate or MCS that is not supported by the receiver STA, as reported in any Supported Rates and BSS Membership Selectors element, Extended Supported Rates and BSS Membership Selectors element, or Supported MCS Set field in Management frames transmitted by the receiver STA.

— A STA shall not transmit a frame using a <VHT-MCS, NSS> tuple that is not supported by the receiver STA, as reported in any Supported VHT-MCS and NSS Set field in Management frames transmitted by the receiver STA.

— A STA shall not transmit a frame using a <S1G-MCS, NSS> tuple that is not supported by the receiver STA, as reported in any Supported S1G-MCS and NSS Set field in Management frames transmitted by the receiver STA.

— If at least one Operating Mode field with the Rx NSS Type subfield equal to 0 was received from the receiver STA:

  — A STA shall not transmit a frame with the number of spatial streams greater than that indicated in the Rx NSS subfield in the most recently received Operating Mode field with the Rx NSS Type subfield equal to 0 from the receiver STA.

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- If at least one Operating Mode field with the Rx NSS Type subfield equal to 1 was received from the receiver STA:
  - A STA shall not transmit an SU PPDU frame using a beamforming steering matrix with the number of spatial streams greater than that indicated in the Rx NSS subfield in the most recently received Operating Mode field with the Rx NSS Type subfield equal to 1 from the receiver STA if the beamforming steering matrix was derived from a VHT Compressed Beamforming report with Feedback Type subfield indicating MU in the VHT Compressed Beamforming frame(s).
- A STA shall not transmit a frame using a value for the CH_BANDWIDTH parameter of the TXVECTOR that is not supported by the receiver STA, as reported in any HT Capabilities element, VHT Capabilities element, or S1G Capabilities element received from the intended receiver.
- An HT STA that is a member of a BSS and that is not a VHT STA shall not transmit a frame using a value for the CH_BANDWIDTH parameter of the TXVECTOR that is not permitted for use in the BSS, as reported in the most recently received HT Operation element, with the exception of transmissions on an off-channel TDLS direct link, which follow the rules described in 11.20.6.2 and 11.20.6.3.
- A VHT STA that is a member of a BSS shall not transmit a frame using a value for the CH_BANDWIDTH parameter of the TXVECTOR that is not permitted for use in the BSS, as reported in the most recently received VHT Operation element with the following exceptions:
  - Transmissions on an off-channel TDLS direct link follow the rules described in 11.20.6.2 and 11.20.6.3.
  - Transmissions by a VHT STA on a TDLS link follow the rules described in 11.20.1 and 11.20.6.5.
- An S1G STA that is a member of a BSS shall not transmit a frame using a value for the CH_BANDWIDTH parameter of the TXVECTOR that is not permitted for use in the BSS, as reported in the most recently received S1G Operation element with the following exceptions:
  - Transmissions on a TDLS off-channel link follow the rules described in 11.20.6.2 and 11.20.6.3.
  - Transmissions by an S1G STA on a TDLS link follow the rules described in 11.20.1 and 11.20.6.5.

  Additionally, the value of the CH_BANDWIDTH parameter for a transmission by an S1G STA that is operating as an SST STA is limited by the Maximum permitted PPDU bandwidth as indicated in the Maximum Transmission Width field of the most recently received SST element or RPS element (see 10.52 and 10.23.5.
- If at least one Operating Mode field with the Rx NSS Type subfield equal to 0 was received from the receiver STA:
  - A STA shall not transmit a frame using a value for the TXVECTOR parameter CH_BANDWIDTH that is not supported by the receiver STA as reported in the most recently received Operating Mode field with the Rx NSS Type subfield equal to 0 from the receiver STA.

When the operational rate set of the receiving STA or STAs is not known, the transmitting STA shall transmit using a rate in the BSSBasicRateSet parameter, or an MCS in the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive, or a <VHT-MCS, NSS> tuple in the basic VHT-MCS and NSS set, or an <S1G-MCS, NSS> tuple in the BSSBasicS1GMCS_NSSSet parameter, or a rate from the mandatory rate set of the attached PHY if the BSSBasicRateSet, the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive, and the basic VHT-MCS and NSS set, and the BSSBasicS1GMCS_NSSSet are empty.

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The rules in this subclause also apply to A-MPDUs that aggregate MPDUs with the Type subfield equal to Data or Management with any other types of MPDU.

10.6.6 Rate selection for Control frames

10.6.6.1 General rules for rate selection for Control frames

Control frames carried in an A-MPDU that does not contain an S-MPDU shall be sent at a rate selected from the rules defined in 10.6.5.7.

NOTE—The rules defined in 10.6.6.2 to 10.6.6.5 apply only to Control frames not carried in an A-MPDU that does not contain an S-MPDU.

A Control frame shall be carried in an S1G PPDU with NSS equal to 1 without using long preamble, short GI, LDPC coding, STBC format, and traveling pilots when the Control frame is transmitted by an S1G STA.

The following rules determine whether a Control frame is carried in a non-HT, HT or VHT PPDU:

a) A control response frame shall be carried in an HT PPDU when the Control frame is a response to a frame that meets any of the following conditions:
   1) The frame eliciting the response included an HT variant HT Control field with the TRQ field equal to 1 and the HT NDP Announcement subfield equal to 0, and this responder set the Implicit Transmit Beamforming Receiving Capable field to 1 in its last transmitted HT Capabilities element; or
   2) The frame eliciting the response was an RTS frame carried in an HT PPDU; or
   3) The frame eliciting the response was an STBC frame, and the Dual CTS Protection field was equal to 1 in the last HT Operation element received from its AP or transmitted by the STA (see 10.3.2.10).

b) A Control frame may be carried in an HT PPDU when the Control frame meets any of the following conditions:
   1) The Control frame contains an HT variant HT Control field with the MRQ subfield equal to 1, or
   2) The Control frame contains an HT variant HT Control field with the TRQ field equal to 1.

c) A Control frame may be carried in a VHT PPDU when the Control frame contains an HT Control field.

d) A Control frame shall be carried in an HT PPDU or a VHT PPDU when the Control frame is sent using an STBC frame.

e) A control response frame shall be carried in a VHT PPDU if the eliciting frame was an RTS frame carried in a VHT PPDU that contains an HT Control field with MRQ subfield equal to 1.

Otherwise, the Control frame shall be carried in a non-HT PPDU. The requirements specified in 10.31, 10.32.2, and 10.34 further constrain the choice of non-HT, HT, or VHT PPDU.

If an Operating Mode field has been received from the intended receiver STA, the following constraints also apply:

— If at least one Operating Mode field with the Rx NSS Type subfield equal to 0 was received from the receiver STA:
  — A STA shall not transmit a frame with the number of spatial streams greater than that indicated in the Rx NSS subfield in the most recently received Operating Mode field with the Rx NSS Type subfield equal to 0 from the receiver STA.

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— If at least one Operating Mode field with the Rx NSS Type subfield equal to 1 was received from the receiver STA:
  — A STA shall not transmit an SU PPDU frame using a beamforming steering matrix with the number of spatial streams greater than that indicated in the Rx NSS subfield in the most recently received Operating Mode field with the Rx NSS Type subfield equal to 1 from the receiver STA if the beamforming steering matrix was derived from a VHT Compressed Beamforming report with Feedback Type subfield indicating MU in the VHT Compressed Beamforming frame(s).

Selection of channel width is defined in 10.6.6.6.

A control response frame is a Control frame that is transmitted as a response to the reception of a frame a SIFS after the PPDU containing the frame that elicited the response, e.g., a CTS frame in response to an RTS frame reception, an Ack frame in response to a Data frame reception, a BlockAck frame in response to a BlockAckReq frame reception. In some situations, the transmission of a Control frame is not a control response transmission, such as when a CTS frame is used to initiate a TXOP.

10.6.6.2 Rate selection for Control frames that initiate a TXOP

This subclause describes the rate selection rules for Control frames that initiate a TXOP and that are either an S-MPDU or not carried in an A-MPDU.

If a Control frame is carried in a non-HT PPDU, the transmitting STA shall transmit the frame using one of the rates in the BSSBasicRateSet parameter or a rate from the mandatory rate set of the attached PHY if the BSSBasicRateSet is empty.

NOTE—Because of their utility in resolving contention and in establishing a NAV, most control subtype frames that initiate a frame exchange are subject to explicit limitations regarding the choice of transmission rate with the intent of ensuring maximum possible coverage and receivability of the frame.

An HT STA shall select an MCS from the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive when protection is required (as defined in 10.27) and shall select an MCS from the SupportedMCSSet parameter of the intended receiver when protection is not required.

When transmitting a VHT PPDU, a STA shall select a <VHT-MCS, NSS> tuple from the basic VHT-MCS and NSS set when protection is required (as defined in 10.27) and shall select a <VHT-MCS, NSS> tuple from the operational VHT-MCS and NSS set parameter of the intended receiver when protection is not required.

10.6.6.3 Rate selection for CF-End frames

A STA that transmits a CF-End frame that is not at the end of a TXOP that was obtained through the use of the dual CTS mechanism shall transmit the frame using a rate in BSSBasicRateSet or from the mandatory rate set of the attached PHY if the BSSBasicRateSet is empty.

A STA that transmits a CF-End frame at the end of a TXOP that was obtained by a non-AP STA through the use of the dual CTS mechanism shall transmit the CF-End frame with the same value for the TXVECTOR parameter STBC, TXVECTOR parameter MCS (if present), and TXVECTOR parameter RATE as was used for the transmission of the matching Control frame at the beginning of the TXOP. The matching Control frame is defined as follows:

— For the first CF-End frame transmitted in the TXOP, the matching Control frame is the first RTS frame transmitted in the TXOP.
— For the second CF-End frame transmitted in the TXOP, the matching Control frame is the first CTS frame that follows the first RTS frame transmitted in the TXOP.

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— For the third CF-End frame transmitted in the TXOP, the matching Control frame is the second CTS frame that follows the first RTS frame transmitted in the TXOP.

A STA that transmits a CF-End frame at the end of a TXOP that was obtained by an AP through the use of the dual CTS mechanism shall transmit the CF-End frame with the same value for the TXVECTOR parameter STBC, TXVECTOR parameter MCS (if present), and TXVECTOR parameter RATE as was used for the transmission of the matching Control frame at the beginning of the TXOP. The matching Control frame is defined as follows:

— For the first CF-End frame transmitted in the TXOP, the matching Control frame is the first CTS-to-self frame transmitted in the TXOP.
— For the second CF-End frame transmitted in the TXOP, the matching Control frame is the first RTS transmitted in the TXOP.

10.6.6.4 Rate selection for Control frames that are not control response frames

This subclause describes the rate selection rules for Control frames that are not control response frames, are not the frame that initiates a TXOP, are not the frame that terminates a TXOP, and are either an S-MPDU or not carried in an A-MPDU.

A frame other than a BlockAckReq or BlockAck that is carried in a non-HT PPDU shall be transmitted by the STA using a rate no higher than the highest rate in the BSSBasicRateSet parameter that is less than or equal to the rate or non-HT reference rate (see 10.6.11) of the previously transmitted frame that was directed to the same receiving STA. If no rate in the BSSBasicRateSet parameter meets these conditions, the Control frame shall be transmitted at a rate no higher than the highest mandatory rate of the attached PHY that is less than or equal to the rate or non-HT reference rate (see 10.6.11) of the previously transmitted frame that was directed to the same receiving STA.

A BlockAckReq or BlockAck frame that is carried in a non-HT PPDU shall be transmitted by the STA using a rate supported by the receiver STA, as reported in the Supported Rates and BSS Membership Selectors element and/or Extended Supported Rates and BSS Membership Selectors element in frames transmitted by that STA. When the operational rate set of the receiving STA or STAs is not known, the transmitting STA shall transmit using a rate from the BSSBasicRateSet parameter or from the mandatory rate set of the attached PHY if the BSSBasicRateSet is empty.

A frame that is carried in an HT PPDU shall be transmitted by the STA using an MCS supported by the receiver STA, as reported in the Supported MCS Set field in the HT Capabilities element received from that STA. When the supported MCS set of the receiving STA or STAs is not known, the transmitting STA shall transmit using an MCS in the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive.

A frame that is carried in a VHT PPDU shall be transmitted by the STA using a <VHT-MCS, NSS> tuple supported by the receiver STA. A <VHT-MCS, NSS> tuple is supported if reported as such in the Supported VHT-MCS and NSS Set field in the VHT Capabilities element received from that STA. When the Supported VHT-MCS and NSS set of the receiving STA or STAs is not known, the transmitting STA shall transmit using a <VHT-MCS, NSS> tuple in the basic VHT-MCS and NSS set.

A frame that is carried in an S1G PPDU shall be transmitted by the STA using a <S1G-MCS, NSS> tuple supported by the receiver STA, as reported in the Supported S1G-MCS and NSS Set field in the S1G Capabilities element received from that STA. When the Supported S1G-MCS for NSS set of the receiving STA or STAs is not known, the transmitting STA shall transmit using a <S1G-MCS, NSS> tuple in the BSSBasicS1GMCS_NSSSet parameter.

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10.6.6.5 Rate selection for control response frames

10.6.6.5.1 Introduction

Subclauses 10.6.6.5.2 to 10.6.6.5.7 describe the rate selection rules for control response frames that are either an S-MPDU or not carried in an A-MPDU.

10.6.6.5.2 Selection of a rate or MCS

To allow the transmitting STA to calculate the contents of the Duration/ID field, a STA responding to a received frame transmits its control response frame at a primary rate, or at an alternate rate, or at an MCS, as specified by the following rules:

— If a CTS or Ack frame is carried in a non-HT PPDU, the primary rate is defined to be the highest rate in the BSSBasicRateSet parameter that is less than or equal to the rate (or non-HT reference rate; see 10.6.11) of the previous frame. If no rate in the BSSBasicRateSet parameter meets these conditions, the primary rate is defined to be the highest mandatory rate of the attached PHY that is less than or equal to the rate (or non-HT reference rate; see 10.6.11) of the previous frame. The STA may select an alternate rate according to the rules in 10.6.6.5.4. The STA shall transmit the non-HT PPDU CTS or Ack frame at either the primary rate or the alternate rate, if one exists.

— If a BlockAck frame is sent as an immediate response to either an Implicit BAR request or to a BlockAckReq frame that was carried in an HT or VHT PPDU and the BlockAck frame is carried in a non-HT PPDU, the primary rate is defined to be the highest rate in the BSSBasicRateSet parameter that is less than or equal to the rate (or non-HT reference rate; see 10.6.11) of the previous frame. If no rate in the BSSBasicRateSet parameter meets these conditions, the primary rate is defined to be the highest mandatory rate of the attached PHY that is less than or equal to the rate (or non-HT reference rate; see 10.6.11) of the previous frame. The STA may select an alternate rate according to the rules in 10.6.6.5.4. The STA shall transmit the non-HT PPDU BlockAck frame at either the primary rate or the alternate rate, if one exists.

— If a BlockAck frame is sent as an immediate response to either an Implicit BAR request or to a BlockAckReq frame that was carried in an S1G PPDU, the primary rate is defined to be the highest rate in the BSSBasicS1GMCS_NSSSet parameter that is less than or equal to the rate of the previous frame. If no rate in the BSSBasicS1GMCS_NSSSet parameter meets these conditions, the primary rate is defined to be the highest mandatory rate of the attached PHY that is less than or equal to the rate of the previous frame. The STA may select an alternate rate according to the rules in 10.6.6.5.4. The STA shall transmit the BlockAck control response frame at either the primary rate or the alternate rate, if one exists.

— When in asymmetric BA operation, the S1G STA shall transmit the BlockAck frame at the MCS according to the rules in 10.6.6.5.5.

— When the S1G STA is not following asymmetric BA operation, then

  — If the STA receives an Accept in the Control Response MCS Negotiation Response frame from a responding STA, then it shall transmit the BlockAck frame to the responding STA with the rate described in 10.6.6.5.3.

  — Otherwise, the STA shall transmit the BlockAck frame at either the primary rate or the alternate rate (according to the rules in 10.6.6.5.4), if one exists.

— If a Basic BlockAck frame is sent as an immediate response to a BlockAckReq frame that was carried in a non-HT PPDU and the Basic BlockAck frame is carried in a non-HT PPDU, the primary rate is defined to be the same rate and modulation class as the BlockAckReq frame, and the STA shall transmit the Basic BlockAck frame at the primary rate.

— If a Compressed BlockAck frame is sent as an immediate response to a BlockAckReq frame that was carried in a non-HT PPDU and the Compressed BlockAck frame is carried in a non-HT PPDU, the primary rate is defined to be the highest rate in the BSSBasicRateSet parameter that is less than or equal to the rate (or non-HT reference rate; see 10.6.11) of the previous frame. If no rate in the

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BSSBasicRateSet parameter meets these conditions, the primary rate is defined to be the highest mandatory rate of the attached PHY that is less than or equal to the rate (or non-HT reference rate; see 10.6.11) of the previous frame. The STA may select an alternate rate according to the rules in 10.6.6.5.4. The STA shall transmit the non-HT PPDU Compressed BlockAck frame at either the primary rate or the alternate rate, if one exists.

— If the control response frame is carried in an HT or VHT PPDU, then it is transmitted using an MCS or <VHT-MCS, NSS> tuple as determined by the procedure defined in 10.6.6.5.3.

— If the control response frame is carried in an S1G PPDU, then it is transmitted using an <S1G-MCS, NSS> tuple as determined by the procedure defined in 10.6.6.5.3.

The modulation class of the PSDU containing the control response frame shall be selected according to the following rules:

— If the PSDU containing the received frame is of a modulation class other than HT, VHT, or S1G and the control response frame is carried in a non-HT PPDU, the control response frame shall be transmitted in a PSDU using the same modulation class as the PSDU containing the received frame. In addition, the control response frame shall be sent using the same value for the TXVECTOR parameter PREAMBLE_TYPE as the received frame.

— If the PSDU containing the received frame is of the modulation class HT or VHT and the control response frame is carried in a non-HT PPDU, the control response frame shall be transmitted in a PSDU using one of the ERP-OFDM or OFDM modulation classes.

— If the control response frame is carried in an HT PPDU, the modulation class shall be HT.

— If the control response frame is carried in a VHT PPDU, the modulation class shall be VHT.

— If the control response frame is carried in an S1G PPDU, the modulation class shall be S1G.

The selection of the value for the channel width (CH_BANDWIDTH parameter of the TXVECTOR) of the response transmission is defined in 10.6.6.6.

10.6.6.5.3 Control response frame MCS computation

If a control response frame is to be transmitted within an HT or VHT PPDU, the channel width (CH_BANDWIDTH parameter of the TXVECTOR) shall be selected first according to 10.6.6.6, and then the MCS or <VHT-MCS, NSS> tuple shall be selected from a set of MCSs and <VHT-MCS, NSS> tuples called the *CandidateMCSSet* as described in this subclause.

If a control response frame is to be transmitted within an S1G PPDU, the channel width (CH_BANDWIDTH parameter of the TXVECTOR) shall be selected first according to 10.6.6.6, and then the <S1G-MCS, NSS> tuple shall be selected from a set of <S1G-MCS, NSS> tuples called the *CandidateMCSSet* as described in this subclause.

If the frame eliciting the response was transmitted by an HT STA that is not a VHT STA, the Rx Supported MCS Set is determined from the Supported MCS Set field in the HT Capabilities element received from the STA as follows:

— If a bit in the Rx MCS Bitmask subfield is equal to 0, the corresponding MCS is not supported.

— If a bit in the Rx MCS Bitmask subfield is equal to 1 and the integer part of the data rate (expressed in megabits per second) of the corresponding MCS is less than or equal to the rate represented by the Rx Highest Supported Data Rate subfield, then the MCS is supported by the STA on receive. If the Rx Highest Supported Data Rate subfield is equal to 0 and a bit in the Rx MCS Bitmask is equal to 1, then the corresponding MCS is supported by the STA on receive.

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If the frame eliciting the response was transmitted by a VHT STA, the Rx Supported MCS Set is determined for VHT PPDUs as described in 10.6.13 and for HT PPDUs from the Supported MCS Set field in the HT Capabilities element received from the STA as follows:

— If a bit in the Rx MCS Bitmask subfield is equal to 0, the corresponding MCS is not supported.

— If a bit in the Rx MCS Bitmask subfield is equal to 1 and the integer part of the data rate (expressed in megabits per second) of the corresponding MCS is less than or equal to the rate represented by the Rx Highest Supported Data Rate subfield, then the MCS is supported by the STA on receive. If the Rx Highest Supported Data Rate subfield is equal to 0 and a bit in the Rx MCS Bitmask is equal to 1, then the corresponding MCS is supported by the STA on receive.

The Rx Supported MCS Set is determined for S1G PPDUs as described in 10.6.14.

The CandidateMCSSet is determined using the following rules:

— If the frame eliciting the response was an STBC frame and the Dual CTS Protection bit is equal to 1, the CandidateMCSSet shall contain only the basic STBC MCS.

— For S1G STAs, if none of the above conditions is true, the CandidateMCSSet is the BSSBasicS1GMCS_NSSSet parameters. If the frame eliciting the response was an RTS frame, then the CandidateMCSSet may additionally include the <S1G-MCS, NSS> tuple with the same MCS and number of spatial streams as the S1G PPDU. If the combined BSSBasicMCSSet parameter is empty, the CandidateMCSSet shall consist of the set of mandatory <S1G-MCS, NSS> tuples corresponding to the mandatory S1G PHY MCSs with NSS = 1.

— For non-S1G STAs, if none of the above conditions is true, the CandidateMCSSet is the union of the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive and the basic VHT-MCS and NSS set. If the frame eliciting the response was an RTS frame carried in a VHT PPDU, then the CandidateMCSSet may additionally include the <VHT-MCS, NSS> tuple with the same MCS and number of spatial streams as the VHT PPDU. If the combined Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive is empty, the CandidateMCSSet shall consist of
  — The set of mandatory HT PHY MCSs if the STA eliciting the response is an HT STA that is not a VHT STA
  — The set of mandatory HT-MCSs plus the set of <VHT-MCS, NSS> tuples corresponding to the mandatory VHT PHY MCSs with NSS = 1 if the STA eliciting the response is a VHT STA

MCS values from the CandidateMCSSet that cannot be transmitted with the selected CH_BANDWIDTH parameter value shall be eliminated from the CandidateMCSSet.

The choice of a response MCS is made as follows:

a) If the frame eliciting the response is within a non-HT PPDU,
   1) Eliminate from the CandidateMCSSet all <VHT-MCS, NSS> tuples. Eliminate all MCSs that have a data rate greater than the data rate of the received PPDU (the mapping of MCS to data rate is defined in 19.5).
   2) Find the highest indexed MCS from the CandidateMCSSet. The index of this MCS is the index of the MCS that is the primary MCS for the response transmission.
   3) If the CandidateMCSSet is empty, the primary MCS is the lowest indexed MCS of the mandatory MCSs.

b) If the frame eliciting the response is within an HT PPDU,
   1) Eliminate from the CandidateMCSSet all <VHT-MCS, NSS> tuples. Eliminate all MCSs that have an index that is higher than the index of the MCS of the received frame. Also eliminate all

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MCSs that have a number of spatial streams greater than that indicated in the Rx NSS subfield in the most recent Operating Mode field with the Rx NSS Type subfield equal to 0 from the intended receiver STA, if at least one Operating Mode field with the Rx NSS Type subfield equal to 0 was received from the intended receiver STA.

2) Determine the highest number of spatial streams (N_{SS}) value of the MCSs in the CandidateMCSSet that is less than or equal to the N_{SS} value of the MCS of the received frame. Eliminate all MCSs from the CandidateMCSSet that have an N_{SS} value that is not equal to this N_{SS} value. The mapping from MCS to N_{SS} is dependent on the attached PHY. For the HT PHY, see 19.5.

3) Find the highest indexed MCS of the CandidateMCSSet for which the modulation value of each stream is less than or equal to the modulation value of each stream of the MCS of the received frame and for which the coding rate is less than or equal to the coding rate of the MCS from the received frame. This MCS is the primary MCS for the response transmission. The mapping from MCS to modulation and coding rate is dependent on the attached PHY. For the HT PHY, see 19.5. For the purpose of comparing modulation values, the following sequence shows increasing modulation values: BPSK, QPSK, 16-QAM, 64-QAM.

4) If no MCS meets the condition in step 3), remove each MCS from the CandidateMCSSet that has the highest value of N_{SS} in the CandidateMCSSet. If the resulting CandidateMCSSet is empty, then set the CandidateMCSSet to the HT PHY mandatory MCSs. Repeat step 3) using the modified CandidateMCSSet.

c) If the frame eliciting the response is within a VHT PPDU,

1) Eliminate from the CandidateMCSSet all MCSs and all <VHT-MCS, NSS> tuples that meet any of the following conditions:

i) Have a data rate that is higher than the data rate of the <VHT-MCS, NSS> tuple of the received frame using the largest possible value of CH_BANDWIDTH that is no larger than the value of CH_BANDWIDTH of the received frame

ii) Have a number of spatial streams greater than that indicated in the Rx NSS subfield in the most recent Operating Mode field with the Rx NSS Type subfield equal to 0 from the intended receiver STA, if at least one Operating Mode field with the Rx NSS Type subfield equal to 0 was received from the intended receiver STA

iii) Have a number of spatial streams greater than that indicated in the Rx NSS subfield in the most recent Operating Mode field with the Rx NSS Type subfield equal to 1 from the intended receiver STA if at least one Operating Mode field with the Rx NSS Type subfield equal to 1 was received from the receiver STA and the control response frame is an SU PPDU frame with a beamforming steering matrix and the beamforming steering matrix was derived from a VHT Compressed Beamforming report with Feedback Type subfield indicating MU in the VHT Compressed Beamforming frame(s)

2) Determine the highest number of spatial streams (N_{SS}) value of the MCSs and <VHT-MCS, NSS> tuples in the CandidateMCSSet that is less than or equal to the N_{SS} value of the received frame. Eliminate all MCSs from the CandidateMCSSet that have an N_{SS} value that is not equal to this N_{SS} value. The mapping from MCS to N_{SS} is dependent on the attached PHY. For the HT PHY, see 19.5.

3) Find the highest rate MCS or <VHT-MCS, NSS> tuple of the CandidateMCSSet for which the modulation value of each stream is less than or equal to the modulation value of each stream of the MCS of the received frame and for which the coding rate is less than or equal to the coding rate of the MCS from the received frame. This MCS or <VHT-MCS, NSS> tuple is the primary MCS for the response transmission. The mapping from MCS or <VHT-MCS, NSS> tuple to modulation and coding rate is dependent on the attached PHY. For the HT PHY, see 19.5; for the VHT PHY, see 21.5. For the purpose of comparing modulation values, the following sequence shows increasing modulation values: BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM.

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4) If no MCS meets the condition in step 3), remove each MCS or <VHT-MCS, NSS> tuple from the CandidateMCSSet that has the highest value of N_{SS} in the CandidateMCSSet. If the resulting CandidateMCSSet is empty, then set the CandidateMCSSet to the VHT PHY mandatory MCSs. Repeat step 3) using the modified CandidateMCSSet.

d) If the frame eliciting the response is within an S1G PPDU,

1) Eliminate from the CandidateMCSSet all MCSs and all <S1G-MCS, NSS> tuples that meet any of the following conditions:

i) Have a data rate that is higher than the data rate of the <S1G-MCS, NSS> tuple of the received frame using the largest possible value of CH_BANDWIDTH that is no larger than the value of CH_BANDWIDTH of the received frame

ii) Have a number of spatial streams greater than one

2) Find the highest rate MCS or <S1G-MCS, NSS> tuple of the CandidateMCSSet for which the modulation value of each stream is less than or equal to the modulation value of each stream of the MCS of the received frame and for which the coding rate is less than or equal to the coding rate of the MCS from the received frame. This MCS or <S1G-MCS, NSS> tuple is the primary MCS for the response transmission. The mapping from MCS or <S1G-MCS, NSS> tuple to modulation and coding rate is dependent on the attached PHY; see 23.5. For the purpose of comparing modulation values, the following sequence shows increasing modulation values: BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM.

3) If no MCS meets the condition in step 2), then set the CandidateMCSSet to the S1G PHY mandatory MCSs. Repeat step 2) using the modified CandidateMCSSet.

Once the primary MCS, <VHT-MCS, NSS> tuple, or <S1G-MCS, NSS> tuple has been selected, the STA may select an alternate MCS according to 10.6.6.5.4. If the STA has not negotiated the control response MCS negotiation as described in 10.6.6.5.6 or has received a Reject indication in the Control Response MCS Negotiation Response frame, then it shall transmit the control response frame using either the primary MCS or the alternate MCS, if one exists. If the STA has received an Accept indication in the Control Response MCS Negotiation Response frame from a responding STA, then it shall transmit the control response frame to the responding STA using the negotiated MCS or alternative MCS provided that the duration of the frame at the alternate MCS is the same as the duration of the frame at the negotiated MCS, if one exists. Negotiated MCS is computed as the highest MCS less than or equal to the MCS that is MCSDifference lower than the primary MCS if one exists, or the MCS 10 otherwise.

10.6.6.5.4 Selection of an alternate rate or MCS for a control response frame

An alternate rate may be selected provided that all of the following conditions are met:

— The duration of frame at the alternate rate is the same as the duration of the frame at the primary rate determined by 10.6.6.5.2.

— The alternate rate is in either the BSSBasicRateSet parameter or is a mandatory rate of the attached PHY.

— The modulation class of the frame at the alternate rate is the same class as that of the primary rate selected by 10.6.6.5.2.

An alternate MCS may be selected provided that both of the following conditions are met:

— The duration of the frame at the alternate MCS is the same as the duration of the frame at the primary MCS.

— The alternate MCS is in the CandidateMCSSet that was generated according to the procedure of 10.6.6.5.3.

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10.6.6.5.5 MCS for asymmetric BA operation

The primary MCS for asymmetric BA operation is defined as the MCS that is MCSDifference (see 10.25.2) lower than that of the eliciting A-MPDU. An alternate MCS may be selected provided that the duration of the frame at the alternate MCS is the same as the duration of the frame at the primary MCS.

10.6.6.5.6 Control response MCS negotiation

Control response MCS negotiation allows two STAs with power imbalance to send the control responses with different MCSs than the primary MCS as defined by the rules in 10.6.6.5.3. A STA may initiate the Control Response Negotiation by sending a Control Response MCS Request frame. After reception of a Control Response MCS Response frame that indicates Accept, the STA sends the control response frames with the Negotiated MCS as defined in 10.6.6.5.3.

An S1G STA with dot11MCSNegotiation equal to true shall set the MCS Negotiation Support field of the S1G Capabilities element to 1. An S1G STA with dot11MCSNegotiation equal to false shall set the MCS Negotiation Support field of the S1G Capabilities element to 0.

An S1G STA shall not transmit a Control Response MCS Negotiation Request frame to another S1G STA unless the MCS Negotiation Support field of the S1G Capabilities element received from that STA contained a value of 1 and dot11MCSNegotiation is true.

An S1G STA shall transmit the Control Response MCS Negotiation Response frame to a STA from which it has received a Control Response MCS Negotiation Request frame. The STA shall include a value that indicates either Accept or Reject in the Command field of the Response frame as defined in Table 9-517.

10.6.6.5.7 Control response frame TXVECTOR parameter restrictions

A STA shall not transmit a control response frame with the TXVECTOR parameter GI_TYPE set to SHORT_GI unless it is in response to a frame with the RXVECTOR parameter GI_TYPE equal to SHORT_GI.

A STA shall not transmit a control response frame with the TXVECTOR parameter FEC_CODING set to LDPC_CODING unless it is in response to a frame with the RXVECTOR parameter FEC_CODING equal to LDPC_CODING.

A STA shall not transmit a control response frame with the TXVECTOR parameter FORMAT set to HT_GF.

10.6.6.6 Channel Width selection for Control frames

The rules in this subclause, combined with the rules in 10.6.6.1, determine the format of control response frames.

If a VHT STA transmits to another VHT STA a Control frame that is not an RTS frame or a CF-End frame, if that Control frame elicits a control response frame or a VHT Compressed Beamforming frame, and

— If the Control frame is transmitted in a non-HT duplicate PPDU (channel width 40 MHz or wider), the transmitting VHT STA shall set the TA field to a bandwidth signaling TA.

— If the Control frame is transmitted in a non-HT PPDU (channel width 20 MHz), the transmitting VHT STA may set the TA field to a bandwidth signaling TA.

If the TA is a bandwidth signaling TA, the transmitting VHT STA shall set the TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and CH_BANDWIDTH to the same value.

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NOTE 1—Such Control frames are BlockAckReq frames, PS-Poll frames, VHT NDP Announcement frames, and Beamforming Report Poll frames.

NOTE 2—Control Wrapper frames follow the rules pertaining to the carried Control frame (see 10.9).

Channel width selection rules for RTS frames are described in 10.3.2.7.

A VHT STA that transmits a CF-End frame in a non-HT duplicate PPDU (channel width 40 MHz or wider) addressed to a VHT AP shall set the Individual/Group bit in the BSSID(TA) field to 1.

A VHT STA that transmits a CF-End frame in a non-HT PPDU (channel width 20 MHz) addressed to a VHT AP may set the Individual/Group bit in the BSSID(TA) field to 1.

If the Individual/Group bit in the BSSID(TA) field of the CF-End frame is set to 1, the transmitting VHT STA shall set the TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and CH_BANDWIDTH to the same value.

A STA that sends a Control frame in response to a frame carried in an HT PPDU or a VHT PPDU shall set the TXVECTOR parameter CH_BANDWIDTH to indicate a channel width that is the same as the channel width indicated by the RXVECTOR parameter CH_BANDWIDTH of the frame eliciting the response.

A STA that sends a Control frame in response to a frame carried in a non-HT or non-HT duplicate PPDU with a nonbandwidth signaling TA

— Should set the TXVECTOR parameter CH_BANDWIDTH to the same value as the RXVECTOR parameter CH_BANDWIDTH for the frame eliciting the response.
— Shall not set the TXVECTOR parameter CH_BANDWIDTH to a value greater than the RXVECTOR parameter CH_BANDWIDTH for the frame eliciting the response.

NOTE 3—According to this rule, a STA can respond with a 20 MHz PPDU if it receives a non-HT duplicate frame but is not able to detect the channel width occupied by the frame (whether by design or because the frame was received over a channel that is narrower than the channel on which it was transmitted).

A VHT STA that sends a Control frame that is in response to a non-HT or non-HT duplicate format frame with a bandwidth signaling TA and that is not a CTS shall set the channel width indicated by the TXVECTOR parameter CH_BANDWIDTH to the same value as the channel width indicated by the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT for the frame eliciting the response. The RA field of a Control frame that is not a CF-End frame and that is sent in response to a Control frame with a bandwidth signaling TA shall be set to a nonbandwidth signaling TA obtained from the TA field of the immediately previous Control frame. For the channel width selection rules for CTS sent in response to an RTS with a bandwidth signaling TA, see 10.3.2.9.

A frame that is intended to provide protection is transmitted using a channel width selected by the rules defined in 10.27.

An HT STA that uses a non-HT duplicate frame to establish protection of its TXOP shall send any CF-End frame using a non-HT duplicate frame.

The TXOP holder should set the TXVECTOR parameter CH_BANDWIDTH of a CF-End frame to the maximum bandwidth allowed by the rules in 10.23.2.8.

NOTE 4—A CF-End frame transmitted by an AP a SIFS duration after receiving a CF-End frame is considered a control response frame.

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An S1G STA that has set the 1 MHz Control Response Preamble Support field to 1 in the S1G Capabilities element transmitted to its peer STA shall use S1G_1M preamble transmission as the response of S1G_SHORT_PREAMBLE or S1G_LONG_PREAMBLE as follows:

— An S1G STA that sends a Control frame in response to a frame carried in an S1G PPDU shall set the TXVECTOR parameter CH_BANDWIDTH to indicate a channel width that is the same or lower as the channel width indicated by the RXVECTOR parameter CH_BANDWIDTH of the frame eliciting the response.
— In a TXOP, a STA shall not set the TXVECTOR parameter CH_BANDWIDTH to a value greater than the RXVECTOR parameter CH_BANDWIDTH for the next frame exchange sequence.

Otherwise, in S1G BSS, S1G_1M preamble transmission as the response of S1G_SHORT_PREAMBLE or S1G_LONG_PREAMBLE is not allowed and the S1G STA behaves as follows:

— An S1G STA that sends a Control frame in response to a frame carried in an S1G PPDU shall set the TXVECTOR parameter CH_BANDWIDTH to indicate a channel width that is the same as the channel width indicated by the RXVECTOR parameter CH_BANDWIDTH of the frame eliciting the response, except when the frame eliciting the response is an S1G RTS frame with the Dynamic Indication field in the Frame Control field equal to 1.

When both transmitting STA and receiving STA indicate OBSS mitigation support in the OBSS Mitigation Support subfield of the S1G Capabilities element, the receiving STA operating in a 2/4/8/16 MHz BSS that sends a (duplicate) NDP_2M Ack frame or NDP_2M BlockAck frame in response to a frame carried in an S1G PPDU may set the TXVECTOR parameter CH_BANDWIDTH to indicate a channel width that is less than or equal to the channel width indicated by the RXVECTOR parameter CH_BANDWIDTH of the frame eliciting the response.

An S1G STA transmitting a Control frame or an NDP CMAC PPDU shall set the TXVECTOR parameter FORMAT depending on the value of the TXVECTOR parameter CH_BANDWIDTH:

— If CH_BANDWIDTH is equal to CBW1 then the FORMAT shall be S1G
— If CH_BANDWIDTH is equal to CBW2 then the FORMAT shall be:
  — S1G_DUP_1M if the RXVECTOR parameter CH_BANDWIDTH of the eliciting Control frame is equal to CBW1 and the Bandwidth Indication field in the Frame Control field is 1.
  — S1G_DUP_1M if the S1G STA intends to transmit a duplicate 1 MHz Control frame to an S1G STA that supports duplicate 1 MHz frames as indicated in the duplicate 1 MHz Support field of the S1G Capabilities element received from that S1G STA.
  — S1G otherwise.
— Otherwise, the FORMAT shall be S1G DUP_2M.

10.6.6.7 Control frame TXVECTOR parameter restrictions

A STA shall not transmit a Control frame that initiates a TXOP with the TXVECTOR parameter GI_TYPE set to a value of SHORT_GI.

A STA shall not transmit a Control frame that initiates a TXOP with the TXVECTOR parameter FEC_CODING set to a value of LDPC_CODING.

10.6.7 Multirate support for DMG STAs

10.6.7.1 Usage of DMG Control modulation class

The DMG Control modulation class has only one MCS, which is DMG MCS 0 defined in Clause 20. The DMG Beacon, SSW-Feedback, SSW-Ack, RTS, DMG CTS, DMG CTS-to-self, DMG DTS, CF-End, Grant, SPR, Poll and first BRP PPDU in beam refinement shall be transmitted using the DMG Control

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modulation class. In the case of an RXSS that was specified through the Beamforming Control field with the value of the RXSSTxRate subfield equal to 1 and the RXSSTxRate Supported field in the DMG Capabilities element of the STA performing the RXSS is 1, the first SSW frame of the RXSS shall be transmitted using the DMG Control modulation class, and the remaining frames of the RXSS shall be transmitted using MCS 1 of the DMG SC modulation class. In all other cases, the SSW frames shall be transmitted using the DMG Control modulation class. Other DMG beamforming training frames may be transmitted using the DMG Control modulation class or the DMG SC modulation class.

10.6.7.2 Rate selection rules for Control frames transmitted by DMG STAs

This subclause describes the rate selection rules for Control frames transmitted by DMG STAs. The rate selection rules apply only for MCSs defined in Clause 20.

A Control frame that does not have an MCS defined in 10.6.7.1 and that is not a control response frame shall be transmitted using an MCS from the mandatory MCS set of the DMG SC modulation class or DMG Control modulation class.

A STA transmitting an Ack or a BlockAck frame that is a response to a frame sent using the DMG low-power SC modulation class shall use an MCS from the DMG low-power SC Supported MCS set of the STA that transmitted the frame that elicited the response as long as (a) the selected MCS has a Data Rate that does not exceed the Data Rate of the frame that elicited the response, and (b) no other MCS satisfying condition (a) results in a shorter frame transmission time.

A STA transmitting a Grant Ack frame shall use the DMG Control modulation class or any MCS from the mandatory MCS set of the DMG SC modulation class.

A STA transmitting an Ack or a BlockAck frame that is a response to a frame sent using the DMG Control modulation class shall use the DMG Control modulation class.

A STA transmitting an Ack frame or a BlockAck frame in response to a frame sent using the DMG SC modulation class shall use an MCS from the mandatory MCS set of the DMG SC modulation class as long as (a) the selected MCS has a Data Rate that does not exceed the Data Rate of the frame that elicited the response, and (b) no other MCS satisfying condition (a) results in a shorter frame transmission time.

NOTE—A control response frame is a Control frame that is transmitted within an MPDU as a response to a reception SIFS after the PPDU containing the frame that elicits the response, e.g., a DMG CTS frame in response to an RTS frame reception, an Ack frame in response to a Data frame reception, a BlockAck frame in response to a BlockAckReq frame reception. In some situations, the transmission of some of these Control frames is not a control response transmission, such as when a DMG CTS frame is used to initiate a TXOP.

Except in an A-MPDU consisting of one of the combinations listed below, the rules in this subclause do not apply to Control frames that are contained in A-MPDUs that also include at least one MPDU with the Type subfield equal to Data or Management. In the following cases, the rate selection rules are the same as those for a standalone Ack or BlockAck frame:

— An Ack frame and a QoS Null frame
— A BlockAck frame and a QoS Null frame
— A BlockAckReq frame and a QoS Null frame
— A BlockAck frame, a BlockAckReq frame, and a QoS Null frame

10.6.7.3 Rate selection for group addressed Data and Management frames transmitted by DMG STAs

This subclause describes the rate selection rules for group addressed Data and Management frames transmitted by DMG STAs. The rate selection rules apply only for MCSs defined in Clause 20.

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If the transmit antenna pattern of a single transmission of a group addressed frame covers more than one receiver, then the sender shall employ an MCS that is supported by all of the receivers. Furthermore, the sender shall not employ π/2-8-PSK modulation unless all receivers support π/2-8-PSK modulation. If the capability of any receiver is not known, the frame shall be transmitted using an MCS from the mandatory MCS set of the DMG control or SC mode.

If the transmit antenna pattern of a single transmission of a group addressed frame covers only one receiver, the frame shall be transmitted following the rate selection rules of individually addressed frames as described in 10.6.7.4.

10.6.7.4 Rate selection for individually addressed Data and Management frames transmitted by DMG STAs

This subclause describes the rate selection rules for individually addressed Data and Management frames as transmitted by DMG STAs. The rate selection rules apply only for MCSs defined in Clause 20.

An individually addressed Data or Management frame shall be sent using an MCS supported by the receiver STA, as reported in the maximum receive MCS subfields in the Supported MCS Set field in Management frames transmitted by the receiver STA.

When the Supported MCS set of the receiving STA is not known, the transmitting STA shall transmit using an MCS from the mandatory MCS set of the DMG control or SC mode.

A DMG STA shall transmit a TPA Request frame and a TPA Response frame using MCS 1.

An individually addressed Data or Management frame with MCS 10 or MCS 11 shall only employ π/2-8-PSK modulation if the receiving STA supports π/2-8-PSK. The receiving STA indicates support by setting the π/2-8-PSK Capable bit to 1 in the Supported MCS Set subfield of the DMG STA Capability Information field of the DMG Capabilities element all DMG Capabilities fields that are included in transmitted Management frames.

The rules in this subclause also apply to A-MPDUs that contain at least one MPDU with Type subfield equal to Control and at least one MPDU with Type subfield equal to Data or Management.

10.6.7.5 Rate selection for BRP PPDUs

The first BRP PPDU transmitted from the initiator to the responder after the SLS phase shall use MCS 0.

The first BRP PPDU transmitted from the responder to the initiator after the SLS phase shall use MCS 0.

A BRP PPDU transmitted during beam refinement at the start of an SP (as defined in 10.39.6.2) should use MCS 0, otherwise a BRP PPDU transmitted during beam refinement should use MCS 1. A BRP PPDU transmitted during beam refinement shall not use any MCS greater than MCS 12.

BRP PPDUs transmitted during the BRP setup subphase, the MID subphase, and the BC subphase shall use MCS 0.

BRP PPDUs transmitted during a BC subphase, as part of a BC subphase only training, may use MCS 0 to MCS 12.

BRP PPDUs transmitted during beam tracking may use any MCS.

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10.6.8 Multirate support for CMMG STAs

10.6.8.1 Usage of CMMG Control modulation class

The CMMG Control modulation class has only one MCS, which is CMMG-MCS 0 defined in 25.6.8.14 with the spreading factor set to 13. The DMG Beacon, SSW-Feedback, SSW-Ack, RTS, CTS, and first BRP PPDU in beam refinement shall be transmitted using the CMMG Control modulation class. In the case of an RXSS that was specified through the Beamforming Control field in which the RXSSTxRate subfield is 1 and the RXSSTxRate Supported field in the CMMG Capabilities element of the STA performing the RXSS is 1, the first SSW frame of the RXSS shall be transmitted using the CMMG Control modulation class, and the remaining frames of the RXSS shall be transmitted using MCS 0 of the CMMG SC modulation class. In all other cases, the SSW frames shall be transmitted using the CMMG Control modulation class. Other CMMG beamforming training frames may be transmitted using the CMMG Control modulation class or the CMMG SC modulation class.

10.6.8.2 Rate selection rules for Control frames transmitted by CMMG STAs

This subclause describes the rate selection rules for Control frames transmitted by CMMG STAs. The rate selection rules apply only for MCSs defined in Clause 25.

A Control frame that does not have an MCS defined in 10.6.8.1 and that is not a control response frame shall be transmitted using an MCS from the mandatory MCS set of the CMMG SC modulation class or CMMG Control modulation class.

A STA transmitting a Grant Ack frame shall use the CMMG Control modulation class or any MCS from the mandatory MCS set of the CMMG SC modulation class.

A STA transmitting an Ack or a BlockAck frame that is a response to a frame sent using the CMMG Control modulation class shall use the CMMG Control modulation class.

A STA transmitting an Ack frame or a BlockAck frame in response to a frame sent using the CMMG SC modulation class or CMMG OFDM modulation class shall use an MCS from the mandatory MCS set of the CMMG SC modulation class as long as

a) The selected MCS has a data rate that does not exceed the data rate of the frame that elicited the response, and
b) No other MCS satisfying condition a) results in a shorter frame transmission time.

NOTE—A control response frame is a Control frame that is transmitted within an MPDU as a response to a reception SIFS after the PPDU containing the frame that elicits the response, e.g., a CTS frame in response to an RTS frame reception, an Ack frame in response to a Data frame reception, a BlockAck frame in response to a BlockAckReq frame reception. In some situations, the transmission of some of these Control frames is not a control response transmission, such as when a DMG CTS frame is used to initiate a TXOP.

Except in an A-MPDU consisting of one of the combinations listed below, the rules in this subclause do not apply to Control frames that are contained in A-MPDUs that also include at least one MPDU with the Type subfield equal to Data or Management. In the following cases, the rate selection rules are the same as those for a standalone Ack or BlockAck frame:

— An Ack frame and a QoS Null frame
— A BlockAck frame and a QoS Null frame
— A BlockAckReq frame and a QoS Null frame
— A BlockAck frame, a BlockAckReq frame, and a QoS Null frame

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10.6.8.3 Rate selection for group addressed Data and Management frames transmitted by CMMG STAs

This subclause describes the rate selection rules for group addressed Data and Management frames transmitted by CMMG STAs. The rate selection rules apply only for MCSs defined in Clause 25.

If the transmit antenna pattern of a single transmission of a group addressed frame covers more than one receiver and the supported set of each of the receivers is known to the sender, then the MCS used for the transmission shall be an MCS common to the supported MCS sets of all of the receivers. If such an MCS is not known, the frame shall be transmitted using an MCS from the mandatory MCS set of the CMMG control or SC mode.

If the transmit antenna pattern of a single transmission of a group addressed frame covers only one receiver, the frame shall be transmitted following the rate selection rules of individually addressed frames as described in 10.6.8.4.

For SC and OFDM MIMO transmission, if the BSSBasicRateSet parameter is empty, the BSSBasicMCSSet parameter is empty, and the BSS basic CMMG-MCS and NSS set is not empty, then the frame shall be transmitted in a CMMG PPDU using one of the <CMMG-MCS, NSS> tuples included in the BSS basic CMMG-MCS and NSS set.

10.6.8.4 Rate selection for individually addressed Data and Management frames transmitted by CMMG STAs

This subclause describes the rate selection rules for individually addressed Data and Management frames as transmitted by CMMG STAs. The rate selection rules apply only for MCSs defined in Clause 25.

An individually addressed Data or Management frame shall be sent using an MCS supported by the receiver STA, as reported in the maximum receive MCS subfields in the Supported MCS Set field in Management frames transmitted by the receiver STA.

When the supported MCS set of the receiving STA is not known, the transmitting STA shall transmit using an MCS from the mandatory MCS set of the CMMG control or SC mode.

The rules in this subclause also apply to A-MPDUs that contain at least one MPDU with Type subfield equal to Control and at least one MPDU with Type subfield equal to Data or Management.

A Data frame or Management frame for SC and OFDM MIMO transmission shall be sent using any data rate, MCS, or <CMMG-MCS, NSS> tuple subject to the following constraints:

- A STA shall not transmit a frame using a rate or MCS that is not supported by the receiver STA, as reported in any Supported Rates and BSS Membership Selectors element, Extended Supported Rates and BSS Membership Selectors element, or Supported MCS Set field in the Management frames transmitted by the receiver STA.
- A STA shall not transmit a frame using a <CMMG-MCS, NSS> tuple that is not supported by the receiver STA, as reported in any Supported CMMG-MCS and NSS Set field in the Management frames transmitted by the receiver STA.
- If at least one CMMG Operating Mode field with the Rx NSS Type subfield equal to 0 was received from the receiver STA:
  - A STA shall not transmit a frame with the number of spatial streams greater than that indicated in the Rx NSS subfield in the most recently received CMMG Operating Mode field with the Rx NSS Type subfield equal to 0 from the receiver STA.

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- A STA shall not transmit a frame using a value for the CH_BANDWIDTH parameter of the TXVECTOR that is not supported by the receiver STA, as reported in any CMMG Capabilities element received from the intended receiver.
- A STA that is a member of a BSS shall not transmit a frame using a value for the CH_BANDWIDTH parameter of the TXVECTOR that is not permitted for use in the BSS, as reported in the most recently received CMMG Operation element with the following exceptions:
  - Transmissions on a TDLS off-channel link follow the rules described in 11.20.
  - Transmissions by a CMMG STA on a TDLS link follow the rules described in 11.20.
- If at least one CMMG Operating Mode field with the Rx NSS Type subfield equal to 0 was received from the receiver STA:
  - A STA shall not transmit a frame using a value for the TXVECTOR parameter CH_BANDWIDTH that is not supported by the receiver STA as reported in the most recently received CMMG Operating Mode field with the Rx NSS Type subfield equal to 0 from the receiver STA.

When the supported rate set of the receiving STA or STAs is not known, the transmitting STA shall transmit using a rate in the BSSBasicRateSet parameter, or an MCS in the BSSBasicMCSSet parameter, or a <CMMG-MCS, NSS> tuple in the BSS basic CMMG-MCS and NSS set, or a rate from the mandatory rate set of the attached PHY if the BSSBasicRateSet, the BSSBasicMCSSet, and the BSS basic CMMG-MCS and NSS set are empty.

The rules in this subclause also apply to A-MPDUs that aggregate MPDUs of type Data or Management with any other types of MPDU.

10.6.8.5 Rate selection for BRP PPDUs for CMMG STAs

The first BRP PPDU transmitted from the initiator to the responder after the SLS phase shall use MCS 0.

The first BRP PPDU transmitted from the responder to the initiator after the SLS phase shall use MCS 0.

BRP PPDUs transmitted during beam refinement should use MCS 0 and shall not use any MCS greater than MCS 8. BRP PPDUs transmitted during beam refinement should use MCS 0 if the BRP PPDU is sent at start of an SP as defined in 10.39.6.2.

BRP PPDUstransmitted during the BRP setup subphase, the MID subphase, and the BC subphase shall use MCS 0.

BRP PPDUs transmitted during a BC subphase, as part of a BC subphase only training, may use MCS 0 to MCS 8. BRP PPDUs transmitted during beam tracking may use any MCS.

10.6.9 Multiple BSSID Rate Selection

If the multiple BSSID capability is supported, Beacon frames shall be transmitted using any basic rate valid for all of the BSSs supported. If no such rate exists, then Beacon frames shall be transmitted using any mandatory PHY rate for any PHY type that all BSSs have in common.

10.6.10 Modulation classes

Table 10-9 defines modulation classes for the rules for response frames in 10.6.

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Table 10-9—Modulation classes

Description of modulation	Condition that selects this modulation class		
	Clause 15 to Clause 18 PHYs or Clause 20 PHY, or Clause 24 PHY, or Clause 25 PHY	Clause 19 PHY	Clause 21 PHY
DSSS and HR/ DSSS	Clause 15 or Clause 16 transmission	FORMAT is NON_HT. NON_HT_MODULATION is ERP-DSSS or ERP-CCK.	N/A
ERP-OFDM	18.4 transmission	FORMAT is NON_HT. NON_HT_MODULATION is ERP-OFDM.	N/A
OFDM	Clause 17 transmission	FORMAT is NON_HT. NON_HT_MODULATION is OFDM or NON_HT_DUP_OFDM.	FORMAT is NON_HT. NON_HT_MODULATION is OFDM or NON_HT_DUP_OFDM.
HT	N/A	FORMAT is HT_MF or HT_GF.	FORMAT is HT_MF or HT_GF.
DMG Control	Clause 20 transmission and MCS is 0	N/A	N/A
DMG SC	Clause 20 transmission and $1 \leq MCS \leq 12.6$	N/A	N/A
DMG Low-power SC	Clause 20 transmission and $25 \leq MCS \leq 31$	N/A	N/A
VHT	N/A	N/A	FORMAT is VHT.
CDMG Control	Clause 24 transmission and MCS is 0	N/A	N/A
CDMG SC	Clause 24 transmission and $1 \leq MCS \leq 16$	N/A	N/A
CDMG Low-power SC	Clause 24 transmission and $17 \leq MCS \leq 23$	N/A	N/A
CMMG Control	Clause 25 transmission and MCS is 0	N/A	N/A
CMMG SC	Clause 25 transmission and $1 \leq MCS \leq 8$	N/A	N/A
CMMG OFDM	Clause 25 transmission and $9 \leq MCS \leq 16$	N/A	N/A

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10.6.11 Non-HT basic rate calculation

This subclause defines how to convert an HT-MCS or a VHT-MCS to a non-HT basic rate for the purpose of determining the rate of the response frame. It consists of two steps as follows:

a) Use the modulation and coding rate determined from the HT-MCS (defined in 19.5) or VHT-MCS (defined in 21.5) to locate a non-HT reference rate by lookup into Table 10-10.[29] In the case of an MCS with UEQM, the modulation of stream 1 is used.

b) The non-HT basic rate is the highest rate in the BSSBasicRateSet that is less than or equal to this non-HT reference rate.

Table 10-10—Non-HT reference rate

Modulation	Coding rate (R)	Non-HT reference rate (Mb/s)
BPSK	1/2	6
BPSK	3/4	9
QPSK	1/2	12
QPSK	3/4	18
16-QAM	1/2	24
16-QAM	3/4	36
64-QAM	1/2	48
64-QAM	2/3	48
64-QAM	3/4	54
64-QAM	5/6	54
256-QAM	3/4	54
256-QAM	5/6	54

NOTE—In a TVWS band, the non-HT reference rate is scaled as described in 22.2.4.

10.6.12 Channel Width in non-HT and non-HT duplicate PPDUs

A non-VHT STA shall include neither the CH_BANDWIDTH_IN_NON_HT parameter nor the DYN_BANDWIDTH_IN_NON_HT parameter in either of the TXVECTOR or RXVECTOR for NON_HT PPDUs. A non-VHT STA shall not set the TA field to a bandwidth signaling TA. A VHT STA shall include neither the CH_BANDWIDTH_IN_NON_HT parameter nor the DYN_BANDWIDTH_IN_NON_HT parameter in the TXVECTOR of a non-HT PPDU containing frames addressed to a non-VHT STA. A VHT STA shall not set the TA field to a bandwidth signaling TA in a frame addressed to a non-VHT STA. A VHT STA that includes the DYN_BANDWIDTH_IN_NON_HT parameter in the TXVECTOR shall also include the CH_BANDWIDTH_IN_NON_HT parameter in the TXVECTOR. A VHT STA shall not include the DYN_BANDWIDTH_IN_NON_HT parameter in the TXVECTOR for transmitted frames other than RTS frames with bandwidth signaling TA and that are sent in a non-HT PPDU. A STA that transmits an RTS frame with a bandwidth signaling TA shall include the DYN_BANDWIDTH_IN_NON_HT

[29] For example, if an HT PPDU transmission uses 64-QAM and coding rate of 3/4, the related non-HT reference rate is 54 Mb/s.

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parameter in the TXVECTOR. A VHT STA shall include both the CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT parameters in the RXVECTOR if the PPDU format is NON_HT.

A bandwidth signaling TA may be included in non-HT and non-HT duplicate PPDUs and shall not be included in other PPDUs. If the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT is present and a Control frame other than a CTS is being transmitted, then the TA field shall be set to a bandwidth signaling TA; otherwise, the TA field shall be set to an individual address.

NOTE—A CTS frame, even though it does not have a TA field, can also be transmitted with the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT present.

An S1G STA transmitting a Control frame that is not a control response frame shall set the Bandwidth Indication field in the Frame Control field of the frame to a value that is equivalent to the TXVECTOR parameter CH_BANDWIDTH.

An S1G STA shall not transmit a Control frame or an NDP CMAC PPDU with the TXVECTOR parameter S1G_DUP_1M to another S1G STA, unless the Duplicate 1 MHz Support field of the S1G Capabilities element received from that STA contained a value of 1.

An S1G STA transmitting a Control frame that is sent as a response to a Control frame shall set the Bandwidth Indication field in the Frame Control field of the frame to the value of the Bandwidth Indication field in the Frame Control field of the eliciting frame, except for an S1G STA that has indicated the use of 1 MHz control response frames (see 10.6.6.6) in which case the Bandwidth Indication field in the Frame Control field of the solicited Control frame shall be set to 0.

An S1G STA shall set the Dynamic Indication field in the Frame Control field of Control frames, other than RTS frame, to 0.

The TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT shall not be present in PPDUs carrying Management or Data frames.

10.6.13 Rate selection constraints for VHT STAs

10.6.13.1 Rx Supported VHT-MCS and NSS Set

The Rx Supported VHT-MCS and NSS Set of a first VHT STA is determined by a second VHT STA for each <VHT-MCS, NSS> tuple NSS = 1, …, 8 and bandwidth (20 MHz, 40 MHz, 80 MHz, and 160 MHz or 80+80 MHz) from the Supported VHT-MCS and NSS Set field received from the first STA as follows:

- If support for the VHT-MCS for NSS spatial streams at that bandwidth is mandatory (see 21.5), then the <VHT-MCS, NSS> tuple at that bandwidth is supported by the first STA on receive.
- Otherwise, if the Max VHT-MCS For *n* SS subfield (*n* = NSS) in the Rx VHT-MCS Map subfield indicates support and the Rx Highest Supported Long GI Data Rate subfield is equal to 0, then
  - the <VHT-MCS, NSS> tuple at that bandwidth is supported by the first STA on receive, except that if dot11VHTExtendedNSSBWCapable of the second STA is true, the supported bandwidth values and NSS values of each <VHT-MCS, NSS> tuple are updated according to Table 9-272 if no OMN has been received from the first STA, otherwise, according to Table 9-81, wherein the VHT Capabilities Information field and the Operating Mode field have been transmitted by the first STA.

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— Otherwise, if the Max VHT-MCS For *n* SS subfield (*n* = NSS) in the Rx VHT-MCS Map subfield indicates support and the data rate for long GI of the MCS for NSS spatial streams at that bandwidth (expressed as the largest integer in Mb/s that is less than or equal to the data rate) is less than or equal to the rate represented by the Rx Highest Supported Long GI Data Rate subfield, then
  — the <VHT-MCS, NSS> tuple at that bandwidth is supported by the first STA on receive, except that if dot11VHTExtendedNSSBWCapable of the second STA is true, the supported bandwidth values and NSS values of each <VHT-MCS, NSS> tuple are updated according to Table 9-272 if no OMN has been received from the first STA, otherwise, according to Table 9-81, wherein the VHT Capabilities Information field and the Operating Mode field have been transmitted by the first STA.
— Otherwise, the <VHT-MCS, NSS> tuple at that bandwidth is not supported by the first STA on receive.

The <VHT-MCS, NSS> tuples excluded by 10.6.13.3 are also eliminated from the Rx Supported VHT-MCS and NSS Set.

A VHT STA shall not, unless explicitly stated otherwise, transmit a VHT PPDU unless the <VHT-MCS, NSS> tuple and bandwidth used are in the Rx Supported VHT-MCS and NSS Set of the receiving STA(s).

NOTE 1—Support for a <VHT-MCS, NSS> tuple at a given bandwidth implies support for both long GI and short GI on receive, if short GI is supported at that bandwidth.

NOTE 2—A STA can determine the expected interpretation of its Supported Channel Width Set and Channel Width and 160/80+80 BW and Extended NSS BW Support fields at a recipient by examining the VHT Extended NSS BW Capable field value in the Supported VHT-MCS and NSS Set field of the recipient.

10.6.13.2 Tx Supported VHT-MCS and NSS Set

The Tx Supported VHT-MCS and NSS Set of a first VHT STA is determined by a second STA for each <VHT-MCS, NSS> tuple NSS = 1, …, 8 and bandwidth (20 MHz, 40 MHz, 80 MHz, and 160 MHz or 80+80 MHz) from the Supported VHT-MCS and NSS Set field received from the first STA as follows:

— If support for the <VHT-MCS, NSS> tuple at that bandwidth is mandatory (see 21.5), then the <VHT-MCS, NSS> tuple at that bandwidth is supported by the first STA on transmit.
— Otherwise, if the Max VHT-MCS for *n* SS subfield (*n* = NSS) in the Tx VHT-MCS Map subfield indicates support and the Tx Highest Supported Long GI Data Rate subfield is equal to 0, then
  — The <VHT-MCS, NSS> tuple at that bandwidth is supported by the first STA on transmit, except that if dot11VHTExtendedNSSBWCapable of the second STA is true, the supported bandwidth values and NSS values of each <VHT-MCS, NSS> tuple are updated according to Table 9-272 if no OMN has been received from the first STA, otherwise, according to Table 9-81, wherein the VHT Capabilities Information field and the Operating Mode field have been transmitted by the first STA.
— Otherwise, if the Max VHT-MCS for *n* SS subfield (*n* = NSS) in the Tx VHT-MCS Map subfield indicates support and the data rate for long GI of the <VHT-MCS, NSS> tuple at that bandwidth (expressed as the largest integer in Mb/s that is less than or equal to the data rate) is less than or equal to the rate represented by the Tx Highest Supported Long GI Data Rate subfield, then
  — The <VHT-MCS, NSS> tuple at that bandwidth is supported by the first STA on transmit, except that if dot11VHTExtendedNSSBWCapable of the second STA is true, the supported bandwidth values and NSS values of each <VHT-MCS, NSS> tuple are updated according to Table 9-272 if no OMN has been received from the first STA, otherwise, according to Table 9-81, wherein the VHT Capabilities Information field and the Operating Mode field have been transmitted by the first STA.
— Otherwise, the <VHT-MCS, NSS> tuple at that bandwidth is not supported by the first STA on transmit.

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NOTE 1—In contrast to reception, support for short GI transmissions by a STA cannot be determined by other STAs.

NOTE 2—A STA can determine the expected interpretation of its Supported Channel Width Set and Channel Width and 160/80+80 BW and Extended NSS BW Support fields at a recipient by examining the VHT Extended NSS BW Capable field value in the Supported VHT-MCS and NSS Set field of the recipient.

10.6.13.3 Additional rate selection constraints for VHT PPDUs

The following apply for a STA that transmits a VHT PPDU with a number of spatial streams (NSS) less than or equal to 4:

— If the channel width of the PPDU is equal to CBW20 or CBW40, then the STA should not use a <VHT-MCS, NSS> tuple if the VHT-MCS is equal to 0, 1, 2, or 3 and the HT-MCS with value VHT-MCS + 8×(NSS – 1) is marked as unsupported in the Rx MCS bitmask of the HT Capabilities element of the receiver STA.

— If the channel width of the PPDU is equal to CBW80, CBW160, or CBW80+80, then the STA should not use a <VHT-MCS, NSS> tuple if the VHT-MCS is equal to 0 or 1 and both the HT-MCS values 2×VHT-MCS + 8×(NSS – 1) and 2×VHT-MCS + 1 + 8×(NSS – 1) are marked as unsupported in the Rx MCS bitmask of the HT Capabilities element of the receiver STA.

An example tabulation of this behavior is given in Table 10-11.

Table 10-11—Example of rate selection for VHT PPDUs

HT-MCSs that are marked as unsupported	<VHT-MCS, NSS> tuples that are not used for CBW20 and CBW40	<VHT-MCS, NSS> tuples that are not used for CBW80, CBW160, and CBW80+80
0, 8, 16	<0, 1>, <0, 2>, <0, 3>	—
1, 9	<1, 1>, <1, 2>	—
10	<2, 2>	—
3	<3, 1>	—
0, 1	<0, 1>, <1, 1>	<0, 1>
2, 3	<2, 1>, <3, 1>	<1, 1>
0, 1, 8, 9	<0, 1>, <1, 1>, <0, 2>, <1, 2>	<0, 1>, <0, 2>

10.6.14 Rate selection constraints for S1G STAs

10.6.14.1 RX Supported S1G-MCS and NSS Set

The Rx Supported S1G-MCS and NSS Set of an S1G STA is determined for each <S1G-MCS, NSS> tuple NSS = 1, …, 4 and bandwidth (1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz) from its Supported S1G-MCS and NSS Set field as follows:

— If support for the S1G-MCS for NSS spatial streams at that bandwidth is mandatory (see 23.5), then the <S1G-MCS, NSS> tuple at that bandwidth is supported by the STA on receive.

— Otherwise, if the Max S1G-MCS For n SS subfield (n = NSS) in the Rx S1G-MCS Map field indicates support and the Rx Highest Supported Long GI Data Rate subfield is equal to 0, then the <S1G-MCS, NSS> tuple at that bandwidth is supported by the STA on receive.

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— Otherwise, if the Max S1G-MCS For n SS subfield (n = NSS) in the Rx S1G-MCS Map subfield indicates support and the data rate (expressed in megabits per second) for long GI of the MCS for NSS spatial streams at that bandwidth (if the data rate is not an integer, the data rate value is rounded down to the next integer) is less than or equal to the rate represented by the Rx Highest Supported Long GI Data Rate subfield, then the <S1G-MCS, NSS> tuple at that bandwidth is supported by the STA on receive.
— Otherwise the <S1G-MCS, NSS> tuple at that bandwidth is not supported by the STA on receive.

An S1G STA shall not, unless explicitly stated otherwise, transmit an S1G PPDU unless the <S1G-MCS, NSS> tuple and bandwidth used are in the Rx Supported S1G-MCS and NSS Set of the receiving STA(s).

NOTE—Support for a <S1G-MCS, NSS> tuple at a given bandwidth implies support for long GI.

10.6.14.2 TX Supported S1G-MCS and NSS Set

The Tx Supported S1G-MCS and NSS Set of an S1G STA is determined for each <S1G-MCS, NSS> tuple NSS = 1, …, 4 and bandwidth (1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz) from its Supported S1G-MCS and NSS Set field as follows:

— If support for the <S1G-MCS, NSS> tuple at that bandwidth is mandatory (see 23.5), then the <S1G-MCS, NSS> tuple at that bandwidth is supported by the STA on transmit.
— Otherwise if the Max S1G-MCS for n SS subfield (n = NSS) in the Tx S1G-MCS Map subfield indicates support and the Tx Highest Supported Long GI Data Rate subfield is equal to 0, then the <S1G-MCS, NSS> tuple at that bandwidth is supported by the STA on transmit.
— Otherwise if the Max S1G-MCS for n SS subfield (n = NSS) in the Tx S1G-MCS Map subfield indicates support and the data rate (expressed in megabits per second) for long GI of the <S1G-MCS, NSS> tuple at that bandwidth (if the data rate is not an integer, the data rate value is rounded down to the next integer) is less than or equal to the rate represented by the Tx Highest Supported Long GI Data Rate subfield, then the <S1G-MCS, NSS> tuple at that bandwidth is supported by the STA on transmit.
— Otherwise the <S1G-MCS, NSS> tuple at that bandwidth is not supported by the STA on transmit.

10.6.14.3 Additional rate selection constraints for S1G PPDUs

The following apply for a STA that transmits an S1G PPDU:

— If the channel width of the PPDU is equal to CBW1, CBW2, CBW4, CBW8 or CBW16, then the STA should not use a <S1G-MCS, NSS> tuple if the S1G-MCS is equal to 0 and the Min S1G-MCS For n SS subfield in the Basic S1G-MCS and NSS Set field of the S1G Operation element of the receiver STA is equal to 1.
— If the channel width of the PPDU is equal to CBW1, CBW2, CBW4, CBW8 or CBW16, then the STA should not use a <S1G-MCS, NSS> tuple if the S1G-MCS is equal to 0 or 1 and the Min S1G-MCS For n SS subfield in the Basic S1G-MCS and NSS Set field of the S1G Operation element of the receiver STA is equal to 2.

If the channel width of the PPDU is equal to CBW1, then the STA should not use a <S1G-MCS, NSS> tuple if the S1G-MCS is equal to 10 and the B7 of the Channel Width subfield in the S1G Operation Information field of the S1G Operation element of the receiver STA is equal to 0.

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10.6.15 Rate selection constraints for CMMG STAs

10.6.15.1 Rx supported CMMG-MCS and NSS set

The Rx supported CMMG-MCS and NSS set of a CMMG STA is determined for each <CMMG-MCS, NSS> tuple NSS = 1,…, 4 and bandwidth (540 MHz and 1080 MHz) from its Supported CMMG-MCS and NSS Set field as follows:

— If support for the CMMG-MCS for NSS spatial streams at that bandwidth is mandatory (see 25.15), then the <CMMG-MCS, NSS> tuple at that bandwidth is supported by the STA on receive.

— Otherwise, the <CMMG-MCS, NSS> tuple at that bandwidth is not supported by the STA on receive.

A CMMG STA shall not, unless explicitly stated otherwise, transmit a CMMG PPDU unless the <CMMG-MCS, NSS> tuple and bandwidth used are in the Rx Supported CMMG-MCS and NSS Set of the receiving STA(s).

10.6.15.2 Tx supported CMMG-MCS and NSS set

The Tx supported CMMG-MCS and NSS set of a CMMG STA is determined for each <CMMG-MCS, NSS> tuple NSS = 1,…, 4 and bandwidth (540 MHz and 1080 MHz) from its Supported CMMG-MCS and NSS Set field as follows:

— If support for the <CMMG-MCS, NSS> tuple at that bandwidth is mandatory (see 25.15), then the <CMMG-MCS, NSS> tuple at that bandwidth is supported by the STA on transmit.

— Otherwise, the <CMMG-MCS, NSS> tuple at that bandwidth is not supported by the STA on transmit.

10.7 MSDU transmission restrictions

To avoid reordering MSDUs between pairs of LLC entities and/or unnecessarily discarding MSDUs, the following restrictions shall be observed by any STA that is able to concurrently process multiple outstanding MSDUs for transmission. The term *outstanding* refers to an MPDU containing all or part of an MSDU or MMPDU for which transmission has been started, and for which delivery of the MSDU or MMPDU has not yet been completed (i.e., an acknowledgment of the final fragment or only corresponding MPDU has not been received and the MSDU or MMPDU has not been discarded due to retries, lifetime, or for some other reason). A STA may have any number (greater than or equal to one) of eligible MSDUs outstanding concurrently, subject to the restrictions below.

A non-QoS STA shall have outstanding at any time:

— No more than one MSDU from any particular SA, and

— No more than one MMPDU

transmitted in one or more MPDUs with a particular individual RA.

NOTE 1—A simpler, more restrictive alternative to the rule in the above paragraph that might be used is that no more than one MSDU transmitted in one or more MPDUs with a particular individual RA be outstanding at any time.

For frames that are not sent within the context of a block ack agreement, a QoS STA shall have outstanding at any time:

— No more than one MSDU or A-MSDU for each TID from any particular SA, and

— No more than one MMPDU

transmitted in one or more MPDUs with a particular individual RA.

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NOTE 2—A simpler, more restrictive alternative to the rule in the above paragraph that might be used is that no more than one MSDU or A-MSDU with any particular TID transmitted in one or more MPDUs with a particular individual RA be outstanding at any time.

A STA should select a value of dot11MaxTransmitMSDULifetime that is sufficiently large that the STA does not discard MSDUs or MMPDUs due to the transmit MSDU/MMPDU timer being exceeded, under normal operating conditions.

An A-MSDU shall contain only MSDUs of a single service class and inherits that service class for the purpose of the following rules. For MSDUs or A-MSDUs belonging to the service class of QoSAck when the receiver is a QoS STA, the QoS Data frames that are used to send these MSDUs or A-MSDUs shall have Normal Ack, Implicit BAR, PSMP Ack or Block Ack ack policy. For MSDUs or A-MSDUs belonging to the service class of QoSNoAck when the receiver is a QoS STA, the QoS Data frames that are used to send these MSDUs or A-MSDUs shall have No Ack ack policy.

10.8 HT Control field operation

If dot11HTControlFieldSupported is true, a STA shall set the +HTC-HT Support subfield of the HT Extended Capabilities field of the HT Capabilities element to 1 in HT Capabilities elements that it transmits. If dot11VHTControlFieldOptionImplemented is true, a STA shall set the +HTC-VHT Support subfield of the VHT Capabilities Information field of the VHT Capabilities element to 1 in VHT Capabilities elements that it transmits.

A STA in which at least one of dot11RDResponderOptionImplemented, dot11MCSFeedbackOptionImplemented, and dot11AlternateEDCAActivated is true has dot11HTControlFieldSupported or dot11VHTControlFieldOptionImplemented or both equal to true.

An HT variant HT Control field shall not be present in a frame addressed to a STA unless that STA declares support for +HTC-HT in the HT Extended Capabilities field of its HT Capabilities element (see 9.4.2.55).

A VHT variant HT Control field shall not be present in a frame addressed to a STA unless that STA declares support for +HTC-VHT in the VHT Capabilities Information field of its VHT Capabilities element or in the S1G Capabilities Information field of S1G Capabilities elements that it transmits.

NOTE—An HT STA that does not support +HTC (HT or VHT variant) that receives a +HTC frame addressed to another STA still performs the CRC on the actual length of the MPDU and uses the Duration/ID field to update the NAV, as described in 10.3.2.4.

If the HT Control field is present in an MPDU aggregated in an A-MPDU, then all MPDUs of the same frame type (i.e., having the same value for the Type subfield of the Frame Control field) aggregated in the same A-MPDU shall contain the same HT Control field. If MSDU(s) received in an MPDU are delivered via an MA-UNITDATA.indication, the drop eligible parameter of the MA-UNITDATA.indication is set to true if the MPDU contains an HT variant HT Control field and the DEI subfield is equal to 1 and set to false otherwise.

If the HT variant HT Control field is present in an MPDU, the DEI subfield provides information on the drop eligibility of the contents of the received MPDU. When there are insufficient resources in a STA, the STA arbitrarily discards frames in order to recover from the lack of resources. With the information from the DEI subfield, a STA may selectively drop frames with the DEI subfield set to 1 in preference to frames with the DEI subfield set to 0, if resources are insufficient. Note that this might not help in the recovery in all conditions, and the STA might still have to fall back to the arbitrary discard strategy. The mechanisms for determining whether resources are insufficient or when to discard MSDUs or A-MSDUs are beyond the scope of this standard.

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If the value of dot11S1GControlFieldOptionImplemented is true, an S1G STA shall set the +HTC-VHT Capable subfield of the S1G Capabilities Information field of the S1G Capabilities element that it transmits to 1.

An S1G shall not use an HT Control field other than a VHT variant HT Control field. An S1G STA shall not use a VHT variant HT Control field for any purpose other than link adaptation (see 10.32.3).

10.9 Control Wrapper operation

A STA supporting the HT Control field that receives a Control Wrapper frame shall process it as though it received a frame of the subtype of the wrapped frame.

10.10 MSDU processing

A STA can use the U-PID element transmitted in ADDTS Request, DMG ADDTS Request, ADDTS Response and DMG ADDTS Response frames to indicate the upper layer protocol responsible for handling MSDUs corresponding to the TID indicated within the frame carrying the U-PID element (see 11.4.4.4).

A STA that participates in a successful ADDTS exchange that included a U-PID element in the ADDTS Response or DMG ADDTS Response frame with the LLC Header Removed field equal to 1 shall strip the number of octets in the LLC Header Copy field of the U-PID element from the start of an MSDU (received in an MA-UNITDATA.request.primitive) corresponding to the TID indicated in the ADDTS exchange before transmission of the MSDU to the peer STA. The MSDU in the MA-UNITDATA.request.primitive must start with the octets specified in the LLC Header Copy field.

NOTE 1—The STA does not verify that the MSDU does indeed start with the octets specified in the LLC Header Copy field.

A STA that participates in a successful ADDTS exchange that included a U-PID element in the ADDTS Response or DMG ADDTS Response frame with the LLC Header Removed field equal to 1 and that receives from the peer STA an MSDU corresponding to the TID indicated in the ADDTS exchange shall insert the octets in the LLC Header Copy field of the U-PID element at the start of the MSDU before delivery of the MSDU (in an MA-UNITDATA.indication.primitive).

NOTE 2—If the LLC Header Removed field is equal to 0, the LLC Header Copy field in the U-PID element is ignored, except for possible implementation-dependent local optimizations.

10.11 A-MSDU operation

An A-MSDU contains only MSDUs whose DA parameter values map to a single RA value (see 9.3.2.2). An A-MSDU contains only MSDUs whose SA parameter values map to a single TA value (see 9.3.2.2).

For the Short A-MSDU case, an A-MSDU contains only MSDUs whose SA and DA parameter values are the same. The Short A-MSDU subframe structure is used only between a pair of STAs that communicate directly (see 9.3.2.1). The Short A-MSDU subframe structure cannot be used for frame forwarding. The constituent MSDUs of an A-MSDU shall all have the same priority parameter value from the corresponding MA-UNITDATA.request primitive.

An A-MSDU shall be carried, without fragmentation, within a single QoS Data frame.

In non-GLK transmissions, the Address 1 field in an MPDU carrying an A-MSDU shall be set to an individual address or to the GCR concealment address. In GLK transmissions by an AP, the Address 1 field may be set

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to a SYNRA. In GLK transmissions by a non-AP STA, the Address 1 field shall be set to an individual address.

The channel access rules for a QoS Data frame carrying an A-MSDU are the same as a Data frame carrying an MSDU (or fragment thereof) of the same TID.

The expiration of the A-MSDU lifetime timer occurs only when the lifetime timer of all of the constituent MSDUs of the A-MSDU have expired.

NOTE 1—This rule implicitly allows an MSDU that is a constituent of an A-MSDU to potentially be transmitted after the expiration of its lifetime.

NOTE 2—Selecting any other value for the timeout would result in loss of MSDUs. Selecting the maximum value avoids this loss of MSDUs at the cost of transmitting MSDUs that have exceeded their lifetime.

The following rules in this paragraph apply to the transmission of an A-MSDU:

— A non-DMG and non-S1G STA that has a value of false for dot11HighthroughputOptionImplemented shall not transmit an A-MSDU.
— A non-DMG and non-S1G STA shall not transmit an A-MSDU to a STA from which it has not received a frame containing an HT Capabilities element.

An S1G STA shall not transmit an A-MSDU to an S1G STA from which it received a frame containing an S1G Capabilities element with the A-MSDU Supported subfield equal to 0.

An S1G STA transmitting an A-MSDU shall use only the Dynamic A-MSDU subframe format (see 9.3.2.2.4). The DA Present and SA Present subfields in the Subframe Control field of each Dynamic A-MSDU subframe shall be set to 1 unless the frame carrying the A-MSDU is a PV1 frame (see 9.8).

An A-MSDU carried in a PV1 frame shall include the DA field in a Dynamic A-MSDU subframe if the value of this field

— Is not equal to the value of the A3 stored at the recipient.
— Is not equal to the value of the A3 field of the frame when an A3 is not stored at the recipient.
— Is not equal to the value of the address identified by the A1 field when an A3 field is not present in the frame and an A3 is not stored at the recipient.

Otherwise, the DA field shall not be included in the Dynamic A-MSDU subframe.

An A-MSDU carried in a PV1 frame shall include the SA field in a Dynamic A-MSDU subframe if the value of this field

— Is not equal to the value of the A4 stored at the recipient.
— Is not equal to the value of the A4 field of the frame when an A4 is not stored at the recipient.
— Is not equal to the value of the address identified by the A2 field when an A4 field is not present in the frame and an A4 is not stored at the recipient.

Otherwise, the SA field shall not be included in the Dynamic A-MSDU subframe.

A non-S1G STA transmitting an A-MSDU shall not use the Dynamic A-MSDU frame format.

The length of an A-MSDU transmitted in an S1G PPDU is limited by the maximum MPDU size supported by the recipient STA (see 10.12.5).

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A STA shall support the reception of an A-MSDU, where the A-MSDU is carried in a QoS Data frame with Normal Ack ack policy in the following cases:

— By an HT STA when the A-MSDU is not aggregated within an A-MPDU
— By a VHT STA when the A-MSDU is sent as an S-MPDU
— For a CMMG STA if the A-MSDU is not aggregated within an A-MPDU

The use of an A-MSDU carried in a QoS Data frame under a block ack agreement is determined for each block ack agreement. A STA shall not transmit an A-MSDU within a QoS Data frame under a block ack agreement unless the recipient indicates support for A-MSDU by setting the A-MSDU Supported field to 1 in its BlockAck Parameter Set field of the ADDBA Response frame.

A STA shall not transmit an A-MSDU to a STA if the A-MSDU length exceeds the value indicated by the Maximum A-MSDU Length field of the HT Capabilities element received from the recipient STA.

A VHT STA that sets the value of the Maximum MPDU Length subfield in the VHT Capabilities Information field of the VHT Capabilities element to indicate 3895 octets shall set the Maximum A-MSDU Length in the HT Capabilities element to indicate 3839 octets. A VHT STA that sets the Maximum MPDU Length in the VHT Capabilities element to indicate 7991 octets or 11 454 octets shall set the Maximum A-MSDU Length in the HT Capabilities element to indicate 7935 octets.

The length of an A-MSDU transmitted in a VHT PPDU is limited by the maximum MPDU size supported by the recipient STA (see 10.12.5).

NOTE 3—An A-MSDU that meets the A-MSDU length limit for transmission in a VHT PPDU might exceed the A-MSDU length limit for an HT PPDU, in which case it cannot be retransmitted in an HT PPDU.

NOTE 4—Support for A-MSDU aggregation does not affect the maximum size of MSDU transported by the MA-UNITDATA primitives.

A VHT STA shall not transmit an A-MSDU that includes a number of MSDUs greater than the value indicated by the Max Number Of MSDUs In A-MSDU field in any Extended Capabilities element sent by the recipient STA. An HT STA should not transmit an A-MSDU that includes a number of MSDUs greater than the value indicated by the Max Number Of MSDUs In A-MSDU field in any Extended Capabilities element sent by the recipient STA. A STA shall not transmit an A-MSDU in a CMMG PPDU to a STA if the A-MSDU length exceeds the value indicated by the Maximum A-MSDU Length field of the CMMG Capabilities element received from the recipient STA.

A DMG STA shall not transmit an A-MSDU that includes a number of Basic A-MSDU subframes greater than the value indicated by the Maximum Number Of Basic A-MSDU Subframes In A-MSDU subfield in any DMG Capabilities element sent by the recipient STA. A DMG STA shall not transmit an A-MSDU that includes a number of Short A-MSDU subframes greater than the value indicated by the Maximum Number Of Short A-MSDU Subframes In A-MSDU subfield in any DMG Capabilities element sent by the recipient STA. A DMG STA that sets the A-MSDU Subframe subfield to 1 in a DMG Attributes field of TSPEC element (9.4.2.29), which indicates Short A-MSDU subframe support, shall be capable of receiving at least 32 Short A-MSDU subframes in A-MSDU. A CMMG STA that sets the Maximum MPDU Length subfield in the CMMG Capabilities element to indicate 3895 octets shall set the maximum A-MSDU length in the CMMG Capabilities element to indicate 3839 octets. A CMMG STA that sets the Maximum MPDU Length subfield in the CMMG Capabilities element to indicate 7991 octets or 11 454 octets shall set the maximum A-MSDU length in the CMMG Capabilities element to indicate 7935 octets.

The transmitter of frames for a TID established using a PTP TSPEC shall use an A-MSDU subframe format that is the result of the PTP TSPEC negotiation for that TID. The A-MSDU subframe format is negotiated using the PTP TSPEC (9.4.2.29): the Short A-MSDU subframe format shall not be used for frames of the corresponding TID if the A-MSDU subframe field of the PTP TSPEC element is 0 either in the ADDTS

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Request frame or in the ADDTS Response frame used to set up the TID. Prior to PTP TSPEC negotiation, a STA shall use the Basic A-MSDU subframe format if the STA employs MSDU aggregation.

A non-PCP DMG STA in a PBSS may use the PCP of the PBSS to forward MSDUs to another non-PCP STA in the PBSS if the value of the PCP Forwarding field within the PCP's DMG Capabilities element is 1. A non-PCP DMG STA in a PBSS shall not use the PCP to forward MSDUs if the value of the PCP Forwarding field within the PCP's DMG Capabilities element is 0. To forward an MSDU via the PCP, a non-PCP STA shall encapsulate the MSDU within an individually addressed A-MSDU sent to the PCP. The DA field of the A-MSDU shall be set to the destination's individual or group address.

The length of an A-MSDU transmitted in a CMMG PPDU is limited by the maximum MPDU size supported by the recipient STA (see 10.12.5).

A CMMG STA shall not transmit to a recipient CMMG STA an A-MSDU that includes a number of MSDUs greater than the value indicated by the Max Number of MSDUs in A-MSDU field in the Extended Capabilities element received from the recipient STA.

When dot11RSNAActivated is true, a STA indicates support for payload protected A-MSDUs (PP A-MSDUs) or signaling and payload protected A-MSDUs (SPP A-MSDUs) during (re)association. On either (re)association, the associating STA and its peer STA both determine and maintain a record of whether an encrypted A-MSDU sent to its peer is to be a PP A-MSDU or an SPP A-MSDU based on the SPP A-MSDU Capable and SPP A-MSDU Required subfields of the RSN Capabilities field of the RSNE (see 9.4.2.24.4).

Table 10-12 defines behavior related to the transmission and reception of individually addressed A-MSDUs of a first HT STA or S1G STA (STA1) that has successfully negotiated an RSNA (re)association with a second HT STA or S1G STA (STA2). Reception and transmission of A-MSDUs using a non-RSN association is unaffected by the values of the SPP A-MSDU Capable and SPP A-MSDU Required subfields.

Table 10-12—A-MSDU STA behavior for RSN associations

STA1 state		STA2 state		STA1 action with respect to STA2
SPP A-MSDU capable	SPP A-MSDU required	SPP A-MSDU capable	SPP A-MSDU required	
0	0	X	0	May transmit PP A-MSDU. Shall not transmit SPP A-MSDU. Shall receive PP A-MSDU. Received SPP A-MSDU MIC fails.
0	0	X	1	Shall not transmit PP A-MSDU. Shall not transmit SPP A-MSDU. Shall discard received (PP and SPP) A-MSDU.
0	1	X	X	Shall not transmit PP A-MSDU. Shall not transmit SPP A-MSDU. Shall discard received (PP and SPP) A-MSDU.
1	0	0	0	May transmit PP A-MSDU. Shall not transmit SPP A-MSDU. Shall receive PP A-MSDU. Received SPP A-MSDU MIC fails.

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Table 10-12—A-MSDU STA behavior for RSN associations *(continued)*

STA1 state		STA2 state		STA1 action with respect to STA2
SPP A-MSDU capable	SPP A-MSDU required	SPP A-MSDU capable	SPP A-MSDU required	
1	0	0	1	Shall not transmit PP A-MSDU. Shall not transmit SPP A-MSDU. Shall discard received (PP and SPP) A-MSDU.
1	X	1	X	Shall not transmit PP A-MSDU. May transmit SPP A-MSDU. Received PP A-MSDU MIC fails. Shall receive SPP A-MSDU.
1	1	0	X	Shall not transmit PP A-MSDU. Shall not transmit SPP A-MSDU. Shall discard received (PP and SPP) A-MSDU.
NOTE—X = Not significant.				

An AP may transmit an SPP A-MSDU for a GCR group address if it has successfully negotiated RSNA (re)associations with all associated STAs that have an active GCR agreement for this group address.

10.12 A-MPDU operation

10.12.1 A-MPDU contents

According to its context (defined in Table 9-529), an A-MPDU shall be constrained so that it contains only MPDUs as specified in the relevant table referenced from Table 9-529.

The values of the Protocol Version field in the Frame Control field of the MPDUs contained in an A-MPDU shall be the same, except for a Control frame with the Protocol Version field equal to 0 in which case the Control frame can be aggregated with PV1 frame.

When an A-MPDU contains multiple QoS Control fields, bits 4 and 8–15 of these QoS Control fields shall be identical.

When an A-MPDU contains multiple MPDUs whose Protocol Version field value is 1, the values of EOSP and Relayed Frame fields in the Frame Control field, and A3 Present, A4 Present subfields in the SID field shall be identical across MPDUs within the A-MPDU.

A DMG STA that transmits an A-MPDU shall do so only in the Data Enabled Immediate Response context or the Control Response context, with contents as specified in Table 9-530 and Table 9-533, respectively.

10.12.2 A-MPDU length limit rules

A STA indicates in the Maximum A-MPDU Length Exponent field in its HT Capabilities element the maximum A-MPDU length that it can receive in an HT PPDU. A STA indicates in the Maximum A-MPDU Length Exponent field in its VHT Capabilities element the maximum length of the A-MPDU pre-EOF padding that it can receive in a VHT PPDU. A STA indicates in the Maximum A-MPDU Length Exponent field in its S1G Capabilities element the maximum length of the A-MPDU pre-EOF padding that it can receive in an

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S1G PPDU. A STA indicates in the Maximum A-MPDU Length Exponent field in its DMG Capabilities element the maximum A-MPDU length that it can receive in a DMG PPDU.

A VHT STA that sets the Maximum A-MPDU Length Exponent field in its VHT Capabilities element to a value in the range 0 to 3 shall set the Maximum A-MPDU Length Exponent in its HT Capabilities to the same value. A VHT STA that sets the Maximum A-MPDU Length Exponent field in the VHT Capabilities element to a value larger than 3 shall set the Maximum A-MPDU Length Exponent in its HT Capabilities element to 3.

Using the Maximum A-MPDU Length Exponent fields in the HT Capabilities and VHT Capabilities elements, the STA establishes at association the maximum length of an A-MPDU pre-EOF padding that can be sent to it. An HT STA shall be capable of receiving A-MPDUs of length up to the value indicated by the Maximum A-MPDU Length Exponent field in its HT Capabilities element. A VHT STA shall be capable of receiving A-MPDUs where the A-MPDU pre-EOF padding length is up to the value indicated by the Maximum A-MPDU Length Exponent field in its VHT Capabilities element. An S1G STA that sets the A-MPDU Supported subfield in the S1G Capabilities element to 1 shall be capable of receiving A-MPDUs where the A-MPDU pre-EOF padding length is up to the value indicated by the Maximum A-MPDU Length Exponent field in its S1G Capabilities element.

A STA shall not transmit an A-MPDU in an HT PPDU that is longer than the value indicated by the Maximum A-MPDU Length Exponent field in the HT Capabilities element received from the intended receiver. MPDUs in an A-MPDU carried in an HT PPDU shall be limited to a maximum length of 4095 octets. A STA shall not transmit an A-MPDU in a VHT PPDU where the A-MPDU pre-EOF padding length is longer than the value indicated by the Maximum A-MPDU Length Exponent field in the VHT Capabilities element received from the intended receiver. An S1G STA shall not transmit an A-MPDU in an S1G PPDU where the A-MPDU pre-EOF padding length field is longer than the value indicated by the Maximum A-MPDU Length Exponent field in the S1G Capabilities element received from the intended receiver. A STA shall not transmit an A-MPDU in a DMG PPDU that is longer than the value indicated by the Maximum A-MPDU Length Exponent field in the DMG Capabilities element received from the intended receiver.

An S1G STA shall not transmit an A-MPDU, except for an S-MPDU, to an S1G STA from which it received a frame containing an S1G Capability element with the A-MPDU Supported subfield equal to 0.

10.12.3 Minimum MPDU Start Spacing field

A STA shall not start the transmission of more than one MPDU within the time limit described in the Minimum MPDU Start Spacing field declared by the intended receiver. To satisfy this requirement, the number of octets between the start of two consecutive MPDUs in an A-MPDU, measured at the PHY SAP, shall be equal to or greater than

$$t_{MMSS} \times r / 8$$

where

t_{MMSS} is the time (in microseconds) defined in the Encoding column of Table 9-185 for an HT STA, of Table 9-300 for an S1G STA for the value of the Minimum MPDU Start Spacing field, and of Table 9-251 for a DMG STA for the value of the Minimum MPDU Start Spacing field

r is the value of the PHY Data Rate (in megabits per second) defined in 19.5 for HT PPDUs, in 21.5 for VHT PPDUs, in 23.5 for S1G PPDUs, and in Clause 20 for a DMG STA

If necessary, in order to satisfy this requirement, a STA shall add padding between MPDUs in an A-MPDU. Any such padding shall be in the form of one or more MPDU delimiters with the MPDU Length field set to 0.

QoS Null frames transmitted by DMG STAs are not subject to this spacing, i.e., no MPDU delimiters with zero length need to be inserted after the MPDU immediately preceding the QoS Null frame in an A-MPDU.

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10.12.4 A-MPDU aggregation of group addressed Data frames

A STA that is neither an AP nor a mesh STA shall not transmit an A-MPDU containing an MPDU with an RA that is a group address.

NOTE 1—An HT AP and an HT mesh STA can transmit an A-MPDU containing MPDUs with an RA that is a group address.

NOTE 2—As a VHT STA is an HT STA, NOTE 1 also applies to VHT APs and VHT mesh STAs.

NOTE 3—An AP providing GCR service can transmit an A-MPDU containing MPDUs with an RA that is a group address.

NOTE 4—An S1G AP can transmit an A-MPDU containing MPDUs with an RA that is a group address.

A STA that is an AP or a mesh STA shall not transmit an A-MPDU containing group addressed MPDUs if the HT Protection field is equal to non-HT mixed mode.

A DMG STA may transmit an A-MPDU containing MPDUs with an RA that is a group address.

When a STA transmits a PPDU containing at least one A-MPDU that contains MPDUs with an RA that is a group address, the following shall apply:

— If the PPDU is an HT PPDU transmitted by an AP, the maximum A-MPDU length exponent value is the minimum value in the Maximum A-MPDU Length Exponent subfield of the A-MPDU Parameters field of the HT Capabilities element of all HT STAs associated with the AP.
— If the PPDU is an HT PPDU transmitted by a mesh STA, the maximum A-MPDU length exponent value is the minimum value in the Maximum A-MPDU Length Exponent subfield of the A-MPDU Parameters field of the HT Capabilities element of all peer HT mesh STAs.
— If the PPDU is a VHT PPDU, the value of maximum A-MPDU length exponent that applies is the minimum value in the Maximum A-MPDU Length Exponent subfields of the A-MPDU Parameters fields of the VHT Capabilities elements across all VHT STAs associated with the transmitting AP or across all peer VHT mesh STAs.
— If the PPDU is a VHT PPDU, the value of minimum MPDU start spacing that applies is the maximum value in the Minimum MPDU Start Spacing subfields of the A-MPDU Parameters fields of the HT Capabilities elements across all VHT STAs associated with the transmitting AP or across all peer VHT mesh STAs of the transmitting mesh STA.
— If the PPDU is an HT PPDU transmitted by an AP, the minimum MPDU start spacing value that applies is the maximum value in the Minimum MPDU Start Spacing subfield of the A-MPDU Parameters field of the HT Capabilities element of all HT STAs associated with the AP.
— If the PPDU is an HT PPDU transmitted by a mesh STA, the minimum MPDU start spacing value that applies is the maximum value in the Minimum MPDU Start Spacing subfield of the A-MPDU Parameters field of the HT Capabilities element of all peer HT mesh STAs.
— If the PPDU is a DMG PPDU, the maximum A-MPDU length exponent value that applies is the minimum value in the Maximum A-MPDU Length Exponent subfield of the A-MPDU Parameters field of the DMG Capabilities element of all DMG STAs associated with the AP or PCP.
— If the PPDU is a DMG PPDU, the minimum MPDU start spacing value that applies is the maximum value in the Minimum MPDU Start Spacing subfield of the A-MPDU Parameters field of the DMG Capabilities element of all DMG STAs associated with the AP or PCP.
— If the PPDU is an S1G PPDU, the value of maximum A-MPDU length exponent that applies is the minimum value in the Maximum A-MPDU Length Exponent subfields of the S1G Capabilities

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Information field of the S1G Capabilities elements across all S1G STAs associated with the transmitting AP.

— If the PPDU is an S1G PPDU, the value of minimum MPDU start spacing that applies is the maximum value in the Minimum MPDU Start Spacing subfields of the S1G Capabilities Information field of the S1G Capabilities elements across all S1G STAs associated with the transmitting AP.

10.12.5 Transport of A-MPDU by the PHY data service

An A-MPDU shall be transmitted in a PSDU associated with a PHY-TXSTART.request primitive with the TXVECTOR parameter AGGREGATION set to 1 or the TXVECTOR parameter FORMAT set to VHT. A received PSDU is determined to be an A-MPDU when the associated PHY-RXSTART.indication primitive RXVECTOR parameter AGGREGATION is equal to 1 or the RXVECTOR parameter FORMAT is equal to VHT.

A STA shall not transmit an MPDU in an S1G PPDU that exceeds the maximum MPDU length capability indicated in the S1G Capabilities element received from the recipient STA.

An S1G STA shall set the TXVECTOR parameter AGGREGATION to 1 when the length of the PSDU to be carried in the S1G PPDU is greater than aPSDUMaxLengthWithNoAggregation.

10.12.6 A-MPDU padding for VHT PPDU or S1G PPDU

A VHT STA that transmits a VHT PPDU or an S1G STA that transmits an S1G PPDU that contains one or more PSDUs, each of which contains an A-MPDU, shall construct the A-MPDU(s) as described in this subclause.

An A-MPDU pre-EOF padding (see 10.12.2) is constructed for each user from any of the following:

— A-MPDU subframes constructed from the MPDUs available for transmission that have a TID value that maps to the primary AC

— A-MPDU subframes with 0 in the MPDU Length field and 0 in the EOF field

provided that each added subframe and the A-MPDU pre-EOF padding meet all of the following:

— A-MPDU content constraints (see 10.12.1) for the intended recipient

— Format and length limit constraints (see 9.7.1 and 10.12.2) for the intended recipient

— Minimum MPDU start spacing constraints (see 10.12.3) for the intended recipient

— TXOP duration limits (see 10.23.2.9) for the primary AC

The A-MPDU_Length[*n*] for user *n* is initialized as the length of the resulting A-MPDU pre-EOF padding.

This initial value of A-MPDU_Length[*n*] for user *n* is used as the APEP_LENGTH[*n*] parameter value for the PLME-TXTIME.request primitive (see 6.5.5). The PLME-TXTIME.request primitive is then invoked once for the VHT PPDU or the S1G PPDU. The PLME-TXTIME.confirm primitive (see 6.5.6) provides the TXTIME parameter and PSDU_LENGTH[] parameters for all of the users for the transmission.

Subsequently, for each user *n*, as permitted by the rules for EDCA TXOP Sharing (see 10.23.2.7), a VHT STA or S1G STA may add A-MPDU subframes to the A-MPDU for that user that meets either of the following conditions:

— Have a TID that maps to an AC that is not the primary AC

— Have 0 in the MPDU Length field and 0 in the EOF field

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provided that each added subframe and the resulting A-MPDU meet all of the following:

- A-MPDU content constraints (see 10.12.1) for the intended recipient
- Length limit constraints (see 9.7.1 and 10.12.2) for the intended recipient
- MPDU start spacing constraints (see 10.12.3) for the intended recipient

and provided that, after incrementing the A-MPDU_Length[*n*] with the length of each such added A-MPDU subframe, the relationship A-MPDU_Length[*n*] ≤ PSDU_LENGTH[*n*] is true.

Subsequently, for each user n, a VHT STA or S1G STA may add A-MPDU subframes to the A-MPDU for that user that meet the following condition:

- Have 0 in the MPDU Length field

provided that each added subframe and the resulting A-MPDU meet the following condition:

- Length limit constraints (see 9.7.1 and 10.12.2) for the intended recipient

and provided that, after incrementing the A-MPDU_Length[n] with the length of each such added A-MPDU subframe, the relationship A-MPDU_Length[*n*] ≤ PSDU_LENGTH[*n*] is true.

An implementation may reduce the A-MPDU_Length[*n*] by the amount of padding for user *n* that was added subsequent to the addition of a subframe for user *n* that contains 1 in the EOF field.

The final value of A-MPDU_Length[] shall be used as APEP_LENGTH[] in the PHY-TXSTART.request primitive for the VHT PPDU or S1G PPDU.

Padding is then added for each user such that the resulting A-MPDU contains exactly PSDU_LENGTH octets for that user as follows:

- First, while A-MPDU_Length[*n*] < PSDU_LENGTH[*n*] and A-MPDU_Length[*n*] mod 4 ≠ 0, add an octet to the final A-MPDU subframe's Padding subfield and increment A-MPDU_Length[*n*] by 1.
- Then, while A-MPDU_Length[*n*] + 4 ≤ PSDU_LENGTH[*n*], add an EOF padding subframe to the EOF Padding Subframes field and increment A-MPDU_Length[*n*] by 4.
- Finally, while A-MPDU_Length[*n*] < PSDU_LENGTH[*n*], add an octet to the EOF Padding Octets subfield and increment A-MPDU_Length[*n*] by 1.

An A-MPDU subframe with EOF set to 0 shall not be added after any A-MPDU subframe with EOF set to 1.

An A-MPDU subframe with EOF set to 1 and with MPDU Length field set to 0 shall not be added before an A-MPDU subframe that contains an S-MPDU (see 10.12.7).

10.12.7 Setting the EOF field of the MPDU delimiter

The EOF field may be set to 1 in an A-MPDU subframe carried in a VHT PPDU or S1G PPDU if the subframe's MPDU Length field is nonzero and the subframe is the only subframe that has a nonzero MPDU Length field. The EOF field of each A-MPDU subframe with an MPDU Length field with a nonzero value that is not the only A-MPDU subframe with MPDU Length field with a nonzero value in the A-MPDU carried in a VHT PPDU or S1G PPDU shall be set to 0. The EOF field shall be set to 0 in all A-MPDU subframes that are carried in an HT PPDU.

An MPDU that is the only MPDU in an A-MPDU and that is carried in an A-MPDU subframe with 1 in the EOF field is called an S-MPDU.

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10.12.8 Transport of S-MPDUs

The rules for S-MPDU operation are the same as the rules for non-A-MPDU frame operation with other types of non-A-MPDU.

NOTE—This affects the following behavior:

a) The frame could carry a fragment of an MSDU or MMPDU (see 10.2.6).
b) Rate selection of control responses (see 10.6).
c) A QoS Data frame cannot have Implicit BAR ack policy, and does not generate a BlockAck frame response (see 9.2.4.5.4).
d) A QoS Data frame could have Normal Ack ack policy, which solicits an Ack frame immediate response. No block ack agreement is needed in this case (see 9.2.4.5.4).
e) The frame could be a Management frame that solicits an Ack frame response (see 9.7.3).

10.13 PPDU duration constraint

A STA shall not transmit an HT PPDU that has a duration (as determined by the PHY-TXTIME.confirm primitive defined in 6.5.6) that is greater than aPPDUMaxTime defined in Table 19-25.

A STA shall not transmit a DMG PPDU that has a duration (as determined by the PHY-TXTIME.confirm primitive defined in 6.5.6) that is greater than aPPDUMaxTime defined in Table 20-30.

A CMMG STA shall not transmit a PPDU that has a duration (as determined by the PHY-TXTIME.confirm primitive defined in 6.5.6) that is greater than aPPDUMaxTime.

A STA shall not transmit a VHT PPDU that has a duration (as determined by the PHY-TXTIME.confirm primitive defined in 6.5.6) that is greater than aPPDUMaxTime defined in Table 21-28.

A STA shall not transmit a VHT MU PPDU with the TXVECTOR parameter APEP_LENGTH for any of the users greater than aAPEPMaxLengthVHTMU20, aAPEPMaxLengthVHTMU40 or aAPEPMaxLengthVHTMU80orMore when TXVECTOR parameter CH_BANDWIDTH is CBW20, CBW40, or other values, respectively.

NOTE—In the case of using aPEPMaxLengthVHTMU80orMore, the constraint from Maximum A-MPDU Length Exponent of 7 is smaller and becomes the actual limiting factor (see 10.12.2).

A STA shall not transmit a VHT PPDU in TVWS bands that has a duration (as determined by the PHY-TXTIME.confirm primitive defined in 6.5.6) that is greater than aPPDUMaxTime defined in Table 22-25.

A STA shall not transmit an S1G PPDU that has a duration (as determined by the PHY-TXTIME.confirm primitive defined in 6.5.6) that is greater than aPPDUMaxTime defined in Table 23-40.

10.14 DMG A-PPDU operation

A DMG STA is aggregate PPDU (A-PPDU) capable if the A-PPDU supported field within the STA's DMG Capabilities element is 1. Otherwise, the STA is not A-PPDU capable.

A DMG STA shall not transmit an A-PPDU aggregate to a STA that is not A-PPDU capable.

An A-PPDU is a sequence of two or more PPDUs transmitted without IFS, preamble, and with a PHY-dependent separation between PPDU transmissions. All PPDUs within an A-PPDU shall have the ADD_PPDU parameter of the TXVECTOR set to ADD-PPDU, except for the last PPDU in the A-PPDU that shall have this parameter set to NO-ADD-PPDU. The value of a TXVECTOR parameter of

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a PPDU belonging to an A-PPDU might differ from the value of the same TXVECTOR parameter of another PPDU in the same A-PPDU, including the MCS parameter.

A PPDU within an A-PPDU shall contain an A-MPDU. All MPDUs within A-MPDUs within an A-PPDU shall have the same values for the TA and RA fields. All QoS Data frames within A-MPDUs within an A-PPDU shall have the same ack policy. If a frame that requires an immediate response is present within an A-PPDU, it shall be transmitted in the last A-MPDU of the A-PPDU.

The transmission duration of an A-PPDU shall be no greater than aPPDUMaxTime (see Table 20-30).

10.15 Low-density parity check code (LDPC) operation

An HT STA shall not transmit a frame in a PSDU with the TXVECTOR parameter FORMAT set to HT_MF or HT_GF and TXVECTOR parameter FEC_CODING set to LDPC_CODING unless the RA of the frame corresponds to an HT STA for which the LDPC Coding Capability subfield of the HT Capabilities element received from that STA contained a value of 1 and dot11LDPCCodingOptionActivated is true (if there is more than one intended receiver, then this requirement applies for each intended receiver).

A VHT STA shall not transmit a frame in a PSDU with the TXVECTOR parameter FORMAT set to VHT and TXVECTOR parameter FEC_CODING set to LDPC_CODING unless the RA of the frame corresponds to a VHT STA for which the Rx LDPC subfield of the VHT Capabilities element received from that STA contained a value of 1 and dot11VHTLDPCCodingOptionActivated is true (if there is more than one intended receiver, then this requirement applies for each intended receiver).

An S1G STA shall not transmit a frame in a PSDU with the TXVECTOR parameter FEC_CODING set to LDPC_CODING unless the RA of the frame corresponds to a STA for which the Rx LDPC subfield of the S1G Capabilities element from that STA contained a value of 1 and dot11S1GLDPCCodingOptionActivated is true (if there is more than one intended receiver, then this requirement applies for each intended receiver).

A STA should not transmit a frame in a PSDU with the TXVECTOR parameter FORMAT set to HT_MF, HT_GF or VHT and TXVECTOR parameter FEC_CODING set to LDPC_CODING if the RA of the frame corresponds to a STA from which it has received a frame containing an Operating Mode field and the most recent Operating Mode field it has received from that STA had the No LDPC subfield equal to 1 (if there is more than one intended receiver, then this requirement applies for each intended receiver).

Further restrictions on TXVECTOR parameter values may apply due to rules found in 10.27 and 10.6.

10.16 STBC operation

A STA that has not set the Tx STBC subfield to 1 in the HT Capabilities element shall not transmit HT PPDUs with a TXVECTOR parameter STBC set to a nonzero value. A STA that has not set the Tx STBC subfield to 1 in the VHT Capabilities element shall not transmit VHT SU PPDUs with a TXVECTOR parameter STBC set to a nonzero value. A STA that has not set the Tx STBC subfield to 1 in the S1G Capabilities element shall not transmit S1G SU PPDUs with the TXVECTOR parameter STBC set to a nonzero value.

A STA shall not send an HT PPDU with the TXVECTOR parameter STBC set to a nonzero value to a recipient STA unless the recipient STA has indicated in the Rx STBC field of its HT Capabilities element that it supports the reception of PPDUs using STBC with a number of spatial streams greater than or equal to the number of spatial streams in the HT PPDU (if there is more than one intended receiver, then this requirement applies for each intended receiver). A STA shall not send a VHT PPDU with the TXVECTOR parameter STBC set to a nonzero value to a recipient STA unless the recipient STA has indicated in the Rx STBC field of its VHT Capabilities element that it supports the reception of PPDUs using STBC with a number of spatial streams

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greater than or equal to the number of spatial streams in the VHT PPDU (if there is more than one intended receiver, then this requirement applies for each intended receiver). A STA shall not send an S1G PPDU with the TXVECTOR parameter STBC set to a nonzero value to a recipient STA unless the recipient STA has indicated in the Rx STBC field of its S1G Capabilities element that it supports the reception of PPDUs using STBC with a number of spatial streams greater than or equal to the number of spatial streams in the S1G PPDU (if there is more than one intended receiver, then this requirement applies for each intended receiver).

A STA that has not set the Tx STBC subfield to 1 in the CMMG Capabilities element shall not transmit CMMG PPDUs with a TXVECTOR parameter STBC set to a nonzero value.

A STA shall not send a CMMG PPDU with the TXVECTOR parameter STBC set to a nonzero value to a recipient STA unless the recipient STA has indicated in the Rx STBC field of its CMMG Capabilities element that it supports the reception of PPDUs using STBC with a number of spatial streams equal to or greater than the number of spatial streams in the CMMG PPDU (if there is more than one intended receiver, then this requirement applies for each intended receiver).

10.17 Short GI operation

A STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to HT_CBW20 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

— The STA is an HT STA.
— The TXVECTOR parameter FORMAT is equal to HT_MF or HT_GF.
— The RA of the frame corresponds to a STA for which the Short GI for 20 MHz subfield of the HT Capabilities element contained a value of 1.
— dot11ShortGIOptionInTwentyActivated is present and is true.

A STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW20 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

— The STA is a VHT STA.
— The TXVECTOR parameter FORMAT is equal to VHT.
— The RA of the frame corresponds to a STA for which the Short GI for 20 MHz subfield of the HT Capabilities element contained a value of 1.
— dot11ShortGIOptionInTwentyActivated is present and is true.

A STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to HT_CBW40 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

— The STA is an HT STA.
— The TXVECTOR parameter FORMAT is equal to HT_MF or HT_GF.
— The RA of the frame corresponds to a STA for which the Short GI for 40 MHz subfield of the HT Capabilities element contained a value of 1.
— dot11ShortGIOptionInFortyActivated is present and is true.

A STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW40 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

— The STA is a VHT STA.
— The TXVECTOR parameter FORMAT is equal to VHT.

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— The RA of the frame corresponds to a STA for which the Short GI for 40 MHz subfield of the HT Capabilities element contained a value of 1.
— dot11ShortGIOptionInFortyActivated is present and is true.

A STA shall not transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW80 and GI_TYPE set to SHORT_GI unless all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

— The STA is a VHT STA.
— The TXVECTOR parameter FORMAT is equal to VHT.
— The RA of the frame corresponds to a STA for which the Short GI for 80 MHz/TVHT_MODE_4C subfield of the VHT Capabilities element contained a value of 1.
— dot11VHTShortGIOptionIn80Activated is present and is true.

A STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW160 or CBW80+80 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

— The STA is a VHT STA.
— The TXVECTOR parameter FORMAT is equal to VHT.
— The RA of the frame corresponds to a STA for which the Short GI for 160 and 80+80 MHz subfield of the VHT Capabilities element contained a value of 1.
— dot11VHTShortGIOptionIn160and80p80Activated is present and is true.

A STA may transmit a frame in a PSDU with TXVECTOR parameters FORMAT set to VHT, NUM_USERS set to greater than 1, and GI_TYPE set to SHORT_GI only if all of the following conditions are met:

— The STA is a VHT STA.
— The TXVECTOR parameter FORMAT is equal to VHT.
— The RAs of all MPDUs in the VHT MU PPDU correspond to STAs for which the Short GI subfield of the following conditions are satisfied:
  — If the TXVECTOR parameter CH_BANDWIDTH is set to CBW20, the Short GI for 20 MHz subfields of the HT Capabilities element contained a value of 1, and dot11ShortGIOptionInTwentyActivated is present and is true.
  — If the TXVECTOR parameter CH_BANDWIDTH is set to CBW40, the Short GI for 40 MHz subfields of the HT Capabilities element contained a value of 1, and dot11ShortGIOptionInFortyActivated is present and is true.
  — If the TXVECTOR parameter CH_BANDWIDTH is set to CBW80, the Short GI for 80 MHz/TVHT_MODE_4C subfields of the VHT Capabilities element contained a value of 1, and dot11VHTShortGIOptionIn80Activated is present and is true.
  — If the TXVECTOR parameter CH_BANDWIDTH is set to CBW160 or CBW80+80, the Short GI for 160 MHz and 80+80 MHz subfields of the VHT Capabilities element contained a value of 1, and dot11VHTShortGIOptionIn160and80p80Activated is present and is true.

An S1G STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW1 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

— The RA of the frame corresponds to a STA for which the Short GI for 1 MHz subfield of the S1G Capabilities element is 1.
— dot11ShortGIOptionIn1MActivated is present and is true.

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An S1G STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW2 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

— The RA of the frame corresponds to a STA for which the Short GI for 2 MHz subfield of the S1G Capabilities element is 1.

— dot11ShortGIOptionIn2MActivated is present and is true.

An S1G STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW4 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

— The RA of the frame corresponds to a STA for which the Short GI for 4 MHz subfield of the S1G Capabilities element is 1.

— dot11ShortGIOptionIn4MActivated is present and is true.

An S1G STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW8 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

— The RA of the frame corresponds to a STA for which the Short GI for 8 MHz subfield of the S1G Capabilities element is 1.

— dot11ShortGIOptionIn8MActivated is present and is true.

An S1G STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW16 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

— The RA of the frame corresponds to a STA for which the Short GI for 16 MHz subfield of the S1G Capabilities element is 1.

— dot11ShortGIOptionIn16MActivated is present and is true.

An S1G STA may transmit a frame in a PSDU with TXVECTOR parameters NUM_USERS set to greater than 1, and GI_TYPE set to SHORT_GI only if all of the following conditions are met:

— The RAs of all MPDUs in the S1G MU PPDU correspond to STAs for which the Short GI subfield of the following conditions are satisfied:
  — If the TXVECTOR parameter CH_BANDWIDTH is set to CBW2, the Short GI for 2 MHz subfield of the S1G Capabilities element is equal to 1, and dot11ShortGIOptionIn2MActivated is present and is true.
  — If the TXVECTOR parameter CH_BANDWIDTH is set to CBW4, the Short GI for 4 MHz subfield of the S1G Capabilities element is equal to 1, and dot11ShortGIOptionIn4MActivated is present and is true.
  — If the TXVECTOR parameter CH_BANDWIDTH is set to CBW8, the Short GI for 8 MHz subfield of the S1G Capabilities element is equal to 1, and dot11ShortGIOptionIn8MActivated is present and is true.
  — If the TXVECTOR parameter CH_BANDWIDTH is set to CBW16, the Short GI for 16 MHz subfield of the S1G Capabilities element is equal to 1, and dot11ShortGIOptionIn16MActivated is present and is true.

An HT STA shall not transmit a frame with TXVECTOR parameter FORMAT set to HT_GF and the GI_TYPE parameter set to SHORT_GI when the MCS parameter indicates a single spatial stream.

Further restrictions on TXVECTOR parameter values may apply due to rules found in 10.27 and 10.6.

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10.18 Greenfield operation

An HT STA shall not transmit a frame in a PSDU with the TXVECTOR parameter FORMAT set to HT_GF unless the RA of the frame corresponds to a STA for which the HT-Greenfield subfield of the HT Capabilities element contained a value of 1 and dot11HTGreenfieldOptionActivated is true (if there is more than one intended receiver, then this requirement applies for each intended receiver). Further restrictions may apply due to rules found in 10.27, 10.6, and 11.8.8.5.

10.19 Group ID and partial AID in VHT and CMMG PPDUs

The partial AID is a nonunique STA identifier defined in Table 10-13 and Table 10-14. The partial AID is carried in the TXVECTOR parameter PARTIAL_AID of a VHT SU PPDU or a CMMG PPDU and is limited to 9 bits.

A STA transmitting a VHT SU PPDU carrying one or more group addressed MPDUs or transmitting a VHT NDP intended for multiple recipients shall set the TXVECTOR parameters GROUP_ID to 63 and PARTIAL_AID to 0. The intended recipient of a VHT NDP is defined in 10.36.6.

A STA transmitting a CMMG PPDU carrying one or more group addressed MPDUs shall set the TXVECTOR parameters PARTIAL_AID to 0.

A STA transmitting a VHT SU PPDU carrying one or more individually addressed MPDUs or a VHT NDP intended for a single recipient shall set the TXVECTOR parameters GROUP_ID and PARTIAL_AID as shown in Table 10-13.

Table 10-13—Settings for the TXVECTOR parameters GROUP_ID and PARTIAL_AID for VHT STAs

Condition	GROUP_ID	PARTIAL_AID
Addressed to AP	0	*int(*BSSID[39:47])
Addressed to Mesh STA	0	*int(*RA[39:47])
Sent by an AP and addressed to a STA associated with that AP or sent by a TDLS STA in a direct path to a TDLS peer STA	63	$(\text{AID} + int(\text{BSSID}[44:47] \oplus \text{BSSID}[40:43]) \times 2^5) \bmod 2^9$ (10-12)
Otherwise (see NOTE)	63	0

NOTE—The last row covers the following cases:
a) A PPDU sent to an IBSS STA
b) A PPDU sent by an AP to a non associated STA
c) Any other condition not explicitly listed elsewhere in the table

A STA transmitting a CMMG PPDU carrying one or more individually addressed MPDUs shall set the TXVECTOR parameter PARTIAL_AID as shown in Table 10-14.

A STA shall include the values computed in Table 10-13 in the PHYCONFIG_VECTOR parameters PARTIAL_AID_LIST_GID00 and PARTIAL_AID_LIST_GID63.

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Table 10-14—Settings for the TXVECTOR parameter PARTIAL_AID for CMMG STAs

Condition	PARTIAL_AID
A frame that is not a Control frame that is addressed to an AP.	$(dec(\text{BSSID}[39:47]) \bmod (2^9 - 1)) + 1$
A frame that is not a Control frame that is addressed to an AP.	$(dec(\text{RA}[39:47]) \bmod (2^9 - 1)) + 1$
A frame that is not a Control frame that is sent by an AP and addressed to a STA associated with that AP or sent by a TDLS STA in a direct path to a TDLS peer STA.	$(dec(AID[0:8]) + dec(\text{BSSID}[44:47] \oplus \text{BSSID}[40:43]) \times 2^5) \bmod 2^6$ (10-13)
Otherwise (see NOTE)	0
NOTE—The last row covers the following cases: a) A PPDU sent to an IBSS STA b) A PPDU sent by an AP to a non associated STA c) Any other condition not explicitly listed elsewhere in the table	

A STA that transmits a VHT or CMMG PPDU to a TDLS peer STA obtains the AID for the peer STA from the TDLS Setup Request or TDLS Setup Response frame.

An AP should not assign to a STA an AID that results in a 0 value PARTIAL_AID [as computed using Equation (10-12) (in Table 10-13)]. A CMMG AP should not assign to a CMMG STA an AID that results in the PARTIAL_AID value [as computed using Equation (10-13) (in Table 10-14)] being equal to one of the following:

$$0 \text{ or } (dec(\text{BSSID}[39:47]) \bmod (2^9 - 1)) + 1 \text{ or } (dec(\text{OBSSID}[39:47]) \bmod (2^9 - 1)) + 1$$

where OBSSID is the BSSID of a BSS that is not the BSS of which the AP is a member and for which the AP might be heard by the STA being assigned the AID.

A STA transmitting a VHT MU PPDU sets the TXVECTOR parameter GROUP_ID as described in 21.3.11.4.

As an example of the GROUP_ID and PARTIAL_AID setting, consider the case of a BSS with BSSID 00-21-6A-AC-53-52 that has as a member a non-AP STA assigned AID 5.[30] In VHT PPDUs sent to an AP, the GROUP_ID is set to 0 and the PARTIAL_AID is set to 164. In VHT PPDUs sent by the AP to the non-AP STA associated with that AP, the GROUP_ID is set to 63 and PARTIAL_AID is set to 229.

As an example of the PARTIAL_AID setting, consider the case of a BSS with BSSID 00-21-6A-AC-53-52 that has as a member a non-AP CMMG STA assigned AID 5. In CMMG PPDUs sent to an AP, the PARTIAL_AID is set to 165. In CMMG PPDUs sent by the AP to the non-AP STA associated with that AP, the PARTIAL_AID is set to 37.

A STA transmitting a CMMG PPDU that is addressed to an AP shall set the TXVECTOR parameter UPLINK_INDICATION to 1. The UPLINK_INDICATION parameter shall be set to 0 for all other cases.

The TXVECTOR parameter COLOR is used to assist a receiving STA in identifying the BSS from which a reception originates so that the receiving STA might increase spatial reuse and reduce power consumption by terminating the reception process in the case when the reception is not from the BSS of which the STA is a

[30] As described in IEEE Std 802, the use of hyphens for the BSSID indicates hexadecimal representation rather than bit-reversed representation.

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member. A STA transmitting a CMMG PPDU that is addressed to an AP need not include the TXVECTOR parameter COLOR in the TXVECTOR. A STA transmitting a CMMG PPDU that is not an NDP and that is sent by a TDLS STA in a direct path to a TDLS peer STA shall set the TXVECTOR parameter COLOR to the value of the COLOR parameter, if present, from the RXVECTOR of the most recently received frame from its associated AP or from the DO of the IBSS of which it is a member that contained a COLOR parameter. An AP transmitting a CMMG PPDU shall set the TXVECTOR parameter COLOR to a value of its choosing and shall maintain that value for the duration of the existence of the BSS. The AP which is a member of a Multiple BSSID Set shall set the TXVECTOR parameter COLOR for each different BSSID(*i*) to a same value.

An AP shall include the value that it is using for the TXVECTOR parameter COLOR in the COLOR field of the CMMG Capabilities Info field of the CMMG Capabilities element in all frames that contain that element. The COLOR field of the CMMG Capabilities Info field of the CMMG Capabilities element in all frames transmitted from a non-AP STA is reserved.

10.20 S1G dynamic AID assignment operation

An S1G STA may support dynamic AID assignment. A STA with dot11DynamicAIDActivated equal to true is defined as a D-AID STA. A D-AID STA shall set the Dynamic AID field of the S1G Capabilities Information field in the S1G Capabilities element to 1. Otherwise it shall set the Dynamic AID field to 0.

A D-AID STA may transmit AID Switch Request or AID Switch Response frames to a D-AID STA. A STA shall not transmit an AID Switch Request frame or AID Switch Response frame to a STA from which it has received an S1G Capabilities element with the Dynamic AID field equal to 0.

When the traffic pattern or the service characteristic or the remaining battery life of a D-AID STA is changed, the D-AID STA may change its listen interval. If the listen interval of the STA is changed, the AID of the STA should be updated so that the STA belongs to the STA group consisting of the STAs having the same listen interval. A D-AID STA requesting a new listen interval may transmit an AID Switch Request frame containing an AID Request element with the AID Request Interval Present subfield of an AID Request Mode field equal to 1 and the AID Request Interval field equal to the requested new listen interval to the AP. The Service Characteristic field may be included in the AID Request element with the Service Characteristic Present subfield of the AID Request Mode field equal to 1 to inform the AP of the service characteristic of the STA if it has been changed. After receiving the AID Switch Request frame, the AP with dot11DynamicAIDActivated equal to true shall respond with an AID Switch Response frame containing an AID Response element with the AID/Group AID field equal to a new AID and the AID Response Interval field equal to a new listen interval. The AP may assign a particular AID to the D-AID STA taking into account the received service characteristic information from the STA if it is included in the AID Switch Request frame.

An illustration of the dynamic AID assignment is shown in Figure 10-22.

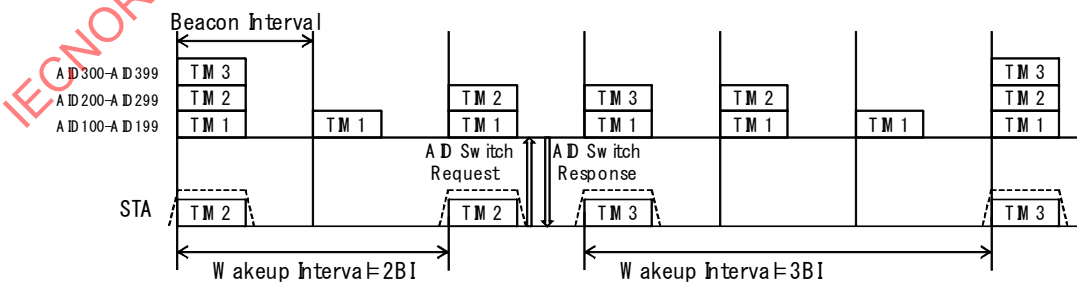

Figure 10-22—Illustration of dynamic AID assignment

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A D-AID STA may switch between TIM mode and non-TIM mode during operation.

The mode switching is initiated by a non-AP D-AID STA. When the D-AID STA switches from TIM mode to non-TIM mode, the STA should inform the AP of its switching through the AID Switch Request frame with the Non-TIM Mode Switch subfield of the AID Request element set to 1 and the TIM Mode Switch subfield set to 0, the STA otherwise should inform the AP of its switching through the AID Switch Request frame with the TIM Mode Switch subfield of AID Request element equal to 1 and Non-TIM Mode Switch subfield set to 0 when the STA switches from non-TIM mode to TIM mode. A D-AID STA that switches between TIM mode and non-TIM mode, which also wants to update its listen interval may request a listen interval change by including a listen interval value in the AID Request Interval field in the AID Request element. The Service Characteristic field may be included in the AID Request element if the service characteristic has been changed.

Upon receiving AID Switch Request frame with the Non-TIM Mode Switch subfield or TIM Mode Switch subfield of AID Request element equal to 1, the AP may reassign a new AID to the STA. The new AID is transmitted to the D-AID STA by including it in the AID Response element of the AID Switch Response frame. The AP may reassign a new value for the listen interval and include it in the AID Response Interval field of the AID Response element. The STA shall update its listen interval to the value indicated in the AID Response.

If the AID included in the AID Response element of the AID Switch Response frame is not the same as the STA's current AID, the STA shall use the AID included in the AID Response element as its new AID. The non-AP STA shall switch to the new AID after the duration specified by the AID Switch Count field in the received AID Response element.

An AP can change the group of a STA for load/traffic distribution of each group. An AP with dot11UnsolicitedDynamicAIDActivated equal to true may transmit an unsolicited AID Switch Response frame containing an AID Response element with the AID/Group AID field equal to a new AID and an the AID Response Interval field equal to a new listen interval to the STA that has the Unsolicited Dynamic AID bit equal to 1 in its S1G Capabilities element. The STA for which dot11UnsolicitedDynamicAIDActivated is true shall set the Unsolicited Dynamic AID field of the S1G Capabilities Information field in the S1G Capabilities element to 1.

When a D-AID STA has buffered frames for a peer non-AP STA, it may request to belong to the group of AIDs having the same listen interval with a the peer non-AP STA. A D-AID STA requesting the same listen interval with a the peer non-AP STA may transmit an AID Switch Request frame containing an AID Request element with the Peer STA Address Present subfield of an AID Request Mode field equal to 1 and a the Peer STA Address field equal to the MAC address of the peer non-AP STA to an the AP. After receiving the AID Switch Request frame, the AP with dot11DynamicAIDActivated equal to true shall respond with an AID Switch Response frame containing an AID Response element with an the AID/Group AID field equal to a new AID and the AID Response Interval field equal to the same listen interval with the peer non-AP STA.

When the AID of a non-AP D-AID STA has changed and that STA has direct connections with other peer STAs (e.g., TDLS), the AP shall transmit a STA Information Announcement frame (see 9.6.24.5) that contains the updated AID of the non-AP STA to each peer STA. A D-AID STA with direct connections with non-AP D-AID STAs that receives a STA Information Announcement frame shall update the AIDs of these STAs with the information contained in the received frame.

If a non-AP STA with direct connections receives a STA Information Announcement frame including an AID Announcement element from a peer STA, the non-AP STA updates the peer STA's AID to the received AID and sends the Ack frame after SIFS.

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An S1G STA may indicate to the AP its service characteristic information by including the Service Characteristic field in the AID Request element in (Re)Association Request frames as described in 11.3.5.11 in which case the AID Request Interval field of the element is equal to the value of the Listen Interval field of the (Re)Association Request frame. Otherwise the AID Request element is not present in the (Re)Association Request frame.

10.21 Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs

The S1G partial AID is a nonunique identifier of an S1G STA as defined in Table 10-15 and Table 10-16. The partial AID is carried in the TXVECTOR parameter PARTIAL_AID of an S1G SU PPDU with the TXVECTOR parameter CH_BANDWIDTH set to CBW2, CBW4, CBW8, or CBW16 and is limited to 9 bits.

A STA transmitting an S1G PPDU carrying one or more group addressed MPDUs that share a single, common group AID value shall set the TXVECTOR parameter PARTIAL_AID according to Table 10-15 and Table 10-16. A STA transmitting an S1G PPDU carrying one or more group addressed MPDUs that do not share a common group AID and a common BSSID or that is transmitting an S1G NDP intended for multiple recipients shall set the TXVECTOR parameter PARTIAL_AID to 0. The intended recipient of an S1G NDP is defined in 10.36.7.

A STA transmitting an S1G SU PPDU carrying one or more individually addressed MPDUs or an S1G NDP intended for a single recipient shall select any one of the AIDs assigned to the recipient and then set the TXVECTOR parameter PARTIAL_AID as shown in Table 10-15 and Table 10-16.

Table 10-15—Settings for the TXVECTOR parameter PARTIAL_AID for an NDP

Condition	PARTIAL_AID
A frame that is addressed to an AP or sent by an AP as a broadcast address	(*int*(BSSID[39:47])) mod $(2^9 - 1) + 1$
A frame that is sent by an AP and addressed to a STA associated with that AP or sent by a TDLS STA in a direct path to a TDLS peer STA, or to a group of STAs with a common group AID and a common BSSID	(AID[0:8] + $2^5 \times$ *int*(BSSID[44:47] $\oplus$ BSSID[40:43])) mod 2^9 (10-14)
Otherwise	0

Table 10-16—Settings for the TXVECTOR parameter PARTIAL_AID for non-1 MHz PPDUs and non-NDPs

Condition	PARTIAL_AID
A frame that is not a Control frame that is addressed to an AP	*int*(BSSID[39:47]) mod $(2^9-1)) + 1$
A frame that is not a Control frame that is sent by an AP and addressed to a STA associated with that AP or is sent by a TDLS STA in a direct path to a TDLS peer STA or is sent to a group of STAs with a common group AID and a common BSSID	(AID[0:8] + $2^5 \times$ *int*(BSSID[44:47] $\oplus$ BSSID[40:43])) mod 2^6 (10-15)
Otherwise	0

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NOTE—In Table 10-15 and Table 10-16, the last row includes the cases of a PPDU carrying MPDUs:

a) Sent by an IBSS STA to one or more IBSS STAs
b) Sent by an AP to a non associated STA
c) Any other condition not explicitly listed elsewhere in the table.

An S1G STA shall include the values computed in Table 10-15 in the PHYCONFIG_VECTOR parameter PARTIAL_AID_LIST_GID00 and PARTIAL_AID_LIST_GID63.

An S1G STA that transmits an S1G PPDU to a TDLS peer STA obtains the AID for the peer STA from TDLS Setup Request, or TDLS Setup Response frame.

An S1G AP should not assign to an S1G STA an AID that results in the PARTIAL_AID value [as computed using Equation (10-14) (in Table 10-15) or Equation (10-15) (in Table 10-16)] being equal to one of the following:

0 or $(int(\text{BSSID}[39:47]) \bmod (2^9 - 1)) + 1$ or $(int(\text{OBSSID}[39:47]) \bmod (2^9 - 1) + 1$

where OBSSID is the BSSID of a BSS that is not the BSS of which the AP is a member and for which the AP might be heard by the STA being assigned the AID.

An S1G STA transmitting an S1G MU PPDU sets the TXVECTOR parameter GROUP_ID as described in 23.3.10.4.

As an example of the PARTIAL_AID setting, consider the case of a BSS with BSSID 00-21-6A-AC-53-52 that has as a member a non-AP S1G STA assigned AID 5. In an NDP sent by the non-AP S1G STA to the S1G AP, the PARTIAL_AID is equal to 165. In an NDP sent by the S1G AP to the non-AP S1G STA associated with that S1G AP, the PARTIAL_AID is equal to 229. In a non-1 MHz S1G PPDU that is not an NDP and that is sent by the non-AP S1G STA to the S1G AP, the PARTIAL_AID is set to 165. In a non-1 MHz S1G PPDU that is not an NDP that is sent by the S1G AP to the non-AP S1G STA associated with that S1G AP, the PARTIAL_AID is set to 37.

A STA transmitting a non-1 MHz S1G PPDU that is not an NDP and that is addressed to an AP shall set the TXVECTOR parameter UPLINK_INDICATION to 1. The UPLINK_INDICATION parameter shall be set to 0 for all other cases. The TXVECTOR parameter UPLINK_INDICATION is not present for 1 MHz PPDUs or NDPs.

The TXVECTOR parameter COLOR is used to assist a receiving STA in identifying the BSS from which a received PPDU originates so that the receiving STA reduces intra-BSS collisions by reporting a busy medium regardless of the received power when COLOR indicates that the current PPDU might be intra-BSS and might reduce power consumption by terminating the reception process when the received PPDU could not be from the BSS of which the STA is a member. A STA transmitting a non-1 MHz S1G PPDU that is not an NDP and that is addressed to an AP need not include the TXVECTOR parameter COLOR in the TXVECTOR. A STA transmitting a non-1 MHz S1G PPDU that is not an NDP and that is sent by a TDLS STA in a direct path to a TDLS peer STA shall set the TXVECTOR parameter COLOR to the value of the COLOR parameter, if present, from the RXVECTOR of the most recently received frame from its associated AP or from the STA transmitting a beacon of the IBSS of which it is a member that contained a COLOR parameter. An AP transmitting a non-1 MHz S1G PPDU that is not an NDP shall set the TXVECTOR parameter COLOR to a value of its choosing and shall maintain that value for the duration of the existence of the BSS. The AP which is a member of a Multiple BSSID Set shall set the TXVECTOR parameter COLOR for each different BSSID(*i*) to a same value.

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When an S1G AP transmits a non-1 MHz S1G PPDU that is not an NDP, the AP shall set the TXVECTOR parameter COLOR to the value of the COLOR field of the S1G Capabilities Information field of the S1G Capabilities element transmitted by the AP. The COLOR field of the S1G Capabilities Information field of the S1G Capabilities element in all frames transmitted from a non-AP STA is reserved.

The partial BSSID is defined to be the PARTIAL_AID of the address of the STA contained in the AP and is equal to

$$(int(\text{BSSID}[39:47]) \bmod (2^9 - 1)) + 1$$

10.22 Operation across regulatory domains

10.22.1 General

The PHY of a WLAN is subject to regulations that might vary significantly from one regulatory domain to another. This subclause provides the framework for operation across regulatory domains and describes the mechanism that supports cross-domain mobility and operation in multiple regulatory domains. When this mechanism is active, dot11MultiDomainCapabilityActivated attribute be true.

NOTE—This subclause does not eliminate the need to obtain type acceptance, regulatory approval, equipment authorization, or equipment certification in each of the regulatory domains in which the equipment operates. The mechanisms described in this subclause provide the information to the STA to identify the regulatory domain in which it is located and to cease operation while in those domains for which it does not have type approval. It is incumbent upon the implementer to provide proof of compliance to the requirements of individual regulatory agencies.

The method for configuring individual STAs is outside the scope of this standard. A STA needs to be properly configured for operation in a particular regulatory domain prior to beginning normal operation. Particular care needs to be taken when operating in an IBSS configuration.

10.22.2 Operation upon entering a regulatory domain

A STA that is enabled for operation across regulatory domains uses passive scanning when it has lost connectivity with its ESS. Passive scanning is performed using only the receive capabilities of the STA and is, thus, compatible with regulatory requirements. The timeout for determining the loss of connectivity is system dependent and beyond the scope of this standard.

When a STA with dot11MultiDomainCapabilityActivated true enters a regulatory domain, before transmitting, it shall passively scan to learn at least one valid channel, i.e., a channel upon which it detects IEEE 802.11 frames. The Beacon frame transmitted by non-DMG STAs and the DMG Beacon or Announce frame transmitted by DMG STAs contains information on the country code, the maximum allowable transmit power, and the channels that may be used for the regulatory domain. Optionally, these frames may also include in the Country element, on a periodic basis, the regulatory information that would be returned in a Probe Response frame. When DSE dependent STA operation is required in a regulatory domain, a dependent STA may be required to receive a Beacon, DMG Beacon, or an Announce frame signaling dependent enablement (11.11.5), and until one of these frames is received, the STA may continue passive scanning to receive one such frame directly from an enabling STA. Once the STA has acquired the information so that it is able to meet the transmit requirements of the regulatory domain, it shall transmit a Probe Request frame to an AP or PCP to gain the additional necessary regulatory domain information contained in the Probe Response frame, unless the information was previously received in a Beacon, DMG Beacon, or Announce frame. The STA then has sufficient information available to configure its PHY for operation in the regulatory domain.

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10.22.3 Operation with operating classes

The following, and only the following, are extended spectrum management capable: a VHT STA and a STA that has dot11ExtendedSpectrumManagementImplemented true. A non-VHT STA that has dot11ExtendedSpectrumManagementImplemented true shall indicate that it is extended spectrum management capable using the Extended Spectrum Management Capable field of the Extended Capabilities element.

When communicating with a STA that supports global operating classes, all requests and Action and Action No Ack frames that convey elements containing operating classes shall use global operating class values.

When dot11OperatingClassesImplemented is true, the following statements apply:

— When dot11OperatingClassesRequired is false, or where operating classes domain information is not present in a STA, that STA is not required to change its operation in response to an element that contains an operating class.

— When dot11OperatingClassesRequired is true, or where operating classes domain information is present in a STA, the STA shall indicate current operating class information in the Country element and Supported Operating Classes element, except that a VHT STA may omit, from the Country element, any Operating Triplet field for an Operating Class for which the Channel spacing (MHz) column indicates 80 MHz or wider and for which the Behavior limits set column in the applicable table in Annex E contains only a blank entry or either or both of “80+” and “UseEirpForVHTTxPowEnv.”

— When dot11OperatingClassesRequired and dot11ExtendedChannelSwitchActivated are true and a STA is capable of operating as specified in more than one operating class, the STA shall include the Supported Operating Classes element in (Re)Association Request and Response frames.

— When dot11OperatingClassesRequired is true, or where operating classes domain information is present and the STA parsing a Country element finds an invalid First Channel Number field or Operating Class field with a value that is reserved, the STA shall ignore the remainder of the Country element and shall parse any remaining management frame body for additional elements.

— When dot11OperatingClassesRequired is true and the STA supports one or more global operating classes, or where global operating classes domain information is present in a STA, the STA shall indicate current operating class information in the Country element and Supported Operating Classes element using the country string for the global operating classes, except that a VHT STA may omit from the Country element any Operating Triplet field for an Operating Class for which the Channel spacing (MHz) column indicates 80 MHz or wider and for which the Behavior limits set column in the applicable table in Annex E contains only a blank entry or either or both of “80+” and “UseEirpForVHTTxPowEnv.”

10.22.4 Operation with the Transmit Power Envelope element

A STA that is extended spectrum management capable and that has dot11SpectrumManagementRequired or dot11RadioMeasurementActivated equal to true shall determine a local maximum transmit power from a Transmit Power Envelope element for which the Local Maximum Transmit Power Unit Interpretation subfield indicates EIRP.

A STA that sends two or more Transmit Power Envelope elements in a frame shall order the elements by increasing values of their Local Maximum Transmit Power Unit Interpretation subfields.

If a STA that is extended spectrum management capable finds an unknown value in the Local Maximum Transmit Power Unit Interpretation subfield in a Transmit Power Envelope element, then the STA shall ignore that and subsequent Transmit Power Envelope elements.

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A STA that receives two or more Transmit Power Envelope elements in the same frame with known values in their Local Maximum Transmit Power Unit Interpretation subfields shall process all of the elements according to the local regulations known at the STA.

NOTE—If a STA receives two Transmit Power Envelope elements, each with a known value in the Local Maximum Transmit Power Unit Interpretation subfield, then the expected possibilities are as follows:

a) The STA complies with either element (shared spectrum),
b) The STA complies with both elements (tightened regulations), or
c) The STA complies with the second element (changed regulations).

10.22.5 Operation with coverage classes

The attribute aSlotTime and other MAC timings are based on the PHY timing parameters, as specified in 10.3.2.3, 10.3.7, and 10.23.2.5, and in particular on aAirPropagationTime. If dot11OperatingClassesRequired is true, it is possible to manage the MAC timings of STAs to increase fairness in contending for the medium. Radio waves propagate at ~300 m/μs in free space, and, for example, 3 μs would be the maximum round-trip delay for a BSS with maximum coverage distance of ~450 m (~900 m round trip). The Coverage Class field of the Country element indicates a value of aAirPropagationTime (see Table 9-95), and the MAC can use the value to calculate aSlotTime (as specified in the relevant PHY clause) and other timings.

If dot11OperatingClassesRequired is true and a Country element containing a Coverage Class field has been received from the AP of the BSS of which a STA is a member, from the DO of the IBSS of which a STA is a member, or from another mesh STA in the same MBSS, an associated STA, dependent STA, IBSS STA, or member of an MBSS shall, if the relevant PHY clause specifies that aAirPropagationTime is indicated by the coverage class, use MAC timings that correspond to the value of aAirPropagationTime indicated (as specified in the relevant PHY clause).

NOTE 1—Some PHYs do not specify a dependency of aSlotTime on aAirPropagationTime.

NOTE 2—Operation over larger BSS diameters is facilitated by relaxing some PHY timing parameters, while maintaining compatibility with existing implementations in small BSS diameters.

NOTE 3—An AP using coverage classes that determines that an associating or associated STA does not support coverage classes may deny association to or disassociate that STA. The mechanism by which the AP makes that determination is outside the scope of the standard.

aAirPropagationTime is 0 μs if

— The relevant PHY clause specifies that aAirPropagationTime is indicated by the coverage class, and
— At least one of the following applies:
  — dot11OperatingClassesRequired is false.
  — No Country element containing a Coverage Class field has been received from the AP of the BSS of which a STA is a member, from the DO of the IBSS of which a STA is a member, or from another mesh STA in the same MBSS.

10.23 HCF

10.23.1 General

Under HCF, the basic unit of allocation of the right to transmit onto the WM is the TXOP. Each TXOP is defined by a starting time and a defined maximum length. In a non-DMG BSS, the TXOP may be obtained by a STA winning an instance of EDCA contention (see 10.23.2) or by a STA receiving a QoS (+)CF-Poll frame (see 10.23.3). The former is called *EDCA TXOP*, while the latter is called *HCCA TXOP* or *polled TXOP*.

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In a DMG BSS, the EDCAF operates only during CBAPs. Operation of the EDCAF is suspended at the end of a CBAP and is resumed at the beginning of the following CBAP. See 10.39.5 and 10.39.5 for additional rules regarding contention based access in DMG BSSs.

HCCA is not used by either DMG or S1G STAs.

10.23.2 HCF contention based channel access (EDCA)

10.23.2.1 Reference model

The EDCA channel access protocol is derived from the DCF procedures described in 10.3 by adding four independent enhanced distributed channel access functions (EDCAFs) to provide differentiated priorities to transmitted traffic, through the use of four different access categories (ACs).

For the case in which dot11AlternateEDCAActivated is false or not present, a model of the reference implementation is shown in Figure 10-23 and for the case in which dot11AlternateEDCAActivated is true, a model is shown in Figure 10-24. These figures illustrate a mapping from frame type or UP to the transmit queues and the four independent EDCAFs. The mapping of UP to the transmit queue and the mapping to AC are described in 10.2.3.2 and Table 10-1. The mapping of frame types to ACs is also described in 10.2.3.2.

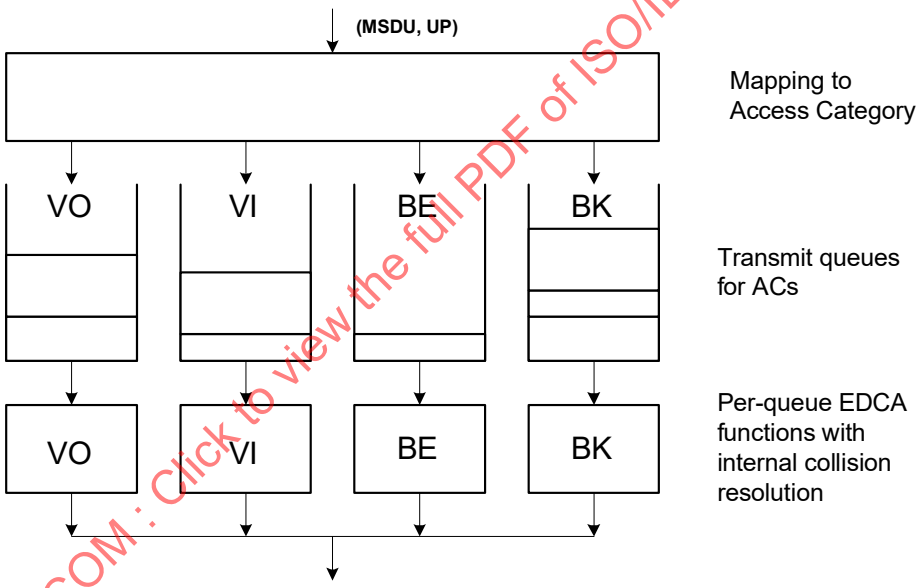

Figure 10-23—Reference implementation model when dot11AlternateEDCAActivated is false or not present

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An S1G STA shall be a QoS STA.

A DMG STA or an S1G STA that is a sensor STA may implement a single AC. If the DMG or S1G STA implements a single AC, all UP and frame types shall be mapped to AC_BE.

NOTE—A DMG or S1G STA that implements a single AC has only one queue in Figure 10-23.

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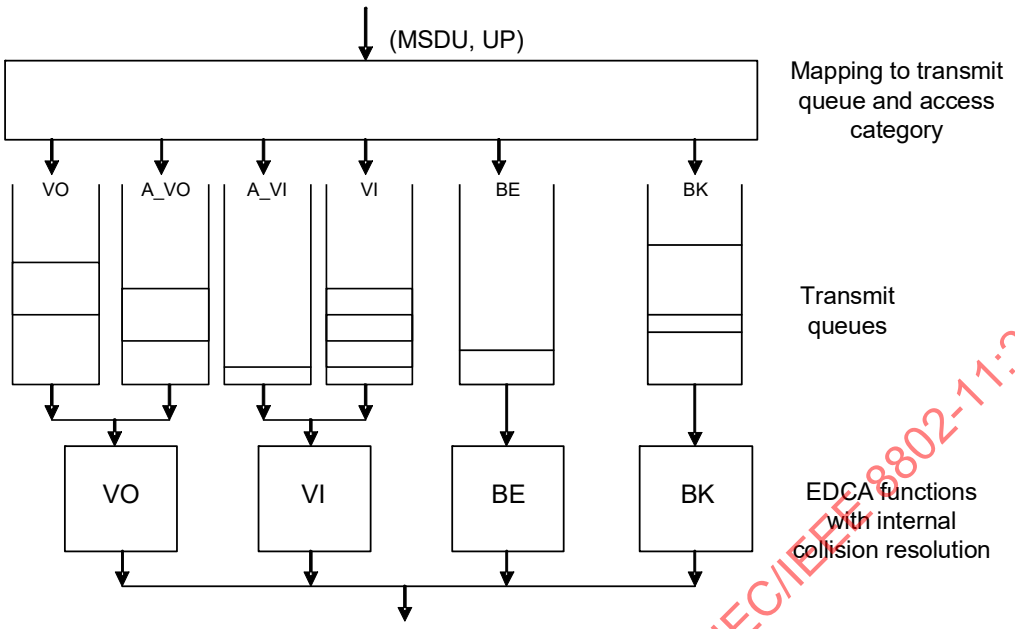

Figure 10-24—Reference implementation model when dot11AlternateEDCAActivated is true

10.23.2.2 EDCA backoff procedure

Each EDCAF shall maintain a MAC variable CW[AC], which shall be initialized to the value of the parameter CWmin[AC], for that EDCAF's AC.

For the purposes of this subclause, transmission failure of an MPDU is defined as follows:

— After transmitting an MPDU (even if it is carried in an A-MPDU or as part of a VHT or S1G MU PPDU that is sent using TXVECTOR parameter NUM_USERS > 1) that requires an immediate response:

  — The STA shall wait for a timeout interval of duration aSIFSTime + aSlotTime + aRxPHYStartDelay, starting when the MAC receives a PHY-TXEND.confirm primitive. If a PHY-RXSTART.indication primitive does not occur during the timeout interval, the transmission of the MPDU has failed.

  — If a PHY-RXSTART.indication primitive does occur during the timeout interval, the STA shall wait for the corresponding PHY-RXEND.indication primitive to recognize a valid response MPDU (see Annex G) that either does not have a TA field or is sent by the recipient of the MPDU requiring a response. If anything else, including any other valid frame, is recognized, the transmission of the MPDU has failed.

  The nonfinal (re)transmission of an MPDU that is delivered using the GCR unsolicited retry retransmission policy (10.23.2.12.2) is defined to be a failure.

— In all other cases, the transmission of the MPDU has not failed.

The TXNAV timer is a single timer, shared by the EDCAFs within a STA, that is initialized with the duration from the Duration/ID field in the frame most recently successfully transmitted by the TXOP holder, except for PS-Poll frames. The TXNAV timer begins counting down from the end of the transmission of the PPDU containing that frame. The Reservation Allocation Vector (RAV) timer for a mesh STA that has dot11MCCAActivated true is initialized with the MCCAOP Duration in the MCCAOP Reservation field at the

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start of an MCCAOP reservation. The RAV timer begins counting down from the start of an MCCAOP reservation (see 10.24.3.9.2).

The backoff procedure shall be invoked by an EDCAF when any of the following events occurs:

a) An MA-UNITDATA.request primitive is received that causes an MPDU corresponding to the EDCAF's AC to be queued for transmission such that all of the following are true:
   1) One of the transmit queues associated with that AC has now become non-empty
   2) Any other transmit queues associated with that AC are empty
   3) The backoff counter has a value of 0 for that AC
   4) The medium is busy on the primary channel as indicated by any of the following:
      — Physical CS
      — Virtual CS
      — A nonzero TXNAV timer value
      — For a mesh STA that has dot11MCCAActivated true, a nonzero RAV timer value
b) For the EDCAF that is the TXOP holder, the transmission of the final PPDU transmitted by the TXOP holder during the TXOP has completed and the TXNAV timer has expired.
c) For the EDCAF that is the TXOP holder, the transmission of an MPDU in the initial PPDU of a TXOP fails, as defined in this subclause.
d) A transmission attempt by the EDCAF collides internally with another EDCAF of an AC that has higher priority, that is, two or more EDCAFs in the same STA are granted a TXOP at the same time.

In addition, the backoff procedure may be invoked by an EDCAF when:

e) For the EDCAF that is the TXOP holder, the transmission by the TXOP holder of an MPDU in a non-initial PPDU of a TXOP fails, as defined in this subclause.

NOTE 1—If the transmission by the TXOP holder of an MPDU in a non-initial PPDU of a TXOP failed, the STA can perform either a PIFS recovery, as described in 10.23.2.8, perform a backoff as described in item e) above, or wait for the TXNAV timer to expire and invoke the backoff procedure per item b) above. How it chooses among these options is implementation dependent.

A STA that performs a backoff within its existing TXOP per item e) above shall not extend the TXNAV timer value (see 10.23.2.8).

NOTE 2—In other words, the backoff is a continuation of the TXOP, not the start of a new TXOP.

If the backoff procedure is invoked for reason a) above, CW[AC] and QSRC[AC] shall be left unchanged.

If the backoff procedure is invoked for reason b) above, CW[AC] shall be set to CWmin[AC], and QSRC[AC] shall be set to 0.

If the backoff procedure is invoked for reason c), d), or e) above, CW[AC] and QSRC[AC] shall be updated as follows:

— If QSRC[AC] is less than dot11ShortRetryLimit,
   — QSRC[AC] shall be incremented by 1.
   — CW[AC] shall be set to the lesser of CWmax[AC] and $2^{QSRC[AC]} \times (CWmin[AC] + 1) - 1$.
— Else
   — QSRC[AC] shall be set to 0.
   — CW[AC] shall be set to CWmin[AC].

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10.23.2.3 EDCA TXOPs

There are three modes of EDCA TXOP defined: initiation of an EDCA TXOP, sharing an EDCA TXOP, and multiple frame transmission within an EDCA TXOP. Initiation of the TXOP occurs when the EDCA rules permit access to the medium. Sharing of the EDCA TXOP occurs when an EDCAF within an AP that supports DL-MU-MIMO has obtained access to the medium, making the corresponding AC the primary AC, and includes traffic from queues associated with other ACs in VHT or S1G MU PPDUs transmitted during the TXOP. Multiple frame transmission within the TXOP occurs when an EDCAF retains the right to access the medium following the completion of a frame exchange sequence, such as on receipt of an Ack frame.

10.23.2.4 Obtaining an EDCA TXOP

Each EDCAF shall maintain a backoff counter, which has a value measured in backoff slots as described below.

When the backoff procedure is invoked, the backoff counter is set to an integer value chosen randomly with a uniform distribution taking values in the range 0 to CW[AC].

The duration AIFS[AC] is a duration derived from the value AIFSN[AC] by the relation

AIFS[AC] = AIFSN[AC] × aSlotTime + aSIFSTime.

In an infrastructure BSS, AIFSN[AC] is advertised by an EDCA AP in the EDCA Parameter Set element in Beacon and Probe Response frames transmitted by the AP. The value of AIFSN[AC] shall be greater than or equal to 2 for non-AP STAs. The value of AIFSN[AC] shall be greater than or equal to 1 for APs. An EDCA TXOP is granted to an EDCAF when the EDCAF determines that it shall initiate the transmission of a frame exchange sequence. Transmission initiation shall be determined according to the following rules:

EDCAF operations shall be performed at slot boundaries, defined as follows on the primary channel, for each EDCAF:

a) Following AIFSN[AC] × aSlotTime – aRxTxTurnaroundTime of idle medium after SIFS (not necessarily idle medium during the SIFS) after the last busy medium on the antenna that was the result of a reception of a frame with a correct FCS or of an S1G frame. Note that upon reception of an S1G frame, an S1G STA updates its RID counter based on information obtained from the RXVECTOR as described in 10.3.2.5 and this update does not depend on the outcome of the FCS check.

b) Following EIFS – DIFS + AIFSN[AC] × aSlotTime + aSIFSTime – aRxTxTurnaroundTime of idle medium after the last indicated busy medium as determined by the physical CS mechanism that was the result of a non-S1G frame reception that has resulted in FCS error, or of a frame reception that has resulted in PHY-RXEND.indication (RXERROR) primitive where the value of RXERROR is not NoError.

c) When any other EDCAF at this STA transmitted a frame requiring immediate acknowledgment, the earlier of

   1) The end of the AckTimeout interval timed from the PHY-TXEND.confirm primitive, followed by AIFSN[AC] × aSlotTime + aSIFSTime – aRxTxTurnaroundTime of idle medium, and

   2) The end of the first AIFSN[AC] × aSlotTime – aRxTxTurnaroundTime of idle medium after SIFS (not necessarily medium idle during the SIFS, the start of the SIFS implied by the length in the PHY header of the previous frame) when a PHY-RXEND.indication primitive occurs as specified in 10.3.2.11.

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d) Following AIFSN[AC] × aSlotTime – aRxTxTurnaroundTime of idle medium after SIFS (not necessarily medium idle during the SIFS) after the last busy medium on the antenna that was the result of a transmission of a frame for any EDCAF and which did not require an acknowledgment and after the expiration of the TXNAV timer if nonzero, and, if dot11MCCAActivated is true, the expiration of the RAV timer if nonzero.

e) Following AIFSN[AC] × aSlotTime + aSIFSTime – aRxTxTurnaroundTime of idle medium after the last indicated busy medium as indicated by the CS mechanism that is not covered by condition a) to condition d).

f) Following aSlotTime of idle medium, which occurs immediately after any of these conditions, a) to f), is met for the EDCAF.

On these specific slot boundaries, each EDCAF shall make a determination to perform one and only one of the following functions:

— Decrement the backoff counter.
— Initiate the transmission of a frame exchange sequence.
— Invoke the backoff procedure due to an internal collision.
— Do nothing.

At each of the above-described specific slot boundaries, each EDCAF shall decrement the backoff counter if the backoff counter for that EDCAF has a nonzero value.

At each of the above-described specific slot boundaries, each EDCAF shall initiate a transmission sequence if

— There is a frame available for transmission at that EDCAF, and
— The backoff counter for that EDCAF has a value of 0, and
— Initiation of a transmission sequence is not allowed to commence at this time for an EDCAF of higher UP.

At each of the above-described specific slot boundaries, each EDCAF shall report an internal collision (which is handled in 10.23.2.4) if

— There is a frame available for transmission at that EDCAF, and
— The backoff counter for that EDCAF has a value of 0, and
— Initiation of a transmission sequence is allowed to commence at this time for an EDCAF of higher UP.

NOTE—If an EDCAF gains access to the channel and transmits MSDUs, A-MSDUs, or MMPDUs from a secondary AC, the EDCAF of the secondary AC is not affected by this operation. If the EDCAF of a secondary AC experiences an internal collision with the EDCAF that gained access to the channel, it performs the backoff procedure regardless of the transmission of any of its MSDUs, A-MSDUs, or MMPDUs (see 10.23.2.7).

An example showing the relationship between AIFS, AIFSN, DIFS, and slot times immediately following a medium busy condition (and assuming that medium busy condition was not caused by a frame in error) is shown in Figure 10-25. In this case, with AIFSN = 2, the EDCAF may decrement the backoff counter for the first time at 2 × aSlotTime following the TxSIFS (where TxSIFS is the time at which the MAC responds to the end of the medium busy condition if it is going to respond “after SIFS”). If, in this example, the backoff counter contained a value of 1 at the time the medium became idle, transmission would start as a result of an EDCA TXOP on-air at a time

aSIFSTime + 3 × aSlotTime

following the end of the medium busy condition.

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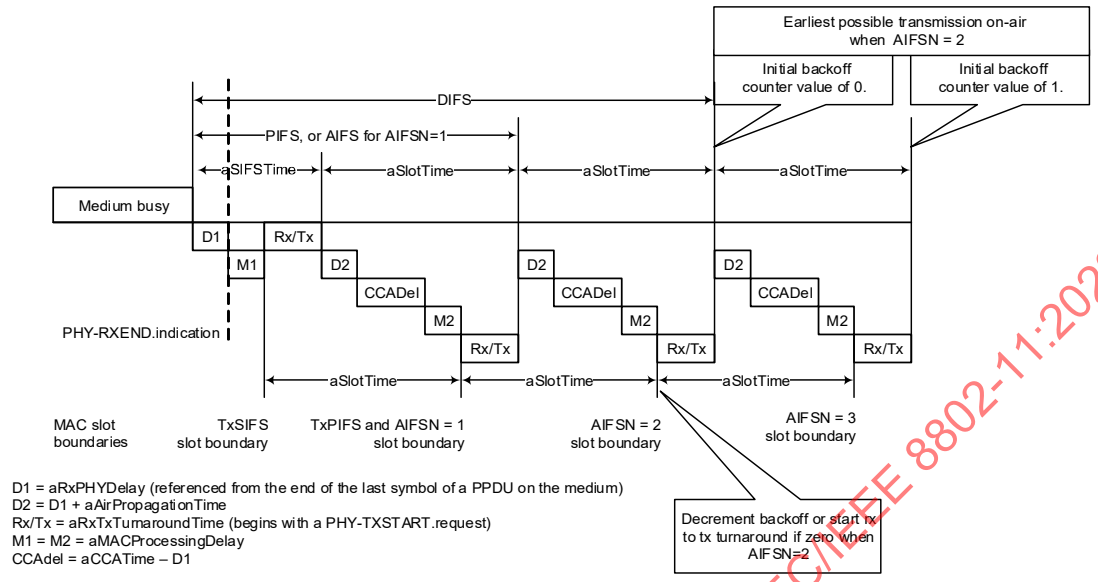

Figure 10-25—EDCA mechanism timing relationships

A STA shall save the TXOP holder address for the BSS in which it is associated, which is the MAC address from the Address 2 field of the frame that initiated a frame exchange sequence except when this is a CTS frame, in which case the TXOP holder address is the Address 1 field. If the TXOP holder address is obtained from a Control frame, a VHT STA shall save the nonbandwidth signaling TA value obtained from the Address 2 field. If a non-VHT STA receives an RTS frame with the RA matching the MAC address of the STA and the MAC address in the TA field in the RTS frame matches the saved TXOP holder address, then the STA shall send the CTS frame after SIFS, without regard for, and without resetting, its NAV. If a VHT STA receives an RTS frame with the RA matching the MAC address of the STA and the nonbandwidth signaling TA value obtained from the Address 2 field in the RTS frame matches the saved TXOP holder address, then the STA shall send the CTS frame after SIFS, without regard for, and without resetting, its NAV. If a CMMG STA receives an RTS frame with the RA matching the MAC address of the STA and the TA value obtained from the Address 2 field in the RTS frame matches the saved TXOP holder address, then the STA shall send the CTS frame after SIFS, without regarding for, and without resetting its NAV. When a STA receives a frame addressed to it that requires an immediate response, except for RTS, it shall transmit the response independent of its NAV. The saved TXOP holder address shall be cleared when the NAV is reset or when the NAV counts down to 0.

10.23.2.5 EDCA channel access in a VHT or TVHT BSS

If the MAC receives a PHY-CCA.indication primitive with the channel-list parameter present, the channels considered idle are defined in Table 10-17.

When a STA and the BSS, of which the STA is a member, both support multiple channel widths, an EDCA TXOP is obtained based solely on activity of the primary channel. “Idle medium” in this subclause means “idle primary channel.” Likewise “busy medium” means “busy primary channel.” Once an EDCA TXOP has been obtained according to this subclause, further constraints defined in 11.15.9 and 10.23.3 might limit the width of transmission during the TXOP or deny the channel access, based on the state of CCA on secondary channel, secondary 40 MHz channel, or secondary 80 MHz channel.

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Table 10-17—Channels indicated idle by the channel-list parameter for VHT or TVHT BSSs

PHY-CCA.indication primitive channel-list parameter entry	Idle channels
primary	None
secondary	Primary 20 MHz channel
secondary40	Primary 20 MHz channel and secondary 20 MHz channel
secondary80	Primary 20 MHz channel, secondary 20 MHz channel, and secondary 40 MHz channel

In the following description, the CCA is sampled according to the timing relationships defined in 10.3.7. Slot boundaries are determined solely by activity on the primary channel. "Channel idle for an interval of PIFS" means that the STATE parameter of the most recent PHY-CCA.indication primitive was IDLE, and no PHY-CCA.indication(BUSY) occurred during the period of PIFS that ends at the start of transmission, the CCA for that channel was determined to be idle.

If a STA is permitted to begin a TXOP (as defined in 10.23.2.4) and the STA has at least one MSDU pending for transmission for the AC of the permitted TXOP, the STA shall perform exactly one of the following actions:

a) Transmit a 160 MHz or 80+80 MHz mask PPDU if the secondary channel, the secondary 40 MHz channel, and the secondary 80 MHz channel were idle during an interval of PIFS immediately preceding the start of the TXOP.

b) Transmit an 80 MHz mask PPDU on the primary 80 MHz channel if both the secondary channel and the secondary 40 MHz channel were idle during an interval of PIFS immediately preceding the start of the TXOP.

c) Transmit a 40 MHz mask PPDU on the primary 40 MHz channel if the secondary channel was idle during an interval of PIFS immediately preceding the start of the TXOP.

d) Transmit a 20 MHz mask PPDU on the primary 20 MHz channel.

e) Restart the channel access attempt by invoking the backoff procedure as specified in 10.23.2 as though the medium is busy on the primary channel as indicated by either physical or virtual CS and the backoff counter has a value of 0.

f) Transmit a TVHT_4W or TVHT_2W+2W mask PPDU if the secondary TVHT_W channel and the secondary TVHT_2W channel were idle during an interval of PIFS immediately preceding the start of the TXOP.

g) Transmit a TVHT_2W or TVHT_W+W mask PPDU if the secondary TVHT_W channel was idle during an interval of PIFS immediately preceding the start of the TXOP.

h) Transmit a TVHT_W mask PPDU on the primary TVHT_W channel.

NOTE 1—In the case of rule e), the STA selects a new random number using the current value of CW[AC], and the retry counts are not updated [as described in 10.23.2.8; backoff procedure invoked for event a)].

NOTE 2—For both an HT and a VHT STA, an EDCA TXOP is obtained based on activity on the primary channel (see 10.23.2.4). The width of transmission is determined by the CCA status of the nonprimary channels during the PIFS before transmission (see VHT description in 10.3.2).

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10.23.2.6 EDCA channel access in an S1G BSS

If the MAC receives a PHY-CCA.indication primitive with the channel-list parameter present, the channels considered idle are defined in Table 10-18.

Table 10-18—Channels indicated idle by the channel-list parameter for S1G BSSs

PHY-CCA.indication primitive channel-list parameter entry	Idle channels
primary1	None
primary2	primary 1 MHz channel
secondary2	primary 1 MHz channel, primary 2 MHz channel
secondary4	primary 1 MHz channel, primary 2 MHz channel and secondary 2 MHz channel
secondary8	primary 1 MHz channel, primary 2 MHz channel, secondary 2 MHz channel and secondary 4 MHz channel

When a STA and the BSS, of which the STA is a member, both support multiple channel widths, an EDCA TXOP is obtained based solely on activity of the primary channel. "Idle medium" in this subclause means "idle primary channel." Likewise "busy medium" means "busy primary channel."

In the following description, the CCA is sampled according to the timing relationships defined in 10.3.7. Slot boundaries are determined solely by activity on the primary channel. "Channel idle for an interval of PIFS" means that whenever CCA is sampled during the period of PIFS that ends at the start of transmission, the CCA for that channel was determined to be idle.

a) If an S1G STA invokes a backoff procedure at the primary 2 MHz channel for ≥ 2 MHz mask PPDU transmission using the CCA conditions defined in 23.3.18.5.4 and the S1G STA is permitted to begin a TXOP (as defined in 10.23.2.4) and the S1G STA has at least one MSDU pending for transmission for the AC of the permitted TXOP, the S1G STA shall perform exactly one of the following steps:
   1) Transmit a 16 MHz mask PPDU if the secondary 2 MHz channel, the secondary 4 MHz channel and the secondary 8 MHz channel were idle during an interval of PIFS immediately preceding the start of the TXOP.
   2) Transmit an 8 MHz mask PPDU on the primary 8 MHz channel if both the secondary 2 MHz channel and the secondary 4 MHz channel were idle during an interval of PIFS immediately preceding the start of the TXOP.
   3) Transmit a 4 MHz mask PPDU on the primary 4 MHz channel if the secondary 2 MHz channel was idle during an interval of PIFS immediately preceding the start of the TXOP.
   4) Transmit a 2 MHz mask PPDU on the primary 2 MHz channel.

b) An S1G STA that intends to transmit an 8 or 16 MHz PPDU may also invoke a backoff procedure at the primary 2 MHz channel using the CCA conditions defined in 23.3.18.5.4.2, if the S1G STA is permitted to begin a TXOP (as defined in 10.23.2.4) and the S1G STA has at least one MSDU pending for transmission for the AC of the permitted TXOP. In this case the S1G STA shall perform exactly one of the following steps:
   1) Transmit a 16 MHz PPDU if the secondary 2 MHz channel, the secondary 4 MHz channel and the secondary 8 MHz channel were idle during an interval of PIFS immediately preceding the start of the TXOP.

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2) Transmit an 8 MHz PPDU on the primary 8 MHz channel if both the secondary 2 MHz channel and the secondary 4 MHz channel were idle during an interval of PIFS immediately preceding the start of the TXOP.

3) Invoke a new backoff procedure if the secondary 2 MHz and/or the secondary 4 MHz channel were busy.

c) If an S1G STA invokes a backoff procedure at the primary 1 MHz channel for 1 MHz PPDU transmission and the S1G STA is permitted to begin a TXOP (as defined in 10.23.2.4) and the S1G STA has at least one MSDU pending for transmission for the AC of the permitted TXOP, the S1G STA shall transmit a 1 MHz mask PPDU on the primary 1 MHz channel.

10.23.2.7 Sharing an EDCA TXOP

The AC associated with the EDCAF that gains an EDCA TXOP is referred to as the primary AC. Frames from ACs other than the primary AC shall not be included in the TXOP, with the following exceptions (TXOP sharing):

— Frames from a higher priority AC may be included when at least one frame from the primary AC has been transmitted and all frames from the primary AC have been transmitted.

NOTE 1—The frames from a higher priority AC might be included in successive PPDUs in the TXOP and/or in one or more MU PPDUs.

— When an AP supports DL-MU-MIMO, frames from a lower priority AC may be included in an MU PPDU with the TXVECTOR parameter NUM_USERS > 1 when these frames do not increase the duration of the MU PPDU beyond that required for the transmissions of the frames of the primary AC and any frames from a high priority AC. For a given user, any frames from the primary AC shall be transmitted first and then any frames from a higher priority AC immediately next

The EDCAF remains bound by the TXOP limit for its AC (i.e., the primary AC), irrespective of the AC(s) of the frames transmitted during the TXOP.

When sharing, the TXOP limit that applies is the TXOP limit of the primary AC.

With respect to admission control (see 10.23.4.2), all frames transmitted under TXOP sharing shall be treated as if they were from the primary AC.

NOTE 2—An AP can protect an immediate response by preceding the DL-MU-MIMO PPDU (which might have TXVECTOR parameter NUM_USERS > 1) with an RTS/CTS exchange or a CTS-to-self transmission.

An illustration of TXOP sharing is shown in Figure 10-26 and Figure 10-27. The AP has frames in queues of three of its ACs. The TXOP was obtained by AC_VI or AC_BE, as shown, and is shared by the other two ACs. The frames target three STAs, STA-1 to STA-3.

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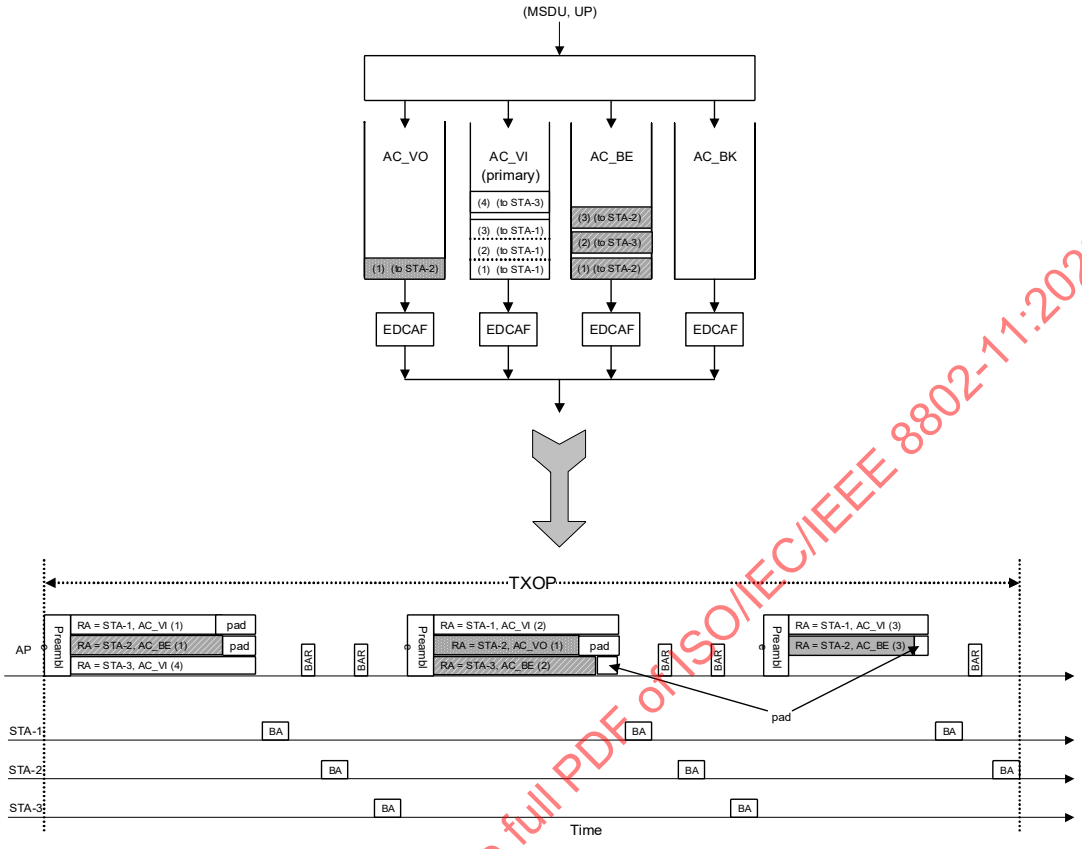

Figure 10-26—Illustration of TXOP sharing and PPDU construction (DL MU-MIMO)

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10.23.2.8 Multiple frame transmission in an EDCA TXOP

A frame exchange, in the context of multiple frame transmission in an EDCA TXOP, may be one of the following:

— A frame not requiring immediate acknowledgment (such as a group addressed frame or a frame transmitted with an ack policy that does not require immediate acknowledgment) or an A-MPDU containing only such frames.

— A frame requiring immediate acknowledgment (such as an individually addressed frame transmitted with an ack policy that requires immediate acknowledgment) or an A-MPDU containing at least one such frame, followed after SIFS by a corresponding acknowledgment frame.

— Either

  — A VHT NDP Announcement frame followed after SIFS by a VHT NDP followed after SIFS by an A-MPDU containing one or more VHT Compressed Beamforming frames, or

  — A Beamforming Report Poll frame followed after SIFS by an A-MPDU containing one or more VHT Compressed Beamforming frames.

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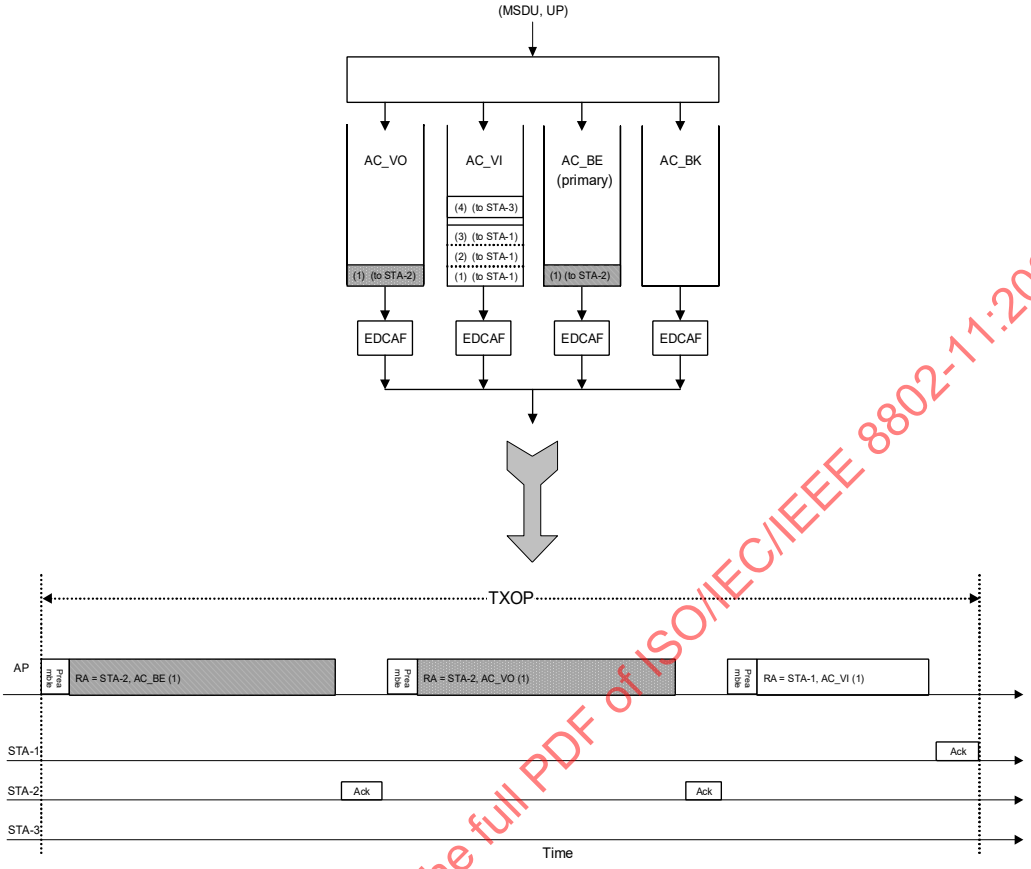

Figure 10-27—Illustration of TXOP sharing and PPDU construction (non-A-MPDUs)

Multiple frames of the primary AC may be transmitted in an EDCA TXOP that was acquired following the rules in 10.23.2.4. Frames that are pending in other ACs shall not be transmitted in this EDCA TXOP except when permitted by the rules in 10.23.2.7. If a TXOP holder has in its transmit queue an additional frame of the primary AC (or, where permitted, a secondary AC) and the duration of transmission of that frame plus any expected acknowledgment for that frame is less than the remaining TXNAV timer value and, if dot11MCCAActivated is true, the remaining RAV timer value, then the TXOP holder may commence transmission of that frame a SIFS (or RIFS, if the conditions defined in 10.3.2.3.2 are met, or PIFS, if the frame contains a bandwidth signaling TA) after the completion of the immediately preceding frame exchange sequence, subject to the TXOP limit restriction as described in 10.23.2.9. A STA shall not commence the transmission of an RTS with a bandwidth signaling TA until at least a PIFS after the immediately preceding frame exchange sequence. A CMMG STA shall not commence the transmission of an RTS frame until at least PIFS time after the immediately preceding frame exchange sequence. An HT STA that is a TXOP holder may transmit multiple MPDUs of the same AC within an A-MPDU as long as the duration of transmission of the A-MPDU plus any expected BlockAck frame response is less than the remaining TXNAV timer value and, if dot11MCCAActivated is true, the remaining RAV timer value. An S1G STA that is a TXOP holder may transmit multiple MPDUs of the same AC within an A-MPDU as long as the duration of transmission of the A-MPDU plus any expected (NDP) BlockAck frame response is less than the remaining TXNAV timer value.

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NOTE 1—PIFS is used by a VHT STA to perform CCA in the secondary 20 MHz, 40 MHz, and 80 MHz channels before receiving RTS (see 10.3.2).

NOTE 2—An RD responder can transmit multiple MPDUs as described in 10.29.4.

NOTE 3—Within a BDT, STAs can transmit multiple MPDUs as described in 10.50.

NOTE 4—A PIFS is required to be present preceding an RTS transmission by a CMMG STA in order to allow a recipient of the RTS to perform CCA in the secondary 540 MHz channels to determine the appropriate response to the RTS.

After a valid response (see Annex G) to the initial frame of a TXOP, if the Duration/ID field is set for multiple frame transmission and there is a subsequent transmission failure, the corresponding channel access function may transmit after the CS mechanism (see 10.3.2.1) indicates that the medium is idle at the TxPIFS slot boundary (see Figure 10-25) provided that the duration of that transmission plus the duration of any expected acknowledgment and applicable IFS is less than the remaining TXNAV timer value and, if dot11MCCAActivated is true, the RAV timer. At the expiration of the TXNAV timer and if dot11MCCAActivated is true, the RAV timer, if the channel access function has not regained access to the medium, then the EDCAF shall invoke the backoff procedure that is described in 10.23.2.4. Transmission failure is defined in 10.23.2.12.

All other channel access functions at the STA shall treat the medium as busy until the expiration of the TXNAV timer.

NOTE 5—A multiple frame transmission is granted to an EDCAF, not to a STA, so that the multiple frame transmission is permitted only for the transmission of a frame of the same AC as the frame that was granted the EDCA TXOP, except as specified in 10.23.2.7.

In the case of PSMP, this AC transmission restriction does not apply to either the AP or the STAs participating in the PSMP sequence, but the specific restrictions on transmission during a PSMP sequence described in 10.30 do apply.

If a TXOP is protected by an RTS or CTS frame carried in a non-HT or a non-HT duplicate PPDU, the TXOP holder shall set the TXVECTOR parameter CH_BANDWIDTH of a PPDU as follows:

— To be the same or narrower than RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT of the last received CTS frame in the same TXOP, if the RTS frame with a bandwidth signaling TA and TXVECTOR parameter DYN_BANDWIDTH_IN_NON_HT set to Dynamic has been sent by the TXOP holder in the last RTS/CTS exchange.
— Otherwise, to be the same or narrower than the TXVECTOR parameter CH_BANDWIDTH of the RTS frame that has been sent by the TXOP holder in the last RTS/CTS exchange in the same TXOP.

If there is no RTS/CTS exchange in non-HT duplicate format in a TXOP, and the TXOP includes at least one non-HT duplicate frame that does not include a PS-Poll, then the TXOP holder shall set the TXVECTOR parameter CH_BANDWIDTH of a PPDU sent after the first non-HT duplicate frame that is not a PS-Poll to be the same or narrower than the TXVECTOR parameter CH_BANDWIDTH of the initial frame in the first non-HT duplicate frame in the same TXOP.

If there is no non-HT duplicate frame in a TXOP, the TXOP holder shall set the TXVECTOR parameter CH_BANDWIDTH of a non-initial PPDU to be the same or narrower than the TXVECTOR parameter CH_BANDWIDTH of the preceding PPDU that it has transmitted in the same TXOP.

If a TXOP is protected by a CTS-to-self frame carried in a non-HT or non-HT duplicate PPDU, the TXOP holder shall set the TXVECTOR parameter CH_BANDWIDTH of a PPDU to be the same or narrower than the TXVECTOR parameter CH_BANDWIDTH of the CTS-to-self frame in the same TXOP.

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Note that when transmitting multiple frames in a TXOP using acknowledgment mechanisms other than immediate acknowledgment, a protective mechanism should be used (such as RTS/CTS or the protection mechanism described in 10.27). A QoS AP or a mesh STA may send group addressed frames without using any protection mechanism. In a QoS IBSS, group addressed frames shall be sent one at a time, and backoff shall be performed after the transmission of each of the group addressed frames. In an MBSS, a mesh STA may send multiple group addressed frames in a TXOP, bounded by the TXOP limit, without performing backoff after the TXOP is obtained.

An S1G STA that intends to transmit an 8 MHz or 16 MHz PPDU invoking a backoff procedure in the primary 2 MHz channel using the channel busy conditions defined in 23.3.18.5.4.2 shall not set the Dynamic Indication field to 1 in any RTS frame that is scheduled for transmission at the expiration of this backoff.

10.23.2.9 TXOP limits

The duration of a TXOP is the time a STA obtaining a TXOP (the TXOP holder) maintains uninterrupted control of the medium, and it includes the time required to transmit frames sent as an immediate response to TXOP holder transmissions. The TXOP holder shall, subject to the exceptions below, ensure that the duration of a TXOP does not exceed the TXOP limit, when nonzero.

The TXOP limits are advertised by the AP in the EDCA Parameter Set element in Beacon and Probe Response frames transmitted by the AP.

A TXOP limit of 0 indicates that the TXOP holder may transmit or cause to be transmitted (as responses) the following within the current TXOP:

a) One of the following at any rate, subject to the rules in 10.6
   1) One or more SU PPDUs carrying fragments of a single MSDU or MMPDU
   2) An SU PPDU or a VHT MU PPDU carrying a single MSDU, a single MMPDU, a single A-MSDU, or a single A-MPDU
   3) A VHT MU PPDU carrying A-MPDUs to different users (a single A-MPDU to each user)
   4) A QoS Null frame or PS-Poll frame that is not an PS-Poll+BDT frame
b) Any required acknowledgments
c) Any frames required for protection, including one of the following:
   1) An RTS/CTS exchange
   2) CTS-to-self
   3) Dual CTS as specified in 10.3.2.10
d) Any frames required for beamforming as specified in 10.31, 10.36.5, and 10.42.
e) Any frames required for link adaptation as specified in 10.32
f) Any number of BlockAckReq frames

NOTE 1—This is a rule for the TXOP holder. A TXOP responder need not be aware of the TXOP limit nor of when the TXOP was started.

NOTE 2—This rule prevents the use of RD, BDT, and TXOP sharing when the TXOP limit is 0.

When dot11OCBActivated is true, TXOP limits shall be 0 for each AC.

The TXOP holder may exceed the TXOP limit only if it does not transmit more than one Data or Management frame in the TXOP, only if it does not transmit a DL-MU-MIMO PPDU in the TXOP, and only for the following situations:

— Retransmission of an MPDU, not in an A-MPDU consisting of more than one MPDU.
— Transmission of an MSDU or MMPDU less than 600 octets by an S1G non-sensor STA.

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- Transmission of a fragment of an MSDU or MMPDU, the fragment being less than 256 octets, by an S1G non-sensor STA.
- Initial transmission of an MSDU under a block ack agreement, where the MSDU is not in an A-MPDU consisting of more than one MPDU and the MSDU is not in an A-MSDU.
- Transmission of a Control frame or a QoS Null frame , not in an A-MPDU consisting of more than one MPDU.
- Initial transmission of a fragment of an MSDU or MMPDU, if a previous fragment of that MSDU or MMPDU was retransmitted.
- Transmission of a fragment of an MSDU or MMPDU fragmented into 16 fragments.
- Transmission of an A-MPDU consisting of the initial transmission of a single MPDU not containing an MSDU and that is not an individually addressed Management frame.
- Transmission of a group addressed MPDU, not in an A-MPDU consisting of more than one MPDU.
- Transmission of a null data PPDU (NDP).
- Transmission of a VHT NDP Announcement frame and NDP or transmission of a Beamforming Report Poll frame, where these fit within the TXOP limit and it is only the response and the immediately preceding SIFS that cause the TXOP limit to be exceeded.

Except as described above, a STA shall fragment an individually addressed MSDU or MMPDU so that the initial transmission of the first fragment does not cause the TXOP limit to be exceeded.

NOTE 3—The TXOP limit is not exceeded for the following situations:

a) Initial transmission of an MPDU containing an unfragmented though fragmentable (see 10.2.6) MSDU/MMPDU.
b) Initial transmission of the first fragment of a fragmented MSDU/MMPDU, except for an MSDU/MMPDU fragmented into 16 fragments.
c) Initial transmission of an A-MSDU.
d) Initial transmission of a fragment of a fragmented MSDU/MMPDU, if no previous fragment of that MSDU/MMPDU was retransmitted, except for an MSDU/MMPDU fragmented into 16 fragments.
e) Transmission of an A-MPDU consisting of a single MPDU containing an A MSDU or individually addressed Management frame, unless this is a retransmission of that MPDU.
f) Transmission of an A-MPDU consisting of more than one MPDU, even if some or all of the MPDUs are retransmissions.

If the TXOP holder exceeds the TXOP limit, it should use as high a PHY rate as possible to minimize the duration of the TXOP.

The duration of a TXOP for a mesh STA that has dot11MCCAActivated true shall not exceed the time between the start of the TXOP and the end of the current MCCAOP reservation.

NOTE 4—The rules in this subclause also apply to priority-downgraded MSDUs and A-MSDUs (see 10.23.4.2).

10.23.2.10 Truncation of TXOP

When a STA gains access to the channel using EDCA and empties its transmission queue, it may transmit a CF-End frame provided that the remaining duration is long enough to transmit this frame. By transmitting the CF-End frame, the STA is explicitly indicating the completion of its TXOP. In a DMG BSS, the STA shall not send a CF-End frame with a nonzero value in the Duration/ID field if the remaining duration is shorter than $2\times T_{CF\text{-}End}$ + 2×SIFS, where $T_{CF\text{-}End}$ is the duration of a CF-End frame. A STA that is an S1G AP may transmit an NDP CF-End frame instead of a CF-End frame. A non-S1G STA shall not transmit an NDP CF-End frame.

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An S1G STA that both

— Transmits either a PPDU with its TXVECTOR parameter RESPONSE_INDICATION value Long Response or an NDP (PS-Poll-)Ack frame with its Idle Indication field value 1 and Duration field value 0 and

— Does not receive (after a SIFS) a response with its RXVECTOR parameter RESPONSE_INDICATION value NDP Response or Normal Response

may, after PIFS, transmit an NDP CF-End frame to truncate any active RID or NAV.

A TXOP holder that transmits a CF-End frame shall not initiate any further frame exchange sequences within the current TXOP.

An S1G STA that transmits an NDP CF-End frame shall set the frame's Duration field to 0 and shall initiate no other frame exchange sequences in the current TXOP.

A non-AP STA that is not the TXOP holder shall not transmit a CF-End frame.

In a non-DMG BSS, a non-S1G STA shall interpret the reception of a CF-End frame as a NAV reset, i.e., it resets its NAV to 0 at the end of the PPDU containing this frame. After receiving a CF-End frame with a matching BSSID(TA) without comparing Individual/Group bit, an AP may respond by transmitting a CF-End frame after SIFS.

NOTE 1—The transmission of a single CF-End frame by the TXOP holder resets the NAV of STAs hearing the TXOP holder. There may be STAs that could hear the TXOP responder that had set their NAV that do not hear this NAV reset. Those STAs are prevented from contending for the medium until the original NAV reservation expires.

NOTE 2—A CF-End sent by a non-AP VHT STA that is a member of a VHT BSS can include the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT as defined in 10.6.6.6 in case it elicits a CF-End response.

In a DMG BSS, a STA that is not in the listening mode (10.39.6.6) shall interpret the reception of a CF-End frame as a NAV reset, i.e., it resets its NAV to 0 at the end of the time interval indicated in the value of the Duration/ID field of the received frame. The interval starts at PHY-RXEND.indication primitive of the frame reception. The STA shall not transmit during the interval if the RA field of the frame is not equal to the STA MAC address. The STA may transmit a CF-End frame if the RA field of the received frame is equal to the STA MAC address and the value of the Duration/ID field in the received frame is not equal to 0.

Figure 10-28 shows an example of TXOP truncation. In this example, the STA accesses the medium using EDCA channel access and then transmits a nav-set sequence (e.g., RTS/CTS for non-DMG STAs or RTS/DMG CTS for DMG STAs) (using the terminology of Annex G). After a SIFS, it then transmits an initiator-sequence, which may involve the exchange of multiple PPDUs between the TXOP holder and TXOP responders. At the end of the second sequence, the TXOP holder has no more data that it can send that fits within the TXOP limit; therefore, it truncates the TXOP by transmitting a CF-End frame.

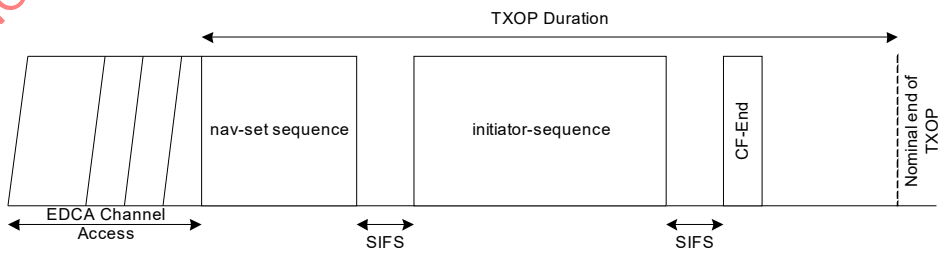

Figure 10-28—Example of TXOP truncation

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Non-DMG STAs that are not S1G STAs that receive a CF-End frame reset their NAV and can start contending for the medium without further delay. A DMG STA that receives a CF-End frame can start contending for the medium at the end of the time interval equal to the value in Duration/ID field of the frame if none of its NAVs has a nonzero value (10.39.10).

An S1G STA that receives an NDP CF-End frame should reset its NAV and may start contending for the medium without further delay.

An S1G STA may transmit a CF-End frame containing a value greater or equal to 0 in the Duration/ID field.

An S1G STA shall interpret the reception of a CF-End frame with the Duration/ID field equal to 0 as a NAV reset, i.e., it resets its NAV timer to 0 at the end of the PPDU containing this frame. After receiving a CF-End frame with the Duration/ID field equal to 0 and a matching BSSID, an AP may respond by transmitting a CF-End frame with the Duration/ID field equal to 0 after SIFS.

When an S1G STA receives a CF-End frame with the Duration/ID field not equal to 0 that falls in the range of [NAV value – 8, NAV value + 8] (microseconds) at the time of the reception of the PHY-RXEND.indication, it shall reset the NAV and may start contending for the medium without further delay. If the received duration value does not fall in the range of [NAV value – 8, NAV value + 8] microseconds at the time of the reception of the PHY-RXEND.indication, the STA shall discard the CF-End frame.

NOTE 3—A NAV value that varies within ± 8 microsecond boundaries accommodates almost all inaccuracies (e.g., due to clock drifting) to the NAV counter at the receiving STA.

After receiving a CF-End frame with a matching BSSID, an S1G AP may respond by transmitting a CF-End frame after SIFS in which the value of the Duration field is equal to the value obtained from the Duration field of the received CF-End frame adjusted by subtracting the value of aSIFSTime and the time required to transmit the CF-End frame, in units of microseconds. If the adjusted value is a negative value, the Duration field of the CF-End frame is set to 0.

10.23.2.11 Termination of TXOP

A TXOP holder that transmits a PPDU using one of the modulation classes in Table 10-19 should transmit a short Control frame as the final transmission in a TXOP, under the conditions specified in Table 10-20.

Table 10-19—Modulation classes eligible for TXOP termination

Modulation classes eligible for TXOP termination (see Table 10-9)
DSSS
HR/DSSS
ERP-OFDM
OFDM (20 MHz channel spacing)
HT
VHT

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Table 10-20—Rate and modulation class of a final transmission in a TXOP

Modulation class and data rate of immediately preceding frame in TXOP	Rate and modulation class of final transmission
DSSS or HR/DSSS with long preamble, data rate > 1 Mb/s	1 Mb/s DSSS
HR/DSSS with short preamble, data rate > 2 Mb/s	2 Mb/s HR/DSSS short preamble
Other eligible modulation classes, data rate > 6 Mb/s	6 Mb/s OFDM

The final transmission can be a CF-End, or a CTS-to-self when no NAV needs to be truncated.

NOTE—The final transmission at the lowest data rate within the modulation class is needed because a final transmission at a higher rate can cause spurious EIFSs to occur, because the PHY header of such frames travels farther than the MPDU.

10.23.2.12 Retransmit procedures

10.23.2.12.1 General

A QoS STA shall maintain a frame retry count for each MSDU, A-MSDU, or MMPDU that belongs to a TC that requires acknowledgment. The initial value for the frame retry count shall be 0.

QoS STAs shall also maintain a QoS STA retry count for each AC, QSRC[AC]. The initial value for the QSRC[AC] counters shall be 0.

When dot11RobustAVStreamingImplemented is true, a QoS STA shall maintain a drop-eligible frame retry count for each QoS Data frame with an HT variant HT Control field with the DEI field equal to 1. The initial value for the drop-eligible frame retry count shall be 0.

APs with dot11RobustAVStreamingImplemented equal to true and mesh STAs with dot11MeshGCRImplemented equal to true, shall maintain an unsolicited frame retry count. The initial value for the unsolicited frame retry count shall be 0.

After transmitting a frame that requires an immediate acknowledgment, the STA shall perform either of the acknowledgment procedures, as appropriate, that are defined in 10.3.2.11. The frame retry count for an MSDU or A-MSDU that is not part of a block ack agreement or for an MMPDU shall be incremented every time transmission fails for that MSDU, A-MSDU, or MMPDU, including of an associated RTS.

For APs with dot11RobustAVStreamingImplemented equal to true and mesh STAs with dot11MeshGCRImplemented equal to true, the unsolicited frame retry count shall be incremented after the transmission of every A-MSDU that is transmitted using the GCR unsolicited retry retransmission policy.

All retransmission attempts by a non-DMG STA for an MPDU with the Type subfield equal to Data or Management that is not sent under a block ack agreement and that has failed the acknowledgment procedure one or more times shall be made with the Retry subfield set to 1.

All retransmission attempts by a DMG STA for an MPDU with the Type subfield equal to Data or Management that has failed the acknowledgment procedure one or more times shall be made with the Retry subfield set to 1.

A QoS STA shall maintain a transmit MSDU/MMPDU timer for each MSDU passed to the MAC and for each MMPDU. dot11EDCATableMSDULifetime specifies the maximum amount of time allowed to transmit an

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MSDU/MMPDU for a given AC. The transmit MSDU/MMPDU timer shall be started when the MSDU/MMPDU is passed to the MAC.

When A-MSDU aggregation is used, the HT STA maintains a single timer for the whole A-MSDU. The timer is restarted each time an MSDU is added to the A-MSDU. The result of this procedure is that no MSDU in the A-MSDU is discarded before a period of dot11EDCATableMSDULifetime has elapsed.

Retries for failed transmission attempts shall continue until one or more of the following conditions occur:

— The frame retry count for the MSDU, A-MSDU, or MMPDU is equal to dot11ShortRetryLimit.
— The drop-eligible frame retry count for the MSDU, A-MSDU, or MMPDU is equal to dot11ShortDEIRetryLimit.
— The unsolicited frame retry count for the A-MSDU is equal to dot11UnsolicitedRetryLimit.
— The transmit MSDU/MMPDU timer for the MSDU/MMPDU or any undelivered fragments of that MSDU/MMPDU exceeds dot11EDCATableMSDULifetime.

When any of these limits is reached, retry attempts shall cease, and the associated MSDU, A-MSDU, or MMPDU shall be discarded.

For internal collisions, the frame retry counts associated with the MSDUs, A-MSDUs, or MMPDUs involved in the internal collision shall be incremented.

With the exception of a frame belonging to a TID for which block ack agreement is set up, a QoS STA shall not initiate the transmission of any Management or Data frame to a specific RA while the transmission of another Management or Data frame with the same RA and having been assigned its sequence number from the same sequence counter has not yet completed to the point of success, retry fail, or other MAC discard (e.g., lifetime expiration).

10.23.2.12.2 Unsolicited retry procedure

When using the GCR unsolicited retry retransmission policy for a group address, an AP or mesh STA may retransmit an MPDU to increase the probability of correct reception at the STAs that are listening to this group address (i.e., the group address is in their dot11GroupAddressesTable). The set of MPDUs that may be retransmitted is dependent upon whether block ack agreements are active with the STAs that are listening to this group address and is defined in 11.21.16.3.6. How an AP or a mesh STA chooses which MPDUs to retransmit is an implementation decision and beyond the scope of this standard.

A protective mechanism (such as a mechanism described in 10.27) should be used to reduce the probability of other STAs transmitting during the GCR TXOP. When using a protection mechanism that requires a response from another STA, the AP should select a STA that is a member of the GCR group.

The TXOP initiation rules defined in 10.23.2.2 and 10.23.3.3 shall be used for initiating a GCR TXOP. The duration of a GCR TXOP shall be subject to the TXOP limits defined in 10.23.2.9.

When transmitting MPDUs using the GCR service with retransmission policy equal to GCR unsolicited retry, the following rules apply:

— Following a MAC protection exchange that includes a response frame, in all GCR unsolicited retry retransmissions, the STA shall either transmit the frames within a GCR TXOP separated by SIFS or invoke its backoff procedure as defined in 10.23.2.2. The STA shall not transmit an MPDU and a retransmission of the same MPDU within the same GCR TXOP. The final frame transmitted within a GCR TXOP shall follow the backoff procedure defined in 10.23.2.2.
— Without MAC protection or with MAC protection that lacks a response frame, in all transmissions, the STA shall invoke the backoff procedure defined in 10.23.2.2, using a value of CWmin[AC] for

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CW, at the PHY-TXEND.confirm primitive that follows the transmission of each unsolicited retry GCR MPDU.

— All retransmissions of an MPDU shall have the Retry subfield in their Frame Control fields set to 1.
— During a GCR TXOP, frames may be transmitted within the GCR TXOP that do not use the GCR unsolicited retry retransmission policy.

10.23.2.13 EDCA channel access in a CMMG BSS

If the MAC receives a PHY-CCA.indication primitive with the channel-list parameter present, the channels considered idle are defined in Table 10-21.

Table 10-21—Channels indicated idle by the channel-list parameter for CMMG BSSs

PHY-CCA.indication primitive channel-list parameter entry	Idle channel
primary	None
secondary	Primary 540 MHz

In the following description, the CCA is sampled according to the timing relationships defined in 10.3.7. Slot boundaries are determined solely by activity on the primary channel. "Channel idle for an interval of PIFS" means that whenever CCA is sampled during the period of PIFS that ends at the start of transmission, the CCA for that channel was determined to be idle.

If a STA is permitted to begin a TXOP (as defined in 10.23.2.3) and the STA has at least one MSDU pending for transmission for the AC of the permitted TXOP, the STA shall perform exactly one of the following steps:

a) Transmit a 1080 MHz mask PPDU if the secondary 540 MHz channel is idle during an interval of PIFS immediately preceding the start of the TXOP.
b) Transmit a 540 MHz mask PPDU on the primary 540 MHz channel.
c) Restart the channel access attempt by invoking the backoff procedure as specified in 10.23.2 as though the medium is busy on the primary channel as indicated by either physical or virtual CS and the backoff counter has a value of 0.

NOTE 1—In the case of rule c), the STA selects a new random number using the current value of CW[AC], and the retry counts are not updated [as described in 10.23.2.5; backoff procedure invoked for event a)].

NOTE 2—For CMMG STAs, an EDCA TXOP is obtained based on activity on the primary channel (see 10.23.2.3). The width of transmission is determined by the CCA status of the nonprimary channels during the PIFS before transmission (see 10.23.2.4).

10.23.3 HCF controlled channel access (HCCA)

10.23.3.1 General

The HCCA mechanism manages access to the WM using an HC that has higher medium access priority than non-AP STAs. This allows it to transfer MSDUs to STAs and to allocate TXOPs to STAs.

The HC grants a STA a polled TXOP with duration specified in a QoS (+)CF-Poll frame. A STA may transmit multiple frame exchange sequences within given polled TXOPs, subject to the limit on TXOP duration.

All STAs inherently obey the NAV rules of the HCF because each frame transmitted under HCF contains a duration value chosen to cause STAs in the BSS to set their NAVs to protect the expected subsequent frames.

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A non-AP QoS STA that is a non-S1G STA shall be able to respond to QoS (+)CF-Poll frames received from an HC with the Address 1 field matching their own addresses.

The HC shall perform delivery of buffered non-GCR-SP group addressed MSDUs/MMPDUs following DTIM Beacon frames.

An HC may perform a backoff following an interruption of a frame exchange sequence due to lack of an expected response under the rules described in 10.23.3.2.3, using the parameters dot11HCCWmin, dot11HCCWmax, and dot11HCCAIFSN and the backoff rules in 10.2 and 10.23.2.2. The decision to perform a backoff by the HC is dependent on conditions such as interference from an overlapping BSS. The mechanism to detect the interference from an overlapping BSS and the decision to perform a backoff, DFS (such as in 11.6), or other techniques (such as inter-BSS scheduling) is beyond the scope of this standard.

10.23.3.2 HCCA procedure

10.23.3.2.1 General

To start an HCCA TXOP, the HC gains control of the WM by waiting a shorter time before initiating the first transmission of the TXOP than STAs using the EDCA procedures. The duration values used in QoS frame exchange sequences reserve the medium to permit completion of the current sequence.

10.23.3.2.2 CAP generation

When the HC needs access to the WM to start a CAP, the HC shall sense the WM. When the WM is determined to be idle at the TxPIFS slot boundary as defined in 10.3.7, the HC shall transmit either a QoS (+)CF-Poll with the duration value set to cover the polled TXOP, or the first frame of any permitted frame exchange sequence with the duration value set to cover the HCCA TXOP. A CAP shall not extend across a TBTT. The occurrence of a TBTT implies the end of the CAP, after which the regular channel access procedure (EDCA or HCCA) is resumed. It is possible that no Data frame was transmitted during an HCCA TXOP. The shortened termination of the HCCA TXOP does not imply an error condition. CAPs are illustrated in Figure 10-29.

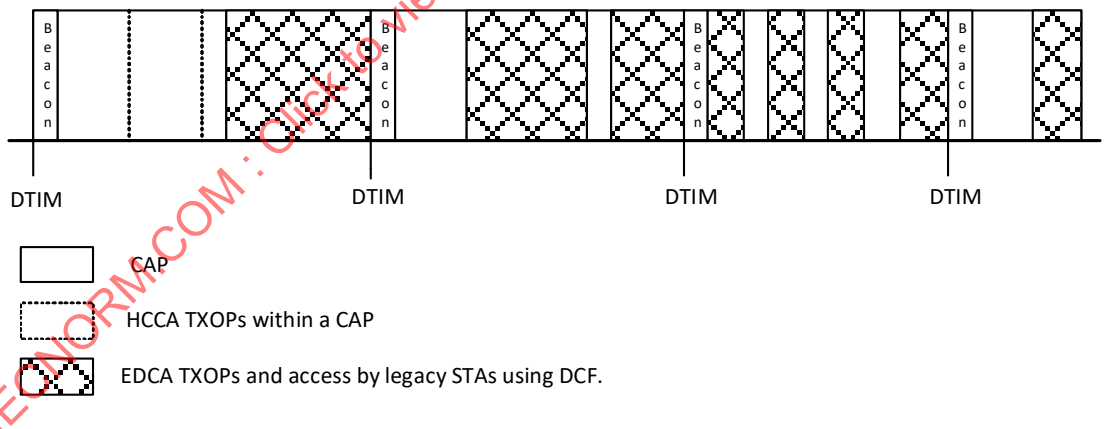

Figure 10-29—CAP periods

After the last frame of all other nonfinal frame exchange sequences (e.g., sequences that convey individually addressed QoS Data or Management frames) during an HCCA TXOP, the holder of the current HCCA TXOP shall wait for one SIFS before transmitting the first frame of the next frame exchange sequence. The HC may sense the channel and reclaim the channel if the WM is determined to be idle at the TxPIFS slot boundary after the HCCA TXOP (see Figure 10-25). A CAP ends when the HC does not reclaim the channel at the TxPIFS slot boundary after the end of an HCCA TXOP.

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10.23.3.2.3 Recovery from the absence of an expected reception

This subclause describes recovery from the absence of an expected reception in a CAP. Note that the recovery rules from the absence of an expected reception are different from EDCA because in this case the NAVs of all of the STAs in the BSS have already been set up by the transmissions by the HC. The recovery rules for the multiple frame transmission are different because a STA may always be hidden and may have not set its NAV due to the transmission by another STA. Finally, since an HC is collocated with the AP, the AP may recover using the rules described in this subclause even if the recovery is from the absence of an expected reception.

The beginning of reception of an expected response is detected by the occurrence of PHY-CCA.indication(BUSY,channel-list) primitive at the STA that is expecting the response where the channel-list parameter is absent or, if present, includes "primary."

If the beginning of such reception does not occur during the first slot time following a SIFS, then:[31]

— If the transmitting STA is the HC, it may initiate recovery by transmitting at the TxPIFS slot boundary after the end of the HC's last transmission only if the PHY-CCA state indicates IDLE during the CCAdel period preceding the TxPIFS slot boundary as shown in 10-21.

— If the transmitting STA is a non-AP QoS STA, and there is an MPDU for transmission, it shall initiate recovery by transmitting at a PIFS after the end of the last transmission if the PHY-CCA state indicates IDLE during the CCAdel period preceding the TxPIFS slot boundary, the polled TXOP limit is nonzero and at least one frame (re)transmissions can be completed within the remaining duration of a nonzero polled TXOP limit.

If the transmitted frame is not of type QoS (+)CF-Poll and the expected response frame is not received correctly, regardless of the occurrence of the PHY-RXSTART.indication primitive, the QoS STA may initiate recovery following the occurrence of PHY-CCA.indication(IDLE) primitive so that a SIFS occurs between the last energy on the WM and the transmission of the recovery frame.

When there is a transmission failure within a polled TXOP, the short retry count (as described in 10.23.2.12) corresponding to the failed MSDU or MMPDU shall be incremented. An MPDU belonging to a TC is subject to the respective retry limit as well as the dot11EDCATableMSDULifetime and is discarded when either of them is exceeded. An MPDU belonging to a TS with a specified delay bound is subject to delay bound and is discarded if the MPDU could not be transmitted successfully since it has been delivered to the MAC. An MPDU belonging to a TS with an unspecified delay is subject to dot11MaxTransmitMSDULifetime and is discarded when it is exceeded.

Non-AP STAs that receive a QoS (+)CF-Poll frame shall respond within a SIFS, regardless of the NAV setting. If a response is not received but a PHY-CCA.indication(BUSY) primitive occurs during the slot following a SIFS and is followed by a PHY-RXSTART.indication or PHY-RXEND.indication primitive prior to a PHY-CCA.indication(IDLE) primitive, then the HC assumes that the transmitted QoS (+)CF-Poll frame was received by the polled STA. In the cases of QoS Data +CF-Poll, QoS Data +CF-Ack +CF-Poll, or QoS CF-Ack +CF-Poll, the PHY-CCA.indication(BUSY) primitive is used only to determine whether the transfer of control of the channel has been successful. The PHY-CCA.indication(BUSY) primitive is not used for determining the success or failure of the transmission. If the CF-Poll is piggybacked onto a QoS Data frame, the HC may have to retransmit that QoS Data frame subsequently.

If an HC receives a frame from a STA with a duration/ID covering only the response frame, the HC shall assume that the STA is terminating its TXOP, and the HC may initiate other transmissions, or send a CF-End frame (see 10.23.3.4).

[31] This restriction is intended to avoid collisions due to inconsistent CCA reports in different STAs, not to optimize the bandwidth usage efficiency.

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If a polled QoS STA has no queued traffic to send or if the MPDUs available to send are too long to be transmitted within the specified TXOP limit, the QoS STA shall send a QoS (+)Null frame. In the case of no queued traffic, this QoS (+)Null frame shall have a QoS Control field that reports a queue size of 0 for any TID with the duration/ID set to the time required for the transmission of one Ack frame, plus one SIFS. In the case of insufficient TXOP size, such as when the maximum MSDU size is not specified, this QoS (+)Null frame shall have a QoS Control field that contains the TID and TXOP duration or a nonzero queue size needed to send the MPDU that is ready for transmission. When a queue size is transmitted, the HC shall combine the queue size information with the rate of the received QoS (+)Null frame to determine the required size of the requested TXOP.

Within a polled TXOP, the unused portion of TXOPs shall not be used by the STA and may be reallocated by the HC as follows:

a) The recipient of the final frame, with Normal Ack ack policy, shall be the HC if there will be time remaining in the TXOP after the transmission of the final frame and its expected Ack frame. If there are no frames to be sent to the HC, then the QoS STA shall send to the HC a QoS Null with the Queue Size subfield in the QoS Control field set to 0.
    1) If a PHY-CCA.indication(BUSY) primitive occurs at the STA that is expecting the Ack frame during the first slot following a SIFS after the end of the transmission of the final frame, it shall be interpreted as indicating that the channel control has been successfully transferred and no further frames shall be transmitted by the STA in the TXOP, even though the Ack frame from HC may be incorrectly received.[32]
    2) If the beginning of the reception of an expected Ack frame to the final frame does not occur, detected as the nonoccurrence of the PHY-CCA.indication(BUSY) primitive at the QoS STA that is expecting the response during the first slot time following a SIFS, the QoS STA shall retransmit the frame or transmit a QoS Null frame, with Normal Ack ack policy and the Queue Size subfield set to 0, after PIFS from the end of last transmission, until such time that it receives an acknowledgment or when there is not enough time remaining in the TXOP for sending such a frame.[33]
b) If there is not enough time within the unused portion of the TXOP to transmit either the QoS Null frame or the frame with the Duration/ID field covering only the response frame, then the STA shall cease control of the channel.[34]

10.23.3.3 HCCA TXOP structure and timing

Any QoS Data frame of a subtype that includes CF-Poll contains a TXOP limit in its QoS Control field. The ensuing polled TXOP is protected by the NAV set by the Duration field of the frame that contained the QoS (+)CF-Poll function, as shown in Figure 10-30. Within a polled TXOP, a STA may initiate the transmission of one or more frame exchange sequences, with all such sequences nominally separated by a SIFS. The STA shall not initiate transmission of a frame unless the transmission and any acknowledgment or other immediate response expected from the peer MAC entity are able to complete prior to the end of the remaining TXOP duration. All transmissions, including response frames, within the polled TXOP are considered to be the part of the TXOP, and the HC shall account for these when setting the TXOP limit. If the TXOP Limit subfield in the QoS Control field of the QoS Data frame that includes CF-Poll is equal to 0, then the STA to which the frame is directed to shall respond with either one MPDU or one QoS Null frame.

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[32] Note that while the PHY-CCA.indication(BUSY) primitive is used in this instance to determine the control of the channel, it is not used for determining the success or failure of the transmission.

[33] This is to avoid the situation where the HC might not receive the frame and might result in an inefficient use of the channel.

[34] In this case the channel is not accessed until the NAVs expire at all of the STAs.

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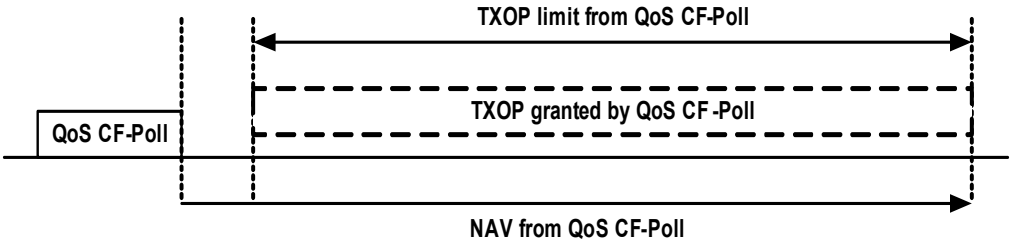

Figure 10-30—Polled TXOP

A TXOP or transmission within a TXOP shall not extend across TBTT, or dot11CAPLimit. The HC shall verify that the full duration of any granted TXOP meets these requirements so that a STA may use the time prior to the TXOP limit of a polled TXOP without checking for these constraints. Subject to these limitations, all decisions regarding what MSDUs, A-MSDUs, and/or MMPDUs are transmitted during any given TXOP are made by the STA that holds the TXOP.[35,36]

10.23.3.4 NAV operation of a TXOP under HCCA

An HC shall set its own NAV to prevent it from transmitting during a TXOP that it has granted to a STA through an HCCA poll. However, the HC may reclaim the TXOP if a STA is not using it or ends the TXOP early (see 10.23.3.2.3).

If the HC has no more STAs to poll and it has no more Data, Management, BlockAckReq, or BlockAck frames to send, it may reset the NAVs of all QoS STAs in the BSS by sending a QoS CF-Poll frame with the RA matching its own MAC address and with the Duration/ID field set to 0.

A STA that receives a QoS (+)CF-Poll frame with a MAC address in the Address 1 field that matches the HC's MAC address and the Duration/ID field value equal to 0 shall reset the NAV value to 0.

When a STA receives a QoS (+)CF-Poll frame containing the BSSID of the BSS of which the STA is a member, that STA shall update the NAV if necessary and shall save the TXOP holder address for that BSS, which is the MAC address from the Address 1 field of the frame containing the QoS (+)CF-Poll. If an RTS frame is received with the RA matching the MAC address of the STA and the MAC address in the TA field in the RTS frame matches the saved TXOP holder address, then the STA shall send the CTS frame after SIFS, without regard for, and without resetting, its NAV. The saved TXOP holder address shall be cleared when the NAV is reset or when the NAV counts down to 0.

When a STA receives a frame addressed to it and requires an acknowledgment, it shall respond with an Ack or QoS +CF-Ack frame independent of its NAV. A non-AP STA shall accept a polled TXOP by initiating a frame exchange sequence independent of its NAV.

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[35] In certain regulatory domains, channel sensing needs to be done at periodic intervals (for example, in Japan, this period is 4 ms). This means that the duration of a TXOP in these regulatory domains might not be more than this periodic interval. In order to extend the TXOP beyond the limit implied by this periodic interval, the TXOP holder needs to sense the channel at least once in the limit imposed in the regulatory domain, by waiting for at least for the duration of one PIFS during which it senses the channel. If it does not detect any energy, it may continue by sending the next frame. In other words, the total TXOP size assigned should include an extra time allocated (i.e., n × aSlotTime, where n is the number of times the STA needs to sense the channel) and is given by ⌊TXOP limit/limit imposed in the regulatory domain⌋.

[36] The TID value in the QoS Control field of a QoS Data +CF-Poll frame pertains only to the MSDU or fragment thereof in the Frame Body field of that frame. This TID value does not pertain to the TXOP limit value and does not place any constraints on what frame(s) the addressed STA may send in the granted TXOP.

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10.23.3.5 HCCA transfer rules

10.23.3.5.1 General

A TXOP obtained by receiving a QoS (+)CF-Poll frame uses the specified TXOP limit consisting of one or more frame exchange sequences with the sole time-related restriction being that the final sequence shall end not later than the TXOP limit. In QoS CF-Poll and QoS CF-Ack +CF-Poll frames, the TID subfield in the QoS Control field indicates the TS for which the poll is intended. The requirement to respond to that TID is nonbinding, and a STA may respond with any frame. Upon receiving a QoS (+)CF-Poll frame, a STA may send any frames, i.e., QoS Data frames belonging to any TID as well as Management frames in the obtained TXOP. MSDUs may be fragmented in order to fit within TXOPs.

The QoS CF-Poll frames shall be sent only by an HC. Non-AP STAs are not allowed to send QoS (+)CF-Poll frames. A STA shall not send QoS (+)Data frames in response to any Data frame other than the QoS (+)CF-Poll frames.

The TXOP limit is inclusive of the PHY and IFS overhead, and an AP should account for the overhead when granting TXOPs.

If a STA has set up at least one TS for which the Aggregation subfield in the associated TSPEC is equal to 0, the AP shall use only QoS CF-Poll or QoS CF-Ack +CF-Poll frames to poll the STA and shall never use QoS (+)Data +CF-Poll to poll the STA. Note that although QoS (+)CF-Poll is a Data frame, but it should be transmitted at one of the rates in the BSSBasicRateSet parameter in order to set the NAV of all STAs that are not being polled (see 10.6). If a CF-Poll is piggybacked with a QoS Data frame, then the frame containing all or part of an MSDU or A-MSDU may be transmitted at a rate that is below the negotiated minimum PHY rate in the TSPEC related to that data.

A QoS STA shall use QoS Data frames for all MSDU transfers to another QoS STA. The TID in the QoS Control fields of these frames shall indicate the TC or TS to which the MPDU belongs. Furthermore, either the Queue Size subfield shall indicate the amount of queued traffic present in the output queue that the STA uses for traffic belonging to this TC or TS, or the TXOP Duration Requested subfield shall indicate the duration that the STA requests for use in the next TXOP for traffic belonging to this TC or TS. The queue size value reflects the amount on the appropriate queue not including the present MPDU. The queue size value may remain constant in all QoS Data frames that carry fragments of the same MSDU even if the amount of queued traffic changes as successive fragments are transmitted. In order to inform the HC of queue status, a STA may use the QoS Null frame indicating the TID and the queue size or TXOP duration request (also see 10.23.3.5.2).

A QoS STA shall be able to receive QoS +CF-Ack frames. The HC may use QoS Data +CF-Ack frames to send frames to the same STA a SIFS after receiving the final transmission of the previous TXOP. The HC may also use QoS Data +CF-Ack frames to send frames to any other STA a SIFS after receiving the final transmission of the previous TXOP, if the STA that sent the final transmission of the previous TXOP has set the Q-Ack subfield in the QoS Capability element in the (Re)Association Request frame to 1. A STA shall respond to QoS Data frames having Normal Ack ack policy with an Ack frame, unless the acknowledgment is piggybacked in which case it shall use a QoS +CF-Ack frame. Piggybacked frames are allowed only within TXOPs initiated by the HC. The HC shall not send a QoS Data frame containing a +CF-Ack with an Address 1 that does not correspond to the address of the STA for which the +CF-Ack is intended, unless the STA to which the +CF-Ack is intended, sets the Q-Ack subfield in the QoS Capability element in the (Re)Association Request frame. STAs are not required to be able to transmit QoS Data frames with subtypes that include +CF-Ack.

An AP that has dot11QAckOptionImplemented true may allow associations with STAs advertising support for the Q-Ack option. Such associations do not require the AP to employ piggyback acknowledgments directed toward that associated STA in frames that are not directed to that associated STA. A QoS STA shall be able to process received QoS Data frames with subtypes that include +CF-Ack when the STA to which the

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acknowledgment is directed is the same as the STA addressed by the Address 1 field of that Data frame. A STA that does not set the Q-Ack subfield to 1 in the QoS Capability element in the (Re)Association Request frame is not required to handle the received QoS (+)Data +CF-Ack frames that are addressed to other STAs. The net effect of these restrictions on the use of QoS +CF-Ack frames is that the principal QoS +CF-Ack subtype that is useful is the QoS Data +CF-Ack frame, which can be sent by a STA as the first frame in a polled TXOP when that TXOP was conveyed in a QoS Data +CF-Poll (+CF-Ack) frame and the outgoing frame is directed to the HC's STA address. QoS (Data +)CF-Poll +CF-Ack frames are useful to allow the HC to grant another TXOP to the same STA a SIFS after receiving the final transmission of that STA's previous TXOP. QoS (Data+)CF-Poll +CF-Ack frames are also useful to allow the HC to grant another TXOP to a different STA a SIFS after receiving the final transmission of a STA's previous TXOP, if the STA that sent the final transmission of the previous TXOP has set the Q-Ack subfield in the QoS Capability element in the (Re)Association Request frame to 1.

HCF contention based channel access shall not be used to transmit MSDUs belonging to an established TS (with the HC's acceptance of the associated TSPEC), unless the granted TSPEC indicates it is permitted to do so when the Access Policy subfield of the TS Info field is equal to "HCCA, EDCA mixed mode" (HEMM), the polled STA utilized the full TXOP provided by the HC, and it has more MPDUs to send. When this STA sends frames belonging to a TS using contention based channel access, it shall encode the TID subfield in the QoS Data frame with the TID associated with the TS. When the AP grants a TSPEC with the Access Policy subfield equal to HEMM and if the corresponding AC needs admission control, the AP shall include the medium time that specifies the granted time for EDCA access in the ADDTS Response frame.

10.23.3.5.2 TXOP requests

STAs may send TXOP requests during polled TXOPs or EDCA TXOPs using the QoS Control field in a QoS Data frame or a QoS Null frame directed to the HC, with the TXOP Duration Requested or Queue Size subfield value and TID subfield value indicated to the HC. APs indicate whether they process TXOP request or queue size in the QoS Info field in the Beacon, Probe Response, and (Re)Association Response frames. An AP shall process requests in at least one format. The AP may reallocate TXOPs if the request belongs to TS or update the EDCA parameter set if the above request belongs to TC. A STA shall use only the request format that the AP indicates it can process.

TXOP Duration Requested subfield values are not cumulative. A TXOP duration requested for a particular TID supersedes any prior TXOP duration requested for that TID. A value of 0 in the TXOP Duration Requested subfield may be used to cancel a pending unsatisfied TXOP request when its MSDU is no longer queued for transmission. The TXOP duration requested is inclusive of the PHY and IFS overhead, and a STA should account for this when attempting to determine whether a given transmission fits within a specified TXOP duration.

The AP may choose to assign a TXOP duration shorter than that requested in the TXOP Duration Requested subfield.

Even if the value of TXOP Duration Requested subfield or Queue Size subfield in a QoS Data frame is 0, the HC shall continue to poll according to the negotiated schedule.

10.23.3.5.3 Use of RTS/CTS

In order to provide improved NAV protection, a STA may send an RTS frame as the first frame of any frame exchange sequence without regard for dot11RTSThreshold.

If a QoS STA sends an RTS frame and does not receive an expected CTS frame, then the recovery rules are as specified in 10.23.3.2.3.

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In order to provide NAV protection for a transmission to the AP in response to a QoS Data frame with a subtype that includes CF-Poll, the polled STA may send a CTS frame with the RA containing its own MAC.

NOTE 1—The CTS frame is shorter than a QoS Data frame and has a higher probability that it will be received by other STAs.

NOTE 2—The transmission of the CTS sets the NAV in its own vicinity without the extra time required to send an RTS frame.[37]

10.23.3.5.4 HCCA transfer rules for a VHT STA

A VHT STA that is a member of a BSS that supports multiple channel widths is granted a TXOP for a specified duration and for a channel width that is equal to the channel width of the frame containing the QoS CF-Poll.

10.23.4 Admission control at the HC

10.23.4.1 General

An IEEE 802.11 network may use admission control to administer policy or regulate the available bandwidth resources. Admission control is used to attempt to provide a guarantee of the amount of time that a STA has available to access the channel. The HC, which is in the AP, is used to administer admission control in the network. As the QoS facility supports two access mechanisms, there are two distinct admission control mechanisms: one for contention based access and another for controlled access.

Admission control, in general, depends on vendors' implementation of the scheduler, available channel capacity, link conditions, retransmission limits, and the scheduling requirements of a given stream. All of these criteria affect the admissibility of a given stream. If the HC has admitted no streams that require polling, it might not find it necessary to perform the scheduler or related HC functions.

10.23.4.2 Contention based admission control procedures

10.23.4.2.1 General

An AP shall support admission control procedures, at least to the minimal extent of advertising that admission is not mandatory on its ACs. The AP uses the ACM (admission control mandatory) subfields advertised in the EDCA Parameter Set element to indicate whether admission control is required for each of the ACs. All ACs with priority higher than that of an AC for which the ACM subfield is set to 1 should have the ACM subfield set to 1. While the CWmin, CWmax, AIFS, and TXOP limit parameters may be adjusted over time by the AP, the ACM subfield shall be static for the duration of the lifetime of the BSS.

A non-AP STA may send frames in an AC where admission control is not mandated.

A non-AP STA may support the admission control procedure in 10.23.4.2.3 to send frames in an AC where admission control is mandated. If it does not support that procedure or admission was denied, and both of the following apply:

— dot11RejectUnadmittedTraffic is false or not present
— there is a lower priority AC (see Table 10-1) that does not require admission control

then it may send such frames using the EDCA parameters of that lower priority AC for channel access; the contents of the frames are unaffected. Otherwise, it shall not send such frames.

[37] This is unnecessary because the NAVs in the vicinity of the QoS AP were set by the QoS (+)CF-Poll frame.

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A STA shall transmit an ADDTS Request frame to the HC in order to request admission of traffic in any direction (i.e., uplink, downlink, direct, or bidirectional) employing an AC that requires admission control. The ADDTS Request frame shall contain the UP associated with the traffic and shall indicate EDCA as the access policy. The AP shall associate the received UP of the ADDTS Request frame with the appropriate AC per the UP-to-AC mappings described in 10.2.3.2.

The HC contained within an AP when dot11SSPNInterfaceActivated is true shall admit a non-AP STA's request based on dot11NonAPStationAuthAccessCategories stored in that non-AP STA's dot11InterworkingEntry, which is part of the dot11InterworkingTable. The dot11InterworkingEntry specifies the EDCA access classes and throughput limitations on each access class for which a non-AP STA is permitted to transmit.

10.23.4.2.2 Procedures at the AP

Regardless of the AC's ACM setting, the AP shall respond to an ADDTS Request frame with an ADDTS Response frame that may be to accept or deny the request. On receipt of an ADDTS Request frame from a non-AP STA, the AP shall make a determination about whether to

a) Accept the request, or
b) Deny the request.

The algorithm used by the AP to make this determination is implementation dependent. An AP when dot11SSPNInterfaceActivated is true shall use the policies delivered by the SSPN that are stored in the dot11InterworkingEntry, which is part of the dot11InterworkingTable. If the AP decides to accept the request, the AP shall also derive the medium time from the information conveyed in the TSPEC element in the ADDTS Request frame. The AP may use any algorithm in deriving the medium time, but K.2.2 provides a procedure that may be used. Having made such a determination, the AP shall transmit a TSPEC element to the requesting non-AP STA contained in an ADDTS Response frame. If the AP is accepting the request, the Medium Time field shall be specified. If the AP is accepting a request for a downlink TS, the Medium Time field shall be set to 0. If the AP is accepting a request corresponding to an AC for which ACM is 0 (e.g., the TSPEC is to change APSD behavior), the Medium Time field shall be set to 0.

10.23.4.2.3 Procedure at non-AP STAs

Each EDCAF shall maintain two MAC variables: admitted_time and used_time.

The admitted_time and used_time shall be set to 0 at the time of (re)association. The STA may subsequently decide to explicitly request medium time for the AC that is associated with the specified priority.

In order to make such a request, the STA shall transmit a TSPEC element contained in an ADDTS Request frame with the following fields specified (i.e., nonzero): Nominal MSDU Size, Mean Data Rate, Minimum PHY Rate, Inactivity Interval, and Surplus Bandwidth Allowance. The Medium Time field is not used in the request frame and shall be set to 0.

On receipt of a TSPEC element contained in an ADDTS Response frame indicating that the request has been accepted, the STA shall recompute the admitted_time for the specified EDCAF as follows:

admitted_time = admitted_time + dot11EDCAAveragingPeriod × medium time of TSPEC.

The STA may choose to tear down the explicit request at any time. For the teardown of an explicit admission, the STA shall transmit a DELTS frame containing the TSID and direction that specify the TSPEC to the AP.

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If the STA sends or receives a DELTS frame, it shall recompute the admitted_time for the specified EDCAF as follows:

admitted_time = admitted_time – dot11EDCAAveragingPeriod × medium time of TSPEC.

The MAC variable used_time is the amount of time used, in units of 32 μs, by the STA in dot11EDCAAveragingPeriod. The MAC variable admitted_time is the medium time allowed by the AP, in units of 32 μs, in dot11EDCAAveragingPeriod. The STA shall update the value of used_time:

a) At dot11EDCAAveragingPeriod second intervals

used_time = max((used_time – admitted_time), 0)

b) After each successful or unsuccessful frame exchange sequence,

used_time = used_time + MPDUExchangeTime

The MPDUExchangeTime is the duration of the frame exchange sequence. For the case of an MPDU transmitted with Normal Ack ack policy and without RTS/CTS protection, this equals the time required to transmit the MPDU plus the time required to transmit the expected response frame plus one SIFS. Frame exchange sequences that do not include any Data frames are excluded from the used_time update. Any RD transmission granted by the AP is excluded from the used_time update. If the used_time value reaches or exceeds the admitted_time value, the corresponding EDCAF shall no longer transmit QoS Data frames or QoS Null frames using the EDCA parameters for that AC as specified in the QoS Parameter Set element. However, a STA may choose to temporarily replace the EDCA parameters for that EDCAF with those specified for an AC of lower priority, if no admission control is required for those ACs.

NOTE—When a frame is transmitted using temporary EDCA parameters, the TID field of that frame is not modified.

If, for example, a STA has made and had accepted an explicit admission for a TS and the channel conditions subsequently worsen, possibly including a change in PHY data rate so that it requires more time to send the same data, the STA may make a request for more admitted_time to the AP and at the same time downgrade the EDCA parameters for that AC for short intervals in order to send some of the traffic at the admitted priority and some at the unadmitted priority, while waiting for a response to the admission request.

10.23.4.3 Controlled-access admission control

This subclause describes the schedule management of the admitted HCCA streams by the HC. When the HC provides controlled channel access to STAs, it is responsible for granting or denying polling service to a TS based on the parameters in the associated TSPEC. If the TS is admitted, the HC is responsible for scheduling channel access to this TS based on the negotiated TSPEC fields. The HC should not initiate a modification of TSPEC fields of an admitted TS unless requested by the STA. The HC should not tear down a TS unless explicitly requested by the STA or at the expiration of the inactivity timer. The polling service based on admitted TS provides a “guaranteed channel access” from the scheduler in order to have its QoS requirements met. This is an achievable goal when the WM operates free of external interference (such as operation within the channel by other technologies and co-channel overlapping BSS interference). The nature of wireless communications may preclude absolute guarantees to satisfy QoS requirements.

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The following are rules for the operation of the scheduler:

— The scheduler shall be implemented so that, under controlled operating conditions, all STAs with admitted TS are offered TXOPs that satisfy the service schedule.

— Specifically, if a TS is admitted by the HC, then the scheduler shall service the STA during an SP. An SP is a period of time during which a set of one or more downlink individually addressed frames and/or one or more polled TXOPs are granted to the STA. An SP starts at fixed intervals of time specified in Service Interval field. The first SP starts when the lower order 4 octets of the TSF timer equals the value specified in Service Start Time field.[38] Additionally, the minimum TXOP duration shall be at least the time to transmit one maximum MSDU size successfully at the minimum PHY rate specified in the TSPEC. If maximum MSDU size is not specified in the TSPEC, then the minimum TXOP duration shall be at least the time to transmit one nominal MSDU size successfully at the minimum PHY rate. The vendors are free to implement any optimized algorithms, such as reducing the polling overheads, increasing the TXOP duration, etc., within the parameters of the transmitted schedule.

— The HC shall admit its request based on Infrastructure Authorization Information in dot11InterworkingEntry, which is part of the dot11InterworkingTable. The dot11InterworkingEntry specifies whether a non-AP STA is permitted to use HCCA, its throughput limitation and its minimum delay bound.

When the HC aggregates the admitted TS, it shall set the Aggregation field in the granted TSPEC to 1. An AP shall schedule the transmissions in HCCA TXOPs and communicate the service schedule to the STA. The HC shall provide an aggregate service schedule if the STA sets the Aggregation field in its TSPEC request. If the AP establishes an aggregate service schedule for a STA, it shall aggregate all HCCA streams for the STA. The service schedule is communicated to the STA in a Schedule element contained in an ADDTS Response frame. In the ADDTS Response frame, the modified service start time shall not exceed the requested service start time, if specified in ADDTS Request frame, by more than one maximum service interval (SI). The HC uses the maximum SI for the initial scheduling only as there might be situations that HC is not be able to service the TS at the scheduled timing, due to an EDCA or DCF transmission or other interferences interrupting the schedule. The Service Interval field value in the Schedule element shall be greater than the minimum SI. The service schedule could be subsequently updated by an AP as long as it meets TSPEC requirements.

The HC may update the service schedule at any time by sending a Schedule element in a Schedule frame. The updated schedule is in effect when the HC receives the Ack frame for the Schedule frame. The service start time in the Schedule element in the Schedule frame shall not exceed the beginning of the immediately previous SP by more than the maximum SI. The service start time shall not precede the beginning of the immediately previous SP by more than the minimum SI.

A STA may affect the service schedule by modifying or deleting its existing TS as specified in 11.4.

K.3.1 provides guidelines for deriving an aggregate service schedule for a single STA from the STA's admitted TS. The schedule shall meet the QoS requirements specified in the TSPEC.

During any time interval [$t1$, $t2$] including the interval that is greater than the specification interval, the cumulative TXOP duration shall be greater than the time required to transmit all MSDUs (of nominal MSDU size) arriving at the mean data rate for the stream, over the period [$t1$, $t2 - D$]. The parameter D is set to the specified maximum SI in the TSPEC. If maximum SI is not specified, then D is set to the delay bound in the TSPEC.

[38] The lower order 4 octets of the TSF timer cover a span of around 71 min. Due to TSF timer wrapover and due to the possibility of receiving the schedule frame after the indicated start time timer, ambiguity may occur. This ambiguity is resolved by using the nearest absolute TSF timer value in past or future when the lower order 4 octets match the Start Time field in the Schedule element.

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The HC shall use the minimum PHY rate in calculating TXOPs if the minimum PHY rate is present in the TSPEC field in the ADDTS response. Otherwise, the HC may use an observed PHY rate in calculating TXOPs. A STA may have an operational rate lower than the minimum PHY rate due to varying conditions on the channel for a short time and still may be able to sustain the TS without changing the minimum PHY rate in the TSPEC.

A minimum set of TSPEC fields shall be specified during the TSPEC negotiation. The specification of a minimum set of parameters is required so that the scheduler can determine a schedule for the stream that is to be admitted. These parameters are Mean Data Rate, Nominal MSDU Size, Minimum PHY Rate, Surplus Bandwidth Allowance, and at least one of Maximum Service Interval and Delay Bound in the ADDTS Request frame. In the ADDTS Response frame, these parameters are Mean Data Rate, Nominal MSDU Size, Minimum PHY Rate, Surplus Bandwidth Allowance, and Maximum Service Interval and shall be nonzero when a stream is admitted.

If any of the elements in the minimum set of parameters does not have the required nonzero value, as specified above in this subclause, in the ADDTS Request frame, the HC may replace the unspecified parameters with nonzero values and admit the stream, or it may reject the stream. If the HC admits the stream with the alternative set of TSPEC fields, these parameters are indicated to the STA through the ADDTS Response frame. If both maximum SI and delay bound are specified, the HC may use only the maximum SI. If any other parameter is specified in the TSPEC element, the scheduler may use it when calculating the schedule for the stream. The HC may also use the UP value in the TS Info field for admission control or scheduling purposes; however, this decision is outside the scope of this standard. The mandatory set of parameters might be set by any higher layer entity or may be generated autonomously by the MAC.

If a STA specifies a nonzero minimum SI and if the TS is admitted, the HC shall generate a schedule that conforms to the specified minimum SI.

A reference design for a sample scheduler and admission control unit is provided in Annex K. A sample use of the TSPEC for admission control is also described in Annex K.

10.23.5 Restricted access window (RAW) operation

10.23.5.1 General

Restricting uplink channel access to a small number of STAs and spreading their uplink access attempts over a period of time might improve the medium utilization's efficiency by reducing collisions. When dot11RAWOperationActivated is true, an AP may allocate a medium access interval, called a restricted access window (RAW), for a group of STAs within a (short) beacon interval and broadcast this information using S1G Beacon frame.

An S1G STA with dot11RAWOperationImplemented equal to true shall set the RAW Operation Support field in the S1G Capabilities element it transmits to 1. An S1G STA with dot11RAWOperationImplemented equal to false shall set the RAW Operation Support field in the S1G Capabilities element it transmits to 0.

A non-AP STA with dot11RAWOperationImplemented equal to true shall be able to follow the RAW procedure, as described in this subclause.

An AP shall not include a non-AP STA in any RAW Group from which it has received an S1G Capabilities element whose RAW Operation Support field value is 0.

An S1G STA in TIM mode with dot11RAWOperationImplemented equal to false that receives an RPS element from the AP it is associated shall not access the WM for the RAW duration indicated in the RPS element.

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An S1G STA in TIM mode is in the RAW group indicated by the RAW Group subfield in the RAW Assignment subfield of the RPS element if the AID of the S1G STA in TIM mode (n) is greater than or equal to the lowest AID of the STA allocated in the RAW (N_1) and the AID of the STA is less than or equal to the highest AID of the S1G STA in TIM mode (N_2) allocated in the RAW (i.e., $N_1 \leq n \leq N_2$), where N_1 is constructed by concatenating the Page Index (2 bits) subfield and the RAW Start AID (11 bits) in the RAW Group subfield of the RPS element and N_2 is constructed by concatenating the Page Index (2 bits) subfield and the RAW End AID (11 bits) in the RAW Group subfield of the RPS element.

An S1G STA in TIM mode that receives an RPS element in an S1G Beacon frame transmitted by the AP with which it is associated determines the RAW timing as the RAW duration specified by RAW Slot Definition subfield in the RAW Assignment subfield of the received RPS element and the start time of the RAW specified by the RAW Start Time subfield in the RAW Assignment subfield of the received RPS element.

The RAW is divided into one or more RAW slots. The Slot Duration Count subfield of the RAW Slot Definition subfield in the RAW Assignment subfield of the RPS element defines the duration of a RAW slot in the RAW.

If the S1G STA in TIM mode belongs to the RAW group, it is allowed to contend for medium access at the start of its assigned RAW slot (see 10.23.5.3) and shall not contend for medium access within a RAW slot not assigned to it during that RAW.

An AP may allocate more than one RAW by including more than one RAW Assignment subfield in the RPS element within a (short) beacon interval with different RAW parameters. The AP may also assign periodic RAWs to a group of S1G STAs in TIM mode where the periodicity information is indicated in the RPS element (see 9.4.2.191).

An AP may assign to each S1G STA in TIM mode or a group of S1G STAs in TIM mode a RAW slot inside the RAW at which the STA(s) is (are) allowed to contend for medium access. After determining its channel access RAW slot assigned by the AP, the S1G STA in TIM mode starts to access the channel not earlier than its assigned RAW slot based on the S1G variant of EDCA (10.23.2.6). An S1G STA in TIM mode that is not a member of the RAW group indicated by the RAW Group subfield in the RAW Assignment subfield of the RPS element or is not allowed to access the RAW implicitly indicated by the values of RAW Type and RAW Type Options subfield for which the RAW Group subfield is not present, shall not access the WM in the indicated channels of the RPS element or in the BSS operating channel if there are no indicated channels for duration of the RAW, except for a non-AP STA that is allowed not to check the Beacon frame (e.g., S1G STA in non-TIM mode). Upon receipt of any frame (e.g., PS-Poll frame or trigger frame) for the RAW duration from an S1G STA in TIM mode not within the RAW group indicated by the RAW Group subfield in the RAW Assignment subfield of the RPS element, the AP shall respond with a Control frame (e.g., NDP PS-Poll ACK frame).

An AP may further indicate on which channel(s) the SST STA(s) that are granted access to the RAW are allowed to transmit for the RAW duration, through the Channel Indication subfield in the RAW Assignment subfield of the RPS element (see 9.4.2.191). An SST STA is an S1G STA that is associated with an AP and that chooses a subset of the allowed operating channels for the SST on which to operate when SST operation is activated by the AP as indicated in the Subchannel Selective Transmission element in Beacon frame. A value of 1 in a bit position in the Channel Activity Bitmap in the Channel Indication subfield of the RPS element indicates that operation is allowed on the BSS operating channel for the RAW duration, with any allowed operating bandwidth that includes that channel, subject to the limitations described in 10.52. Access to the channel shall be performed according to the signaling of the procedure described in 10.52 followed by the Channel Indication signaling in RPS element, assuming the primary channel is a channel identified by a value of 1 in one of the Channel Activity bits in the Channel Indication subfield in the RAW Assignment subfield of the RPS element. The channels that are allowed for SST operation in the RPS element can be different from the channels allowed for SST operation in the SST element. An AP shall not include an S1G

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STA in TIM mode that is not supporting the SST Operation in the RAW Group of an RPS element that has a Channel Indication that does not include the primary BSS operating channel.

An S1G AP may protect the access of sensor STAs in some S1G Beacon frames by allocating the PRAW (10.23.5.8). During the allocated PRAW, only sensor STAs can access the wireless medium. An S1G AP may determine the duration of the PRAW based on the number of sensor STAs in its network, their expected uplink data amount and data rate and any other factors that the S1G AP chooses.

AP may designate a RAW for S1G STAs in non-TIM mode by setting the RAW Type to Simplex RAW and setting the RAW Type Options to Non-TIM RAW in the RPS element. In a non-TIM RAW, only S1G STAs in non-TIM mode that have been previously scheduled within the RAW such as TWT STAs or doze awake cycle rescheduled STAs (as described in 10.48.2) are allowed to access the medium.

10.23.5.2 RAW structure and timing

An illustration of the RAW structure and timing diagram is shown in Figure 10-31.

An AP indicates the RAW allocation and RAW slot assignment within the RAW by including the RPS element and the TIM element in an S1G Beacon frame.

An AP allows or prohibits transmission at the end of the assigned RAW slot by using the Cross Slot Boundary subfield in the RAW Slot Definition subfield within the RAW Assignment subfield of the RPS element (9.4.2.191).

If the Cross Slot Boundary subfield in the RAW Slot Definition subfield within the RAW Assignment subfield of the RPS element is set to 1, a STA is allowed to cross its assigned RAW slot boundary to complete the ongoing frame exchange sequence.

If the Cross Slot Boundary subfield in the RAW Slot Definition subfield within the RAW Assignment subfield of the RPS element is set to 0, a STA shall not transmit or cause to be transmitted a frame exchange sequence that would exceed boundary of its allocated RAW slot.

As shown in Figure 10-31, if the Cross Slot Boundary subfield in RAW Assignment subfield of the RPS element is equal to 0, a STA may initiate frame transmission only if the remaining time to the end of the assigned RAW slot duration is greater than or equal to the transmission time and reception of any immediate response expected from the peer MAC entity prior to the end of the allocated RAW slot boundary. Otherwise, it shall not initiate transmission of a frame even though the remaining RAW slot duration is nonzero.

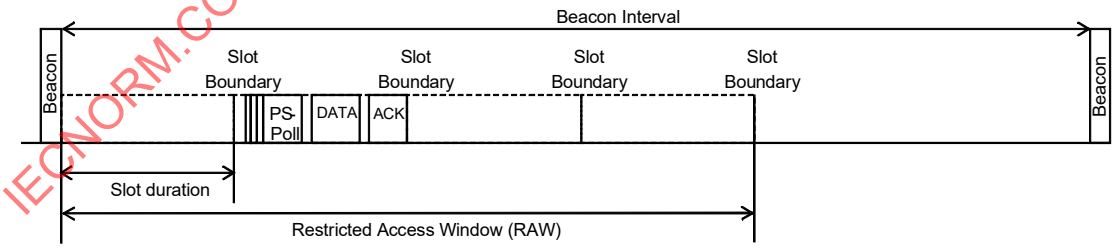

Figure 10-31—Restricted Access Window (RAW)

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10.23.5.3 Slot assignment procedure in RAW

This subclause defines a RAW slot assignment procedure for STAs that are allowed to access the medium within a RAW based on the RPS element and the TIM element in a Beacon frame. Further restrictions apply to a RAW for which the RA Frame Indication field in the RPS element is 1 as described in 10.23.5.7.

A STA shall obtain the number of RAW slots in the RAW (N_{RAW}) from the Number of Slots subfield in the RAW Slot Definition subfield of RAW Assignment subfield of the RPS element. The RAW slots in the RAW are indexed from 0 to ($N_{RAW} - 1$) as shown in Figure 10-32.

The STA shall determine the index of the RAW slot, i_{slot}, in which the STA is allowed to start contending for the medium based on the following mapping function:

$$i_{slot} = (x + N_{offset}) \bmod N_{RAW}$$

where

x	is the position index of the AID of the STA or the AID of the STA
N_{offset}	represents the offset value in the mapping function
N_{RAW}	is the value of the Number of Slots subfield

The value x is the position index of the AID of the STA if the RAW is restricted to STAs whose AID bits in the TIM element are equal to 1 (the RAW Type field is equal to 0 and the Bit 0 of the RAW Type Options field is equal to 1 or the RAW Type field is equal to 3), and AIDs are arranged in ascending order and each AID is assigned with a position index, which starts from 0 (see Figure 10-33). Otherwise, if the RAW is not restricted to STAs whose AID bits in the TIM element are equal to 1 (the RAW Type field is equal to 0 and the Bit 0 of the Raw Type Options field is equal to 0), x is the AID of the STA (see Figure 10-32); N_{offset} represents the offset value in the mapping function, which improves the fairness among the STAs in the RAW, and the STA shall use the 2 least significant octets of the FCS field of the S1G Beacon frame for the N_{offset}.

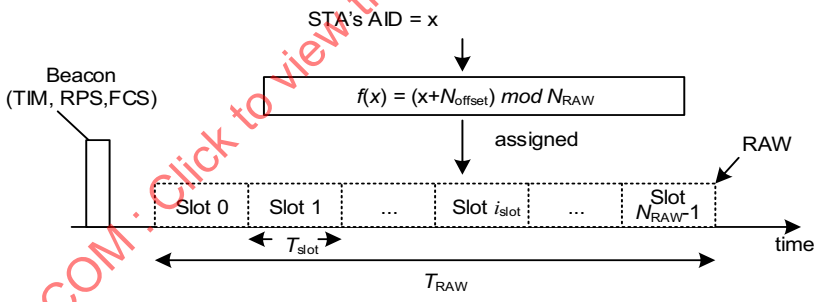

Figure 10-32—Illustration of the RAW slot assignment procedure (RAW not restricted to STAs whose AID bits in the TIM element are equal to 1)

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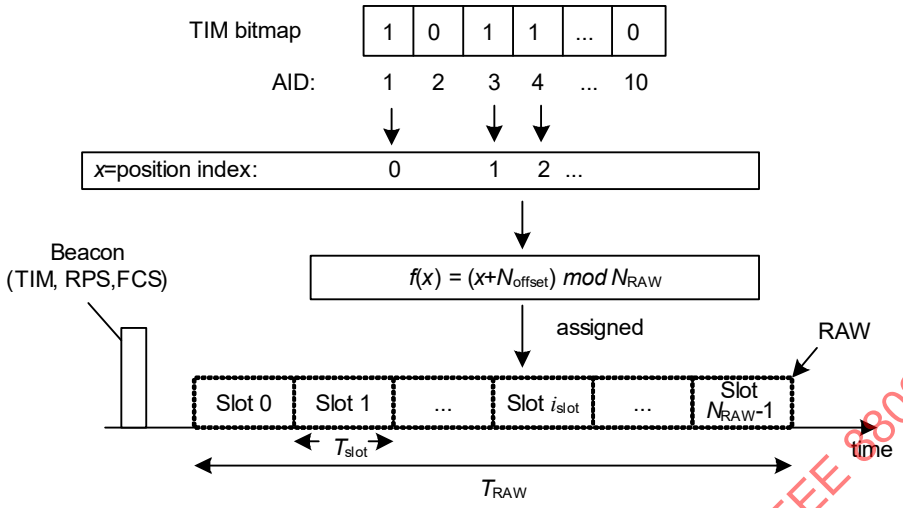

Figure 10-33—Illustration of the RAW slot assignment procedure (RAW restricted to STAs whose AID bits in the TIM element are equal to 1)

10.23.5.4 Slotted channel access procedure in RAW

When the RAW is not restricted to STAs with DL BU indication in the TIM element (the RAW is a generic RAW and the Paged STA indication is equal to 0), all STAs that belong to a RAW group are allowed to access the medium in the RAW of the RAW group, an AP assigns a RAW slot for each STA that belongs to the RAW group (10.23.5.3). Each STA that belongs to the RAW group shall start to contend for the WM not earlier than the start of the assigned RAW slot. The channel access is based on EDCA.

When the RAW is restricted to STAs with DL BU indication in the TIM element (the RAW is a generic RAW and the Paged STA indication is equal to 1 or the RAW is a triggering frame RAW), paged STAs only are allowed to access the medium in the RAW, after receiving a TIM element, the paged STA starts to contend for the WM not earlier than the allocated RAW slot within the RAW defined as the function of STA position in the TIM element and the RAW group information in the RPS element (10.23.5.3), and non-paged STAs are not allowed to access the RAW.

An AP may designate a RAW for trigger frames by setting the RAW type to Triggering Frame RAW. When the RAW type is Triggering Frame RAW, each STA in the RAW Group is only allowed to send up to one trigger frame during its assigned RAW slot as described in 10.23.5.3. In the Triggering Frame RAW, a trigger frame is limited to a QoS Null contained in a non-A-MPDU frame or a (NDP) PS-Poll frame. In the Triggering Frame RAW, the STA transmits a trigger frame to the AP not earlier than the start of its assigned RAW slot. The duration of the trigger frame exchange sequence shall not exceed a RAW slot duration calculated by the RAW Slot Definition subfield in the RAW Assignment subfield of the RPS element. And, in the Triggering Frame RAW, crossing RAW slot boundary is not allowed.

After receiving the trigger frame from the paged STA in the Triggering Frame RAW, the AP shall not respond with the downlink buffered BU during the Triggered Frame RAW and may deliver the downlink buffered BU for the corresponding paged STAs after the end of the current Triggering Frame RAW.

An AP may protect transmissions of PS-Poll or trigger frames by setting the NAV for the RAW immediately following the S1G Beacon frame as specified in at least one of the RPS elements (see 10.3.2.4). The STAs with dot11RAWOperationImplemented equal to true that are allowed to access the medium during this RAW shall ignore the NAV set by the S1G Beacon frame as described in 10.3.2.4.

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10.23.5.5 EDCA backoff procedure in generic RAW or triggering frame RAW

An illustration of EDCA backoff procedure in RAW is shown in Figure 10-34.

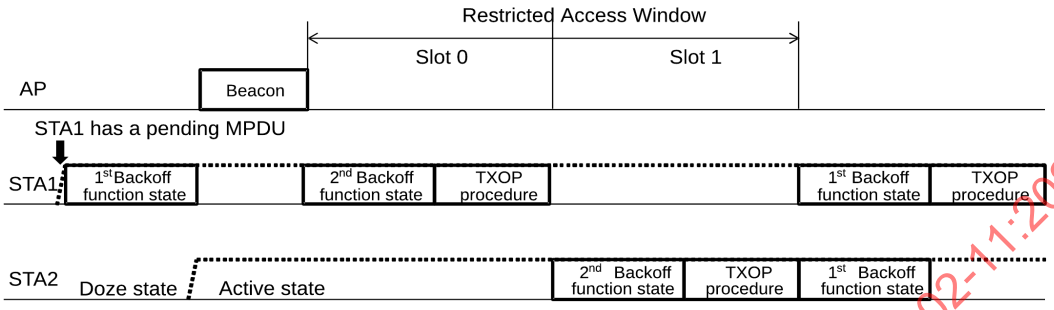

Figure 10-34—Backoff procedure for restricted channel access control

For supporting the restricted channel access control based on EDCA, a STA maintains two backoff function states. First backoff function state is used outside RAW and second backoff function state is used inside RAW.

Each STA performing EDCA access suspends an operation of its EDCAF at the start of each RAW and stores the value of the backoff counter, CW[AC], and QSRC[AC] as the first backoff state. At the end of the RAW, the stored first backoff function state is restored and an operation of the EDCAF is resumed. If the previously stored first backoff function state is empty, the EDCAF of a STA shall invoke a backoff procedure, even if no additional transmissions are currently queued.

If the STA is participating in the RAW and has a pending MPDU, the EDCAF of the STA shall invoke a new backoff procedure for accessing the WM in the RAW using the access category indicated by the RAW_ACI subfield in an EDCA Parameter Set element. At the beginning of the allocated RAW slot, the STA sets the CW[AC] of the secondary backoff procedure to CWmin[AC]. The values of the backoff and CW[AC] used in the RAW is called the second backoff function state.

If the Cross Slot Boundary subfield in RAW Assignment subfield of the RPS element is 0, the STA shall count down backoff only in its assigned RAW slots within the RAW. If the Cross Slot Boundary subfield in RAW Assignment subfield of the RPS element is 1, the STA shall continue to count down backoff after its assigned RAW slots within the RAW.

After the end of the RAW, STAs with the second backoff counter shall reset and disregard the second backoff function state.

10.23.5.6 EDCA backoff procedure in RAWs other than generic or triggering frame RAW

When the S1G STA is performing EDCA in any RAW other than generic or triggering frame RAW, it shall follow the rules defined in 10.23.2.

An S1G STA performing EDCA outside a RAW shall suspend an operation of its EDCA at the start of the RAW and may resume it at the end of the RAW if the STA is not included in that RAW.

An S1G STA performing EDCA outside a RAW shall continue its EDCA operation at the start of the RAW if it is included in that RAW.

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10.23.5.7 RAW Operation with Resource Allocation frame

An AP transmits a Resource Allocation (RA) frame if Bit 1 of the RAW Type Options subfield is equal to 1 in the RAW Control subfield of the RAW Assignment subfield of the RPS element.

The AP transmits the RA frame to non-AP STAs belonging to the RAW group allocated to access the RAW as specified in the previously transmitted RPS element. A non-AP STA that does not belong to the RAW group may ignore the RA frame.

An AP shall schedule the Resource Allocation frame as the first frame to be transmitted at the beginning of the RAW following the channel access rules. The beginning of the RAW is further defined in the RAW start time subfield of the RAW assignment subfield of the RPS element.

AP shall defer the transmission of the RA frame till the channel is free but since the preallocated RAW duration information in the RPS frame may be shortened by the delay of the transmission of the RA frame, the AP and STA shall check the transmission time of the allocated RAW slot against the end of RAW period. If the transmission of the RA frame is later than the end of RAW period, the AP and STA shall discard the information indicated in the RPS element and follow the channel access rules defined outside the RAW (10.23.5).

The AP assigns a RAW slot to either an individual STA indicated by the Partial AID subfield or a group of STAs indicated by the Group ID subfield within the Slot Assignment field of the RA frame when Slot Assignment Mode subfield in the Frame Control field of the RA frame is equal to 0. The AP assigns a RAW slot to an individual STA indicated by the Slot Assignment Indication field of the RA frame when Slot Assignment Mode subfield in the Frame Control field of the RA frame is equal to 1.

An intended STA identified by the RPS element should wake up before the RAW start time indicated in the RAW start time subfield of the RAW assignment subfield of the RPS element to receive the RA frame. The STA shall not access the medium during its assigned RAW with the RA indication if it fails to receive the RA frame. The STA can resume medium access according to the channel access rule after the RAW.

An intended STA identified by the RPS element of a RAW learns its assigned RAW slots for both uplink and downlink service periods according to the Slot Assignment subfield or the Slot Assignment Bitmap subfield in Slot Assignment Indication field of the RA frame. The STA should be awake before the start of the RAW slot time assigned to it. The AP shall start the delivery of BUs addressed to the STA using the EDCA procedure at the beginning of the RAW slot assignment if the TIM bit for the STA in the TIM element is equal to 1 after receiving an (NDP) PS-Poll or trigger frame from the STA. The STA may transmit uplink data as listed below:

— When the AP explicitly signals permission for the non-AP STA to begin UL transmission using the explicit signaling provided by BDT (10.50) or RD protocol (10.29).
— Using EDCA procedure when the AP transmits a frame to the STA with more data bit equal to 0.
— Using EDCA procedure at the beginning of its RAW slot assignment if the TIM bit for this STA is 0 and this STA has not negotiated with the AP to use the UL-Sync procedure (10.49).
— After receiving a frame sequence that contains a sync frame if the STA has negotiated with the AP to use the UL-Sync procedure.

10.23.5.8 Periodic RAW (PRAW) operation

An AP may schedule a RAW in periodic manner by setting Periodic RAW Indication subfield to 1 for the RAW Assignment subfield of an RPS element, and this RAW is called a PRAW.

PRAW allocation may be indicated by an RPS element included in S1G Beacon frames and/or Probe Response frames. Once a PRAW is allocated, the allocation indication is broadcasted by the AP such that

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every S1G STA in TIM mode can identify the allocation of PRAW. However, it is not necessary for an AP to indicate the PRAW allocation in every S1G Beacon frame transmitted in the beacon interval or short beacon interval, for which PRAW is allocated. The parameters in the RAW Assignment subfield for PRAW shall not be changed until updated PRAW information is broadcasted. A non-AP STA updates the PRAW information and accesses the channel according to the parameters in the RAW Assignment subfield of the PRAW indicated by the Periodic Operation Parameters subfield of the most recently received RPS element.

If an AP allocates more than one PRAW assignments, all active PRAW assignments shall be included in one or more RPS elements in the same S1G Beacon frame.

The S1G Beacon frame after which the first window of the PRAW appears is indicated by the PRAW Start Offset subfield of Periodic Operation Parameters of RPS element, and the starting time of the first window of the PRAW with respect to the S1G Beacon frame is equal to the RAW start time indicated by the same RAW Assignment subfield.

The periodicity of RAW assignment for a group of STAs indicated in the RAW Group subfield of the RAW Assignment subfield of RPS element is valid for a fixed number of periods indicated in the PRAW Validity subfield of the Periodic Operation Parameters subfield in the RAW Assignment subfield of RPS element. An AP may extend current PRAW assignment by indicating the PRAW assignment with the PRAW Validity subfield value extended before it expires.

At each RPS element with one or more PRAW assignments included, an AP indicates next scheduled PRAW indication time at which the AP will send another RPS element with PRAW assignments. The next scheduled PRAW indication time is the closest DTIM Beacon frame before any of PRAW Validity subfield value of PRAW assignments included in current RPS element expires.

An AP may send another RPS element with PRAW assignments before next scheduled PRAW indication time. However, an AP shall not modify currently active PRAW assignment until next scheduled PRAW indication time. If an AP intends to add a new PRAW assignment, the new PRAW assignment shall be indicated from the next scheduled PRAW indication time.

10.24 Mesh coordination function (MCF)

10.24.1 General

Under MCF, the basic unit of allocation of the right to transmit onto the WM is the TXOP. Each TXOP is defined by a starting time and a defined maximum length.

There are two types of TXOP in MCF: EDCA TXOPs and MCCA TXOPs. The EDCA TXOP is obtained by a mesh STA winning an instance of EDCA contention (see 10.23.2). The MCCA TXOP is obtained by a mesh STA gaining control of the WM during an MCCAOP. The MCCAOP is an interval of time for frame transmissions that has been reserved by means of the exchange of MCCA frames (see 10.24.3).

EDCA TXOPs of a mesh STA that has dot11MCCAActivated true shall not overlap with the time periods of any of its tracked MCCAOP reservations.

The process of tracking MCCAOP reservations involves the recording of the MCCAOP reservations and the data that structure the MCCAOP advertisements of these reservations, namely the advertisement set sequence number, advertisement elements bitmap, and the advertisement element indexes, in a local database, and the updating of this database on the basis of received advertisements as described in 10.24.3.7.5.

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10.24.2 MCF contention based channel access

MCF implements the same EDCA (see 10.23.2) as does HCF.

10.24.3 MCF controlled channel access (MCCA)

10.24.3.1 General

MCF controlled channel access (MCCA) is an optional access method that allows mesh STAs to access the WM at selected times with lower contention than would otherwise be possible. This standard does not require all mesh STAs to use MCCA. MCCA might be used by a subset of mesh STAs in an MBSS. However, MCCAOP reservations may be set up among mesh STAs that have dot11MCCAActivated true and that operate on the same channel; MCCAOP reservations shall not be set up otherwise. The performance of MCCA might be impacted by STAs that do not respect MCCAOP reservations.

MCCA enabled mesh STAs use Management frames to make reservations for transmissions. The mesh STA transmitting an MCCA Setup Request frame to initiate a reservation becomes the MCCAOP owner of the MCCAOP reservation. The receivers of the MCCA Setup Request frame are the MCCAOP responders. The MCCAOP owner and the MCCAOP responders advertise this MCCAOP reservation to their neighbors via an MCCAOP advertisement. An MCCA enabled neighbor mesh STA shall not transmit during these reserved MCCAOP time periods. During its MCCAOP, the MCCAOP owner obtains a TXOP by winning an instance of EDCA contention. Because of its reservation, the MCCAOP owner experiences no competition from other MCCA enabled neighbor mesh STAs. At the start of an MCCAOP, the EDCAF of the MCCAOP owner replaces the AIFSN, CWmin, and CWmax value of its dot11EDCATable with MCCA access parameters.

In order to use MCCA, a mesh STA maintains synchronization with its neighboring mesh STAs. Mesh STAs that use MCCA shall use a DTIM interval with a duration of $2^n \times 100$ TU with n being a non-negative integer less than or equal to 17. Additionally, a mesh STA shall track the reservations of its neighboring mesh STAs.

NOTE 1—The DTIM interval of this form was chosen so that the starting times of the reservations do not change relative to each other between consecutive DTIM intervals. The restriction that n be less than or equal to 17 was chosen for compatibility with the maximum DTIM interval as well as the compatibility of the reservation's MCCAOP offset range (see 9.4.2.105.2) with the maximal DTIM interval length.

NOTE 2—It is allowed that a different value for the DTIM interval is used for mesh STAs that use MCCA in an MBSS that is centrally controlled and the central authority provides a coordination of the DTIM interval of the mesh STAs that use MCCA in the MBSS.

10.24.3.2 MCCA activation

When it receives an MLME-ACTIVATEMCCA.request primitive from its SME, a mesh STA shall set the MCCA Enabled subfield of the Mesh Capability field in the Mesh Configuration element to 1 in Beacon and Probe Response frames it transmits. It shall not initiate or accept MCCA Setup Request frames for dot11MCCAScanDuration TUs after the receipt of the MLME-ACTIVATEMCCA.request primitive.

During the dot11MCCAScanDuration waiting period, the mesh STA learns its neighborhood MCCAOP periods by receiving Beacon, Probe Response, or MCCA Advertisement frames from neighboring mesh STAs.

After this period, the mesh STA may initiate and accept MCCA Setup Request frames as per 10.24.3.6.

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10.24.3.3 MCCAOP reservations

An MCCAOP reservation specifies a schedule for frame transmissions. The time periods scheduled for frame transmissions in the reservation are called *MCCAOPs*. The schedule is set up between an MCCAOP owner and one (for individually addressed frames) or more (for group addressed frames) MCCAOP responders. MCCAOPs are set up by means of the procedure defined in 10.24.3.6. Once an MCCAOP reservation is set:

— Access to the channel by MCCA enabled mesh STAs is governed by the procedures in 10.24.3.9.
— The MCCAOP reservation is advertised according to the procedures in 10.24.3.7.

The schedule is defined by means of the MCCAOP Reservation field defined in 9.4.2.105.2. An MCCAOP reservation schedules a series of MCCAOPs with a common duration given in the MCCAOP Duration subfield of the MCCAOP Reservation field. This series is started after the first DTIM Beacon following the successful completion of the MCCAOP setup procedure and terminated when the MCCAOP reservation is torn down.

The reservation defines a regular schedule of MCCAOPs in the DTIM interval of the MCCAOP owner. The number of MCCAOPs in the DTIM interval is given by the value of the MCCAOP Periodicity subfield of the MCCAOP Reservation field. The MCCAOP Offset subfield specifies the offset of the first scheduled MCCAOP of the transmission schedule relative to the beginning of the DTIM interval of the MCCAOP owner. The following MCCAOPs are separated by a time interval with a duration equal to the length of the DTIM period divided by the value in the MCCAOP Periodicity subfield.

An example of an MCCAOP reservation schedule is shown in Figure 10-35. In this example, the MCCAOP Periodicity equals two, so that there are two MCCAOPs in each DTIM interval. As further illustrated in the figure, the MCCAOP Offset value indicates the beginning of the first MCCAOP in each DTIM interval.

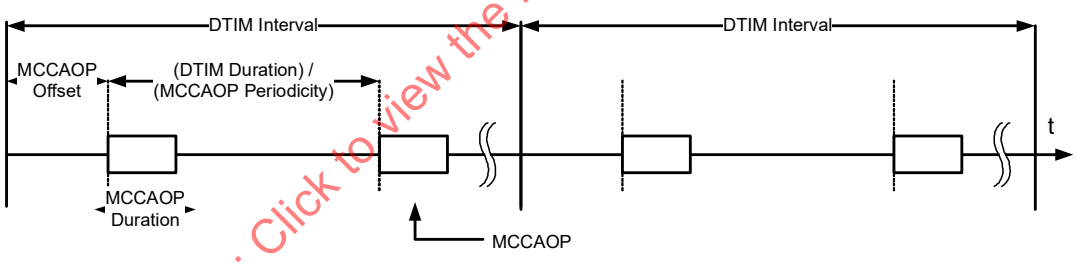

Figure 10-35—Example MCCAOP reservation with MCCAOP Periodicity equal to 2

If a mesh STA adjusts its TBTT, e.g., in response to a TBTT adjustment request, it shall adjust the MCCAOP reservations by modifying the MCCAOP Offset of each MCCAOP reservation.

An MCCAOP reservation is identified by an MCCAOP reservation ID. The MCCAOP owner shall select an MCCAOP reservation ID that is unique among all of its MCCAOP reservations. The MCCAOP reservation ID and MAC address of the MCCAOP owner uniquely identify the MCCAOP reservation in the mesh BSS. The MCCAOP reservation ID is an 8-bit unsigned integer and included in the MCCAOP Reservation ID field of an MCCAOP Setup Request element. If this MCCAOP setup request is for an individually addressed transmission, the MCCAOP Reservation ID is between 0 and 127. If this MCCAOP setup request is for a group addressed transmission, the MCCAOP Reservation ID is between 128 and 254. The value 255 is not used to identify a specific MCCAOP reservation but is reserved for usage in the MCCAOP teardown procedure as described in 10.24.3.8.

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A mesh STA with dot11MCCAActivated equal to true shall be able to track at least dot11MCCATrackStatesActive MCCAOP reservations, including its own reservations. If the number of tracked MCCAOP reservations is less than dot11MCCATrackStatesActive, the mesh STA shall be able to track, set up, and accept additional reservations. In this case, the mesh STA shall set the Accept Reservations subfield in the Flags field to 1 in the MCCAOP Advertisement Overview elements it transmits.

If the number of tracked MCCAOP reservations is greater than or equal to dot11MCCATrackStatesActive, the mesh STA shall not track, set up, or accept additional reservations. In this case, the mesh STA shall set the Accept Reservations subfield in the Flags field to 0 in the MCCAOP Advertisement Overview elements it transmits. Moreover, it shall reply to MCCA Setup Request frames with an MCCA Setup Reply frame with the MCCA Reply Code field in the MCCAOP Setup Reply element equal to 3: Reject: MCCAOP track limit exceeded.

The tracked MCCAOP reservations are advertised as described in 10.24.3.7. How to access the medium during the tracked MCCAOP reservations is specified in 10.24.3.9.

10.24.3.4 Neighborhood MCCAOP periods at a mesh STA

The set of MCCAOP reservations in which a mesh STA is involved as an MCCAOP owner or an MCCAOP responder and that are used for individually addressed transmissions are referred to as the *TX-RX periods of this mesh STA*.

The set of MCCAOP reservations in which a mesh STA is involved as an MCCAOP owner or an MCCAOP responder and that are used for group addressed transmissions are referred to as the *broadcast periods of this mesh STA*. Optionally, the broadcast periods of a mesh STA includes known target beacon transmission times of Beacon frames for which this mesh STA is either the transmitter or the receiver, and transmission or reception periods of a STA that is collocated with the reporting mesh STA, for example, beacon or HCCA times of a collocated AP.

The interference periods of a mesh STA comprise the TX-RX periods and the broadcast periods of its neighbor mesh STAs in which the mesh STA is not involved as the owner or as a responder. The TX-RX periods, the broadcast periods, and the interference periods of a mesh STA shall not be used for a new MCCAOP reservation with the mesh STA as transmissions in these periods might experience interference from the transmissions in the new MCCAOPs or might cause interference to them.

The interference periods are directly derived from the TX-RX Periods Report field and Broadcast Periods Report field of the MCCAOP Advertisement elements transmitted by the neighbor mesh STAs. The Interference Periods Report field reflects the latest TX-RX Periods Report and Broadcast Periods Report fields received from the neighbor mesh STAs.

The MCCAOP reservations of a mesh STA and its neighbors define a set of MCCAOPs that are already reserved for frame transmissions in the mesh neighborhood of a mesh STA. This set of MCCAOPs is referred to as the *neighborhood MCCAOP periods for the mesh STA*. Thus, neighborhood MCCAOP periods at a mesh STA include all MCCAOPs for which the mesh STA or one of its neighbors, including neighbors from other MBSSs, is either transmitter or receiver.

10.24.3.5 MCCA access fraction (MAF)

The MCCA access fraction at a mesh STA is the ratio of the time reserved for MCCAOPs in the DTIM interval of this mesh STA to the duration of the DTIM interval. This parameter is reported in the MCCA Access Fraction field of the MCCAOP Advertisement Overview elements. The maximum value for the MAF that is allowed at a mesh STA is specified by dot11MAFlimit. The dot11MAFlimit is copied into the MAF Limit field of the MCCAOP Advertisement Overview element as described in 9.4.2.107.

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The MAF and the MAF Limit may be used to limit the use of MCCA in the mesh neighborhood of a mesh STA, as specified in 10.24.3.6. Before attempting to set up an MCCAOP reservation with a neighbor peer mesh STA, a mesh STA shall verify that the new MCCAOP reservation does not cause its MAF to exceed its MAF Limit and that the new MCCAOP reservation does not cause the MAF of any of its neighbor peer mesh STAs to exceed their MAF Limit. An MCCAOP setup request shall be refused by the intended MCCAOP responder if the MAF limit of one of its neighbors is exceeded due to the new setup.

10.24.3.6 MCCAOP setup procedure

The setup of an MCCAOP reservation is initiated by the MCCAOP owner and is accepted or rejected by the MCCAOP responder. The setup procedure for an MCCAOP reservation is as follows:

a) The MCCAOP owner shall build a map of the neighborhood MCCAOP periods in the DTIM interval after hearing advertisements from all of its neighbor mesh STAs with the MCCA Enabled subfield of the Mesh Capability field in the Mesh Configuration element equal to 1. It shall request an MCCAOP advertisement, as described in 10.24.3.7.8, from each neighbor mesh STA from which no advertisement was heard in the last dot11MCCAAdvertPeriodMax DTIM intervals.

b) The MCCAOP owner shall determine the MCCAOP reservation. The MCCAOP parameters shall be chosen in such a way that they satisfy the following conditions:

   1) The reservation shall not overlap with the neighborhood MCCAOP periods of the MCCAOP owner.
   2) The reservation shall not overlap with the interference periods of the intended MCCAOP responder or responders.
   3) The reservation shall not cause the MAF limit to be exceeded for either itself or its neighbor mesh STAs.
   4) The Accept Reservations subfield of the Flags field equals 1 in the most recent MCCAOP Advertisement Overview element received from all intended MCCAOP responders.

c) If the conditions in item b) are satisfied, the MCCAOP owner shall transmit an MCCAOP Setup Request element to the intended MCCAOP responder with the chosen MCCAOP parameters.

d) The MCCAOP responder shall verify the following conditions:

   1) The reservation does not overlap with its neighborhood MCCAOP periods.
   2) The reservation does not cause the MAF limit to be exceeded for itself or its neighbor mesh STAs.
   3) The number of reservations in its neighborhood MCCAOP periods does not exceed dot11MCCATrackStatesActive.

e) If the conditions in item d) are satisfied, the responder shall send an MCCA Setup Reply frame to the MCCAOP owner with the MCCA Reply Code field in the MCCAOP Setup Reply element equal to 0: Accept, as defined in Table 9-245.

f) If the conditions in item d) are satisfied and the MCCAOP request has been intended for group addressed transmissions, the responder shall include the reservation in its MCCAOP advertisement only after the MCCAOP advertisement from the MCCAOP owner is received.

g) If not all of the conditions in item d) are satisfied and the MCCAOP request is intended for individually addressed transmissions, the responder shall transmit to the MCCAOP owner an MCCA Setup Reply frame that is constructed as follows:

   1) If the condition in item d)1) is not satisfied and both conditions in item d)2) and item d)3) are satisfied, the responder may calculate an alternative MCCAOP reservation and include it in the MCCAOP Reservation field of the MCCAOP Setup Reply element. It shall set the MCCA Reply Code field of the MCCAOP Setup Reply element to 1: Reject: MCCAOP reservation conflict, as defined in Table 9-245.
   2) If the condition in item d)2) is not satisfied, it shall set the MCCA Reply Code field of the MCCAOP Setup Reply element to 2: Reject: MAF limit exceeded, as defined in Table 9-245.

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3) If the condition in item d)2) is satisfied and the condition in item d)3) is not satisfied, it shall set the MCCA Reply Code field of the MCCAOP Setup Reply element to 3: Reject: MCCAOP track limit exceeded, as defined in Table 9-245.

h) If not all of the conditions in item d) are satisfied and the MCCAOP request is intended for group addressed transmissions, the responder shall send an MCCA Setup Reply frame to the MCCAOP owner with the MCCA Reply Code field in the MCCAOP Setup Reply element equal to 1: Reject: MCCAOP reservation conflict.

i) If the MCCAOP owner receives an MCCA Setup Reply frame with MCCA Reply Code equal to Accept, the MCCAOP reservation is established. Otherwise, the mesh STA may repeat the MCCAOP setup procedure using a modified MCCAOP Setup Request. If an alternative MCCAOP reservation is included in the MCCAOP Setup Reply element, the mesh STA may consider this alternative in its modified MCCAOP Setup Request.

10.24.3.7 MCCAOP advertisement

10.24.3.7.1 General

A mesh STA with dot11MCCAActivated equal to true tracks MCCAOP reservations. The tracked MCCAOP reservations contain the neighborhood MCCAOP periods and optionally other periodic transmission of itself or of neighboring STAs.

The MCCAOP advertisement set contains all MCCAOP reservations tracked by the mesh STA. The MCCAOP advertisement set is represented by an MCCAOP Advertisement Overview element and zero (if the MCCAOP advertisement set is empty) or more (if the MCCAOP advertisement set is nonempty) MCCAOP Advertisement elements. An MCCAOP Advertisement element contains one or more tracked MCCAOP reservations.

The mesh STA advertises its MCCAOP advertisement set to its neighbor mesh STAs.

This subclause describes how the mesh STA constructs the MCCAOP Advertisement Overview element and the MCCAOP Advertisement elements. Further, this subclause describes the procedure to advertise an MCCAOP advertisement set, the procedure to request an MCCAOP advertisement from a neighboring mesh STA, and the procedure to process a received MCCAOP advertisement.

10.24.3.7.2 Construction of an MCCAOP advertisement set

The following terminology is used in this subclause:

— TX-RX report: an MCCAOP Reservation field contained in the TX-RX Periods Report field of an MCCAOP Advertisement element

— Broadcast report: an MCCAOP Reservation field contained in the Broadcast Periods Report field of an MCCAOP Advertisement element

— Interference report: an MCCAOP Reservation field contained in the Interference Periods Report field of an MCCAOP Advertisement element

Each MCCAOP reservation tracked by a mesh STA is one of the following types:

— TX-RX period:

  — An MCCAOP reservation for individually addressed frames for which the mesh STA is the MCCAOP owner or the MCCAOP responder.

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- Broadcast period:
  - An MCCAOP reservation for group addressed frames for which the mesh STA is the MCCAOP owner or the MCCAOP responder.
  - Optionally, known target beacon transmission times of Beacon frames for which the mesh STA is either the transmitter or the receiver.
  - Optionally, a transmission or reception period of a STA that is collocated with the mesh STA, for example, beacon or HCCA times of a collocated AP.
- Interference period:
  - A TX-RX or a broadcast period reported by a neighbor peer mesh STAs of the mesh STA excluding those periods for which this mesh STA is either the MCCAOP owner or the MCCAOP responder.
  - Optionally, a TX-RX or a broadcast period reported by neighbor nonpeer mesh STAs of the mesh STA.

The MCCAOP reservations are grouped into the following sets:

- MCCAOP TX-RX advertisement set, which includes all TX-RX periods
- MCCAOP broadcast advertisement set, which includes all broadcast periods
- MCCAOP interference advertisement set, which includes all interference periods

These three sets constitute the MCCAOP advertisement set. The mesh STA uses the MCCAOP Overview element and MCCAOP Advertisement elements to advertise its MCCAOP advertisement set to its neighbor mesh STAs.

The mesh STA acts as follows to construct the MCCAOP Overview elements and the MCCAOP Advertisement elements:

a) If the MCCAOP advertisement set is nonempty, the mesh STA constructs one or more MCCAOP reports according to the format described in 9.4.2.108.3 as follows:
   1) If the MCCAOP TX-RX advertisement set is nonempty, the mesh STA constructs one or more TX-RX reports according to the format described in 9.4.2.108.3 such that each reservation in the MCCAOP TX-RX advertisement set occurs exactly in one TX-RX report.
   2) If the MCCAOP broadcast advertisement set is nonempty, the mesh STA constructs one or more broadcast reports according to the format described in 9.4.2.108.3 such that each reservation in the MCCAOP broadcast advertisement set occurs exactly in one broadcast report.
   3) If the MCCAOP interference advertisement set is nonempty, the mesh STA constructs one or more interference reports according to the format described in 9.4.2.108.3 such that each reservation in the MCCAOP interference advertisement set occurs exactly in one interference report.

b) If the MCCAOP advertisement set is nonempty, the mesh STA constructs one or more MCCAOP Advertisement elements as follows:
   1) The MCCAOP Advertisement Set Sequence Number field is set to the MCCAOP advertisement set sequence number as explained in 10.24.3.7.3.
   2) The MCCAOP Advertisement Element Index subfield is set to an identifier that uniquely identifies the MCCAOP Advertisement element in the MCCAOP advertisement set.
   3) Each MCCAOP Advertisement element includes at least one of the TX-RX reports, broadcast reports, or interference reports. Moreover, it includes at most one of the TX-RX reports, at most one of the broadcast reports, and at most one of the interference reports. In case the MCCAOP Advertisement element contains a TX-RX report, the TX-RX Report Present subfield of the MCCAOP Advertisement Element Information field is set to 1; otherwise this

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subfield is set to 0. In case the MCCAOP Advertisement element contains a broadcast report, the Broadcast Report Present subfield of the MCCAOP Advertisement Element Information field is set to 1; otherwise this subfield is set to 0. In case the MCCAOP Advertisement element contains an interference report, the Interference Report Present subfield of the MCCAOP Advertisement Element Information field is set to 1; otherwise, this subfield is set to 0.

4) Each report as constructed in step a) is present in exactly one MCCAOP Advertisement element.

c) The mesh STA constructs one MCCAOP Advertisement Overview element such that

1) The MCCAOP Advertisement Set Sequence Number field is set to the advertisement set sequence number as explained in 10.24.3.7.3.
2) The Medium Access Fraction field is set to the medium access fraction.
3) The MAF limit field is set to dot11MAFlimit.
4) The Accept Reservations field is set to 1 if the number of tracked reservations of this mesh STA is less than dot11MCCATrackStatesActive, and set to 0 otherwise.
5) Bit *i* of the Advertisement Elements Bitmap field is set to 1 if an MCCAOP Advertisement element with the MCCAOP Advertisement Element Index subfield equal to *i* is part of the representation of this MCCAOP advertisement set, and set to 0 otherwise.

10.24.3.7.3 Setting the MCCAOP advertisement set sequence number

The MCCAOP advertisement set sequence number identifies an MCCAOP advertisement set. Mesh STAs with dot11MCCAActivated equal to true assign MCCAOP advertisement set sequence numbers from a single modulo 256 counter. The MCCAOP advertisement set sequence number is initialized to 0. The MCCAOP advertisement set sequence number shall be incremented by 1 if one of the following conditions holds:

a) The mesh STA sets the bit for an MCCAOP Advertisement element in the Advertisement Elements Bitmap from 0 to 1 and this bit has been set to 1 under the same MCCAOP Advertisement Sequence Number before.
b) The bit of the Advertisement Elements Bitmap corresponding to an MCCAOP Advertisement element is equal to 1 and the content of this MCCAOP Advertisement element changes.

However, the MCCAOP advertisement set sequence number may remain unchanged if

— The mesh STA changes a bit in the Advertisement Element Bitmap from 0 to 1 and this bit has not been set to 1 under the same MCCAOP Advertisement Sequence Number before, or
— The mesh STA changes a bit in the Advertisement Elements Bitmap from 1 to 0.

NOTE—The Advertisement Set Sequence Number identifies the current distribution of the MCCAOP advertisement set over the MCCAOP Advertisement elements. Using a new MCCAOP advertisement set sequence number signals a new, (possibly) completely different distribution of the MCCAOP advertisement set over the MCCAOP Advertisement elements, and requires an advertisement of all reservations of the MCCAOP advertisement set. Leaving the MCCAOP advertisement set sequence number unchanged as in the previous MCCAOP Advertisement Overview element indicates MCCAOP Advertisement elements that have previously been advertised are not changed and remain current. This enables a limited advertisement procedure in which only new MCCAOP Advertisement elements are advertised. Additionally, this enables mesh STAs that operate in light or deep sleep mode to request a limited update of the MCCAOP advertisement set of a neighboring mesh STA in which only new MCCAOP Advertisement elements are included.

10.24.3.7.4 Advertisement procedure

To advertise its MCCAOP advertisement set, the mesh STA constructs a representation of the MCCAOP advertisement set as described in 10.24.3.7.2. The MCCAOP advertisement set is advertised by transmitting an MCCAOP Advertisement Overview element and zero or more MCCAOP Advertisement elements (see 10.24.3.7.2) to neighbor peer mesh STAs. The MCCAOP Advertisement Overview element and the

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MCCAOP Advertisement elements are transmitted in Beacon frames, Probe Response frames, or MCCA Advertisement frames.

The mesh STA shall advertise its MCCAOP advertisement set according to the following rules:

a) The mesh STA shall advertise at least one MCCAOP Advertisement Overview element in every dot11MCCAAdvertPeriodMax DTIM intervals.

b) The mesh STA shall advertise its MCCAOP Advertisement Overview element and any new MCCAOP Advertisement elements at the latest with the transmission of its next Beacon frame after its MCCAOP advertisement set has changed.

c) The mesh STA shall advertise the requested MCCAOP Advertisement elements as described in 10.24.3.7.8 if the mesh STA receives an MCCA Advertisement Request frame.

10.24.3.7.5 Receipt of an MCCAOP advertisement

Upon receipt of an MCCAOP advertisement a mesh STA with dot11MCCAActivated shall compare the Advertisement Set Sequence Number contained in the MCCAOP Advertisement Overview element of the received MCCAOP advertisement with the last advertisement set sequence number that this mesh STA tracked for the sender of the received MCCAOP advertisement.

If the tracked advertisement set sequence number does not equal the Advertisement Set Sequence Number of the received MCCAOP advertisement, the mesh STA shall perform the procedure described in 10.24.3.7.6.

If the tracked advertisement set sequence number equals the Advertisement Set Sequence Number of the received MCCAOP advertisement, the mesh STA shall compare the Advertisement Elements Bitmap contained in the received MCCAOP Advertisement Overview element with the last Advertisement Elements Bitmap that this mesh STA tracked for the sender of the received MCCAOP advertisement. If the tracked Advertisement Elements Bitmap does not equal the Advertisement Elements Bitmap of the received MCCAOP advertisement, the mesh STA shall perform the procedure described in 10.24.3.7.7.

NOTE—If both the tracked advertisement set sequence number equals the Advertisement Set Sequence Number of the received MCCAOP advertisement and the tracked Advertisement Elements Bitmap equals the Advertisement Elements Bitmap of the received MCCAOP advertisement, the MCCAOP advertisement set of the sender of the MCCAOP advertisement tracked by the mesh STA is current, and no update of the MCCAOP advertisement set is needed.

10.24.3.7.6 Complete update of the tracked MCCAOP reservations of a neighbor mesh STA

The mesh STA performed the steps in 10.24.3.7.5 and detected that the MCCAOP advertisement set sequence number has been updated. Consequently, the mesh STA shall operate as follows.

The mesh STA shall discard all MCCAOP reservations that it tracked for the sender of the received MCCAOP advertisement. The mesh STA shall record the Advertisement Set Sequence Number and the source address (SA) of the received MCCAOP advertisement. The mesh STA shall record all reservations in the MCCAOP Advertisement elements of the received MCCAOP advertisement.

If the mesh STA does not receive all MCCAOP Advertisement elements of the sender of the MCCAOP advertisement before a frame exchange sequence on the wireless medium causes the mesh STA to set its NAV, the mesh STA shall perform the MCCAOP advertisement request procedure as described in 10.24.3.7.8.

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10.24.3.7.7 Partial update of the tracked MCCAOP reservations of a neighbor mesh STA

The mesh STA performed the steps in 10.24.3.7.5 and detected that part of the MCCAOP advertisement set of the sender of the MCCAOP advertisement has been updated. Consequently, the mesh STA shall operate as follows for each bit in the Advertisement Elements Bitmap contained in the MCCAOP Advertisement Overview element of the received MCCAOP advertisement.

If the bit in position n of the Advertisement Elements Bitmap in the received MCCAOP Advertisement is equal to 0 and if the bit in position n of the Advertisement Elements Bitmap tracked for the sender of the received MCCAOP advertisement is equal to 1, the mesh STA shall delete the reservations with the same Advertisement Sequence Number and the same MCCAOP Advertisement Element Index received from the same sender from its tracked reservations.

If the bit in position n of the Advertisement Elements Bitmap in the received MCCAOP Advertisement is equal to 1 and if the bit in position n of the Advertisement Elements Bitmap tracked for the sender of the received MCCAOP advertisement is equal to 0, the mesh STA shall add the reservations of the received MCCAOP Advertisement element with the MCCAOP Advertisement Element Index set to n to its tracked reservations. If the mesh STA does not receive this MCCAOP Advertisement element of the sender of the MCCAOP Advertisement before a frame exchange sequence on the wireless medium causes the mesh STA to set its NAV, the mesh STA shall perform the MCCAOP Advertisement request procedure as described in 10.24.3.7.8.

NOTE—If the bit in position n of the received Advertisement Elements Bitmap contained in the received MCCAOP Advertisement is equal to the bit in position n of the Advertisement Elements Bitmap tracked for the sender of the received MCCAOP advertisement, then the Advertisement element with the MCCAOP Advertisement Element Index equal to n is current, and no update of this Advertisement element is needed.

10.24.3.7.8 MCCAOP advertisement request procedure

To request all MCCAOP Advertisement elements from a neighbor peer mesh STA, the mesh STA transmits an MCCA Advertisement Request frame without an MCCAOP Advertisement Overview element.

To request a subset of the MCCAOP Advertisement elements of a neighbor peer mesh STA, the mesh STA transmits an MCCA Advertisement Request frame including an MCCAOP Advertisement Overview element. The mesh STA shall set the contents of the MCCAOP Advertisement Overview element as follows. The mesh STA sets

a) The Advertisement Set Sequence Number field to the Advertisement Sequence Number that it tracks for the recipient of this frame
b) In the Advertisement Element Bitmap, the bit to 1 for each MCCAOP Advertisement element that the mesh STA requests from the recipient of this frame
c) The Flags field, the MCCA Access Fraction field, and the MAF Limit field to 0

The mesh STA shall discard the MCCA Advertisement Request frame from its frame queue if it receives all of the MCCAOP Advertisement elements that it requests in the MCCAOP Advertisement Request.

10.24.3.8 MCCAOP teardown

10.24.3.8.1 Conditions that trigger an MCCAOP teardown

The MCCAOP owner and the MCCAOP responder may initiate a teardown of an MCCAOP reservation, e.g., when the reservation is no longer needed. A mesh STA shall act as follows to resolve conflicts between MCCAOP reservations in its neighborhood MCCAOP periods. If the conflict is caused by overlapping reservations from its TX-RX periods and broadcast periods, it shall select one of these reservations and initiate a teardown for it. If the conflict is caused by an overlap between a reservation from its TX-RX

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periods or broadcast periods, and another reservation from its interference periods, it shall act as follows. It creates a first unsigned integer by inverting the bit order of its MAC address and a second unsigned integer by inverting the bit order of the lowest of the known MAC addresses of the owner and responder(s) of the reservation in the interference periods. If the first unsigned integer is smaller than the second unsigned integer, it shall initiate a teardown of the reservation in its TX-RX or broadcast periods. Otherwise, it may initiate a teardown of the reservation in its TX-RX or broadcast periods.

There are also other conditions that trigger the MCCAOP owner and responder to delete a reservation, without an explicit tear down. An MCCAOP owner shall delete a reservation for an individually addressed transmission when it has not received an acknowledgment for any frame transmission in the MCCAOPs corresponding to the reservation for greater than dot11MCCAOPtimeout time. An MCCAOP responder shall delete a reservation for individually addressed transmission or group addressed transmissions when it has not received a frame transmission in any of the MCCAOPs corresponding to the reservation for greater than dot11MCCAOPtimeout time.

10.24.3.8.2 MCCAOP teardown procedure

The teardown is initiated by transmitting an MCCA Teardown frame. The MCCAOP Reservation ID field in the MCCAOP Teardown element is set to the MCCAOP Reservation ID of the reservation that is to be torn down. In case the tear down is initiated by an MCCAOP responder, the MCCAOP Owner field of the MCCAOP Teardown element is set to the MAC address of the MCCAOP owner.

The transmitter of the MCCA Teardown frame deletes the reservation after the MCCA Teardown frame has been successfully transmitted. The receiver of the MCCA Teardown frame acts as follows. In case the MCCAOP Reservation ID field corresponds to a reservation for individually addressed transmissions, it deletes the reservation. If the reservation is for group addressed transmissions for which it is the MCCAOP owner, it deletes the reservation if there are no other MCCAOP responders for this reservation.

The MCCAOP owner acts as follows when deleting a reservation:

- It stops executing the access procedure described in 10.24.3.9.1 at the start of the MCCAOPs corresponding to the reservation that was deleted.
- In case the reservation was for individually addressed frames, it stops advertising the MCCAOP reservation in its TX-RX Periods Report field.
- In case the reservation was for group addressed frames, it stops advertising the MCCAOP reservation in its Broadcast Periods Report field.

The MCCAOP responder acts as follows when deleting a reservation:

- It stops executing the procedure described in 10.24.3.9.2 during the MCCAOPs corresponding to the reservation that was deleted.
- In case the reservation was for individually addressed frames, it stops advertising the MCCAOP reservation in its TX-RX Periods Report field.
- In case the reservation was for group addressed frames, it stops advertising the MCCAOP reservation in its Broadcast Periods Report field.

10.24.3.9 Access during MCCAOPs

10.24.3.9.1 Access by MCCAOP owners

At the start of the MCCAOP, the EDCAF of the MCCAOP owner shall set AIFSN[AC] equal to dot11MCCAAIFSN, CWmax[AC] equal to dot11MCCACWmax, CW[AC] equal to dot11MCCACWmin, and QSRC[AC] to 0 for all ACs. The TXOP limit shall specify a duration value no larger than the MCCAOP Duration.

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During the MCCAOP, the EDCAFs of the ACs operates as specified in 10.23.2, with the following modifications.

— During the MCCAOP, the EDCAF of each AC shall consider only those frame whose RA matches the MAC address of the MCCAOP responder.
— When the access to the medium is delayed, the TXOP limit shall specify a duration to end no later than the MCCAOP start time plus the MCCAOP Duration.
— As specified in 10.24.3.9.2, a neighboring STA shall not access the WM during an MCCAOP, until it receives a frame from either the MCCAOP owner or the MCCAOP responder. With the exception of truncation of an MCCA TXOP by means of a CF-End, standard EDCA TXOP rules apply for the remainder of the MCCAOP. For HT mesh STAs, these include the reverse direction protocol as specified in 10.29.
— At the end of the MCCAOP, the parameters used by the EDCAF of the MCCAOP owner shall be set to dot11EDCATable, and QSRC[AC] shall be set to 0 for all ACs.

The MCCAOP owner may adjust the duration of an MCCAOP by setting the Duration/ID field in the frames it transmits. In particular, if an MCCAOP owner has no data to transmit in an MCCAOP corresponding to an MCCAOP reservation that is intended for individually addressed frames, it may transmit an individually addressed QoS Null frame during the MCCAOP to end the MCCAOP.

NOTE—It is recommended to send a QoS Null frame to end the MCCAOP although there might be situations in which the transmission of a QoS Null is not needed or undesirable.

If an MCCAOP owner has no data to transmit in an MCCAOP reservation that is intended for group addressed frames, it may transmit a group addressed QoS Null frame during the MCCAOP to end the MCCAOP.

10.24.3.9.2 Access during an MCCAOP by mesh STAs that are not the MCCAOP owner

The MAC of a mesh STA with dot11MCCAActivated is true shall provide a Reservation Allocation Vector (RAV) mechanism to indicate a busy medium from the start of an MCCAOP corresponding to a reservation in its interference periods until the receipt of a frame transmitted by either the MCCAOP owner or the MCCAOP responder. The RAV mechanism is provided in addition to the PHY and virtual CS mechanisms described in 10.3.2.1. It is different from the virtual CS mechanism in two aspects. Firstly, a mesh STA might be neighbor to multiple ongoing MCCAOPs corresponding to different reservations and the regular NAV setting and updating rules do not suffice to prevent interference during these reservations. Secondly, the virtual CS mechanism is set immediately upon receipt of a frame, whereas the RAV mechanism is based on reservation frames received at some earlier time instant. When either the CS function provided by the PHY, the virtual CS function provided by the MAC via the NAV, or the RAV mechanism indicate a busy medium during an MCCAOP for which the mesh STA is neither the MCCAOP owner nor the MCCAOP responder, the medium shall be considered busy; otherwise, it shall be considered idle.

The RAV mechanism maintains an index of future MCCAOPs based on the reservation information that is available in the interference periods of a mesh STA. At the start of each MCCAOP corresponding to a reservation in the interference periods, a RAV is set to indicate a busy medium for the duration of the MCCAOP given in the MCCAOP Duration subfield of the MCCAOP reservation. At the start of each MCCAOP corresponding to a reservation in the TX-RX or broadcast periods for which the mesh STA is an MCCAOP responder, a RAV is set to indicate a busy medium for the duration of the MCCAOP given in the MCCAOP Duration subfield of the MCCAOP reservation. The RAV may be thought of as a counter, corresponding to an MCCAOP corresponding to a reservation in the interference periods. The RAV counts down to zero at a uniform rate. When the counter is zero, the RAV indication is that the medium is idle; when nonzero, the indication is busy.

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The mesh STA clears the RAV timer, i.e., sets it to 0, upon receipt of a frame from either the MCCAOP owner or responder. If a mesh STA receives an RTS frame during an MCCAOP for which it is an MCCAOP responder, with the RA matching its MAC address and with the MAC address in the TA field in the RTS frame matching the MAC address of the MCCAOP owner, then the STA shall send the CTS frame after SIFS, without regard for the NAV and the RAV, and without resetting its NAV. The RAV for an MCCAOP is not cleared upon receipt of a frame originating from stations that are not the MCCAOP owner or responder. Since the NAV is set upon receipt of frames with a Duration/ID field, the MCCAOP owner and responder adjust the reservation period of an MCCAOP to their actual traffic needs by the Duration/ID field in the transmitted frame and obtain protection of the frame transmission via the NAV setting.

The RAV mechanism might be represented by a number of counters, where each counter corresponds to one MCCAOP. The number of counters needed at any instant is equal to the number of MCCAOPs at this instant corresponding to reservations in the interference periods of the mesh STA.

10.24.3.10 Interaction with time synchronization

If a mesh STA adjusts its TBTT, e.g., in response to a TBTT Adjustment Request, it shall adjust the reservations by modifying the MCCAOP Offset of each of the tracked MCCAOP reservations. If a mesh STA adjusts its timing offset value with respect to a neighbor mesh STA, as specified in 14.13.2.2, it shall adjust the reservations by modifying the MCCAOP Offset of each of the tracked MCCAOP reservations for which this neighbor mesh STA is the owner. In either case, an MCCAOP advertisement of a mesh STA shall always contain the most recent MCCAOP Offsets.

10.25 Block acknowledgment (block ack)

10.25.1 Introduction

The block ack mechanism improves channel efficiency by aggregating several acknowledgments into one frame. In this subclause, the STA with data to send using the block ack mechanism is referred to as the *originator*, and the receiver of that data as the *recipient*.

The block ack mechanism is initialized by an exchange of ADDBA Request/Response frames except for GLK-GCR block ack. After initialization, blocks of QoS Data frames may be transmitted from the originator to the recipient. A block may be started within a polled TXOP, within an SP, or by winning EDCA contention. The number of frames in the block is limited, and the amount of state that is to be kept by the recipient is bounded. The MPDUs within the block of frames are acknowledged by a BlockAck frame, which is requested by a BlockAckReq frame.

For GLK-GCR block ack, the block ack mechanism is initialized when the GLK STA associates with the GLK AP. The MPDUs within a block of SYNRA addressed Data frames are acknowledged by a BlockAck frame, which is requested by a BlockAckReq frame.

The block ack mechanism does not require the setting up of a TS; however, QoS STAs using the TS facility may choose to signal their intention to use block ack mechanism for the scheduler's consideration in assigning TXOPs. The block ack mechanism is also used by the GCR service. Acknowledgments of frames belonging to the same TID, but transmitted during multiple TXOPs/SPs, may also be combined into a single BlockAck frame. This mechanism allows the originator to have flexibility regarding the transmission of Data frames. The originator may split the block of frames across TXOPs/SPs, separate the data transfer and the block ack exchange, and interleave blocks of MPDUs carrying all or part of MSDUs or A-MSDUs for different TIDs or RAs.

An S1G non-AP STA may negotiate an asymmetric BA with an S1G AP as described in 10.25.2. A non-S1G STA shall not transmit NDP BlockAck frames and shall not initiate an asymmetric BA. An S1G AP with dot11AsymmetricBlockAckActivated equal to false shall not support asymmetric BA. Under

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asymmetric BA operation, the responding S1G STA may use a lower MCS for transmitting the immediate BlockAck frame as described in 10.6.6.5.2. The intended recipient STA maintains a measure of the degree of asymmetry between the AP and the STA and implicitly indicates the value to the originator AP during the block ack setup phase. This degree of asymmetry is represented as the difference in MCS values between AP and STA, and referred to as MCSDifference (see 10.25.2). After an asymmetric BA agreement is established, the originator AP uses the MCSDifference to calculate the Duration field of PV0 frames carried in the A-MPDU that elicits the BlockAck frame.

An S1G STA that sets the STA Type Support subfield in a transmitted S1G Capabilities element to 0 or 2, as described in 10.63, shall support the HT-immediate block ack extension. An S1G STA that sets the A-MPDU Supported field in the S1G Capabilities element to 1 shall support the HT-immediate block ack extension.

All arithmetic and equations (including inequalities) in 10.25 are to be understood as being modulo the size of the relevant counter space (typically 4096).

10.25.2 Setup and modification of the block ack parameters

Where the generic terms ADDBA Request frame, ADDBA Response frame, and DELBA frame are used throughout 10.25 in reference to a block ack agreement between S1G STAs, the appropriate variant according to this subclause (e.g., NDP ADDBA Request, BAT ADDBA Request, and ADDBA Request) is referenced by the generic term.

To set up a block ack agreement, an originator sends an ADDBA Request frame indicating the TID for which the block ack agreement is being set up. The Buffer Size and Block Ack Timeout fields in the ADDBA Request frame are advisory. A block ack agreement shall not be set up between a non-HT non-DMG non-S1G STA and another STA.

If the intended S1G recipient is capable of participating in an HT-immediate block ack agreement, the S1G originator shall send an NDP ADDBA Request to indicate that it expects only NDP BlockAck frames during the block ack agreement with the following exceptions:

a) If the S1G originator has the dot11BATImplemented equal to true and the BAT Support subfield in the S1G Capabilities element received from the S1G recipient is 1 and a TWT has been set up with the S1G recipient as described in 10.47, then the S1G originator shall send a BAT ADDBA Request to indicate that it expects only BAT frames during the block ack agreement.

b) When any of the conditions below is satisfied then the S1G originator may send an ADDBA Request to indicate that it expects only BlockAck frames during the block ack agreement:

   1) The value of the Buffer Size field in the ADDBA Request, carried in an S1G_LONG or S1G_SHORT PPDU, is greater than 16.

   2) The value of the Buffer Size field of the ADDBA Request, carried in an S1G_1M PPDU, is greater than 8.

   3) The dot11AsymmetricBlockAckActivated is true and Asymmetric BA Supported field in the S1G Capabilities element received from the S1G recipient is 1.

The recipient STA shall respond by an ADDBA Response frame. The recipient STA has the option of accepting or rejecting the request. When the recipient STA accepts, then a block ack agreement exists between the originator and recipient.

When the S1G recipient STA rejects the request it may indicate a status code of 109 (REJECTED_NDP_BLOCK_ACK_SUGGESTED) to indicate to the S1G originator that it prefers to generate only NDP BlockAck frames.

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When the recipient STA accepts, it indicates the type of block ack agreement, the type of BlockAck frames, and the number of buffers that it shall allocate for the support of this block ack agreement within the ADDBA Response frame and the block ack timeout that is used. Each block ack agreement that is established by a STA may have a different buffer allocation. If the intended recipient STA rejects the request, then the originator shall not use the block ack mechanism.

An S1G recipient STA that accepts an HT-immediate block ack agreement shall respond with the following:

- An NDP ADDBA Response if the value of the Buffer Size field of the NDP ADDBA Response is not greater than the value of the maximum number of MSDUs and A-MSDUs that can be acknowledged with the selected NDP BlockAck frame and no TWT has already been set up with the S1G originator as described in 10.47.
  - This value is 8 for NDP_1M BlockAck frames and 16 for NDP_2M BlockAck frames as described in 23.3.12.2.6. The NDP ADDBA Response frame shall be carried in an S1G_1M PPDU to indicate the use of NDP_1M BlockAck frames and shall be carried in an S1G_SHORT or S1G_LONG PPDU to indicate the use of NDP_2M BlockAck frames.
- Otherwise, a BAT ADDBA Response as a response to a BAT ADDBA Request if a TWT has already been set up with the S1G originator as described in 10.47.
  - The value of the Buffer Size field in the BAT ADDBA Response shall not be greater than 32.
- Otherwise, a ADDBA Response to indicate the use of BlockAck frames.

The MCS subfield in the Originator Preferred MCS field shall be set to 15 unless the dot11AsymmetricBlockAckActivated is true and the Asymmetric BA Supported field in the S1G Capabilities element received from the S1G originator is 1 in which case the MCS subfield may indicate the value of the preferred MCS if asymmetric BA operation is used. The preferred MCS implicitly indicates the MCSDifference value, which is the difference between the preferred MCS and the MCS at which the ADDBA Response is sent.

When the Block Ack Policy subfield value is set to 1 by the originator of an ADDBA Request frame between HT STAs, then the ADDBA Response frame accepting the ADDBA Request frame shall contain 1 in the Block Ack Policy subfield.

For each accepted block ack agreement, the originator shall set the sequence number of the first frame transmitted under the agreement to the value of the Block Ack Starting Sequence Control field of the ADDBA Request frame of the accepted block ack agreement.

When a block ack agreement is established between two HT STAs, two DMG STAs, or two S1G STAs, the originator may change the size of its transmission window if the value in the Buffer Size field of the ADDBA Response frame is larger than the value in the ADDBA Request frame. If the value in the Buffer Size field of the ADDBA Response frame is smaller than the value in the ADDBA Request frame, the originator shall change the size of its transmission window ($WinSize_O$) so that it is not greater than the value in the Buffer Size field of the ADDBA Response frame and is not greater than the value 64.

The originator STA may send an ADDBA Request frame in order to update block ack timeout value. If the updated ADDBA Request frame is accepted, both STAs initialize the timer to detect block ack timeout. Even if the updated ADDBA Request frame is not accepted, the original block ack setup remains active.

NOTE 1—A block ack associated with a GCR group address does not use an inactivity timer because the GCR originator might switch between the DMS delivery method, the GCR unsolicited retry retransmission policy, and the GCR block ack retransmission policy during the lifetime of a GCR agreement.

NOTE 2—A GLK-GCR block ack is set up at the time the general link is established and might be used by the general link originator whenever the GCR block ack retransmission policy is active. Therefore, an explicit block ack setup or modification procedure is not defined for GLK-GCR block ack. The GLK-GCR block ack is deleted when the corresponding general link gets reassociated or disassociated.

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The A-MSDU Supported field indicates whether an A-MSDU may be sent under the particular block ack agreement. The originator sets this field to 1 to indicate that it might transmit A-MSDUs with this TID. The recipient sets this field to 1 to indicate that it is capable of receiving an A-MSDU with this TID.

NOTE 3—The recipient is free to respond with any setting of the A-MSDU supported field. If the value in the ADDBA Response frame is not acceptable to the originator, it can delete the block ack agreement and transmit data using normal acknowledgment.

If the block ack mechanism is being set up for a TS, bandwidth negotiation (using ADDTS Request and Response frames) should precede the setup of the block ack mechanism. If the block ack mechanism is being set up for the GCR service, then the following steps apply:

— One or more GCR Request/Response exchanges precede the setup of the block ack mechanism.
— The ADDBA Request and Response frames exchanged to set up the block ack shall include the GCR Group Address element indicating the group address of the GCR service.

Once the block ack exchange has been setup, QoS Data frames are transferred in A-MPDUs and acknowledged using the procedure described in 10.25.3.

10.25.3 Data and acknowledgment transfer using immediate block ack policy

After setting up an immediate block ack agreement following the procedure in 10.25.2, and having gained access to the medium and established protection, if necessary, the originator may transmit an A-MPDU. The RA field of the frames that are not delivered using the GCR block ack retransmission policy shall be the recipient's individual address. The RA field in GCR frames delivered using the GCR block ack retransmission policy shall be set to the GCR concealment address. The RA field in Data frames delivered using the GLK-GCR block ack retransmission policy shall be set to a SYNRA. The originator requests acknowledgment of outstanding QoS Data frames by sending a BlockAckReq frame.

10.25.4 Teardown of the block ack mechanism

When the originator has no data to send and the final block ack exchange has completed, it shall signal the end of its use of the block ack mechanism by sending the DELBA frame to its recipient. The DELBA frame sent by the S1G originator shall be a BAT DELBA if a BAT ADDBA Request was sent during block ack setup or NDP DELBA if an NDP ADDBA Request was sent during block ack setup or DELBA if ADDBA Request was sent during block ack setup. The recipient does not generate a Management frame in response to the DELBA frame.[39] The recipient of the DELBA frame shall release all resources allocated for the block ack transfer.

The block ack agreement may be torn down if there are no BlockAck, BlockAckReq, or MPDUs received from the peer under the block ack agreement, for the block ack's TID, within a duration of block ack timeout value (see 11.5.4).

The DELBA frame transmitted to release the block ack setup of a GCR service shall include the GCR Group Address element to indicate the group address of the GCR service. For general links using a GLK-GCR block ack retransmission policy, there is no explicit teardown of the block ack mechanism. The GLK-GCR block ack agreement terminates when the general link is reassociated/disassociated.

10.25.5 Selection of BlockAck and BlockAckReq variants

The Compressed Bitmap subfield of the BA Control field or BAR Control field shall be set to 1 in all BlockAck and BlockAckReq frames sent from one HT STA to another HT STA and shall be set to 0 otherwise.

[39] Normal Ack rules apply.

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The Multi-TID subfield of the BA Control field shall be set to 1 in all BlockAck frames related to an HT-immediate agreement transmitted inside a PSMP sequence and shall be set to 0 otherwise. The Multi-TID subfield of the BAR Control field shall be set to 1 in all BlockAckReq frames related to an HT-immediate agreement transmitted inside a PSMP sequence and shall be set to 0 otherwise.

In a DMG BSS, if the Compressed Bitmap subfield of the BAR Control field within a BlockAckReq frame related to an HT-immediate agreement is equal to 1, then all of the following BlockAck and BlockAckReq frames transmitted as part of the HT-immediate agreement shall have the Compressed Bitmap subfield of the BA Control and BAR Control fields set to 1. In this case, the Multi-TID subfield of the BA Control field and BAR Control field shall be set to 0 in all BlockAck and BlockAckReq frames transmitted as part of the HT-immediate agreement.

In a DMG BSS, if the Compressed Bitmap subfield of the BAR Control field within a BlockAckReq frame related to an HT-immediate agreement is equal to 0, then all of the following BlockAck and BlockAckReq frames transmitted as part of the HT-immediate agreement shall have the Compressed Bitmap subfield of the BA Control and BAR Control fields set to 0. In this case, the Multi-TID subfield of the BA Control field and BAR Control field shall be set to 1 in all BlockAck and BlockAckReq frames transmitted as part of the HT-immediate agreement.

Where the terms BlockAck and BlockAckReq are used within 10.25.6, the appropriate variant according to this subclause (e.g., Compressed, Multi-TID) is referenced by the generic term. The term BlockAck as used in 10.25.6 includes the additional NDP_1M BlockAck, NDP_2M BlockAck, BAT, and BlockAck frame variants.

The GCR Mode subfield of the BAR Control field (see Table 9-27) shall be set to

— GCR BlockAck: in all BlockAckReq frames within a GCR block ack agreement, or
— GLK-GCR BlockAck: in all BlockAckReq frames within a GLK-GCR block ack agreement.

The GCR Mode subfield in the corresponding BA Control field (see Table 9-28) shall be set to

— GCR BlockAck: in all BlockAck frames within a GCR block ack agreement, or
— GLK-GCR BlockAck: in all BlockAck frames within a GLK-GCR block ack agreement.

The S1G recipient of an accepted block ack agreement that was negotiated with NDP ADDBA shall use NDP BlockAck frames instead of BlockAck frames to acknowledge MPDUs within A-MPDUs during an HT-immediate block ack agreement.

The S1G recipient of an accepted block ack agreement that was negotiated with BAT ADDBA shall use BAT frames instead of BlockAck frames to acknowledge MPDUs within A-MPDUs during an HT-immediate block ack agreement. Otherwise, the S1G recipient of an accepted block ack agreement shall not use BAT frames.

The S1G recipient of an accepted block ack agreement that was negotiated with ADDBA shall use BlockAck frames to acknowledge MPDUs within A-MPDUs during an HT-immediate block ack agreement.

The S1G recipient of an accepted block ack agreement that was negotiated with either ADDBA Request/NDP ADDBA Response or NDP ADDBA Request/ADDBA Response shall use either NDP BlockAck or BlockAck frames depending on the type of response frame elicited by the S1G originator. The type of response shall be:

— An NDP BlockAck frame if the RXVECTOR parameter RESPONSE_INDICATION of the eliciting PPDU that contains a BlockAckReq or an A-MPDU is equal to NDP Response

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— A BlockAck frame if the RXVECTOR parameter RESPONSE_INDICATION of the eliciting PPDU that contains a BlockAckReq or an A-MPDU is equal to Normal Response
— A PPDU that contains a BlockAck frame if the RXVECTOR parameter RESPONSE_INDICATION of the eliciting PPDU is equal to Long Response

10.25.6 HT-immediate block ack extensions

10.25.6.1 Introduction to HT-immediate block ack extensions

An HT extension to the block ack feature (defined in 10.25.1 to 10.25.4), called *HT-immediate block ack*, is defined in 10.25.6.2 to 10.25.6.9.

The HT-immediate extensions simplify immediate block ack use with A-MPDUs and reduce recipient resource requirements.

An HT STA shall support HT-immediate block ack in the role of recipient.

A DMG STA shall support HT-immediate block ack.

10.25.6.2 HT-immediate block ack architecture

The HT-immediate block ack rules are explained in terms of the architecture shown in Figure 10-36 and explained in this subclause.

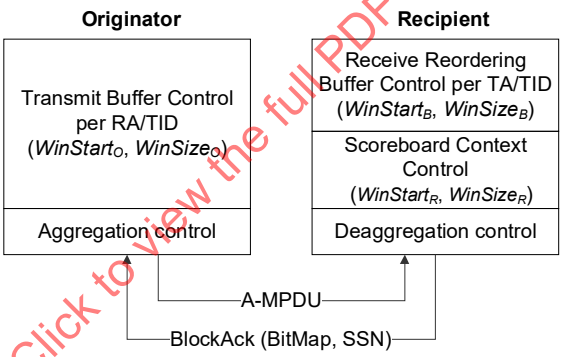

Figure 10-36—HT-immediate block ack architecture

The originator contains a transmit buffer control that uses $WinStart_O$ and $WinSize_O$ to submit MPDUs for transmission and releases transmit buffers upon receiving BlockAck frames from the recipient.

$WinStart_O$ is the starting sequence number of the transmit window, and $WinSize_O$ is the number of buffers negotiated in the block ack agreement.

The Aggregation control creates A-MPDUs. It may adjust the ack policy of transmitted QoS Data frames according to the rules defined in 10.25.6.7 in order to solicit BlockAck frame responses.

The recipient contains a receive reordering buffer control per TA/TID, which contains a related control state. The receive reordering buffer is responsible for reordering MSDUs or A-MSDUs so that MSDUs or A-MSDUs are eventually passed up to the next MAC process in order of received sequence number. It is also responsible for identifying and discarding duplicate frames (i.e., frames that have the same sequence number as a currently buffered frame) that are part of this block ack agreement. It maintains its own state independent of the scoreboard context control to perform this reordering as specified in 10.25.6.6.

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For each HT-immediate block ack agreement, the recipient chooses either full-state or partial-state operation (this choice is known only to the recipient). A STA may simultaneously use full-state operation for some agreements and partial-state operation for other agreements. The scoreboard context control stores an acknowledgment bitmap containing the current reception status of MSDUs or A-MSDUs for HT-immediate block ack agreements. Under full-state operation, status is maintained in statically assigned memory. Under partial-state operation, status is maintained in a cache memory; therefore, the status information is subject to cache replacement. This entity provides the bitmap and the value for the Starting Sequence Number subfield to be sent in BlockAck frame responses to the originator.

The deaggregation control entity separates frames contained in an A-MPDU.

Each received MPDU is analyzed by the scoreboard context control as well as by the receive reordering buffer control.

Each HT-immediate block ack agreement is uniquely identified by a tuple of Address 1, Address 2, and TID from the ADDBA Response frame that successfully established the HT-immediate block ack agreement. The STA that corresponds to Address 1 of the ADDBA Response frame is the originator. The STA that corresponds to Address 2 of the ADDBA Response frame is the recipient. Data frames that contain the same values for Address 1, Address 2, and TID as a successful ADDBA Response frame are related with the HT-immediate block ack agreement that was established by the receipt of that ADDBA Response frame provided that the HT-immediate block ack agreement is still active.

10.25.6.3 Scoreboard context control during full-state operation

For each HT-immediate block ack agreement that uses full-state operation, a recipient shall maintain a block acknowledgment record. This record includes a bitmap, indexed by sequence number; a 12-bit unsigned integer starting sequence number, $WinStart_R$, representing the lowest sequence number position in the bitmap; $WinEnd_R$, representing the highest sequence number in the current transmission window; and the maximum transmission window size, $WinSize_R$, which is set to the smaller of 64 and the value of the Buffer Size field of the associated ADDBA Response frame that established the block ack agreement. A STA implementing full-state operation for an HT-immediate block ack agreement shall maintain the block acknowledgment record for that agreement according to the following rules:

a) At HT-immediate block ack agreement establishment:

   1) $WinStart_R = SSN$ from the ADDBA Request frame that elicited the ADDBA Response frame that established the HT-immediate block ack agreement.

   2) $WinEnd_R = WinStart_R + WinSize_R - 1$.

b) For each received Data frame that is related with a specific full-state operation HT-immediate block ack agreement, the block acknowledgment record for that agreement is modified as follows, where SN is the value of the Sequence Number subfield of the received Data frame, and FN is equal to 0 except when the received Data frame is part of an A-MPDU that is not an S-MPDU carried in an S1G PPDU in which case FN is equal to the value of the Fragment Number subfield of the received Data frame:

   1) If $WinStart_R \le SN \le WinEnd_R$, set to 1 the bit in position SN within the bitmap.

      i) If $WinEnd_R < SN + FN$, set $WinEnd_R = SN+FN$ and $WinStart_R = SN+FN-WinSize_R+1$.

   2) If $WinEnd_R < SN < WinStart_R+2^{11}$,

      i) Set to 0 the bits corresponding to MPDUs with Sequence Number subfield values from $WinEnd_R+1$ to $SN + FN - 1$.

      ii) Set $WinStart_R = SN + FN - WinSize_R + 1$.

      iii) Set $WinEnd_R = SN + FN$.

      iv) Set to 1 the bit at position SN in the bitmap.

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3) If $WinStart_R+2^{11} \le SN < WinStart_R$, make no changes to the record.

NOTE 1—A later-arriving Data frame might validly contain a sequence number that is lower than an earlier-arriving one. This might happen because the transmitter may choose to send Data frames in a nonsequential sequence number order or because a previous Data frame transmission with lower sequence number is not successful and is being retransmitted.

NOTE 2—Fragmentation is not allowed during an HT-immediate block ack agreement as described in 10.2.6. All Data frames included in an A-MPDU that is not an S-MPDU generated during HT-immediate block ack with NDP BlockAck have the Fragment Number subfield equal to an offset to $WinEnd_O$ as described in 10.25.6.7.

c) For each received BlockAckReq frame that is related with a specific full-state operation HT-immediate block ack agreement that is not a protected block ack agreement, the block acknowledgment record for that agreement is modified as follows, where *SSN* is the value from the Starting Sequence Number subfield of the received BlockAckReq frame:

1) If $WinStart_R < SSN \le WinEnd_R$,
   i) Set $WinStart_R = SSN$.
   ii) Set to 0 the bits corresponding to MPDUs with Sequence Number subfield values from $WinEnd_R + 1$ to $WinStart_R + WinSize_R - 1$.
   iii) Set $WinEnd_R = WinStart_R + WinSize_R - 1$.
2) If $WinEnd_R < SSN < WinStart_R+2^{11}$,
   i) Set $WinStart_R = SSN$.
   ii) Set $WinEnd_R = WinStart_R + WinSize_R - 1$.
   iii) Set to 0 bits the corresponding to MPDU with Sequence Number subfield values from $WinStart_R$ to $WinEnd_R$.
3) If $WinStart_R+2^{11} \le SSN \le WinStart_R$, make no changes to the record.

10.25.6.4 Scoreboard context control during partial-state operation

In an HT-immediate block ack agreement that uses partial-state operation, a recipient shall maintain a temporary block acknowledgment record. This temporary record includes a bitmap, indexed by sequence number; a 12-bit unsigned integer $WinStart_R$ (the lowest sequence number represented in the bitmap); a 12-bit unsigned integer $WinEnd_R$ (the highest sequence number in the bitmap); the originator address; TID; and the maximum transmission window size, $WinSize_R$, which is set to the smaller of 64 and the value of the Buffer Size field of the associated ADDBA Response frame that established the block ack agreement.

During partial-state operation of scoreboard context control, the recipient retains the current record for an HT-immediate block ack agreement at least as long as it receives data from the same originator. If a frame for an HT-immediate block ack agreement from a different originator is received, the temporary record may be discarded if the resources it uses are needed to store the temporary record corresponding to the newly arriving frame.

A STA implementing partial-state operation for an HT-immediate block ack agreement shall maintain the temporary block acknowledgment record for that agreement according to the following rules:

a) During partial-state operation, $WinStart_R$ is determined by the Sequence Number subfield value of received Data frames and by the Starting Sequence Number subfield value of received BlockAckReq frames as described below.

b) For each received Data frame that is related with a specific partial-state operation HT-immediate block ack agreement, when no temporary record for the agreement related with the received Data frame exists at the time of receipt of the Data frame, a temporary block acknowledgment record is created as follows, where *SN* is the value of the Sequence Number subfield of the received Data frame and *FN* is equal to 0 except when the received Data frame is part of an A-MPDU that is not an

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S-MPDU carried in an S1G PPDU in which case *FN* is equal to the value of the Fragment Number subfield of the received Data frame:

1) $WinEnd_R = SN + FN$.
2) $WinStart_R = WinEnd_R - WinSize_R + 1$.
3) Create a bitmap of size $WinSize_R$, with the first bit corresponding to sequence number $WinStart_R$ and the last bit corresponding to sequence number $WinEnd_R$, and set all bits in the bitmap to 0.
4) Set to 1 the bit in the position in the bitmap that corresponds to *SN*.

c) For each received Data frame that is related with a specific partial-state operation HT-immediate block ack agreement, when a temporary record for the agreement related with the received Data frame exists at the time of receipt of the Data frame, the temporary block acknowledgment record for that agreement is modified in the same manner as the acknowledgment record for a full-state agreement described in 10.25.6.3.

d) For each received BlockAckReq frame that is related with a specific partial-state operation HT-immediate block ack agreement that is not a protected block ack agreement, when no temporary record for the agreement related with the received frame exists at the time of receipt of the frame, a temporary block acknowledgment record is created as follows, where *SSN* is the starting value of the Sequence Number subfield of the received BlockAckReq frame:

1) $WinStart_R = SSN$.
2) $WinEnd_R = WinStart_R + WinSize_R - 1$.
3) Create a bitmap of size $WinSize_R$, and set all bits in the bitmap to 0.

e) For each received BlockAckReq frame that is related with a specific partial-state operation HT-immediate block ack agreement that is not a protected block ack agreement, when a temporary record for the agreement related with the received frame exists at the time of receipt of the frame, the temporary block acknowledgment record for that agreement is modified in the same manner as the acknowledgment record for a full-state agreement described in 10.25.6.3.

10.25.6.5 Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA

Except when operating within a PSMP exchange, a STA that receives a PPDU that contains a BlockAckReq frame in which the Address 1 field matches its MAC address during either full-state operation or partial-state operation shall transmit a PPDU containing a BlockAck frame that is separated on the WM by a SIFS from the PPDU that elicited the BlockAck frame as a response. A STA that receives an A-MPDU that contains one or more QoS Data frames with Implicit BAR ack policy during either full-state operation or partial-state operation shall transmit a PPDU containing a BlockAck frame that is separated on the WM by a SIFS from the PPDU that elicited the BlockAck frame as a response.

When responding with a BlockAck frame to either a received BlockAckReq frame or a received QoS Data frame with Implicit BAR ack policy during either full-state operation or partial-state operation, any adjustment to the value of $WinStart_R$ according to the procedures defined within 10.25.6.3 and 10.25.6.4 shall be performed before the generation and transmission of the response BlockAck frame. The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield of the BlockAck frame shall be set to any value in the range ($WinEnd_R - 63$) to $WinStart_R$. The Starting Sequence Number subfield stored in the Starting Sequence Control field of NDP BlockAck and BAT frames shall be set to $WinStart_R$. The values in the recipient's record of status of MPDUs beginning with the MPDU for which the Sequence Number subfield value is equal to $WinStart_R$ and ending with the MPDU for which the Sequence Number subfield value is equal to $WinEnd_R$ shall be included in the bitmap of the BlockAck frame. The bitmap of the NDP BlockAck frame is protected using the encoding procedure described in 10.57.

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When responding with a BlockAck frame to either a received BlockAckReq frame or a received QoS Data frame with Implicit BAR ack policy during either full-state or partial-state operation, if the adjusted value of $WinStart_R$ is greater than the value of the starting sequence number of the BlockAck frame, within the bitmap of the BlockAck frame, the status of MPDUs with sequence numbers that are less than the adjusted value of $WinStart_R$ may be set to any value.

When responding with a BlockAck frame to either a received BlockAckReq frame or a received QoS Data frame with Implicit BAR ack policy during either full-state or partial-state operation, if the adjusted value of $WinEnd_R$ is less than the value of the starting sequence number of the BlockAck frame plus 63, within the bitmap of the BlockAck frame, the status of MPDUs with sequence numbers that are greater than the adjusted value of $WinEnd_R$ shall be reported as not received (i.e., the corresponding bit in the bitmap shall be set to 0).

If a BlockAckReq frame is received and no matching partial state is available, the recipient shall send a null BlockAck frame in which the bitmap is set to all 0s.

10.25.6.6 Receive reordering buffer control operation

10.25.6.6.1 General

The behavior described in this subclause, 10.25.6.6.2, and 10.25.6.6.3 applies to a STA that uses either partial-state operation or full-state operation for an HT-immediate block ack agreement.

A receive reordering buffer shall be maintained for each HT-immediate block ack agreement. Each receive reordering buffer includes a record comprising the following:

— Buffered MSDUs or A-MSDUs that have been received, but not yet passed up to the next MAC process
— A $WinStart_B$ parameter, indicating the value of the Sequence Number subfield of the first (in order of ascending sequence number) MSDU or A-MSDU that has not yet been received
— A $WinEnd_B$ parameter, indicating the highest sequence number expected to be received in the current reception window
— A $WinSize_B$ parameter, indicating the size of the reception window

$WinStart_B$ is initialized to the Starting Sequence Number subfield value of the ADDBA Request frame that elicited the ADDBA Response frame that established the HT-immediate block ack agreement.

$WinEnd_B$ is initialized to $WinStart_B + WinSize_B - 1$, where $WinSize_B$ is set to the smaller of 64 and the value of the Buffer Size field of the ADDBA Response frame that established the block ack agreement.

Any MSDU or A-MSDU that has been passed up to the next MAC process shall be deleted from the receive reordering buffer.

The recipient shall always pass MSDUs or A-MSDUs up to the next MAC process in order of increasing Sequence Number subfield value.

10.25.6.6.2 Operation for each received Data frame

For each received Data frame that is related to a specific HT-immediate block ack agreement, the receive reordering buffer record shall be modified as follows, where SN is the value of the Sequence Number subfield of the received MPDU:

a) If $WinStart_B \le SN \le WinEnd_B$,
   1) Store the received MPDU in the buffer, if no MSDU with the same sequence number is already present; otherwise discard the MPDU.

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2) Pass MSDUs or A-MSDUs up to the next MAC process if they are stored in the buffer in order of increasing value of the Sequence Number subfield starting with the MSDU or A-MSDU that has $SN=WinStart_B$ or if $SN>WinStart_B$, the STA is a DMG STA, and one of the following conditions is met:
   i) The MPDU is received as non-first frame in the A-MPDU; the bit at position $SN=WinStart_R - 1$ is set to 1; and all delimiters between the received MPDU and the preceding MPDU ($SN=WinStart_R - 1$) are valid.
   ii) The MPDU is received as first frame in the A-MPDU; the A-MPDU is received in SIFS or RIFS after an A-MPDU or in SIFS after transmission of a BlockAck frame; the bit at position $SN=WinStart_R - 1$ is set to 1; and all delimiters after the MPDU ($SN=WinStart_R - 1$) in the preceding A-MPDU are valid.
   iii) The MPDU is received in SIFS or RIFS after an A-MPDU or in SIFS after transmission of a BlockAck frame; the bit at position $SN=WinStart_R - 1$ is set to 1; and all delimiters after the MPDU ($SN=WinStart_R - 1$) in the preceding A-MPDU are valid.
   iv) The MPDU is received as first frame in the A-MPDU; the A-MPDU is received in SIFS or RIFS after an MPDU or in SIFS after transmission of an Ack frame; and the bit at position $SN=WinStart_R - 1$ is set to 1.
   v) The MPDU is received in SIFS or RIFS after the preceding MPDU or in SIFS after transmission of an Ack frame; and the bit at position $SN=WinStart_R - 1$ is set to 1.

   This process is continued sequentially until there is no buffered MSDU or A-MSDU for the next sequential value of the Sequence Number subfield.
3) Set $WinStart_B$ to the value of the Sequence Number subfield of the last MSDU or A-MSDU that was passed up to the next MAC process plus one.
4) Set $WinEnd_B = WinStart_B + WinSize_B - 1$.

b) If $WinEnd_B < SN < WinStart_B + 2^{11}$,
1) Store the received MPDU in the buffer, if no MSDU with the same sequence number is already present; otherwise discard the MPDU.
2) Set $WinEnd_B = SN$.
3) Set $WinStart_B = WinEnd_B - WinSize_B + 1$.
4) Pass any complete MSDUs or A-MSDUs stored in the buffer with Sequence Number subfield values that are lower than the new value of $WinStart_B$ up to the next MAC process in order of increasing Sequence Number subfield value. Gaps may exist in the Sequence Number subfield values of the MSDUs or A-MSDUs that are passed up to the next MAC process.
5) In a non-DMG STA, pass MSDUs or A-MSDUs stored in the buffer up to the next MAC process in order of increasing value of the Sequence Number subfield starting with $WinStart_B$ and proceeding sequentially until there is no buffered MSDU or A-MSDU for the next sequential Sequence Number subfield value. For a DMG STA, follow rules defined in item a)2) above.
6) Set $WinStart_B$ to the Sequence Number subfield value of the last MSDU or A-MSDU that was passed up to the next MAC process plus one.
7) Set $WinEnd_B = WinStart_B + WinSize_B - 1$.

c) If $WinStart_B + 2^{11} \leq SN < WinStart_B$, discard the MPDU (do not store the MPDU in the buffer, and do not pass the MSDU or A-MSDU up to the next MAC process).

10.25.6.6.3 Operation for each received BlockAckReq

For each received BlockAckReq frame that is related with a specific HT-immediate block ack agreement, the receive reordering buffer record is modified as follows, where *SSN* is the Starting Sequence Number subfield value of the received BlockAckReq frame:

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a) If $WinStart_B < SSN < WinStart_B+2^{11}$,
   1) In a block ack agreement that is not a protected block ack agreement, set $WinStart_B = SSN$. See 10.25.7 for a protected block ack agreement.
   2) Set $WinEnd_B = WinStart_B + WinSize_B - 1$.
   3) Pass any complete MSDUs or A-MSDUs stored in the buffer with Sequence Number subfield values that are lower than the new value of $WinStart_B$ up to the next MAC process in order of increasing Sequence Number subfield value. Gaps may exist in the Sequence Number subfield values of the MSDUs or A-MSDUs that are passed up to the next MAC process.
   4) Pass MSDUs or A-MSDUs stored in the buffer up to the next MAC process in order of increasing Sequence Number subfield value starting with $SN=WinStart_B$ and proceeding sequentially until there is no buffered MSDU or A-MSDU for the next sequential Sequence Number subfield value.
   5) Set $WinStart_B$ to the Sequence Number subfield value of the last MSDU or A-MSDU that was passed up to the next MAC process plus one.
   6) Set $WinEnd_B = WinStart_B + WinSize_B - 1$.

b) If $WinStart_B+2^{11} \le SSN \le WinStart_B$, do not make any changes to the receive reordering buffer record.

10.25.6.7 Originator's behavior

A STA may send a block of data in a single A-MPDU where each QoS Data frame has Normal Ack ack policy. The originator expects to receive a BlockAck frame response immediately following the A-MPDU if at least one Data frame is received without error.

If the received BlockAck response is of an expected NDP_1M BlockAck frame (or an NDP_2M BlockAck frame), the S1G originator shall accept it as correctly received if the value obtained from the BlockAck ID field equals the 2 LSBs (or the 6 LSBs) of the Scrambler Initialization value of the immediately previously transmitted A-MPDU that is not an S-MPDU, or BlockAckReq frame and the Starting Sequence Number obtained from the Starting Sequence Control field equals $WinStart_O$. The Scrambler Initialization value is obtained from the PHY-TXEND.confirm parameter SCRAMBLER_OR_CRC. The values of the BlockAck ID and Starting Sequence Number fields are obtained after decoding the NDP BlockAck frame as described in 10.57. The S1G originator shall otherwise consider the NDP BlockAck frame to be lost.

Alternatively, the originator may send an A-MPDU where each QoS Data frame has Block Ack ack policy under an HT-immediate block ack agreement if it does not require a BlockAck frame response immediately following the A-MPDU.

If the BlockAck frame is lost, the originator may transmit a BlockAckReq frame to solicit an immediate BlockAck frame or it may retransmit the Data frames.

During an accepted HT-immediate block ack agreement, the S1G originator shall set the TXVECTOR parameter RESPONSE_INDICATION of a PPDU transmitted to the S1G recipient that elicits a block acknowledgment frame to

— NDP Response if the block ack agreement was negotiated with NDP ADDBA Request/NDP ADDBA Response exchange
— Normal Response if the block ack agreement was negotiated with either BAT ADDBA Request/ BAT ADDBA Response or ADDBA Request/ADDBA Response exchange

During an accepted HT-immediate block ack agreement, the S1G originator is allowed to elicit an NDP BlockAck or a BlockAck frame on a per-PPDU basis only if the block ack agreement was negotiated with either ADDBA Request/NDP ADDBA Response or NDP ADDBA Request/ADDBA Response exchanges. In

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this case the S1G originator may set the TXVECTOR parameter RESPONSE_INDICATION of a PPDU transmitted to the S1G recipient that elicits a block acknowledgment frame to either NDP Response or Normal Response.

The S1G originator shall not set the TXVECTOR parameter RESPONSE_INDICATION to Long Response for a PPDU transmitted to the S1G recipient that elicits a block acknowledgment frame, if neither BlockAck frame nor BAT frames have been negotiated with the S1G recipient. The S1G originator may set the TXVECTOR parameter RESPONSE_INDICATION to Long Response if either BlockAck frame or BAT frames have been negotiated with the S1G recipient.

The originator may transmit QoS Data frames with a TID matching a block ack agreement in any order provided that their sequence numbers lie within the current transmission window. The originator may transmit an MPDU with a sequence number that is beyond the current transmission window ($SN > WinStart_O + WinSize_O - 1$), in which case the originator's transmission window (and the recipient's window) is moved forward. The originator should not transmit an MPDU with a sequence number that is before the current transmission window (i.e., $SN < WinStart_O$).

During an accepted HT-immediate block ack agreement, the S1G originator of an A-MPDU that is not an S-MPDU eliciting an NDP BlockAck frame shall set the Fragment Number subfield in the Sequence Control field of each MPDU in the A-MPDU to $WinStart_O + WinSize_O - 1 - SN$, where SN is the value of the Sequence Number subfield in the corresponding MPDU within the A-MPDU.

The originator shall not retransmit an MPDU after that MPDU's appropriate lifetime limit.

The originator may send a BlockAckReq frame for block ack agreement that is not a protected block ack agreement or a robust ADDBA Request frame for protected block ack agreement when a QoS Data frame that was previously transmitted within an A-MPDU that had Normal Ack ack policy is discarded due to exhausted MSDU lifetime. The purpose of this BlockAckReq or robust ADDBA Request frame is to shift the recipient's $WinStart_B$ value past the hole in the sequence number space that is created by the discarded Data frame and thereby to allow the earliest possible passing of buffered frames up to the next MAC process.

An originator that is a DMG STA shall transmit MPDUs sent under a block ack agreement such that:

— MPDUs that need to be retransmitted are transmitted first, in sequential order of sequence number, starting from the oldest MPDU that needs to be retransmitted
— MPDUs that are being transmitted for the first time are sent after any MPDUs that need to be retransmitted, in sequential order of sequence number, starting from the oldest MPDU that has not been transmitted
— QoS Data MPDUs are transmitted with Block Ack ack policy if the A-MPDU that contains them is followed after SIFS or RIFS by another A-MPDU

An originator that is a DMG STA shall not start a new TXOP or SP with a PPDU containing a QoS Data MPDU that has an ack policy other than Normal Ack or Implicit BAR if at least one frame transmitted by the originator to the recipient in the last PPDU did not require an immediate response.

10.25.6.8 Maintaining block ack state at the originator

If an originator receives a BlockAck frame, the originator updates the status of MPDUs in its transmit buffer that have the same TID as the BlockAck frame, RA equal to the TA of the BlockAck frame and TA equal to the RA of the BlockAck frame. Status update is performed as follows:

— The originator shall not update the status of MPDUs with Sequence Number subfield values between $WinStart_O$ and $SSN - 1$ of the received BlockAck frame, and

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NOTE 1—It is possible for the Starting Sequence Number subfield value (*SSN*) of the received BlockAck frame to be greater than $WinStart_O$ because of the lack of reception of a nonzero number of MPDUs beginning with the MPDU with Sequence Number subfield value equal to $WinStart_O$ at a recipient that is using partial-state operation.

— For each MPDU for which the status is not acknowledged, and for which the corresponding bit of the received bitmap contains a value of 1, and for which the Sequence Number subfield value is between SSN of the received BlockAck frame and $WinStart_O + WinSize_O - 1$, the originator shall change its status to acknowledged.

NOTE 2—This second rule means that if an originator successfully delivered an MPDU and received the BlockAck frame in one TXOP and then receives a BlockAck frame in a later TXOP in which the MPDU is not indicated as received (i.e., the corresponding bit of the received bitmap is 0 because the partial state has been reset), the originator knows not to retry the MPDU.

10.25.6.9 Originator's support of recipient's partial state

A recipient may choose to employ either full-state operation or partial-state operation for each individual block ack agreement. An originator is unaware of the recipient's choice of full-state or partial-state operation.

NOTE—The originator might solicit a BlockAck frame as the last activity associated with that block ack agreement in the current TXOP to reduce the probability that data are unnecessarily retransmitted due to loss of partial state.

10.25.7 Protected block ack agreement

A STA indicates support for protected block ack by setting the RSN Capabilities field subfields MFPC, MFPR and PBAC to 1. Such a STA is a PBAC STA; otherwise, the STA is a non-PBAC STA. A block ack agreement that is successfully negotiated between two PBAC STAs is a protected block ack agreement. A block ack agreement that is successfully negotiated between two STAs when either or both of the STAs is not a PBAC STA is a block ack agreement that is not a protected block ack agreement.

A PBAC STA may choose to negotiate a block ack agreement with a non-PBAC STA if dot11RSNAPBACRequired is 0; otherwise, it shall negotiate a block ack agreement only with other PBAC STAs. If a PBAC STA is communicating with a non-PBAC STA, it shall follow the rules for a nonprotected block ack agreement.

A STA that has successfully negotiated a protected block ack agreement shall obey the following rule as a block ack originator in addition to rules specified in 10.25.6.7 and 10.25.6.8:

— To change the value of $WinStart_B$ at the receiver, the STA shall use a robust ADDBA Request frame.

A STA that has successfully negotiated a protected block ack agreement shall obey the following rules as a block ack recipient in addition to rules specified in 10.25.6.3 to 10.25.6.6:

— The recipient STA shall respond to a BlockAckReq frame from a PBAC enabled originator with an immediate BlockAck frame. The Block Ack Starting Sequence Control subfield value shall be ignored for the purposes of updating the value of $WinStart_B$. The Block Ack Starting Sequence Control subfield value may be utilized for the purposes of updating the value of $WinStart_R$. If the Block Ack Starting Sequence Control subfield value is greater than $WinEnd_B$ or less than $WinStart_B$, dot11PBACErrors shall be incremented by 1.

— Upon receipt of a valid robust ADDBA Request frame for an established protected block ack agreement whose TID and transmitter address are the same as those of the block ack agreement, the STA shall update its $WinStart_R$ and $WinStart_B$ values based on the starting sequence number in the robust ADDBA Request frame according to the procedures outlined for reception of BlockAckReq frames in 10.25.6.3, 10.25.6.4, 10.25.6.6.1, and 10.25.6.6.3, while treating the starting sequence

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number as though it were the *SSN* of a received BlockAckReq frame. Values in other fields of the ADDBA Request frame shall be ignored.

10.25.8 GCR and GLK-GCR block ack

10.25.8.1 Introduction

Subclause 10.25.8 extends the block ack mechanism to group addressed frames that are transmitted using the GCR block ack and GLK-GCR retransmission policies. Other than the exceptions noted in 10.25.8.2 to 10.25.8.4, the operation of GCR block ack is the same as is described in 10.25.6.

10.25.8.2 Scoreboard context control during GCR block ack

For each GCR block ack agreement, each recipient shall maintain a block acknowledgment record. This record includes the following information:

— A bitmap, indexed by sequence number
— A 12-bit unsigned integer starting sequence number
— $WinStart_R$, representing the lowest sequence number position in the bitmap
— $WinEnd_R$, representing the highest sequence number in the current transmission window
— The maximum transmission window size, $WinSize_R$

$WinSize_R$ is set to the smaller of 64 and the value of the Buffer Size field of the associated ADDBA Response frame that established the block ack agreement. $WinEnd_R$ is defined as the highest sequence number in the current transmission window. A STA implementing a GCR block ack agreement shall maintain the block acknowledgment record for that agreement according to the following rules:

a) At GCR block ack agreement establishment:
   1) $WinStart_R$ = the Starting Sequence Number subfield value (*SSN*) from the ADDBA Request frame that elicited the ADDBA Response frame that established the GCR block ack agreement.
   2) $WinEnd_R = WinStart_R + WinSize_R - 1$.
b) For each received Data frame that is related with a specific GCR block ack agreement, the block acknowledgment record for that agreement is modified as follows, where *SN* is the value of the Sequence Number subfield of the received Data frame:
   1) If $WinStart_R \le SN \le WinEnd_R$, set to 1 the bit in position *SN* within the bitmap.
   2) If $WinEnd_R < SN < WinStart_R + 2^{11}$,
      i) Set to 0 the bits corresponding to MPDUs with Sequence Number subfield values from $WinEnd_R + 1$ to $SN - 1$.
      ii) Set $WinStart_R = SN - WinSize_R + 1$.
      iii) Set $WinEnd_R = SN$.
      iv) Set to 1 the bit at position *SN* in the bitmap.
   3) If $WinStart_R + 2^{11} \le SN \le WinStart_R$, make no changes to the record.
c) For each received BlockAckReq frame that is related with a specific GCR block ack agreement, the block acknowledgment record for that agreement is modified as follows, where *SSN* is the value from the Starting Sequence Number subfield of the received BlockAckReq frame:
   1) If $WinStart_R < SSN \le WinEnd_R$,
      i) Set $WinStart_R = SSN$.
      ii) Set to 0 the bits corresponding to MPDUs with Sequence Number subfield values from $WinEnd_R + 1$ to $WinStart_R + WinSize_R - 1$.
      iii) Set $WinEnd_R = WinStart_R + WinSize_R - 1$.

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2) If $WinEnd_R < SSN < WinStart_R + 2^{11}$,
   i) Set $WinStart_R = SSN$.
   ii) Set $WinEnd_R = WinStart_R + WinSize_R - 1$.
   iii) Set to 0 bits the corresponding to MPDU with Sequence Number subfield values from $WinStart_R$ to $WinEnd_R$.
3) If $WinStart_R + 2^{11} \leq SSN \leq WinStart_R$, make no changes to the record.

10.25.8.3 Scoreboard context control during GLK-GCR block ack

GLK-GCR scoreboarding accounts for all GLK-GCR frames received under the GLK-GCR block ack agreement. The received frame may be discarded after SYNRA filtering (see 10.65) but still accounted for in the scoreboarding.

A GLK AP may set up a GLK-GCR block ack agreement with each GLK STA that has indicated support for GLK-GCR in the Association/Reassociation Request frame when the GLK STA associated/reassociated with the GLK AP. Each of those GLK STAs with GLK-GCR block ack agreement shall maintain a block acknowledgment record for full state operation as defined in 10.25.3. This record includes the following information:

— A bitmap, indexed by sequence number
— A 12-bit unsigned integer starting sequence number
— $WinStart_R$, representing the lowest sequence number position in the bitmap
— $WinEnd_R$, representing the highest sequence number in the current transmission window
— The maximum transmission window size, $WinSize_R$

$WinSize_R$ is set to the smaller of 64 and the value of the Buffer Size subfield in the GLK-GCR Parameter Set element in the most recently received Association Response or the Reassociation Response frame that established the GLK-GCR block ack agreement, or the GLK Groupcast Mode Change Notification frame. $WinEnd_R$ is defined as the highest sequence number in the current transmission window. A STA implementing a GLK-GCR block ack agreement shall maintain the block acknowledgment record for that agreement according to the following rules:

a) At GCR block ack agreement establishment (either during general link establishment or when GLK-GCR groupcast mode changes):
   1) $WinStart_R$ = the Starting Sequence Number subfield value (SSN) from the GLK-GCR Parameter Set element included in the Association Response frame, Reassociation Response frame or in the GLK-GCR Groupcast Mode Change Notification frame.
   2) $WinEnd_R = WinStart_R + WinSize_R - 1$.
b) For each Data frame that is received under the GLK-GCR block ack agreement, the block acknowledgment record for that agreement is modified as follows, where SN is the value of the Sequence Number subfield in the received Data frame:
   1) If $WinStart_R \leq SN \leq WinEnd_R$, set to 1 the bit in position SN within the bitmap.
   2) If $WinEnd_R < SN < WinStart_R + 2^{11}$,
      i) Set to 0 the bits corresponding to MPDUs with Sequence Number subfield values from $WinEnd_R + 1$ to SN – 1.
      ii) Set $WinStart_R = SN - WinSize_R + 1$.
      iii) Set $WinEnd_R = SN$.
      iv) Set to 1 the bit at position SN in the bitmap.
   3) If $WinStart_R + 2^{11} \leq SN \leq WinStart_R$, make no changes to the record.

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c) For each BlockAckReq frame received under the GLK-GCR block ack agreement, the block acknowledgment record for that agreement is modified as follows, where SSN is the value from the Starting Sequence Number subfield in the received BlockAckReq frame:

1) If $WinStart_R < \text{SSN} \leq WinEnd_R$,
   i) Set $WinStart_R = \text{SSN}$.
   ii) Set to 0 the bits corresponding to MPDUs with Sequence Number subfield values from $WinEnd_R + 1$ to $WinStart_R + WinSize_R - 1$.
   iii) Set $WinEnd_R = WinStart_R + WinSize_R - 1$.
2) If $WinEnd_R < \text{SSN} < WinStart_R + 2^{11}$,
   i) Set $WinStart_R = \text{SSN}$.
   ii) Set $WinEnd_R = WinStart_R + WinSize_R - 1$.
   iii) Set to 0 bits the corresponding to MPDU with Sequence Number subfield values from $WinStart_R$ to $WinEnd_R$.
3) If $WinStart_R + 2^{11} \leq \text{SSN} \leq WinStart_R$, make no changes to the record.

10.25.8.4 GCR block ack BlockAckReq and BlockAck frame exchanges

A protective mechanism (such as transmitting an HCCA CAP, MCCA, or RTS/CTS; setting the Duration field in the first frame and response frames to update the NAVs of STAs in the BSS and OBSS(s); or using another mechanism described in 10.27 and 10.3.2.10) should be used to reduce the probability of other STAs transmitting during the GCR TXOP.

When the retransmission policy for a group address is GCR Block Ack, an originator shall not transmit more than the GCR buffer size number of A-MSDUs with RA set to the GCR concealment address and the DA field of the A-MSDU subframe set to the GCR group address before sending a BlockAckReq frame to one of the STAs that has a GCR block ack agreement for this group address. The RA field of the BlockAckReq frame shall be set to the MAC address of the destination STA. Upon reception of the BlockAck frame, an originator may send a BlockAckReq frame to another STA that has a block ack agreement for this group address, and this process may be repeated multiple times.

NOTE 1—If the originator sends a BlockAckReq frame to a STA with a MAC address that matches the SA in any of the A-MSDUs transmitted during the GCR TXOP, the Block Ack Bitmap subfield does not indicate the MSDUs sourced from this STA. This is because the STA will have discarded all group addressed MPDUs transmitted by the AP that have the source address equal to their MAC address (see 10.3.6).

When a recipient receives a BlockAckReq frame with the GCR Group Address subfield equal to a GCR group address, the recipient shall transmit a BlockAck frame at a delay of SIFS after the BlockAckReq frame. The BlockAck frame acknowledges the STA's reception status of the block of group addressed frames requested by the BlockAckReq frame.

Figure 10-37 shows an example of a frame exchange when the GCR block ack retransmission policy is used. The AP sends several A-MSDUs using the GCR block ack retransmission policy. The AP then sends a BlockAckReq frame to group member 1 of the GCR group, waits for the BlockAck frame, and then sends a BlockAckReq frame to group member 2. After receiving the BlockAck frame from GCR group member 2, the AP determines whether any A-MSDUs need to be retransmitted and sends additional A-MSDUs (some of which might be retransmissions of previous A-MSDUs) using the GCR block ack retransmission policy.

After completing the BlockAckReq and BlockAck frame exchanges, the originator determines from the information provided in the BlockAck bitmap and from the missing BlockAck frames which, if any, A-MSDUs need to be retransmitted.

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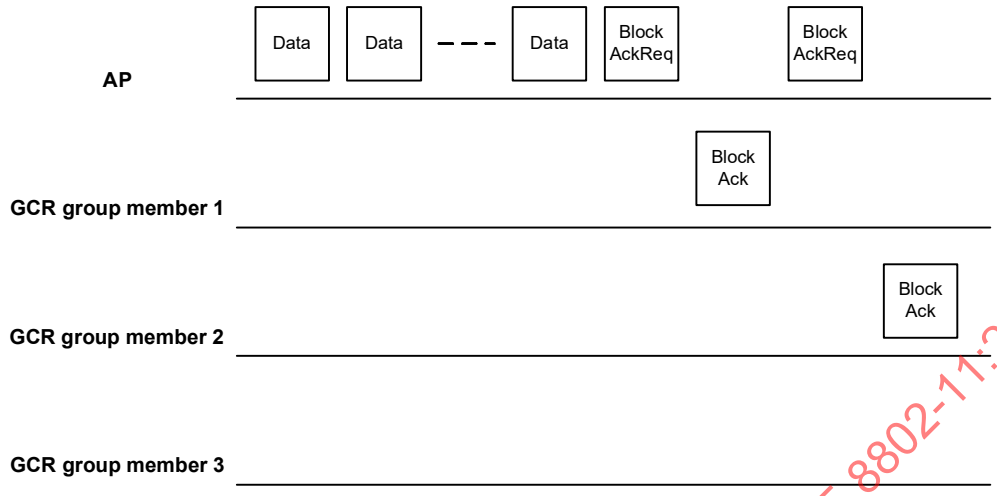

Figure 10-37—Example of frame exchange with GCR block ack retransmission policy

An originator adopting the GCR block ack retransmission policy for a GCR group address chooses a lifetime limit for the group address. The originator may vary the lifetime limit for the group address at any time and may use different lifetime limits for different GCR group addresses. The originator transmits and retries each A-MSDU until the appropriate lifetime limit is reached or until each one has been received by all group members to which a BlockAckReq frame has been sent, whichever occurs first.

For GCR streams with retransmission policy equal to GCR Block Ack, an originator may regularly send a BlockAckReq frame with the GCR Group Address subfield in the BAR Information field set to the GCR group address and the Block Ack Starting Sequence Control subfield set to the Sequence Number field of the earliest A-MSDU of the GCR stream that has not been acknowledged by all group members and has not expired due to lifetime limits, in order to minimize buffering latency at receivers in the GCR group.

NOTE 2—This is because an originator might transmit Management frames, QoS Data frames with a group address in the Address 1 field (including different GCR streams), and non-QoS Data frames intermingled. Since these are transmitted using a single sequence counter, missing frames or frames sent to group addresses absent from a receiving STA's dot11GroupAddresses table complicate receiver processing for GCR streams with a GCR block ack retransmission policy since the cause of a hole in a receiver's block ack bitmap is ambiguous: it is due either to an MPDU being lost from the GCR stream or to transmissions of MPDUs not related to the GCR service using the same sequence number counter.

For GLK-GCR transmissions with retransmission policy equal to GLK-GCR block ack, an originator may send a BlockAckReq frame with the Block Ack Starting Sequence Control subfield set to the Sequence Number field in the MPDU containing the earliest MSDU that has not been acknowledged and has not expired due to lifetime limits, in order to minimize buffering latency at the receivers of the GLK-GCR transmission.

If an originator accepts two or more GCR agreements with multiple STAs where the GCR agreements have the same Ethernet classifiers, but different additional classifiers, then each STA receives multiple GCR flows from the originator and sends them to upper layers where the MSDUs irrelevant to the STA are discarded, in the same manner that non-GCR MSDUs irrelevant to the STA are discarded. In the Block Ack Bitmap field sent to the originator, each STA sets bits corresponding to MPDUs received from any of the multiple GCR streams. The originator should not retry MPDUs to the STA for the bit positions that are irrelevant to that STA.

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The beginning of reception of an expected response to a BlockAckReq frame is detected by the occurrence of a PHY-CCA.indication(BUSY, channel-list) primitive at the STA that is expecting the response where the channel-list parameter is absent or, if present, includes "primary."

If the beginning of such reception does not occur during the first slot time following a SIFS, then the originator may perform error recovery by retransmitting a BlockAckReq frame PIFS after the previous BlockAckReq frame when both of the following conditions are met:

— The carrier sense mechanism (see 10.3.2.1) indicates that the medium is idle at the TxPIFS slot boundary (see Figure 10-25) after the expected start of a BlockAck frame, and

— The remaining duration of the GCR TXOP is longer than the total time required to retransmit the GCR BlockAckReq frame plus one slot time.

NOTE 3—If an originator fails to receive a BlockAck frame in response to a BlockAckReq frame and there is insufficient time to transmit a recovery frame, the AP retransmits the BlockAckReq frame in a new TXOP.

10.25.9 DMG block ack with flow control

10.25.9.1 General

A DMG STA indicates that it is capable of supporting DMG block ack with flow control by setting the BA with Flow Control field to 1 within the STA's DMG Capabilities element. A DMG block ack agreement with flow control can be established only when both originator and recipient support this capability.

10.25.9.2 DMG block ack architecture with flow control

The DMG block ack rules are explained in terms of the architecture shown in Figure 10-38 and explained in this subclause.

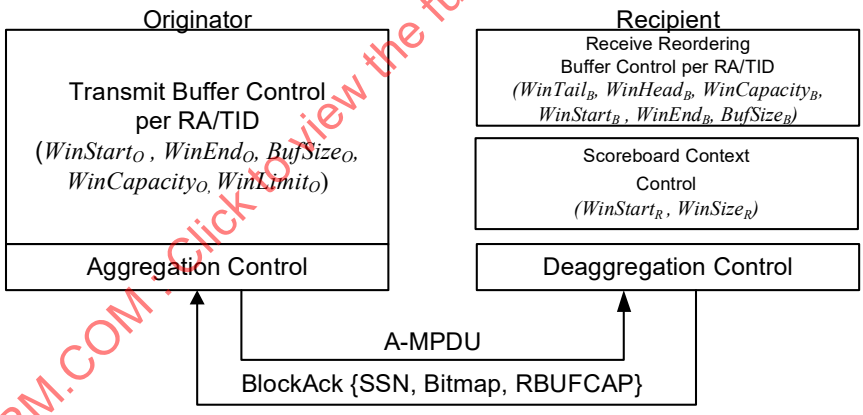

Figure 10-38—DMG block ack architecture

The originator contains a transmit buffer control that uses $WinStart_O$, $BufSize_O$, and $WinLimit_O$ to submit MPDUs for transmission, and releases transmit buffers upon receiving BlockAck frames from the recipient or when it advances the transmit control buffer window.

$WinStart_O$ is the starting sequence number of the transmit range, $WinLimit_O$ is the last sequence number expected to exhaust the receiver buffer capacity, and $BufSize_O$ is the number of buffers negotiated in the block ack agreement.

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Figure 10-39 shows the DMG block ack with flow control and its associated parameters from the originator perspective.

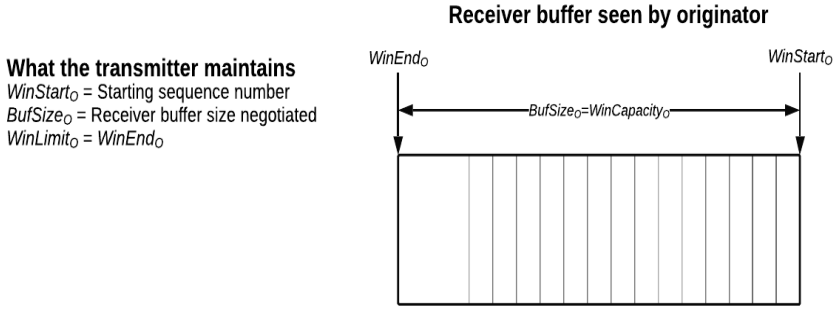

Figure 10-39—Flow control and its associated parameters as a function of receiver buffer size

The Aggregation control creates A-MPDUs. It can adjust the ack policy of transmitted QoS Data frames according to the rules defined in 10.25.6.7 in order to solicit block ack responses.

The recipient contains a Receive Reordering Buffer Control per TA/TID, which contains related control state.

The receive reordering buffer is responsible for reordering MSDUs or A-MSDUs so that MSDUs or A-MSDUs are eventually passed up to the next MAC process in order of received sequence number (SN). It maintains its own state independent of the scoreboard context control to perform this reordering as specified in 10.25.6.6. The delivery of in order MSDUs or A-MSDUs to the next MAC process is implementation dependent. In some cases, the receiver reordering buffer might be forced to hold on to MSDUs ready for in order delivery due to deferred reception at the next MAC process. This behavior can impose additional buffering requirements on the receiver, causing the actual available buffer capacity to vary dynamically. The reordering buffer is required to manage its lowest and highest (in order) SN, which are marked as $WinTail_B$ and $WinHead_B$, respectively.

The scoreboard context control provides the $WinCapacity_B$, actually controlled by the Reordering buffer in addition to the bitmap field and the Starting Sequence Number (SSN) field to be sent in BlockAck frame responses to the originator.

10.25.9.3 Scoreboard context control with flow control

The scoreboard context control with flow control is defined in 10.25.6.3 and 10.25.6.4.

10.25.9.4 Receive Reordering Buffer with flow control operation

10.25.9.4.1 General

A recipient shall maintain a receive reordering buffer for each DMG block ack agreement. Each receive reordering buffer includes a record comprising the following:

— Buffered MSDUs or A-MSDUs that have been received, but not yet passed up to the next MAC process
— A $WinStart_B$ parameter, indicating the value of the Sequence Number field (SN) of the first (in order of ascending sequence number) MSDU or A-MSDU that has not yet been received
— A $WinEnd_B$ parameter, indicating the highest SN expected to be received in the current reception range

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— A $BufSize_B$ parameter, indicating the size of the reception window
— A $WinTail_B$ parameter, indicating the value of the Sequence Number field (SN) of the first (in order of ascending sequence number) MSDU or A-MSDU that has not yet been delivered to the next MAC process
— A $WinHead_B$ parameter, indicating the highest SN received in the current reception range

$WinStart_B$ is initialized to the Starting Sequence Number field value (SSN) of the ADDBA Request frame that elicited the ADDBA Response frame that established the DMG block ack agreement.

$WinEnd_B$ is initialized to $WinStart_B + BufSize_B - 1$, where $BufSize_B$ is set to the value of the Buffer Size field of the ADDBA Response frame that established the block ack agreement.

Both $WinTail_B$ and $WinHead_B$ are initialized to the preceding Starting Sequence Number field value (SSN – 1), to indicate no MPDU was received, within the current reception window.

Any MSDU or A-MSDU that has been passed up to the next MAC process shall be deleted from the receive reordering buffer, advancing the $WinTail_B$.

The recipient shall pass MSDUs or A-MSDUs up to the next MAC process in order of increasing Sequence Number field value.

10.25.9.4.2 Operation for DMG block ack agreement initialization

At DMG block ack agreement establishment:

a) $WinStart_B = SSN$ from the ADDBA Request frame that elicited the ADDBA Response frame that established the DMG block ack agreement
b) $WinEnd_B = WinStart_B + BufSize_B - 1$
c) $WinCapacity_B = BufSize_B$
d) $WinHead_B = SSN - 1$, where SSN is taken from the ADDBA Request, similar to $WinStart_B$
e) $WinTail_B = SSN - 1$

10.25.9.4.3 Operation for each received Data frame

For each received Data frame that is related to a specific DMG block ack agreement, the receive reordering buffer record is modified as follows, where SN is the value of the Sequence Number field of the received MPDU:

a) If $WinStart_B \le SN \le WinEnd_B$
    1) Store the received MPDU in the buffer.
        i) If $SN > WinHead_B$, Set $WinHead_B = SN$.
        ii) If $SN > (WinTail_B + BufSize_B)$,
            1) All MSDU buffers with sequence numbers from $WinTail_B$ to $SN - BufSize_B$ that were received correctly are passed to the next MAC process.
            2) Set $WinTail_B = SN - BufSize_B$.
        iii) Set $WinCapacity_B = WinTail_B + BufSize_B - WinHead_B$.
    2) Set $WinStart_B$ to the value of the Sequence Number field of the first MSDU or A-MSDU that is missing to allow in-order delivery to the next MAC process.
    3) Set $WinEnd_B = WinStart_B + BufSize_B - 1$.
b) If $WinEnd_B < SN < WinStart_B + 2^{11}$
    1) Store the received MPDU in the buffer.

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2) Set $WinEnd_B = SN$.
3) Set $WinStart_B = WinEnd_B - BufSize_B + 1$.
4) All MSDU buffers with sequence numbers from $WinTail_B$ to $SN - BufSize_B$ that were received correctly are passed to the next MAC process.
5) Set $WinTail_B = SN - BufSize_B$.
6) Set $WinHead_B = SN$.
7) Set $WinCapacity_B = WinTail_B + BufSize_B - WinHead_B$.

c) If $WinStart_B + 2^{11} \leq SN < WinStart_B$, discard the MPDU (do not store the MPDU in the buffer, do not pass the MSDU or A-MSDU up to the next MAC process).

d) For each received BlockAckReq frame the block acknowledgment record for that agreement is modified as follows, where SSN is the value from the Starting Sequence Number field of the received BlockAckReq frame:

1) If $WinStart_B < SSN \leq WinEnd_B$
   i) Set $WinStart_B = SSN$.
   ii) Set $WinEnd_B = WinStart_B + BufSize_B - 1$.
   iii) If $SSN > WinHead_B$, set $WinHead_B = SSN - 1$.
   iv) If $SSN > (WinTail_B + BufSize_B)$,
      1) All MSDU buffers with sequence numbers from $WinTail_B$ to $SSN - BufSize_B$, are discarded from the buffer.
      2) Set $WinTail_B = SSN - BufSize_B$.
   v) Set $WinCapacity_B = WinTail_B + BufSize_B - WinHead_B$.
2) If $WinEnd_B < SSN < WinStart_B + 2^{11}$
   i) Set $WinStart_B = SSN$.
   ii) Set $WinEnd_B = WinStart_B + BufSize_B - 1$.
   iii) Set $WinHead_B = SSN - 1$.
   iv) If $SSN > (WinTail_B + BufSize_B)$,
      1) All MSDU buffers with sequence numbers from $WinTail_B$ to $SSN - BufSize_B$, are discarded from the buffer.
      2) Set $WinTail_B = SSN - BufSize_B$.
   v) Set $WinCapacity_B = WinTail_B + BufSize_B - WinHead_B$.
3) If $WinStart_B + 2^{11} \leq SSN \leq WinStart_B$, make no changes to the record.

10.25.9.4.4 Operation for ongoing release of received MPDUs

The reordering buffer shall continue to pass MSDUs or A-MSDUs up to the next MAC process that are stored in the buffer in order of increasing value of the Sequence Number field, starting with the MSDU or A-MSDU that has $SN = WinTail_B$ and proceeding sequentially until there is no ready in-order MSDU or A-MSDU buffered for the next sequential value of the Sequence Number field.

a) Set $WinTail_B$ to the value of the Sequence Number field of the last MSDU or A-MSDU that was passed up to the next MAC process plus one.

10.25.9.5 Generation and transmission of BlockAck frame by a STA with flow control

In addition to the behavior specified in 10.25.6.5 when responding with a BlockAck frame, the RBUFCAP field shall be updated with the value of $WinCapacity_B$.

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10.25.9.6 Originator's behavior with flow control support

If the BA with Flow Control field within a recipient's DMG Capabilities element is equal to 1, the originator shall not transmit an MPDU with a SN that is beyond the current recipient's buffer capacity ($WinLimit_O$).

The BlockAck frame indicates the number of free buffer slots available at the recipient for reception of additional MPDUs.

The originator shall update $WinLimit_O$ upon reception of a valid BlockAck:

— Set $WinCapacity_O$ to the received value of the RBUFCAP field in the BlockAck frame.
— Set *MostSuccSN* to the highest *SN* of positively acknowledged MPDUs
— Set $WinLimit_O = MostSuccSN + WinCapacity_O$

NOTE—Updating $WinLimit_O$ limits the transmission of the following MPDUs.

Originator's support of recipient's partial state is defined in 10.25.6.9.

10.26 No Acknowledgment (No Ack)

When a QoS Data frame is transmitted with No Ack ack policy, there is no MAC-level recovery, and the reliability of this traffic is reduced, relative to the reliability of traffic with other ack policy, due to the increased probability of lost frames from interference, collisions, or time-varying channel parameters. A protective mechanism (such as transmitting using HCCA, RTS/CTS, or the mechanism described in 10.27) should be used to reduce the probability of other STAs transmitting during the TXOP.

10.27 Protection mechanisms

10.27.1 Introduction

These protection mechanisms cause a STA that is a potential interferer to defer any transmission for a known period of time. When these mechanisms are used, non-ERP STAs do not interfere with frame exchanges using ERP PPDUs between ERP STAs and non-HT STAs do not interfere with frame exchanges using HT PPDUs between HT STAs.

10.27.2 Protection mechanism for non-ERP receivers

The intent of a protection mechanism is to cause a STA not to transmit an MPDU with the Type subfield equal to Data or an MMPDU with an ERP-OFDM preamble and header unless it has attempted to update the NAV of receiving non-ERP STAs. The updated NAV period shall be longer than or equal to the total time required to send the Data and any required response frames. An ERP STA shall use protection mechanisms (such as RTS/CTS or CTS-to-self) for ERP-OFDM MPDUs with the Type subfield equal to Data or an MMPDU when the Use_Protection field of the ERP element is equal to 1 (see the requirements of 10.6). Protection mechanisms frames shall be sent using one of the mandatory Clause 15 or Clause 16 rates and using one of the mandatory Clause 15 or Clause 16 waveforms, so all STAs in the BSA are able to learn the duration of the exchange even if they cannot detect the ERP-OFDM signals using their CCA function.

In the case of a BSS composed of only ERP STAs, but with knowledge of a neighboring co-channel BSS having non-ERP traffic, the AP might need protection mechanisms to protect the BSS's traffic from interference. This provides propagation of NAV to all attached STAs and all STAs in a neighboring co-channel BSS within range by messages sent using rates contained in the BSSBasicRateSet parameter. The frames that propagate the NAV throughout the BSS include RTS/CTS/Ack frames, all Data frames with the More Fragments field equal to 1, all Data or Management frames sent in response to PS-Poll frame that are not

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proceeded in the frame exchange sequence by a Data frame with the More Fragments field equal to 1, and CF-End frames.

When RTS/CTS is used as the protection mechanism, cases exist such as NAV resetting (discretionary, as indicated in 10.3.2.4), where a hidden STA may reset its NAV and this might cause a collision. The likelihood of occurrence is low, and it is not considered to represent a significant impairment to overall system operation. A mechanism to address this possible situation would be to use alternative protection mechanisms or to revert to alternative modulation methods.

The rules for calculating RTS/CTS NAV fields are unchanged when using RTS/CTS as a protection mechanism.

Additionally, if any of the rates in the BSSBasicRateSet parameter of the protection mechanism frame transmitting STA's BSS are Clause 15 or Clause 16 rates, then the protection mechanism frames shall be sent at one of those Clause 15 or Clause 16 basic rates.

The NonERP_Present bit shall be set to 1 when a non-ERP STA is associated with the BSS. In an IBSS if an IBSS STA detects one or more non-ERP STAs that are members of the same IBSS the NonERP_Present bit should be set to 1. Examples of when the NonERP_Present bit may additionally be set to 1 include, but are not limited to, when:

a) A non-ERP infrastructure BSS or non-ERP IBSS is overlapping (a non-ERP BSS may be detected by the reception of a Beacon frame where the supported rates contain only Clause 15 or Clause 16 rates).
b) In an IBSS if a Beacon frame is received from one of the IBSS participants where the operational rate set contains no Clause 18 rates and no BSS membership selectors.
c) A Management frame (excluding a Probe Request) is received where the operational rate set contains no Clause 18 rates and no BSS membership selectors.

A non-ERP mesh STA shall set the NonERP_Present and Use_Protection bits to 1, when establishing a mesh peering with a mesh STA.

When a mesh STA establishes a mesh peering with a non-ERP mesh STA, the mesh STA shall set the NonERP_Present bit to 1 and the mesh STA should set the Use_Protection bit to 1. In addition, a mesh STA should set the NonERP_Present bit and the Use_Protection bit to 1 when

— A mesh STA detects the overlapped presence of either a non-ERP BSS, a non-ERP IBSS, or a non-ERP MBSS, or
— A Beacon frame is received from a neighbor STA where the operational rate set contains no Clause 18 rates and no BSS membership selectors, or
— A Management frame (excluding Probe Request) is received where the operational rate set contains no Clause 18 rates and no BSS membership selectors.

A mesh STA may set the NonERP_Present and the Use_Protection bits to 1 based on its internal policies, which is beyond the scope of the standard.

The Use_Protection bit may be set to 1 when the NonERP_Present bit is 1.

If one or more non-ERP STAs are associated in the BSS, the Use_Protection bit shall be set to 1 in transmitted ERP elements.

In an IBSS the setting of the Use_Protection bit is left to the STA. In an IBSS there is no uniform concept of association; therefore, a typical algorithm for setting the Use_Protection bit takes into account the traffic pattern and history on the network. If an IBSS STA detects one or more non-ERP STAs that are members of

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the same IBSS or receives a Beacon from a member of the same IBSS with the Use_Protection bit equal to 1, then the Use_Protection bit should be set to 1 in the ERP element of transmitted Beacon and Probe Response frames.

An ERP STA shall invoke the use of a protection mechanism after transmission or reception of the Use_Protection bit with a value of 1 in an MMPDU to or from the BSS that the ERP STA has joined or started. An ERP STA may additionally invoke protection mechanism use at other times. An ERP STA may disable protection mechanism use after transmission or reception of the Use_Protection bit with a value of 0 in an MMPDU to or from the BSS that the ERP STA has joined or started.

An ERP mesh STA shall invoke the use of a protection mechanism after the transmission of the Use_Protection bit with a value of 1 in an MMPDU. In addition, an ERP mesh STA may invoke protection mechanism at other times. An ERP mesh STA may disable protection mechanism use after transmission of the Use_Protection bit with a value of 0 in an MMPDU.

When there are no non-ERP STAs associated with the BSS and the ERP element sender's dot11ShortPreambleOptionImplemented is true, then the Barker_Preamble_Mode bit may be set to 0. The Barker_Preamble_Mode bit shall be set to 1 by the ERP element sender if one or more associated non-ERP STAs are not short preamble capable as indicated in their Capability Information field, or if the ERP element senders dot11ShortPreambleOptionImplemented is false.

When dot11ShortPreambleOptionImplemented is true and all peer mesh STAs support the short preamble, the mesh STA may set the Barker_Preamble_Mode bit to 0. When dot11ShortPreambleOptionImplemented is false or any of its peer mesh STAs do not support the short preamble, the mesh STA shall set the Barker_Preamble_Mode field to 1.

If an IBSS STA detects one or more nonshort-preamble-capable STAs that are members of the same IBSS, then the Barker_Preamble_Mode bit should be set to 1 in the transmitted ERP element.

An ERP STA shall use long preambles when transmitting Clause 15, Clause 16, and Clause 18 frames after transmission or reception of an ERP element with a Barker_Preamble_Mode value of 1 in an MMPDU to or from the BSS that the ERP STA has joined or started, regardless of the value of the short preamble capability bit from the same received or transmitted MMPDU that contained the ERP element. An ERP STA may additionally use long preambles when transmitting Clause 15, Clause 16, and Clause 18 frames at other times. An ERP STA may use short preambles when transmitting Clause 15, Clause 16, and Clause 18 frames after transmission or reception of an ERP element with a Barker_Preamble_Mode value of 0 in an MMPDU to or from the BSS that the ERP STA has joined or started, regardless of the value of the short preamble capability bit from the same received or transmitted MMPDU. A non-ERP STA may also follow the rules given in this paragraph.

An ERP mesh STA shall use long preambles when transmitting Clause 15, Clause 16, and Clause 18 frames after transmission or reception of an ERP element with a Barker_Preamble_Mode value of 1 in an MMPDU to or from the MBSS to which the ERP mesh STA belongs. A Mesh STA may use long preambles when transmitting Clause 15, Clause 16, and Clause 18 frames at other times.

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10.27.3 Protection mechanisms for transmissions of HT PPDUs

10.27.3.1 General

Transmissions of HT PPDUs, referred to as *HT transmissions*, are protected if there are other STAs present that cannot interpret HT transmissions correctly. The HT Protection and Nongreenfield HT STAs Present fields in the HT Operation element within Beacon and Probe Response frames are used to indicate the protection requirements for HT transmissions.

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The HT Protection field may be set to no protection mode only if the following are true:

- All STAs detected (by any means) in the primary or the secondary channel are HT STAs, and
- All STAs that are known by the transmitting STA to be a member of this BSS are either
  - 20/40 MHz HT STAs in a 20/40 MHz BSS, or
  - 20 MHz HT STAs in a 20 MHz BSS.

The HT Protection field may be set to nonmember protection mode only if the following are true:

- A non-HT STA is detected (by any means) in either the primary or the secondary channel or in both the primary and secondary channels, that is not known by the transmitting STA to be a member of this BSS, and
- All STAs that are known by the transmitting STA to be a member of this BSS are HT STAs.

The HT Protection field may be set to 20 MHz protection mode only if the following are true:

- All STAs detected (by any means) in the primary channel and all STAs detected (by any means) in the secondary channel are HT STAs and all STAs that are members of this BSS are HT STAs, and
- This BSS is a 20/40 MHz BSS, and
- There is at least one 20 MHz HT STA associated with this BSS.

The HT Protection field is set to non-HT mixed mode otherwise.

NOTE 1—The rules stated above allow an HT AP to select non-HT mixed mode at any time.

In an IBSS, the HT Protection field is reserved, but an HT STA shall protect HT transmissions as though the HT Protection field were equal to non-HT mixed mode. An IBSS STA shall protect HT-greenfield format PPDUs and RIFS sequences, adhering to the same requirements as described in the line of Table 10-22 labeled "Use_Protection = 0 or ERP element is not present (HT Protection field equal to non-HT mixed mode)."

Table 10-22—Protection requirements for HT Protection field values nonmember protection mode and non-HT mixed mode

Condition	Requirements
Use_Protection = 0 or ERP element is not present (HT Protection field equal to non-HT mixed mode)	The protection requirements for HT transmissions using HT-greenfield format are specified in 10.27.3.1. The protection requirements for HT transmissions using RIFS within the HT transmission burst are specified in 10.27.3.3. The protection mechanism for other transmissions not already described above is based on one of the sequences defined in Table 10-23.
Use_Protection = 1 (HT Protection field equal to nonmember protection mode or non-HT mixed mode)	All HT transmissions shall be protected using mechanisms as described in 10.27.2.

In an MBSS, the HT Protection field and the Nongreenfield HT STAs Present field are determined as described in 10.27.3.5.

In an IBSS and an MBSS, the RIFS Mode field of the HT Operation element is reserved, but an HT STA shall operate as though this field were equal to 1.

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When the HT Protection field is equal to no protection mode or 20 MHz protection mode and the Nongreenfield HT STAs Present field is equal to 0, no protection is required since all HT STAs in the BSS are capable of decoding HT-mixed format and HT-greenfield format transmissions.

When the HT Protection field is equal to no protection mode or 20 MHz protection mode and the Nongreenfield HT STAs Present field is equal to 1, HT transmissions that use the HT-greenfield format shall be protected. This protection may be established by transmitting a PPDU with the TXVECTOR FORMAT parameter set to HT_MF or any of the methods described in Table 10-23.

Table 10-23—Applicable HT protection mechanisms

HT protection mechanism
Control frames such as RTS/CTS or CTS-to-self prior to the HT transmissions: — 20 MHz transmissions use the rates defined in Clause 17 or Clause 18 — 40 MHz transmissions use non-HT duplicate frames defined in Clause 19
As the first PPDU in the TXOP, send one of: — A non-HT PPDU containing a frame that requires an immediate response — An HT-mixed format PPDU containing a frame that requires an immediate response in a non-HT PPDU PPDUs after the first PPDU exchange may be HT-greenfield format PPDUs and/or be separated by RIFS.

When the HT Protection field is equal to nonmember protection mode and the Use_Protection field in the ERP element is equal to 0, HT transmissions should be protected. When the HT Protection field is equal to nonmember protection mode, the Use_Protection field in the ERP element is equal to 0, and the Nongreenfield HT STAs Present field is equal to 1, HT transmissions using HT-greenfield format shall be protected. When the HT Protection field is equal to nonmember protection mode and the Use_Protection field in the ERP element is equal to 1, HT transmissions shall be protected according to the requirements described in Table 10-22.

When the HT Protection field is equal to non-HT mixed mode, HT transmissions shall be protected. The type of protection required depends on the type of transmission as well as the type of the non-HT STAs that are present in the BSS. Protection requirements that apply when the HT Protection field is equal to non-HT mixed mode are described in Table 10-22.

NOTE 2—Rules for rate selection for the HT protection mechanisms listed in Table 10-23 are described in 10.6.

If the HT Protection field is equal to no protection mode and the Secondary Channel Offset field is equal to SCA or SCB, a STA may transmit a 40 MHz HT PPDU (TXVECTOR parameter CH_BANDWIDTH set to HT_CBW40) to initiate a TXOP provided that the restrictions specified in 10.6 are obeyed. When the HT Protection field is not equal to no protection mode or the Secondary Channel Offset field is equal to SCN, a STA shall not transmit a 40 MHz HT PPDU (TXVECTOR parameter CH_BANDWIDTH set to HT_CBW40) to initiate a TXOP.

10.27.3.2 Protection rules for HT STA operating a direct link

An HT STA operating a direct link with another HT STA in a non-HT BSS shall operate according to the rules found in 10.27 as though the following fields have the settings indicated:

a) The RIFS Mode field of the HT Operation element equal to 1
b) The HT Protection field equal to non-HT mixed mode

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c) The Nongreenfield HT STAs Present field equal to 1
d) The OBSS Non-HT STAs Present field equal to 1
e) The Basic HT-MCS Set field equal to all 0s

10.27.3.3 RIFS protection

If the HT Protection field is equal to nonmember protection mode or non-HT mixed mode, the AP may set the RIFS Mode field to 0 according to implementation-specific criteria (i.e., such as to protect overlapping non-HT BSSs in the primary or secondary channels).

If the HT Protection field is not equal to nonmember protection mode and it is not equal to non-HT mixed mode, the RIFS Mode field shall be set to 1.

If the RIFS Mode field of an AP's HT Operation element is equal to 1:

a) A STA that is associated with the AP may protect RIFS sequences when the HT Protection field of the HT Operation element transmitted by the AP is equal to nonmember protection mode.
b) A STA that is associated with the AP shall protect RIFS sequences when the HT Protection field of the HT Operation element transmitted by the AP is equal to non-HT mixed mode.

10.27.3.4 Use of OBSS Non-HT STAs Present field

The OBSS Non-HT STAs Present field allows HT APs to report the presence of non-HT STAs that are not members of its BSS in the primary channel, the secondary channel, or in both primary and secondary channels.

A second HT AP that detects a first HT AP's Beacon frame with the OBSS Non-HT STAs Present field equal to 1 may cause HT-greenfield format and RIFS sequence transmissions of the second AP's BSS to be protected by setting the HT Protection field of its HT Operation element to non-HT mixed mode. If the NonERP_Present field is equal to 1 in the first AP's Beacon frame, the Use_Protection field may also be set to 1 by the second AP.

An HT STA may also scan for the presence of non-HT devices either autonomously or, for example, after the STA's AP transmits an HT Operation element with the HT Protection field equal to nonmember protection mode. Non-HT devices can be detected as follows:

— Reception of a Management frame that does not carry an HT Capabilities element and the frame is required to carry this element when transmitted by an HT STA, or
— Reception of a Beacon frame containing an HT Operation element with the OBSS Non-HT STAs Present field equal to 1.

When non-HT devices are detected, the STA may enable protection of its HT-greenfield format and RIFS sequence transmissions.

NOTE—If a non-HT device is detected and the STA determines that its HT-greenfield format or RIFS sequence transmissions are affecting the operation of the non-HT device, then the STA might enable protection of its HT-greenfield format and RIFS sequence transmissions.

See also 11.8.8.5, which defines rules for the OBSS Non-HT STAs Present field related to HT-greenfield transmissions in certain operating classes.

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10.27.3.5 Protection rules for an HT mesh STA

A mesh STA determines the HT Protection and Nongreenfield HT STAs Present fields in the HT Operation element in the transmitting frame as follows:

The HT Protection field in a mesh STA may be set to no protection mode only if

- All STAs detected in the primary or the secondary channel are HT STAs, and
- All mesh STA members of this MBSS that are one-hop neighbors of the transmitting mesh STA are either:
  - 20/40 MHz HT mesh STAs in a 20/40 MHz MBSS, or
  - 20 MHz HT mesh STAs in a 20 MHz MBSS.

The HT Protection field in a mesh STA may be set to nonmember protection mode only if

- A non-HT STA is detected in either the primary or the secondary channel or in both the primary and secondary channels, that is not known by the transmitting mesh STA to be a member of this MBSS, and
- All mesh STA members of this MBSS that are one-hop neighbors of the transmitting mesh STA are HT mesh STAs.

The HT Protection field in a mesh STA may be set to 20 MHz protection mode only if

- All STAs detected in the primary and all STAs detected in the secondary channel are HT STAs, and
- All mesh STA members of this MBSS that are one-hop neighbors of the transmitting mesh STA are HT mesh STAs, and
- The MBSS is a 20/40 MHz MBSS, and
- There is at least one 20 MHz HT mesh STA that is one-hop neighbor of the transmitting mesh STA.

The HT Protection field in a mesh STA is set to non-HT mixed mode otherwise.

If two peer HT mesh STAs report the same protection mode in HT Protection field, the protection mechanisms of the related mode shall be used to protect the transmission between the peer HT mesh STAs.

If an HT mesh STA and its peer HT mesh STA report different protection modes in HT Protection field, the following rules shall be used:

a) If an HT mesh STA or its peer HT mesh STA reports non-HT mixed mode, the protection mechanisms of non-HT mixed mode shall be used to protect the transmission between the peer HT mesh STAs.

b) If an HT mesh STA or its peer HT mesh STA reports nonmember protection mode and non-HT mixed mode is not reported by any of these HT mesh STAs, the protection mechanisms of nonmember protection mode shall be used to protect the transmission between the peer HT mesh STAs.

c) If an HT mesh STA or its peer HT mesh STA reports 20 MHz protection mode and neither non-HT mixed mode nor nonmember protection mode is reported by any of these HT mesh STAs, the protection mechanisms of 20 MHz protection mode shall be used to protect the transmission between the peer HT mesh STA.

If at least one HT peer mesh STA in its mesh neighborhood indicates the Nongreenfield HT STAs Present equal to 1, the protection rules related to Nongreenfield HT STAs Present should also be applied to the communication between HT peer mesh STAs.

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10.27.4 L_LENGTH and L_DATARATE parameter values for HT-mixed format PPDUs

L_LENGTH and L_DATARATE determine the duration that non-HT STAs do not transmit, equal to the remaining duration of the HT PPDU, following the non-HT portion of the preamble of the HT-mixed format PPDU.

The L_DATARATE parameter of the TXVECTOR shall be set to the value 6 Mb/s.

A STA that is transmitting a PPDU with the FORMAT parameter of the TXVECTOR equal to HT_MF shall set the value of the L_LENGTH parameter to the value (in octets) given by Equation (10-16):

$$\text{L_LENGTH} = \left\lceil \frac{((\text{TXTIME} - \text{Signal Extension}) - \text{NonHTLength})}{\text{aSymbolLength}} \right\rceil \times N_{OPS} - \left\lceil \frac{\text{PHYServiceLength} + \text{PHYConvolutionalTailLength}}{8} \right\rceil \quad (10\text{-}16)$$

where

TXTIME	is the duration (in microseconds) of the HT PPDU defined in 6.5.5
Signal Extension	is 0 μs when TXVECTOR parameter NO_SIG_EXTN is true and is aSignalExtension as defined in Table 19-25 of 19.4.4 when TXVECTOR parameter NO_SIG_EXTN is false
aSymbolLength	is the duration of a symbol (in microseconds), defined in 6.5.4
NonHTLength	is 20 μs, the duration of the non-HT PHY preamble and L-SIG
N_{OPS}	is the number of octets transmitted during a period of aSymbolLength at the rate specified by L_DATARATE
PHYServiceLength	is 16 bits, the number of bits in the PHY SERVICE field
PHYConvolutionalTailLength	is 6 bits, the number of bits in the convolutional code tail bit sequence

NOTE 1—The last term of the L_LENGTH definition corrects for the fact that non-HT STAs add the length of the SERVICE field and tail bits (assuming a single convolutional encoder) to the value communicated by the L_LENGTH field.

Equation (10-16) can be simplified to Equation (10-17)

$$\text{L_LENGTH} = \left\lceil \frac{((\text{TXTIME} - \text{Signal Extension}) - 20)}{4} \right\rceil \times 3 - 3 \quad (10\text{-}17)$$

A STA shall not transmit a PPDU with the FORMAT parameter set to HT_MF in TXVECTOR if the corresponding L_LENGTH value calculated with Equation (10-16) exceeds 4095 octets.

NOTE 2—The transmission of frames with L_LENGTH above 2332 octets (i.e., a Data frame containing an unencrypted 2304-octet MSDU) might be accompanied by a protection mechanism (e.g., RTS/CTS or CTS-to-self protection) if it is determined that the use of L_LENGTH fails to effectively suppress non-HT transmissions. How this is determined is outside the scope of this standard.

10.27.5 Protection rules for VHT STAs

A VHT STA is subject to all of the rules for HT STAs that apply to its operating band, except that a PPDU with the TXVECTOR FORMAT parameter set to VHT may be substituted for a PPDU with the TXVECTOR FORMAT parameter set to HT_MF and that the applicable HT protection mechanisms are extended to include 80, 160 and 80+80 MHz transmissions using non-HT duplicate frames defined in Clause 21.

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10.28 MAC frame processing

10.28.1 Introduction

Subclauses 10.28.2 to 10.28.9 describe MAC frame and element processing requirements to provide frame, Action and Action No Ack frame, element, and subelement extensibility.

10.28.2 Revision level field processing

A MAC entity that receives a frame with a higher revision level than it supports shall discard the frame without indication to the sending STA or to LLC.

10.28.3 Duration/ID field processing

When the contents of a received Duration/ID field, treated as an unsigned integer and without regard for address values, type, and subtype (even when type or subtype contain reserved values), are less than 32 768, the duration value is used to update the network allocation vector (NAV) according to the procedures defined in 10.3.2.4, 10.23.3.4, or 10.39.10, as appropriate.

When the contents of a received Duration/ID field, treated as an unsigned integer, are greater than 32 768, the contents are interpreted as appropriate for the frame type and subtype or ignored if the receiving MAC entity does not have a defined interpretation for that type and subtype.

10.28.4 Response to an invalid Action and Action No Ack frame

If a STA receives an individually addressed Action and Action No Ack frame with an unrecognized Category field or some other syntactic error and the MSB of the Category field equal to 0, then the STA shall return the Action and Action No Ack frame to the source without change except that the MSB of the Category field is set to 1.

10.28.5 Operation of the Dialog Token field

A dialog token is an integer value that assists a STA in grouping Management frames sent or received at different times as part of the same dialog. The algorithm by which the integer value for the dialog is selected is implementation specific, but should be selected in a manner that minimizes the probability of a frame associated with one dialog being incorrectly associated with another dialog.

10.28.6 Element parsing

A STA that encounters an element with an unknown or reserved element ID value, or an element with an element ID extension whose element ID extension value is unknown or reserved, in a Management frame received without error, shall ignore that element and shall parse any remaining management frame body for additional elements with recognizable element ID (and, if present, element ID extension) values.

The MME of a Vendor-Specific Protected Action frame is located at the end of the frame body.

NOTE—It is not necessary to be able to parse the vendor-specific content to locate the MME.

10.28.7 Vendor specific element parsing

A STA receiving a Vendor Specific element that it does not support shall ignore the Vendor Specific element.

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10.28.8 Extensible element parsing

Table 9-92 indicates which elements are considered extensible in future revisions of the standard, by placing a Yes in the Extensible column. Each element that has a Yes in the Extensible column has an Information field with a known length that can be determined from the definition of the Information field in this standard; i.e., the Information field has a fixed structure or has a variable structure whose length is determined by fields within the Information field. A STA that receives an extensible element in which the Length field exceeds the known length of the Information field of that element shall discard any part of the Information field beyond the known length and shall otherwise process the element as though this truncated element had been received.

10.28.9 Extensible subelement parsing

A subelement has the structure defined in 9.4.3 and is contained within an element or subelement.

A STA that encounters an unknown, unsupported, or reserved subelement ID value contained in an element or subelement shall ignore the subelement with that subelement ID value and shall continue to parse any remaining element or subelement body for additional subelements with recognizable subelement ID values.

A STA that receives an element or subelement for which a vendor-specific subelement is defined and that contains a vendor-specific subelement that it does not support shall ignore this vendor-specific subelement and shall continue to parse any remaining element or subelement body for additional subelements with recognizable subelement ID values.

Subelements are defined locally in each subclause that defines a structure containing subelements. Subelement ID numbering is private to that structure. A STA that receives an extensible subelement that is not extensible using subelements and in which the Length field exceeds the length of the structure of the subelement defined in this standard shall discard any part of the subelement beyond that length and shall otherwise process the subelement as though this truncated subelement had been received.

10.28.10 Extensible TLV parsing

A TVHT STA that receives a frame containing a TLV tuple with an unknown Type value shall discard the tuple and continue processing the next tuple.

10.28.11 Element fragmentation

The general format of elements limits the size of the information to 255 octets in an element without Element ID Extension field (Figure 10-40) or 254 octets in an element with Element ID Extension field (Figure 10-41). A STA may transmit information that is too large to fit in a single element by fragmenting the element into a series of elements consisting of the element that the information does not fit, immediately followed by one or more Fragment elements as illustrated in Figure 10-40. Information that fits in a single element shall not be fragmented. All the information for a fragmented element shall be in the same MMPDU.

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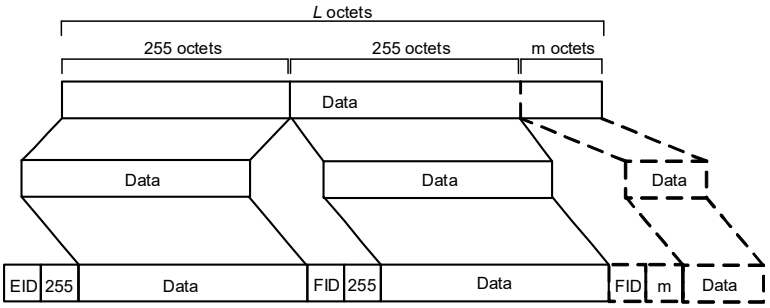
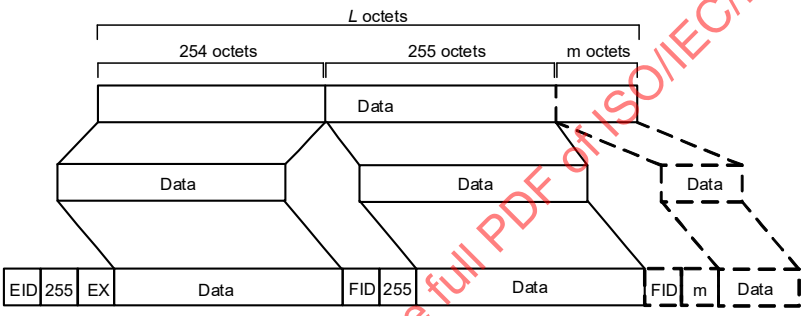


EID: The element ID of the fragmented element
FID: The Fragment element ID
m: *L* mod 255

Figure 10-40—Example of the element fragmentation without Element ID Extension



EID: The element ID of the fragmented element
EX: the element ID extension of the fragmented element
FID: The Fragment element ID
m: (*L*–254) mod 255 (The dashed Fragment element is present when (*L*–254) mod 255 is not equal to 0)

Figure 10-41—Example of the element fragmentation with Element ID Extension

The information to be fragmented is divided into $M + N$ portions, where the following define each variable:

For an element without an Element ID Extension field:

— L is the size of the information in octets.
— M is $\lfloor L/255 \rfloor$.
— N is equal to 1 if L mod 255 > 0 and equal to 0 otherwise.

For an element with an Element ID Extension field:

— L is the size of the information in octets.
— M is $(L + 1)/255 \rfloor$.
— N is equal to 1 if $(L–254)$ mod 255 > 0 and equal to 0 otherwise.

The element into which the information does not fit is filled with the first portion of information and is termed the leading element. The leading element contains 255 octets of information for the element without Element

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ID Extension or 254 octets of information for the element with Element ID Extension. This element is immediately followed by $M - 1$ Fragment elements, each containing the next portion of 255 octets of information. If $N = 1$ these elements are immediately followed by the last portion of information.

NOTE—A Fragment element never follows an element with fewer than 255 octets of information without Element ID Extension, and an element with fewer than 254 octets of information with Element ID Extension. A Fragment element is never fragmented.

10.28.12 Element defragmentation

Elements that have had their information fragmented shall be followed by one or more Fragment elements. To reconstruct the original information, the portion of information from the leading element shall be concatenated, in order, with the portions of information from the series of Fragment elements that follow it. The defragmentation procedure shall complete when any element other than a Fragment element is encountered, or the end of the MMPDU is reached.

10.29 Reverse direction protocol

10.29.1 General

The RD protocol may be supported by an HT STA, by an S1G STA, and by a DMG STA. A STA receiving an RDG is never required to use the grant.

An HT STA indicates support of the RD feature as an RD responder using the RD Responder subfield of the HT Extended Capabilities field of the HT Capabilities element. A STA shall set the RD Responder subfield to 1 in frames that it transmits containing the HT Capabilities element if dot11RDResponderOptionImplemented is true. Otherwise, the STA shall set the RD Responder subfield to 0. In an HT STA, the RDG/More PPDU subfield and the AC Constraint subfield are present in the HTC field.

A DMG STA indicates support of the RD feature using the Reverse Direction subfield of the DMG STA Capability Information field of the DMG Capabilities element. A STA shall set the Reverse Direction subfield to 1 in frames that it transmits containing the DMG Capabilities element if dot11RDResponderOptionImplemented is true. Otherwise, the STA shall set the Reverse Direction subfield to 0. In a DMG STA, the RDG/More PPDU subfield and the AC Constraint subfield are present in the QoS Control field.

An S1G STA indicates support of the RD feature as an RD responder using the RD Responder subfield of the S1G Capabilities element. A STA shall set the RD Responder subfield to 1 in frames that it transmits containing the S1G Capabilities element if dot11RDResponderOptionImplemented is true. Otherwise, the STA shall set the RD Responder subfield to 0. For an S1G STA, the RDG/More PPDU subfield and the AC Constraint subfield are present in the HTC field.

10.29.2 Reverse direction (RD) exchange sequence

An RD exchange sequence comprises the following:

a) The transmission of a PPDU by a TXOP holder or SP source containing an RD grant (the *RDG PPDU*), which is indicated by the PPDU containing one or more +HTC or DMG MPDUs in which the RDG/More PPDU subfield is equal to 1. The STA that transmits this PPDU is known as the *RD initiator*. The rules for an RD initiator apply only during a single RD exchange sequence, i.e., after the transmission of an RDG PPDU and up to the end of the last PPDU in the RD exchange sequence.

b) The transmission of one or more PPDUs (the *RD response burst*) by the STA addressed in the MPDUs of the RDG PPDU. The first (or only) PPDU of the RD response burst contains at most one immediate BlockAck or Ack frame. The last (or only) PPDU of the RD response burst contains any

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MPDUs requiring a response that is an immediate BlockAck or Ack frame. The STA that transmits the RD response burst is known as the *RD responder*. The rules for an RD responder apply only during a single RD exchange sequence, i.e., following the reception of an RDG PPDU and up to the transmission of a PPDU by the RD responder in which the RDG/More PPDU subfield is equal to 0.

c) The transmission of a PPDU by the RD initiator containing an immediate BlockAck frame or Ack frame (the *RD initiator final PPDU*), if so required by the last PPDU of the RD response burst.

NOTE 1—An RD initiator might include multiple RD exchange sequences within a single TXOP or SP. Each RD exchange sequence within a single TXOP or SP might be addressed to a different recipient, and any single recipient might be given more than one RDG within a single TXOP or SP.

NOTE 2—If the RD responder is a VHT AP, the RD response burst can contain VHT MU PPDUs that might have TXVECTOR parameter NUM_USERS > 1.

NOTE 3—If the RD responder is an S1G AP, the RD response burst can contain S1G MU PPDUs that might have TXVECTOR parameter NUM_USERS > 1.

An example of an RD exchange sequence is given in O.3.

10.29.3 Rules for RD initiator

An RDG shall not be present unless the MPDU carrying the grant, or every MPDU carrying the grant in an A-MPDU, matches one of the following conditions:

— A QoS Data frame with an ack policy other than PSMP Ack (i.e., including Implicit BAR), or
— A BlockAckReq frame related to an HT-immediate block ack agreement, or
— An MPDU not needing an immediate response (e.g., block ack under an HT-immediate block ack agreement, or Action No Ack).

An RDG shall not be present within a PSMP sequence.

NOTE 1—These rules together with the rules in 9.7.3 cause an RDG to be delivered in a PPDU that either requires no immediate response or requires an immediate response that is a BlockAck or Ack frame.

NOTE 2—An RD initiator is not required to examine the RD Responder field of a potential responder before deciding whether to send a PPDU to that STA in which the RDG/More PPDU subfield is set to 1.

NOTE 3—An RD initiator is required according to 10.8 to examine the +HTC-HT Support field of a potential responder before deciding whether to send a PPDU to that STA in which the RDG/More PPDU subfield is set to 1.

Transmission of a +HTC or DMG frame by an RD initiator with the RDG/More PPDU subfield equal to 1 (either transmitted as a non-A-MPDU frame,, or within an A-MPDU) indicates that the duration indicated by the Duration/ID field is available for the RD response burst and RD initiator final PPDU (if present).

An RD initiator that sets the RDG/More PPDU field to 1 in a +HTC or DMG frame transmitted during a TXOP shall set the AC Constraint subfield to 1 in that frame if the TXOP was gained through the EDCA channel access mechanism and shall otherwise set it to 0. An RD initiator that sets the RDG/More PPDU field to 1 in a DMG frame transmitted during an SP can set the AC Constraint subfield to 1 to limit the Data frames transmitted by the RD responder.

An RD initiator shall not transmit a +HTC or DMG frame with the RDG/More PPDU subfield set to 1 that requires a response MPDU that is not one of the following frames:

— Ack
— Compressed BlockAck
— Extended Compressed BlockAck

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Subject to TXOP or SP constraints, after transmitting an RDG PPDU, an RD initiator may transmit its next PPDU as follows:

a) *Normal continuation:* The RD initiator may transmit its next PPDU a minimum of a SIFS after receiving a response PPDU that meets one of the following conditions:
   1) Contains one or more received +HTC or DMG frames with the RDG/More PPDU subfield equal to 0
   2) In an HT STA or an S1G STA, contains one or more received frames that are capable of carrying the HT Control field but did not contain an HT Control field
   3) Contains a received frame that requires an immediate response
   4) In a DMG STA, none of the correctly received frames in the PPDU carry the QoS Control field
b) *Error recovery:* For TXOPs and non-DMG SPs, the RD initiator may transmit its next PPDU when the CS mechanism (see 10.3.2.1) indicates that the medium is idle at the TxPIFS slot boundary (see Figure 10-25). For DMG SPs, the RD initiator shall not transmit its next PPDU earlier than PIFS following its last PPDU transmission. Transmission is a continuation of the current TXOP or SP.

NOTE 4—Error recovery of the RDG mechanism is the responsibility of the RD initiator.

A STA that transmits a QoS +CF-Ack Data frame according to the rules in 10.23.3.5 may also include an RDG in that frame provided that

— It is a non-A-MPDU frame, and
— The target of the +CF-Ack is equal to the Address 1 field of the frame.

NOTE 5—In a non-DMG BSS, the RD initiator can transmit a CF-End frame according to the rules for TXOP truncation in 10.23.2.10 following an RD transmit sequence. An RD responder never transmits a CF-End.

NOTE 6—In a DMG network, the RD initiator can transmit a CF-End frame according to the rules for TXOP truncation in 10.23.2.10 or SP truncation in 10.39.8, as appropriate, following an RD transmit sequence. An RD responder never transmits a CF-End.

10.29.4 Rules for RD responder

An RD responder shall transmit the initial PPDU of the RD response burst a SIFS after the reception of the RDG PPDU. PPDUs in a response burst are separated by SIFS or RIFS. The RIFS rules in the RD are the same as in the forward direction; the use of RIFS is constrained as defined in 10.3.2.3.2 and 10.27.3.3.

NOTE 1—The transmission of a response by the RD responder does not constitute a new channel access but a continuation of the RD initiator's TXOP or SP. An RD responder ignores the NAV when responding to an RDG.

The recipient of an RDG may decline the RDG by

— Not transmitting any frames following the RDG PPDU when no response is otherwise required, or
— Transmitting a control response frame with the RDG/More PPDU subfield set to 0, or
— Transmitting a control response frame that contains no HT Control field.

An RD responder that is a non-DMG STA may transmit a +CF-Ack non-A-MPDU frame in response to a QoS Data +HTC non-A-MPDU frame that has the Normal Ack ack policy and the RDG/More PPDU subfield equal to 1.

The RD responder shall ensure that its PPDU transmission(s) and any expected responses fit entirely within the remaining TXOP or SP duration, as indicated in the Duration/ID field of MPDUs within the RDG PPDU.

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An RD responder shall not transmit an MPDU (either individually or aggregated within an A-MPDU) that is not one of the following frames:

— Ack
— Compressed BlockAck
— Compressed BlockAckReq
— Extended Compressed BlockAck
— Extended Compressed BlockAckReq
— QoS data
— Management

If the AC Constraint subfield is equal to 1, the RD responder shall transmit Data frames of only the same AC as the last frame received from the RD initiator. For a BlockAckReq or BlockAck frame, the AC is determined by examining the TID field. For a Management frame, the AC is AC_VO. The RD initiator shall not transmit a +HTC or DMG MPDU with the RDG/More PPDU subfield set to 1 from which the AC cannot be determined. If the AC Constraint subfield is equal to 0, the RD responder may transmit Data frames of any TID.

NOTE 2—If the RD initiator's last PPDU contained an A-MPDU, the last frame is the last Data frame in the A-MPDU.

During an RD response burst any PPDU transmitted by an RD responder shall contain at least one MPDU with an Address 1 field that matches the MAC address of the RD initiator, and the inclusion of traffic to STAs other than the RD initiator in a VHT MU PPDU or an S1G MU PPDU shall not increase the duration of the VHT MU PPDU beyond that required to transport the traffic to the RD initiator. The RD responder shall not transmit any frame causing a response after SIFS with an Address 1 field that does not match the MAC address of the RD initiator. The RD responder shall not transmit any PPDUs with a CH_BANDWIDTH that is wider than the CH_BANDWIDTH of the PPDU containing the frame(s) that delivered the RD grant.

If an RDG PPDU also requires an immediate block ack response, the BlockAck frame shall be included in the first PPDU of the response.

When a PPDU is not the final PPDU of a response burst, an HT Control field carrying the RDG/More PPDU subfield set to 1 shall be present in every MPDU within the PPDU capable of carrying the HT Control field, or if the PPDU is transmitted in a DMG BSS, the RDG/More PPDU subfield within the QoS Control field shall be set to 1 in every MPDU within the PPDU. The last PPDU of a response burst shall have the RDG/More PPDU subfield set to 0 in all +HTC or DMG MPDUs contained in that PPDU.

The RD responder shall not set the RDG/More PPDU subfield to 1 in any MPDU in a PPDU that contains an MPDU that requires an immediate response.

NOTE 3—If the RD responder transmits a PPDU that expects a transmission by the RD initiator after SIFS and no such transmission is detected, the RD responder does not retry the exchange before either another RDG or its own TXOP or SP.

After transmitting a PPDU containing one or more +HTC or DMG MPDUs in which the RDG/More PPDU subfield is equal to 0, the RD responder shall not transmit any more PPDUs within the current response burst.

NOTE 4—If an RD-capable STA that is not the TXOP holder or SP source receives a PPDU that does not indicate an RDG, there is no difference in its response compared to a STA that is not RD-capable.

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10.30 PSMP operation

10.30.1 General

PSMP is obsolete. Support for this mechanism might be removed in a later revision of the standard.

A DMG or S1G STA shall not use PSMP.

10.30.2 Frame transmission mechanism during PSMP

10.30.2.1 PSMP frame transmission (PSMP-DTT and PSMP-UTT)

The attribute aDTT2UTTTime is the minimum time between the end of the PSMP-DTT and the start of a PSMP-UTT addressed to the same STA. This value represents the minimum time the STA is provided to react to Multi-TID BlockAck, BlockAck, Multi-TID BlockAckReq, BlockAckReq, and Data frames received during the PSMP-DTT with data, BlockAck, BlockAckReq, Multi-TID BlockAckReq, and Multi-TID BlockAck frames transmitted in the PSMP-UTT. In a PSMP sequence, if the traffic conditions are such that the time between the PSMP-DTT and PSMP-UTT of a STA would otherwise be less than the value of aDTT2UTTTime, the AP shall delay the start of entire PSMP-UTT phase to meet this requirement.

A PSMP sequence may be used to transmit non-GCR-SP group addressed frames along with individually addressed frames. Individually addressed frames shall be scheduled after group addressed frames.

In a PSMP frame the STA_ID subfields of all its STA Info fields with STA_INFO Type equal to 2 (individually addressed) shall be unique, i.e., each STA identified in the PSMP frame is identified exactly once.

Individually addressed entries in the PSMP frame should have their PSMP-DTT and PSMP-UTT start offsets scheduled to minimize the number of on/off transitions or to maximize the delay between their PSMP-DTT and PSMP-UTT periods. Entries that have only PSMP-DTT should be scheduled closer to the start of the PSMP-DTTs. Entries that have only PSMP-UTT should be scheduled toward the end of PSMP-UTTs. Entries that have both PSMP-DTT and PSMP-UTT should be scheduled closer to the transition point from downlink to uplink transmissions.

NOTE—For effective resource allocation the AP needs to precisely estimate the PSMP-UTT duration for each STA using the information indicated in a TSPEC, such as Minimum Data Rate, Mean Data Rate, Peak Data Rate, Burst Size, and Delay Bound fields. However, when the traffic characteristic is quite bursty (e.g., a real-time video application), precise estimation of PSMP-UTT duration is difficult without timely and frequent feedback of the current traffic statistics. In order to avoid wasting the available bandwidth by overestimating the PSMP-UTT duration, the AP can allocate the minimum amount of time to each STA using the PSMP-UTT Duration subfield in the PSMP frame, based on the value of the Minimum Data Rate field specified in the TSPEC. When the STA receives the PSMP frame, it decides whether the allocated resource indicated by the PSMP-UTT duration is sufficient for its queued data. If the allocated resource is sufficient, the STA can transmit all of the queued data at the allocated time.

Frames of different TIDs may be transmitted within a PSMP-DTT or PSMP-UTT allocation of a PSMP sequence without regard to user priority.

Within a PSMP-DTT or PSMP-UTT between HT STAs, BlockAckReq and BlockAck frames for which an HT-immediate block ack agreement exists shall be the multi-TID variants, i.e., Multi-TID BlockAckReq and Multi-TID BlockAck, respectively. Within a PSMP-DTT or PSMP-UTT between STAs where one is not an HT STA, BlockAckReq and BlockAck frames shall be exchanged through the use of an immediate block ack agreement and shall be the basic variants, i.e., Basic BlockAckReq and Basic BlockAck, respectively.

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10.30.2.2 PSMP downlink transmission (PSMP-DTT)

During a PSMP sequence, a STA shall be able to receive frames during its scheduled PSMP-DTT and is not required to be able to receive frames at other times.

The AP shall verify that any transmissions within a PSMP sequence to a STA participating in the PSMP sequence occur wholly within the STA's PSMP-DTT.

The PSMP-DTT may contain one or more PPDUs, each of which may contain either an A-MPDU or a single MPDU. Data may be transmitted using either format, provided that the format is supported by both the transmitter and the receiver.

PPDUs within a PSMP-DTT may be separated using RIFS or SIFS. The use of RIFS is limited as defined in 10.3.2.3.2 and 10.27.3.3.

Each PSMP-DTT shall contain only frames addressed to the RA signaled by the corresponding STA_INFO field. PPDUs from adjacent PSMP-DTTs shall be separated by at least SIFS. In other words, PPDUs to a different RA are separated by at least SIFS.

10.30.2.3 PSMP uplink transmission (PSMP-UTT)

A STA that has frames to send that are valid for transmission within the PSMP-UTT shall start transmission without performing CCA and regardless of NAV at the start of its PSMP-UTT.

The STA shall complete its transmission within the allocated PSMP-UTT, even if it has more data queued than can be transmitted during its allocated PSMP-UTT.

NOTE—PSMP-UTT is a scheduled transmission period for the STA, and transmission within a PSMP-UTT does not imply that the STA is a TXOP holder. This lack of being a TXOP holder disallows a STA from using TXOP truncation during PSMP-UTT.

The uplink schedule in a PSMP frame shall include an interval between the end of one PSMP-UTT and the start of the following PSMP-UTT within the same PSMP sequence. This interval shall be either aIUStime or SIFS. The aIUStime value shall not be used unless the use of RIFS is permitted, as defined in 10.27.3.3. The PSMP-UTT Duration subfield in the PSMP frame does not include this interval.

PPDUs transmitted within a PSMP-UTT may be separated using RIFS or SIFS. The use of RIFS is limited as defined in 10.3.2.3.2 and 10.27.3.3.

An AP may transmit a PSMP frame (called a *PSMP recovery frame*) during a PSMP-UTT when both of the following conditions are met:

— The CS mechanism (see 10.3.2.1) indicates that the medium is idle at the TxPIFS slot boundary (see Figure 10-25) after the start of the PSMP-UTT, and
— The PSMP-UTT duration is longer than the total time of the PSMP recovery frame plus PIFS.

The PSMP recovery frame shall not modify the schedule of a STA that is not scheduled to use this PSMP-UTT. The schedules of other STAs shall remain unchanged. The PSMP recovery frame may include:

a) A modified PSMP-UTT (and/or PSMP-DTT) for the currently scheduled STA by adjusting the time remaining by a PIFS plus the duration of the PSMP recovery frame, and
b) PSMP-UTTs for other STAs that were originally scheduled after this PSMP-UTT in the PSMP sequence in which the PSMP-UTT start offset values are reduced by the time difference between the end of the original PSMP frame and the end of the PSMP recovery frame.

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If the currently scheduled PSMP-UTT duration is shorter than the total time of PSMP recovery frame plus PIFS, no PSMP recovery frame is transmitted.

Figure 10-42 illustrates a PSMP sequence with and without PSMP recovery.

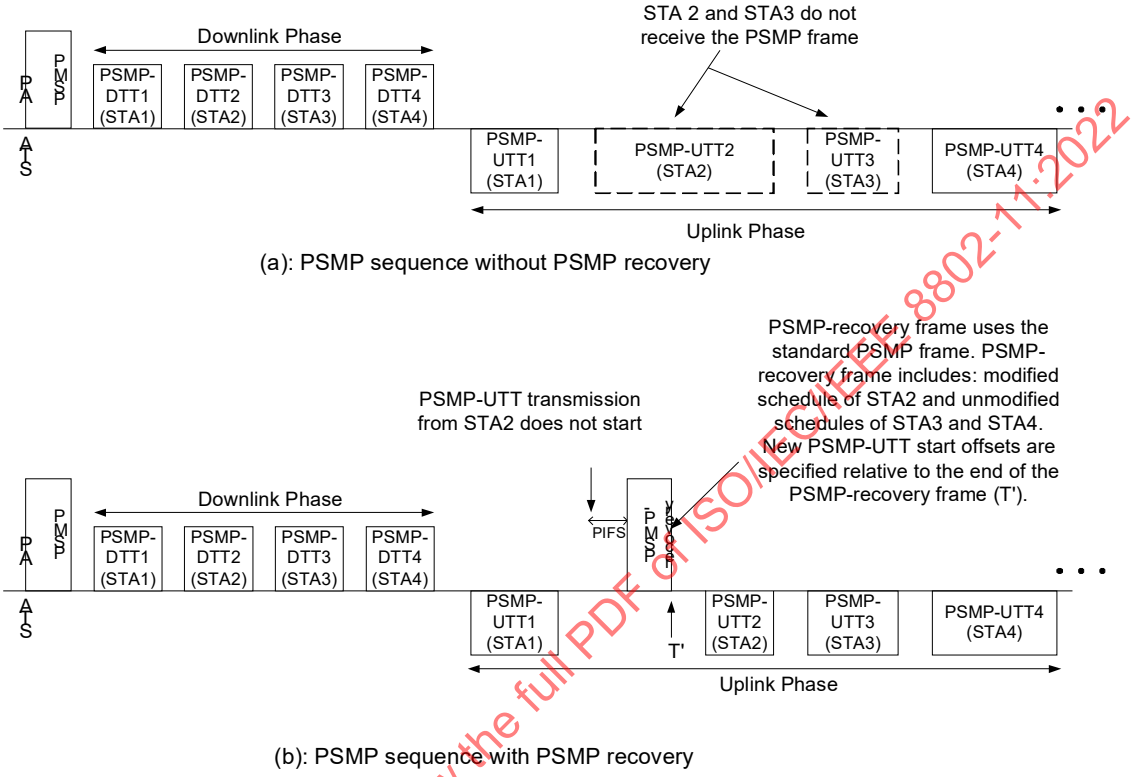

Figure 10-42—Illustration of PSMP sequence with and without PSMP recovery

10.30.2.4 PSMP burst

After transmission of an initial PSMP sequence, additional PSMP sequences may be transmitted by the AP in order to support resource allocation and error recovery. An initial PSMP sequence followed by one or more PSMP sequences is termed a *PSMP burst* and is shown in Figure 10-43.

A STA shall not transmit a +HTC MPDU in which the RDG/More PPDU subfield is set to 1 during a PSMP burst.

An AP may transmit a CF-End frame a SIFS after the end of a PSMP sequence to end the PSMP burst.

NOTE 1—A non-AP STA does not transmit a CF-End frame during the PSMP burst because it is not a TXOP holder during its PSMP-UTT.

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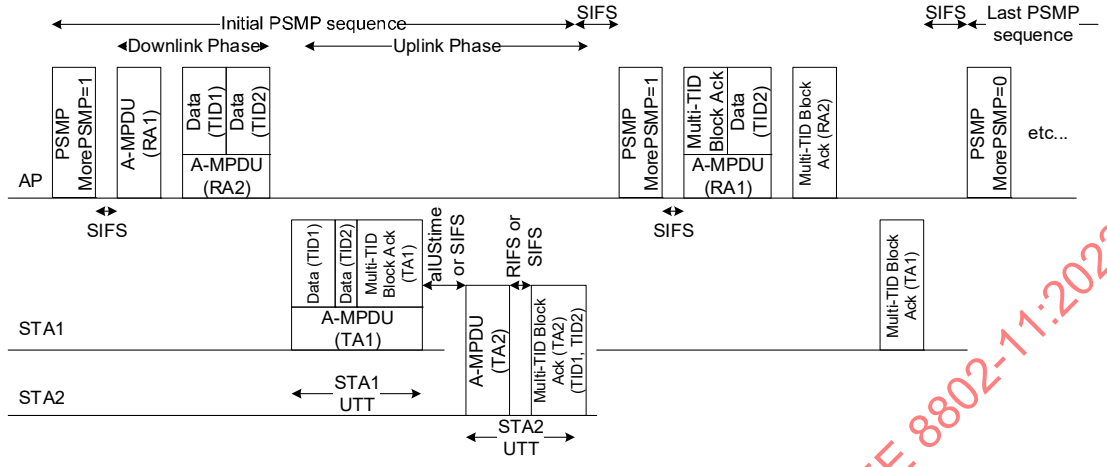

Figure 10-43—PSMP burst

During the PSMP-DTT or PSMP-UTT, a STA shall not transmit a frame unless it is one of the following:

- Multi-TID BlockAck under HT-immediate policy
- Multi-TID BlockAckReq under HT-immediate policy
- BlockAck under an immediate policy with the BA Ack Policy subfield set to 1 (representing No Acknowledgment)
- BlockAckReq under an immediate policy with the BAR Ack Policy subfield set to 1 (representing No Acknowledgment)
- QoS data
- PSMP (a PSMP recovery frame as described in 10.30.2.3)
- An MPDU that does not require an immediate response (e.g., Action No Ack)

NOTE 2—An AP can gain access to the channel after a PIFS in order to start transmission of a PSMP sequence.

10.30.2.5 Resource allocation within a PSMP burst

If the allocated PSMP-UTT duration is not long enough for its queued data, the STA transmits only the part of the queued data that fits within the allocated PSMP-UTT duration and may transmit a resource request to the AP within that PSMP-UTT. The resource request is communicated by setting either the Queue Size field or the TXOP Duration Request field of the QoS Control field that is carried in a QoS Data frame (see Figure 10-44).

If a STA receives an PSMP-UTT that is not long enough to transmit data from its queues, it may transmit within the PSMP-UTT a QoS Null frame containing information about the state of its transmit queues.

NOTE 1—An HT AP might use this information to schedule a PSMP-UTT either in the current PSMP burst or a later PSMP burst.

NOTE 2—An HT AP might allocate a PSMP-UTT duration in the next PSMP sequence based on the resource request from the STA sufficient to allow transmission of the remaining queued data.

NOTE 3—The PSMP burst supports retransmission as well as additional resource allocation (see Figure 10-45). Frames transmitted under an HT-immediate block ack agreement during the PSMP-DTT are acknowledged by a Multi-TID BlockAck frame during the PSMP-UTT period of the current PSMP sequence. Frames transmitted under an immediate block ack agreement during the PSMP-DTT are acknowledged by a Basic BlockAck frame during the PSMP-UTT

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period of the current PSMP sequence. Frames transmitted under an HT-immediate block ack agreement during the PSMP UTT can be acknowledged using a Multi-TID BlockAck frame during the PSMP-DTT period of the next PSMP sequence. Frames transmitted under an immediate block ack agreement during the PSMP-UTT can be acknowledged using a Basic BlockAck frame during the PSMP-DTT period of the next PSMP sequence. Any failed transmissions during the PSMP-DTT or PSMP-UTT periods can be respectively retransmitted during the PSMP-DTT or PSMP-UTT period of the next PSMP sequence.

Figure 10-44 and Figure 10-45 illustrate the operation of resource allocation. STA1 requests the AP to provide additional resources in its transmission to the AP. The box labeled "Queued data" represents the duration that would be required to transmit data queued for transmission at the STA. In Figure 10-45, since the AP does not receive an acknowledgment from STA2, the AP retransmits the data addressed to STA2 and also allocates resources to STA2 so that STA2 can transmit in the next PSMP sequence.

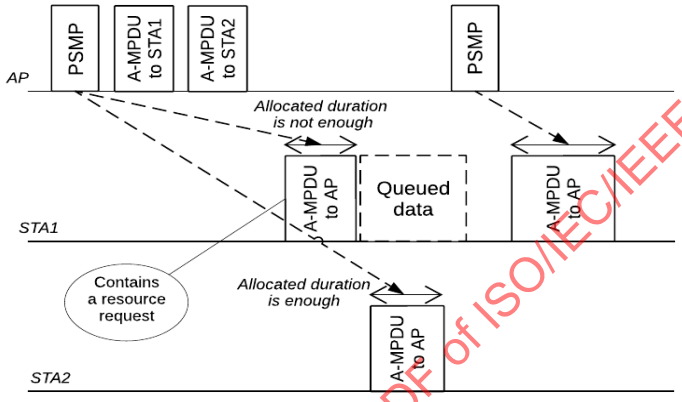

Figure 10-44—PSMP burst showing resource allocation

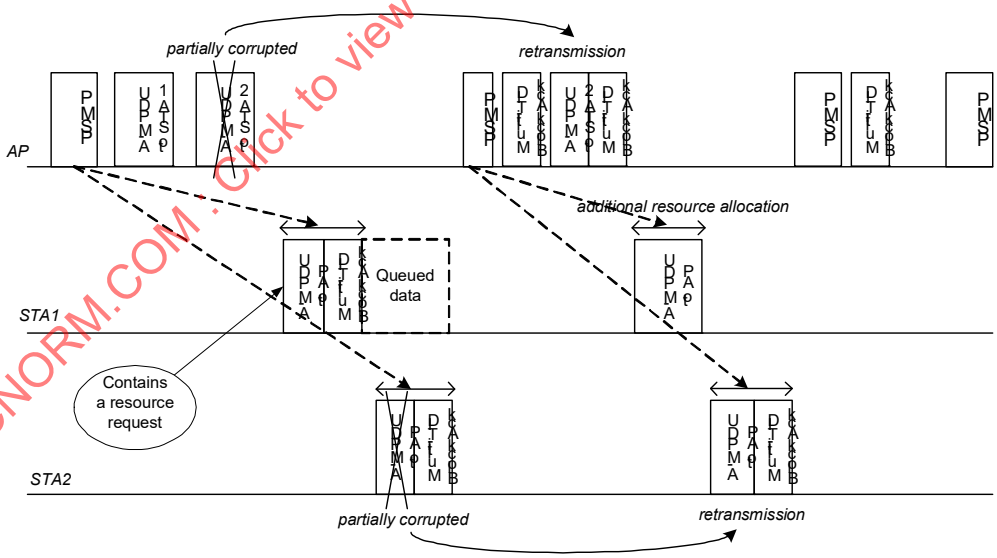

Figure 10-45—PSMP burst showing retransmission and resource allocation

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10.30.2.6 PSMP-UTT retransmission

An AP transmits BlockAck frame or Multi-TID BlockAck frame responses, if any, to a STA's PSMP-UTT data transmissions under an immediate or HT-immediate block ack agreement, respectively, in the PSMP-DTT of a subsequent PSMP sequence.

NOTE 1—An AP might reserve a PSMP-UTT in a subsequent PSMP sequence to allow a STA to retransmit failed frames. The STA can retransmit failed frames in a PSMP sequence of the current PSMP burst if a PSMP-UTT reservation is present or in a subsequent SP.

A STA that cannot complete its retransmissions in the last PSMP sequence of the PSMP burst because not enough time is allocated in its PSMP-UTT may transmit the data outside any PSMP sequence.

NOTE 2—In the case of uplink frames transmitted outside the scheduled SP, the Multi-TID BlockAck frame that acknowledges these frames is delivered in the PSMP-DTT within the next SP.

NOTE 3—A non-AP STA might transmit data outside the PSMP sequence. The acknowledgment of such frames is based on their ack policy and whether a block ack agreement has been established, as follows:

— An ack policy of Block Ack, Normal Ack, or Implicit BAR results in the behavior defined in 9.2.4.5.4.
— An ack policy of PSMP Ack causes the AP to record the received Data frame and results in the transmission of a Multi-TID BlockAck frame in the next PSMP-DTT allocated to the STA.

10.30.2.7 PSMP acknowledgment rules

A non-AP STA shall transmit a Multi-TID BlockAck frame during its PSMP-UTT for data received with PSMP Ack ack policy or for TIDs in a received Multi-TID BlockAckReq frame for which a BlockAck frame (Compressed BlockAck or Multi-TID BlockAck) has not yet been transmitted. An AP shall transmit a Multi-TID BlockAck frame during a PSMP-DTT addressed to the STA for the data received from that STA with PSMP Ack ack policy or for TIDs in a Multi-TID BlockAckReq frame received from that STA for which a BlockAck frame (Compressed BlockAck or Multi-TID BlockAck) has not yet been transmitted.

Data sent and received by a non-AP STA within a PSMP sequence may be contained in an A-MPDU that contains MPDUs of multiple TIDs. Frames of differing TIDs may be transmitted in the same PSMP-DTT or PSMP-UTT and are not subject to AC prioritization.

The subtype subfield of Data frames and the ack policy of QoS Data frames transmitted during either PSMP-DTT or PSMP-UTT periods are limited by the following rules:

— A QoS Data frame transmitted under an immediate or HT-immediate block ack agreement during either a PSMP-DTT or a PSMP-UTT shall have one of the following: PSMP Ack or Block Ack ack policy.
— A Data frame with the RA field containing an individual address transmitted during either a PSMP-DTT or a PSMP-UTT and for which no block ack agreement exists shall be a QoS data subtype and shall have No Ack ack policy.
— The ack policy of a QoS Data frame transmitted during a PSMP sequence shall not be Normal Ack or Implicit BAR.

All TID values within a Multi-TID BlockAck frame or Multi-TID BlockAckReq frame shall identify a block ack agreement that is HT-immediate. QoS Data frames transmitted with PSMP Ack ack policy shall have a TID value that identifies a block ack agreement that is immediate or HT-immediate block ack.

NOTE 1—In this case, HT-immediate relates to the keeping of acknowledgment state for timely generation of a Multi-TID BlockAck frame. It does not imply that there is any response mechanism for sending a Multi-TID BlockAck frame after a SIFS. The timing of any response is determined by the PSMP schedule.

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Acknowledgment for data transmitted under an HT-immediate block ack agreement may be requested implicitly using PSMP Ack ack policy in QoS Data frames or explicitly with a BlockAckReq or Multi-TID BlockAckReq frame. An AP that transmits QoS Data frames with PSMP Ack ack policy or that transmits a BlockAckReq or Multi-TID BlockAckReq frame addressed to a STA in a PSMP-DTT shall allocate sufficient time for the transmission of a BlockAck frame or Multi-TID BlockAck frame, respectively, in a PSMP-UTT allocated to that STA within the same PSMP sequence. A STA that has received a PSMP frame and that receives a QoS Data frame with PSMP Ack ack policy or that receives a BlockAckReq or Multi-TID BlockAckReq frame shall transmit a BlockAck frame or Multi-TID BlockAck frame, respectively, in the PSMP-UTT of the same PSMP sequence.

NOTE 2—If the STA does not receive the PSMP frame, it might still receive the downlink data, in which case it can record the status of the data in its block ack buffer, but it cannot transmit a Multi-TID BlockAck frame.

NOTE 3—A Multi-TID BlockAck frame or Multi-TID BlockAckReq frame might contain any TID related to an HT-immediate block ack agreement regardless of the contents of any prior transmission of Multi-TID BlockAck, Multi-TID BlockAckReq, or QoS Data frames.

An AP that receives a QoS Data frame with PSMP Ack ack policy during a PSMP-UTT shall transmit a response that is a BlockAck frame or Multi-TID BlockAck frame in the next PSMP-DTT that it schedules for that STA, except if it has transmitted a BlockAck frame for such TIDs to the STA outside the PSMP mechanism.

NOTE 4—The exception might occur if the non-AP STA transmits one or more BlockAckReq frames or QoS Data frames with Implicit BAR ack policy outside the PSMP mechanism.

NOTE 5—An AP might receive a Multi-TID BlockAck frame in the PSMP-UTT of the current PSMP sequence. If the Multi-TID BlockAck frame indicates lost frames or if the AP does not receive an expected Multi-TID BlockAck frame, the AP might schedule and retransmit those frames in a PSMP sequence within the current PSMP burst or in the next SP.

A Multi-TID BlockAck frame shall include all of the TIDs for which data were received with PSMP Ack ack policy and for the TIDs listed in any Multi-TID BlockAckReq frame received during the previous PSMP-DTT (STA) or PSMP-UTT (AP). The originator may ignore the bitmap for TIDs in the Multi-TID BlockAck frame for which the originator has not requested a Multi-TID BlockAck frame to be present either implicitly (by the transmission of QoS Data frames with PSMP Ack ack policy) or explicitly (by the transmission of a Multi-TID BlockAckReq frame).

10.30.2.8 PSMP group addressed transmission rules

10.30.2.8.1 Rules at the AP

This subclause defines rules that shall be followed by a PSMP-capable AP for the transmission of group addressed Data and Management frames during a PSMP sequence.

Each separate group address for which frames are transmitted during a PSMP sequence shall have a single STA_INFO record with STA_INFO Type set to 1 (group addressed) present in the PSMP frame and transmit frames with the matching Address 1 field only during the PSMP-DTT indicated in this record.

The DA of the PSMP shall be set to the broadcast address, except if the PSMP contains only a single non-null PSMP-DTT and this PSMP-DTT contains frames for a group address, in which case the DA of the PSMP frame may be set to this group address.

NOTE—The transmission of a group addressed frame within a PSMP sequence does not change the rules regarding when that frame can be transmitted. In other words, if there is a power saving STA in the BSS, the group addressed frame is transmitted following a DTIM beacon according to the rules in 11.2.3.

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10.30.2.8.2 Rules at the STA

This subclause defines rules that shall be followed by a PSMP-capable STA for the reception of group addressed frames during a PSMP sequence.

The STA shall be awake to receive during all PSMP-DTTs identified by a group addressed STA_INFO record where the PSMP Group Address ID subfield matches the LSBs of any address within its dot11GroupAddressesTable.

10.30.3 Scheduled PSMP

A PSMP session exists while any periodic TS exists that was established by a TSPEC with the APSD field equal to 0 and the Schedule field equal to 1 (representing Scheduled PSMP). The creation of a PSMP session is described in 11.4.6.

While one or more PSMP sessions exist with the same SP, the AP shall periodically initiate a PSMP sequence by transmitting a PSMP frame using the SP indicated to the STA in response to the received TSPEC. Under S-PSMP rules, the AP shall not transmit a PSMP frame containing a STA_INFO record addressed to a STA unless the transmission occurs within an SP of that STA. The PSMP-DTT and PSMP-UTT allocated to a STA shall occur within a SP of that STA.

NOTE—An AP might simultaneously maintain multiple PSMP sessions with distinct SIs. The SIs of an AP's PSMP sessions are multiples of the SI granularity. An AP might combine the schedule of multiple PSMP sessions into a single PSMP frame if the start times of the PSMP sessions coincide. For example, the schedule carried by a PSMP frame related to a PSMP session at 20 ms and 30 ms SIs can be combined into a single PSMP frame once every 3 SIs of PSMP session at 20 ms or once every 2 SIs of the PSMP session at 30 ms.

The start time of a PSMP sequence should be aligned with the start time of the SP.

10.30.4 Unscheduled PSMP

An HT AP may start an unscheduled PSMP sequence that includes STAs that are PSMP-capable at any time that these STAs are awake.

NOTE—A STA in power save is awake as defined in 11.2.3.5 (U-APSD, S-APSD), as defined in 11.2.3.7 (PS-Poll frame), or during a DTIM period.

U-APSD STAs can signal the queue size or TXOP duration required to transmit its queued data to the AP in the QoS Control field of the trigger frame. This information might be used by the AP to estimate the duration of the PSMP-UTT so that the STA can transmit the queued data.

All of the behavior defined in 11.2.3.5, 11.2.3.6, and 11.2.3.8 applies to unscheduled PSMP with the following exceptions:

— PSMP allows the STA to sleep during PSMP-DTTs and PSMP-UTTs in which it has no interest.
— In addition to the EOSP mechanism, the AP may indicate the end of an SP through the transmission of a PSMP frame with the More PSMP field set to 0 or by transmission of a CF-End frame when a PSMP frame was expected.

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10.31 Sounding PPDUs

The behavior described in this subclause is specific to the use of the HT variant HT Control field and CMMG variant HT Control field.

A sounding PPDU is a PPDU for which the SOUNDING parameter of the corresponding RXVECTOR or TXVECTOR has the value SOUNDING. Sounding PPDUs are transmitted by STAs to enable the receiving STAs to estimate the channel between the transmitting STA and the receiving STA.

A STA transmits sounding PPDUs when it operates in the following roles:

- MFB requester (see 10.32.2 and 10.32.4)
- HT beamformee responding to a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.34.2.2, 10.34.2.3, and 10.34.2.4)
- HT beamformer involved in explicit transmit beamforming (see 10.34.3)
- ASEL transmitter and ASEL sounding-capable transmitter involved in ASEL (see 10.35.2)
- CMMG beamformer involved in explicit transmit beamforming (see 10.34.5)

A STA receives sounding PPDUs when it operates in the following roles:

- MFB responder (see 10.32.2 and 10.32.4)
- HT beamformer sending a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.34.2.2, 10.34.2.3, and 10.34.2.4)
- HT beamformee involved in explicit transmit beamforming (see 10.34.3)
- Transmit ASEL responder and ASEL receiver involved in ASEL (see 10.35.2)
- CMMG beamformee involved in explicit transmit beamforming (see 10.34.5)

When transmitting a sounding PPDU, the transmitting STA follows the rules stated below to determine the maximum number of space-time streams for which channel coefficients can be simultaneously estimated:

- When transmitting a sounding PPDU that
  - Contains a +HTC frame with the MRQ subfield equal to 1, or
  - Is sent as a response to a +HTC frame with the TRQ field equal to 1, or
  - Is sent during a calibration sounding exchange, or
  - Is sent by an HT beamformer involved in explicit transmit beamforming, or
  - Is sent in transmit or receive ASEL exchanges,
  - Is sent by a CMMG beamformer involved in explicit transmit beamforming
- Then:
  - If the sounding PPDU is not an NDP sounding PPDU, the NUM_EXTEN_SS parameter in the TXVECTOR shall not be set to a value greater than the limit indicated by the Channel Estimation Capability subfield in the Transmit Beamforming Capabilities field transmitted by the STA that is the intended receiver of the sounding PPDU.

    NOTE—The maximum number of space-time streams for which channel coefficients can be simultaneously estimated using the HT-LTFs corresponding to the data portion of the PPDU is limited by the Rx MCS Bitmask subfield of the Supported MCS Set field and by the Rx STBC subfield of the HT Capability Information field. Both fields are part of the HT Capabilities element.

  - If the sounding PPDU is an NDP, the number of spatial streams corresponding to the MCS parameter of the TXVECTOR shall not exceed the limit indicated by the Channel Estimation Capability subfield in the Transmit Beamforming Capabilities field transmitted from the STA that is the intended receiver of the NDP (see 10.36.2 for details on setting the MCS parameter).

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If a STA sets the Receive Staggered Sounding Capable bit in the Transmit Beamforming Capabilities field to 1, the STA shall set the Channel Estimation Capability bit in the Transmit Beamforming Capabilities field to indicate a dimension that is greater than or equal to the dimension indicated by the Supported MCS Set field of the HT Capabilities element.

10.32 Link adaptation

10.32.1 Introduction

To fully exploit MIMO channel variations and transmit beamforming on a MIMO link, a STA can request that another STA provide MIMO channel sounding and MFB.

Link adaptation may be supported by immediate response or delayed response as described below. Unsolicited MFB is also possible.

— *Immediate.* An immediate response occurs when the MFB responder transmits the response in the TXOP obtained by the TXOP holder. This approach allows the MFB requester to obtain the benefit of link adaptation within the same TXOP.

— *Delayed.* A delayed response occurs when the MFB responder transmits the response in the role of a TXOP holder in response to an MRQ in a previous TXOP obtained by the MFB requester.

— *Unsolicited.* An unsolicited response occurs when a STA sends MFB independent of any preceding MRQ.

For an S1G STA, the same link adaptation procedure specified in 10.32.3 is applied with the following qualifications:

— "VHT" is replaced by "S1G" when referring to characteristics of an S1G STA or when referring to the contents of an S1G PPDU. More specifically:
  — "VHT Capabilities Info field in the VHT Capabilities element" is replaced by "S1G Capabilities Information field in the S1G Capabilities element"
  — "VHT NDP Announcement frame" is replaced by "VHT NDP Announcement frame carried in an S1G PPDU"
  — "VHT MU PPDU" is replaced by "S1G MU PPDU"

10.32.2 Link adaptation using the HT variant HT Control field

The behavior described in this subclause is specific to the HT variant HT Control field.

A STA that supports link adaptation using the HT Control field shall set the MCS Feedback field of the HT Extended Capabilities field to Unsolicited or Both, depending on its specific MFB capability, in HT Capabilities elements that it transmits. A STA shall not send an MRQ to a STA that has not set the MCS Feedback subfield to Both in the HT Extended Capabilities field of the HT Capabilities element. A STA whose MCS Feedback field of the HT Extended capabilities field of the HT Capabilities element is equal to Unsolicited or Both may transmit unsolicited MFB in any frame that contains a +HTC field.

The MFB requester may set the MRQ subfield to 1 in the MAI subfield of the HT Control field of a +HTC frame to request a STA to provide MFB. In each MRQ, the MFB requester shall set the MSI subfield in the MAI subfield to a value in the range 0 to 6. How the MFB requester chooses the MSI value is implementation dependent.

The appearance of more than one instance of an HT Control field with the MRQ subfield equal to 1 within a single PPDU shall be interpreted by the receiver as a single request for MFB.

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An MFB requester shall transmit +HTC frames with the MRQ subfield equal to 1 in one of the following ways:

— Within a sounding PPDU, or

— With the HT NDP Announcement subfield in the +HTC frame set to 1 and following the +HTC frame by an NDP transmission.

The number of HT-LTFs sent in the sounding PPDU or in the NDP is determined by the total number of spatial dimensions to be sounded, including any extra spatial dimensions beyond those used by the data portion of the frame.

An MFB-capable STA (identified by the MCS Feedback field in the Extended HT Capability Information field equal to 3) shall support the following:

— MFB estimate computation and feedback on the receipt of MRQ (MRQ=1 in +HTC) in a sounding PPDU for which the RXVECTOR NUM_EXTEN_SS parameter contains 0 in the PHY-RXSTART.indication primitive.

— MFB estimate computation and feedback on the receipt of MRQ (MRQ=1 in +HTC) in a staggered sounding PPDU if this STA declares support for receive staggered sounding by setting the Receive Staggered Sounding Capable subfield of the Transmit Beamforming Capabilities field to 1.

— MFB estimate computation and feedback on the receipt of NDP (see 10.36) if this STA declares support for receiving NDP sounding by setting the Receive NDP Capable subfield of the Transmit Beamforming Capabilities field to 1. The MFB requester shall set the MRQ subfield to 1 in the frame where the HT NDP Announcement subfield is equal to 1.

On receipt of a +HTC frame with the MRQ subfield equal to 1, an MFB responder initiates computation of the MCS estimate based on the associated sounding PPDU and labels the result of this computation with the MSI value. The MFB responder includes the received MSI value in the MFSI field of the corresponding response frame. In the case of a delayed response, this use of MSI and MFSI fields allows the MFB requester to correlate the MFB with the related MRQ.

The responder may send a response frame with any of the following combinations of MFB and MFSI:

— MFB = 127, MFSI = 7: no information is provided for the immediately preceding request or for any other pending request. This combination is used when the responder is required to include an HT Control field due to other protocols that use this field (i.e., the reverse direction protocol) and when no MFB is available. It has no effect on the status of any pending MRQ.

— MFB = 127, MFSI in the range 0 to 6: the responder is not now providing, and will never provide, feedback for the request that had the MSI value that matches the MFSI value.

— MFB in the range 0 to 126, MFSI in the range 0 to 6: the responder is providing feedback for the request that had the MSI value that matches the MFSI value.

— MFB in the range 0 to 126, MFSI = 7: the responder is providing unsolicited feedback.

Hardware and buffer capability may limit the number of MCS estimate computations that an MFB responder is capable of computing simultaneously. When a new MRQ is received either from a different MFB requester or from the same MFB requester with a different MSI value, and the MFB responder is not able to complete the computation for MRQ, the MFB responder may either discard the new request or may abandon an existing request and initiate an MCS estimate computation for the new MRQ.

An MFB responder that discards or abandons the computation for an MRQ should indicate this action to the MFB requester by setting the MFB to the value 127 in the next transmission of a frame addressed to the MFB requester that includes the HT Control field. The value of the MFSI is set to the MSI value of the sounding frame for which the computation was abandoned.

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When computing the MCS estimate for an MFB requester whose Tx MCS Set Defined field is equal to 1, the number of spatial streams corresponding to the recommended MCS shall not exceed the limit indicated by the Tx Maximum Number Spatial Streams Supported field. The MFB responder shall not recommend an MCS corresponding to UEQM unless the MFB requester supports such modulation, as indicated by the Tx Unequal Modulation Supported bit in the Supported MCS Set field.

If the MFB is in the same PPDU as a Noncompressed Beamforming frame or a Compressed Beamforming frame, the MFB responder should estimate the recommended MCS under the assumption that the MFB requester uses the steering matrices contained therein.

After the MCS estimate computation is completed, the MFB responder should include the MFB in the MFB field in the next transmission of a frame addressed to the MFB requester that includes an HT Control field. When the MFB requester sets the MRQ subfield to 1 and sets the MSI subfield to a value that matches the MSI subfield value of a previous request for which the responder has not yet provided feedback, the responder shall discard or abandon the computation for the MRQ that corresponds to the previous use of that MSI subfield value.

A STA may respond immediately to a current request for MFB with a frame containing an MFSI field value and MFB field value that correspond to a request that precedes the current request.

Bidirectional request/responses are supported. A STA may act as both the MFB requester for one direction of a duplex link and the MFB responder for the other direction and include both MRQ and MFB in the same HT Data frame.

If an HT beamformer transmits a PPDU with the TXVECTOR EXPANSION_MAT_TYPE set to either COMPRESSED_SV or NON_COMPRESSED_SV, it should use the recommended MCS associated with those matrices reported in a Noncompressed Beamforming frame or a Compressed Beamforming frame.

10.32.3 Link adaptation using the VHT variant HT Control field

This subclause applies to frame exchange sequences that include PPDUs containing an HT variant HT Control field. The VHT variant HT Control field may be used by VHT STAs and S1G STAs.

A STA that supports VHT link adaptation using the VHT variant HT Control field shall set the VHT Link Adaptation Capable subfield in the VHT Capabilities Information field in the VHT Capabilities element to Unsolicited or Both, depending on its specific link adaptation feedback capability. A STA shall not send an MRQ to a STA that has not set the VHT Link Adaptation Capable subfield to Both in the VHT Capabilities Information field of the VHT Capabilities element. A STA whose VHT Link Adaptation Capable subfield of the VHT Capabilities Information field of the VHT Capabilities element is either set to Unsolicited or Both may transmit unsolicited MFB in any frame that contains a VHT variant HT Control field.

The MFB requester or MFB responder that is an S1G STA shall set the S1G subfield in the VHT variant HT Control field to 1. Otherwise the S1G field shall be reserved.

An S1G STA shall not transmit a +HTC Control frame to another S1G STA that does not support VHT link adaptation.

An S1G STA that sets the +HTC VHT Capable to 1 and supports sending control response frames that are not NDP CMAC PPDUs for link adaptation shall set Link Adaptation Without NDP CMAC PPDU Capable bit in the S1G Capabilities element to 1. Otherwise it shall set it to 0. An S1G STA shall not elicit a Control frame that is not an NDP CMAC PPDU for link adaptation from another S1G STA when the received Link Adaptation Without NDP CMAC PPDU Capable subfield in the received S1G Capabilities element from the STA is 0.

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An S1G STA that is an MFB requester shall set the TXVECTOR parameter RESPONSE_INDICATION to NORMAL_RESPONSE if it intends to elicit link adaptation feedback in the immediate control response frame. Otherwise, it shall not set the TXVECTOR parameter RESPONSE_INDICATION to Normal Response, unless it is permitted to do so as described in 10.25, 10.3.2.11, and 10.47.

An S1G STA that is an MFB responder may transmit a +HTC Control frame as an immediate response to an eliciting frame for which the RXVECTOR parameter RESPONSE_INDICATION is equal to NORMAL_RESPONSE. The +HTC control response frame shall be one of the following:

— +HTC Ack frame if the eliciting frame requires an Ack frame as a response (see 10.3.2.11)
— +HTC BlockAck frame or +HTC BAT frame if the eliciting frame requires a BlockAck frame or BAT frame as a response (see 10.25)
— +HTC TACK frame or +HTC STACK frame if the eliciting frame requires a TACK frame or STACK frame as a response (see 10.47.2)
— +HTC CTS frame in the eliciting frame requires an CTS frame as a response (see 10.3.2.9)

Otherwise, the S1G STA shall not transmit a +HTC control response frame.

The MFB requester may set the MRQ field to 1 in the VHT variant HT Control field of a frame to request a STA to provide link adaptation feedback. In each request the MFB requester shall set the MSI/STBC field to a value in the ranges 0 to 6, 0 to 2, or 0 to 3, depending on the settings in the Unsolicited MFB and STBC fields (see 9.2.4.6.3). The choice of MSI value is implementation dependent.

The appearance of more than one instance of a VHT variant HT Control field with the MRQ field equal to 1 within a single PPDU shall be interpreted by the receiver as a single request for link adaptation feedback.

An MFB responder that has set the VHT Link Adaptation Capable subfield to Both in the VHT Capabilities Information field of the VHT Capabilities element shall support both of the following:

— Computation and feedback of the MFB estimate on the receipt of an MFB request (MRQ equal to 1 in the VHT variant HT Control field) in a PPDU that is not a VHT NDP Announcement frame.
— Computation and feedback of the MFB estimate on the receipt of an MFB request (MRQ equal to 1 in VHT variant HT Control field) in a VHT NDP Announcement frame and the receipt of VHT NDPs (see 10.36) if this STA set the SU Beamformee Capable subfield of the VHT Capabilities Information field of the VHT Capabilities element to 1.

On receipt of a VHT variant HT Control field with the MRQ field equal to 1, an MFB responder computes the VHT-MCS, NUM_STS, and SNR estimates based on the PPDU carrying the MRQ or, in the case of a VHT NDP Announcement frame carrying the MRQ, based on the subsequent VHT NDP. The MFB responder labels the result of this computation with the MSI value from the VHT variant HT Control field in the received frame carrying the MRQ. The MFB responder may include the received MSI value in the MFSI field of the corresponding response frame. In the case of a delayed response, this allows the MFB requester to associate the MFB with the soliciting MRQ.

An MFB responder that sends a solicited MFB shall set the Unsolicited MFB subfield in VHT variant HT Control field to 0.
The MFB responder may send a solicited response frame with any of the following combinations of VHT-MCS, NUM_STS, and MFSI:

— VHT-MCS = 15, NUM_STS = 7 in the MFB subfield, MFSI = 7 in a VHT PPDU; and VHT-MCS = 15, NUM_STS = 3, and MFSI = 7 in an S1G PPDU: no information is provided for the immediately preceding request or for any other pending request. This combination is used when the responder is required to include a VHT variant HT Control field due to other protocols that use this field (e.g., the Reverse Direction Protocol) and when no MFB is available. It has no effect on the status of any pending MRQ.

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— VHT-MCS = 15, NUM_STS = 7 in the MFB subfield, MFSI in the range 0 to 6 in a VHT PPDU; and VHT-MCS = 15, NUM_STS = 3, and MFSI in the range 0 to 6 in an S1G PPDU: the responder is not now providing, and will never provide, feedback for the request that had the MSI value that matches the MFSI value.
— VHT-MCS = valid value, NUM_STS = valid value in the MFB subfield, MFSI in the range 0 to 6: the responder is providing feedback for the request that had the MSI value that matches the MFSI value.

An MFB responder that discards or abandons the MFB estimates computed in response to an MRQ may indicate that it has done so by setting the VHT-MCS to 15 and NUM_STS to 7 in the MFB subfield in the next VHT PPDU frame if the frame is carried in a VHT PPDU or by setting the VHT-MCS to 15 and NUM_STS to 3 if the frame is carried in an S1G PPDU containing frames addressed to the MFB requester that includes the VHT variant HT Control field. The value of the MFSI is set to the value of the MSI/STBC subfield of the frame that contains an MRQ for which the computation was abandoned, regardless of whether the MSI/STBC subfield contains an MSI or a Compressed MSI and STBC Indication subfields.

The STA receiving MFB may use the received MFB to compute the appropriate VHT-MCS, SNR, and NUM_STS.

A STA sending unsolicited MFB using the VHT variant HT Control field shall set the Unsolicited MFB subfield to 1.

Unsolicited VHT-MCS, NUM_STS, BW, and SNR estimates reported in the MFB subfield of a VHT variant HT Control field sent by a STA are computed based on the most recent PPDU received by the STA that matches the description indicated by the GID-L, GID-H, Coding Type, STBC Indication, and FB Tx Type fields in the same VHT variant HT Control field.

In an unsolicited MFB response the GID-L, GID-H, Coding Type, STBC Indication, FB Tx Type, and BW fields are set according to the RXVECTOR parameters of the received PPDU from which the VHT-MCS, SNR, BW, and NUM_STS are estimated, as follows:

— If the VHT-MCS, SNR, BW, and NUM_STS are estimated from a VHT MU PPDU, then the GID-L field is set to the 3 least significant bits and the GID-H field to the 3 most significant bits of the parameter GROUP_ID.
— If the VHT-MCS, SNR, BW, and NUM_STS are estimated from an SU PPDU, then the GID-L field and GID-H field are set to all 1s.
— The Coding Type field is set to 0 if the parameter FEC_CODING is equal to BCC_CODING and set to 1 if equal to LDPC_CODING.
— The STBC Indication field is set to 1 if the parameter STBC is equal to 1 and set to 0 if the STBC parameter is equal to 0.
— The FB TX Type field is set to 1 if the parameter BEAMFORMED is equal to 1 and set to 0 if equal to 0.
— The BW field shall indicate a bandwidth less than or equal to the bandwidth indicated by the parameter CH_BANDWIDTH.

In an MFB response solicited by an MRQ that was not carried in a VHT NDP Announcement frame, the MFB is computed based on RXVECTOR parameters CH_BANDWIDTH, GROUP_ID, NUM_STS, FEC_CODING, BEAMFORMED, and STBC of the received PPDU that carried the MRQ and might additionally be based on other factors that are not part of the RXVECTOR. The NUM_STS subfield of the MFB subfield of VHT variant HT Control field shall be set to an equal or smaller value than the RXVECTOR parameter NUM_STS of the received PPDU that triggered the MRQ.

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If the MFB is in the same MPDU as a VHT Compressed Beamforming frame, the MFB responder shall estimate the recommended MFB under the assumption that the beamformer will use the steering matrices contained therein for performing an SU beamformed transmission. In this case the value of the NUM_STS field in the MFB subfield of the VHT variant HT Control field shall be the same as the value of the Nc Index field in the VHT MIMO Control field of the VHT Compressed Beamforming frame and, if the MFB is unsolicited, the Coding Type shall be set to BCC and the FB Tx Type shall be set to 0. Additionally, MFB estimate shall be based on the bandwidth indicated by the Channel Width subfield of the VHT MIMO Control field of the VHT Compressed Beamforming frame. In this case the SNR and BW subfields are reserved and set to 0.

If an unsolicited MFB is not in the same MPDU as a VHT Compressed Beamforming frame, the NUM_STS subfield of the MFB subfield of the VHT variant HT Control field shall be set to an equal or smaller value than the RXVECTOR parameter NUM_STS of the received PPDU from which the MFB parameters are estimated.

If the MFB requester sends the MRQ in a VHT NDP Announcement frame, then the MFB responder shall include the corresponding MFB in (all of) the VHT Compressed Beamforming frame(s) sent in response to the same VHT NDP Announcement frame and NDP sequence.

If the value of the NUM_STS subfield of the MFB field (solicited or unsolicited) is a smaller value than the RXVECTOR parameter NUM_STS of the received PPDU on which the MFB is based, the MFB responder shall estimate the recommended VHT-MCS under the assumption that the MFB requester will transmit the first N_{STS} space-time streams in the corresponding PPDU carrying MRQ. If the MFB is based on an SU PPDU the first N_{STS} space-time streams correspond to columns 1, ..., N_{STS} of the spatial mapping matrix Q. If the MFB is based on a VHT MU PPDU, then for the user u the first N_{STS} space-time streams correspond to columns M_u+1, ..., M_u+$N_{STS,u}$ of the spatial mapping matrix Q (M_u is defined in 21.3.10.11.1 and in 23.3.9.11). The VHT-MCS recommendation shall be a value from the peer's Tx Supported VHT-MCS and NSS Set (see 10.6.13.2).

A VHT NDP Announcement frame that contains multiple STA Info fields and that contains a VHT format of HT Control field with the MRQ subfield equal to 1 solicits an MFB response from all of the STAs listed in the STA Info fields.

When the MFB requester sets the MRQ subfield to 1 and sets the MSI/STBC subfield to a value that matches the MSI/STBC subfield value of a previous request for which the responder has not yet provided feedback, the responder shall discard or abandon the computation for the MRQ that corresponds to the previous use of that MSI/STBC subfield value and start a new computation based on the new request.

A STA may respond immediately to a current request for MFB with a frame containing an MFSI field value and an MFB field value that correspond to a request that precedes the current request.

Bidirectional request/responses are supported. A STA may act as both the MFB requester for one direction of a duplex link and the MFB responder for the other direction and include both an MRQ and an MFB in the same VHT variant HT Control field.

10.32.4 Link adaptation using the CMMG variant HT Control field

The behavior described in this subclause is specific to the CMMG variant HT Control field.

A STA that supports link adaptation using the CMMG variant HT Control field shall set the CMMG Link Adaptation Capable subfield in the CMMG Capabilities Info field of the CMMG Capabilities element to Unsolicited or Both, depending on its specific link adaptation feedback capability. A STA shall not send an MRQ to STAs that have not set the CMMG Link Adaptation Capable subfield to Both in the CMMG Capabilities Info field of the CMMG Capabilities element. A STA whose most recently transmitted MCS Feedback field of the CMMG Extended capabilities field of the CMMG Capabilities element is equal to

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Unsolicited or Both may transmit unsolicited MFB in any frame that contains a CMMG variant HT Control field.

The MFB requester may set the MRQ field to 1 in the CMMG variant HT Control field of a frame to request a STA to provide link adaptation feedback. In each request the MFB requester shall set the MSI/STBC field to a value in the ranges 0 to 6, 0 to 2, or 0 to 3, depending on the settings in the Unsolicited MFB and STBC fields (see 9.2.4.6.4). The choice of MSI value is implementation dependent.

NOTE 1—The MFB requester might use the MSI subfield as an MRQ sequence number, or it might implement any other encoding of the field.

The appearance of more than one instance of a CMMG variant HT Control field with the MRQ field equal to 1 within a single PPDU shall be interpreted by the receiver as a single request for link adaptation feedback.

In OFDM transmission the number of MCTFs sent in the sounding PPDU or in the NDP is determined by the total number of spatial dimensions to be sounded, including any extra spatial dimensions beyond those used by the data portion of the frame.

On receipt of a CMMG variant HT Control field with the MRQ subfield equal to 1, an MFB responder computes the CMMG-MCS, NUM_STS, and SNR estimates based on the PPDU carrying the MRQ or, in the case of a CMMG with the NDP Announcement subfield set to 1 carrying the MRQ, based on the subsequent CMMG NDP. The MFB responder labels the result of this computation with the MSI value from the CMMG variant HT Control field in the received frame carrying the MRQ. The MFB responder may include the received MSI value in the MFSI field of the corresponding response frame. In the case of a delayed response, this allows the MFB requester to associate the MFB with the soliciting MRQ.

An MFB responder that sends a solicited MFB shall set the Unsolicited MFB subfield in CMMG variant HT Control field to 0.

The MFB responder may send a solicited response frame with any of the following combinations of CMMG-MCS, NUM_STS, and MFSI:

- CMMG-MCS = 31, NUM_STS = 3 in the MFB subfield, MFSI = 7: no information is provided for the immediately preceding request or for any other pending request. This combination is used when the responder is required to include a CMMG variant HT Control field due to other protocols that use this field (e.g., the reverse direction protocol) and when no MFB is available. It has no effect on the status of any pending MRQ.
- CMMG-MCS = 31, NUM_STS = 3 in the MFB subfield, MFSI in the range 0 to 6: the responder is not now providing, and will never provide, feedback for the request that had the MSI value that matches the MFSI value.
- CMMG-MCS = valid value, NUM_STS = valid value in the MFB subfield, MFSI in the range 0 to 6: the responder is providing feedback for the request that had the MSI value that matches the MFSI value.

An MFB responder that discards or abandons the MFB estimates computed in response to an MRQ may indicate that it has done so by setting the CMMG-MCS to 31 and NUM_STS to 3 in the MFB subfield in the next frame addressed to the MFB requester that includes the CMMG variant HT Control field. The value of the MFSI is set to the value of the MSI/STBC subfield of the frame that contains an MRQ for which the computation was abandoned, regardless of whether the MSI/STBC subfield contains an MSI or a Compressed MSI and STBC Indication subfields.

The STA receiving MFB may use the received MFB to compute the appropriate CMMG-MCS, SNR, BW, and NUM_STS.

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When computing the MCS estimate for an MFB requester whose Tx MCS Set Defined field is equal to 1, the number of spatial streams corresponding to the recommended MCS shall not exceed the limit indicated by the Tx Maximum Number Spatial Streams Supported field.

Hardware and buffer capability may limit the number of MCS estimate computations that a MFB responder is capable of computing simultaneously. When a new MRQ is received either from a different MFB requester or from the same MFB requester with a different MSI value and when the MFB responder is not able to complete the computation for MRQ, then the MFB responder may either discard the new request or abandon an existing request in order to initiate computation for the new MRQ.

A STA sending unsolicited MFB feedback using the CMMG variant HT Control field shall set the Unsolicited MFB subfield to 1.

Unsolicited CMMG-MCS, NUM_STS, BW, and SNR estimates reported in the MFB subfield of a CMMG variant HT Control field sent by a STA are computed based on the most recent PPDU received by the STA that matches the description indicated by the STBC Indication and FB Tx Type fields in the same CMMG variant HT Control field.

In an unsolicited MFB response the STBC Indication, FB Tx Type, and BW fields are set according to the RXVECTOR parameters of the received PPDU from which the CMMG-MCS, SNR, BW, and NUM_STS are estimated, as follows:

— The STBC Indication field is set to 1 if the parameter STBC is equal to 1 and set to 0 if the parameter STBC is equal to 0.
— The FB TX Type field is set to 1 if the parameter BEAMFORMED is equal to 1 and set to 0 if the parameter BEAMFORMED is equal to 0.
— The BW field shall indicate a bandwidth equal to or less than the bandwidth indicated by the parameter CH_BANDWIDTH.

In an MFB response solicited by an MRQ that was not carried in a CMMG NDP Announcement frame, the MFB is computed based on RXVECTOR parameters CH_BANDWIDTH, NUM_STS, BEAMFORMED, and STBC of the received PPDU that carried the MRQ and might additionally be based on other factors that are not part of the RXVECTOR. The NUM_STS subfield of the MFB subfield of the CMMG variant HT Control field shall be set to an equal or smaller value than the RXVECTOR parameter NUM_STS of the received PPDU that triggered the MRQ.

If the MFB is in the same PPDU as a CMMG Compressed Beamforming frame, the MFB responder should estimate the recommended MFB under the assumption that the MFB requester uses the steering matrices contained therein.

If the MFB is in the same MPDU as a CMMG Compressed Beamforming frame, the MFB responder shall estimate the recommended MFB under the assumption that the beamformer uses the steering matrices contained therein. In this case the value of the NUM_STS field in the MFB subfield of the CMMG variant HT Control field shall be the same as the value of the Nc Index field in the CMMG MIMO Control field of the CMMG Compressed Beamforming frame; and, if the MFB is unsolicited, the FB Tx Type shall be set to 0. Additionally, MFB estimate shall be based on the bandwidth indicated by the Channel Width subfield of the CMMG MIMO Control field of the CMMG Compressed Beamforming frame. In this case the SNR and BW subfields are reserved and set to 0.

If an unsolicited MFB is not in the same MPDU as a CMMG Compressed Beamforming frame, the NUM_STS subfield of the MFB subfield of the CMMG variant HT Control field shall be set to an equal or smaller value than the RXVECTOR parameter NUM_STS of the received PPDU from which the MFB parameters are estimated.

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After the MFB estimate computation is completed, the MFB responder should include the MFB in the MFB field in the next transmission of a frame addressed to the MFB requester that includes a CMMG variant HT Control field. When the MFB requester sets the MRQ subfield to 1 and sets the MSI subfield to a value that matches the MSI subfield value of a previous request for which the responder has not yet provided feedback, the responder shall discard or abandon the computation for the MRQ that corresponds to the previous use of that MSI subfield value.

A STA may respond immediately to a current request for MFB with a frame containing an MFSI field value and MFB field value that correspond to a request that precedes the current request.

NOTE 2—If a CMMG STA includes the CMMG variant HT Control field in the initial frame of an immediate response exchange and the responding CMMG STA includes the CMMG variant HT Control field in the immediate response frame, the immediate response exchange effectively permits the exchange of the CMMG variant HT Control field elements.

NOTE 3—If an MRQ is included in the last PPDU in a TXOP and there is not enough time for a response, the recipient might transmit the response MFB in a subsequent TXOP.

NOTE 4—Bidirectional request/responses are supported. In this case, a STA acts as the MFB requester for one direction of a duplex link and a MFB responder for the other direction and transmits both MRQ and MFB in the same CMMG Data frames.

10.33 CMMG beamforming

A CMMG STA may use beamforming transmission to achieve diversity gain with directional beamforming or the spatial multiplex gain with transmit beamforming.

— Directional beamforming (BF) that does not use an omnidirectional antenna pattern or quasi-omni antenna pattern is a mechanism that is used by a pair of STAs to achieve the necessary link budget for subsequent communication. Directional BF training is a bidirectional sequence of BF frame transmissions that uses sector sweep and provides the necessary signaling to allow each STA to determine appropriate antenna system settings for both transmission and reception. CMMG STAs shall follow the same beamforming training rules defined in 10.42. BF frame transmitted by a CMMG STA is contained in CMMG PPDU.

— Transmit beamforming (see 10.34) that uses an omnidirectional antenna pattern or quasi-omni antenna pattern.

10.34 Transmit beamforming

10.34.1 HT steering matrix calculations

In order for an HT beamformer to calculate an appropriate steering matrix for transmit spatial processing when transmitting to a specific HT beamformee, the HT beamformer needs to have an accurate estimate of the channel over which it is transmitting. Two methods of calculation are defined as follows:

— *Implicit feedback*: When using implicit feedback, the beamformer receives long training symbols transmitted by the HT beamformee, which allow the MIMO channel between the HT beamformee and HT beamformer to be estimated. If the channel is reciprocal, the HT beamformer can use the training symbols that it receives from the HT beamformee to make a channel estimate suitable for computing the transmit steering matrix. Generally, calibrated radios in MIMO systems can improve reciprocity. See 10.34.2.

— *Explicit feedback*: When using explicit feedback, the HT beamformee makes a direct estimate of the channel from training symbols sent to the HT beamformee by the HT beamformer. The HT beamformee may prepare CSI or steering feedback based on an observation of these training

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symbols. The HT beamformee quantizes the feedback and sends it to the HT beamformer. The HT beamformer can use the feedback as the basis for determining transmit steering vectors. See 10.34.3.

An HT STA shall not transmit a PPDU with the TXVECTOR EXPANSION_MAT parameter present if dot11BeamFormingOptionActivated is false.

In order for a CMMG beamformer to calculate an appropriate steering matrix for transmit spatial processing when transmitting to a specific CMMG beamformee, the CMMG beamformer needs to have an accurate estimate of the channel over which it is transmitting. The method of calculation for CMMG beamformer based on explicit feedback is defined as follows:

— When using explicit feedback, the CMMG beamformee makes a direct estimate of the channel from training symbols sent to the CMMG beamformee by the CMMG beamformer. The CMMG beamformee may prepare CSI or steering feedback based on an observation of these training symbols. The CMMG beamformee quantizes the feedback and sends it to the CMMG beamformer. The CMMG beamformer can use the feedback as the basis for determining transmit steering vectors. See 10.34.5.

A CMMG STA shall not transmit a PPDU with the TXVECTOR EXPANSION_MAT parameter present if dot11BeamFormingOptionActivated is false.

10.34.2 HT transmit beamforming with implicit feedback

10.34.2.1 General

The procedures for HT transmit beamforming with implicit feedback use only HT and non-HT PPDUs, and the HT Control field, when present, is the HT variant HT Control field.

Transmit beamforming with implicit feedback can operate in a unidirectional or bidirectional manner. In unidirectional implicit transmit beamforming, only the HT beamformer sends beamformed transmissions. In bidirectional implicit transmit beamforming, both STAs send beamformed transmissions, i.e., a STA may act as both HT beamformer and HT beamformee.

Calibration of receive/transmit chains should be done to improve performance of transmit beamforming using implicit feedback. Over-the-air calibration is described in 10.34.2.4. For implicit transmit beamforming, only the HT beamformer, which is sending the beamformed transmissions, needs to be calibrated.

A STA that advertises itself as being capable of being an HT beamformer and/or HT beamformee using implicit feedback shall support the requirements in Table 10-24.

A STA that performs one of the roles related to transmit beamforming with implicit feedback shall support the associated capabilities shown in Table 10-25.

When an HT beamformee transmits a sounding PPDU, the SOUNDING parameter in the TXVECTOR in the PHY-TXSTART.request primitive shall be set to SOUNDING. If the HT beamformee is capable of implicit transmit beamforming and the HT beamformer is capable of receiving implicit transmit beamforming, the sounding PPDU from the HT beamformee may be steered.

A PPDU containing one or more +HTC MPDUs in which the TRQ field is equal to 1 shall not be sent to a STA that sets the Implicit Transmit Beamforming Receiving Capable subfield of the Transmit Beamforming field of the HT Capabilities element to 0.

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Table 10-24—STA type requirements for transmit beamforming with implicit feedback

STA capability	Required support
Beamformer	Shall set the Implicit Transmit Beamforming Capable subfield to 1 of the Transmit Beamforming Capability field of the HT Capabilities element in HT Capabilities elements that it transmits. Shall set the Implicit Transmit Beamforming Receiving Capable subfield to 1 of the Transmit Beamforming Capability field of the HT Capabilities element. Shall be capable of receiving a sounding PPDU for which the SOUNDING parameter is SOUNDING and the NUM_EXTEN_SS is equal to 0 in the RXVECTOR in the PHY-RXSTART.indication primitive, independently of the values of the Receive Staggered Sounding Capable and Receive NDP Capable subfields. Shall set the Calibration subfield to 3 of the Transmit Beamforming Capability field of the HT Capabilities element to advertise full calibration support.
Beamformee	Shall set the Implicit Transmit Beamforming Receiving Capable subfield to 1 of the Transmit Beamforming Capability field of the HT Capabilities element in HT Capabilities elements that it transmits. Shall be capable of setting the SOUNDING parameter to SOUNDING and the NUM_EXTEN_SS to 0 in the TXVECTOR in the PHY-TXSTART.request primitive when transmitting a sounding PPDU, as a response to TRQ=1, independently of the values of the Transmit Staggered Sounding Capable and Transmit NDP Capable subfields.

Table 10-25—Transmit beamforming support required with implicit feedback

Role	Required support
HT beamformee: A receiver of transmit beamformed PPDUs	Shall transmit sounding PPDUs as a response to TRQ=1.
Beamformer: A transmitter of beamformed PPDUs	Can receive sounding PPDUs. Can compute steering matrices from MIMO channel estimates obtained from long training symbols in sounding PPDUs received from the HT beamformee.
A responder in a calibration exchange	Can receive and transmit sounding PPDUs. Can respond with a CSI frame that contains channel measurement information obtained during reception of a sounding PPDU.
An initiator in a calibration exchange	Can receive and transmit sounding PPDUs. Can receive a CSI frame sent by a calibration responder.

If a PPDU containing one or more +HTC MPDUs in which the TRQ field is equal to 1 requires an immediate response, either the response from the HT beamformee shall be included in a sounding PPDU, or the HT NDP Announcement subfield of the HT Control field shall be set to 1 and the PPDU shall be followed by an NDP. If the PPDU in which the TRQ field is equal to 1 does not require an immediate response, either the HT beamformee shall transmit a sounding PPDU in the next TXOP obtained by the HT beamformee, or the HT beamformee shall transmit a PPDU in the next TXOP obtained by the HT beamformee in which the HT NDP Announcement subfield of the HT Control field is set to 1 and that PPDU shall be followed by an NDP. The use of NDP as a sounding PPDU is described in 10.36.

NOTE—A STA that acts as an HT beamformer using implicit feedback expects to receive a sounding PPDU in response to a training request. The STA can compute steering matrices from the channel estimates obtained from the received sounding PPDU.

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At the end of the TXOP the final PPDU from the HT beamformer shall not have the TRQ field set to 1 in a frame that requests an immediate response if there is not enough time left in the TXOP for the HT beamformee to transmit the longest valid sounding PPDU with its response.

10.34.2.2 Unidirectional implicit transmit beamforming

Figure 10-46 shows an example of a PPDU exchange used in unidirectional implicit transmit beamforming using the Clause 19 PHY. In this example, sounding PPDUs are used that carry MPDUs (i.e., an example of implicit beamforming using NDPs is not shown here.) STA A is the beamformer that initiates the PPDU exchange, and STA B is the beamformee.

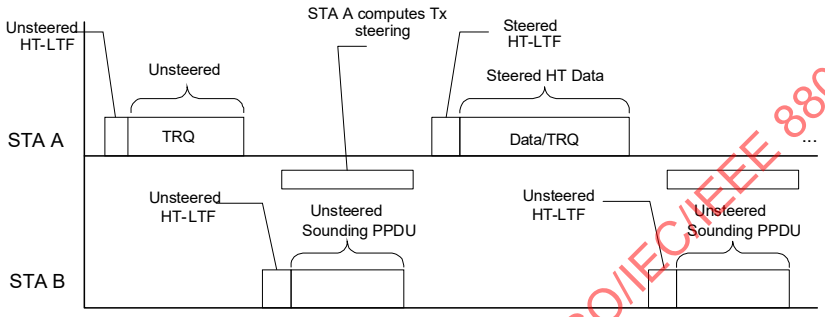

Figure 10-46—Example PPDU exchange for unidirectional implicit transmit beamforming

The PPDU exchange can be summarized as follows:

a) STA A initiates the frame exchange sequence by sending an unsteered PPDU to STA B. The PPDU includes a training request (TRQ= 1) in a +HTC MPDU.

b) STA B sends a sounding PPDU in response to the training request from STA A.

c) On receiving the sounding PPDU, STA A uses the resulting channel estimate to compute steering matrices and uses these matrices to send a steered PPDU back to STA B.

d) The steered PPDU transmitted in step c) and subsequent steered PPDUs transmitted by STA A may include training requests (TRQ=1) in a +HTC MPDU. In response to each training request, STA B returns a sounding PPDU to STA A, which enables STA A to update its steering vectors. If the steering vectors resulting from step c) or subsequent sounding PPDUs are deemed stale due to delay, the sequence may be restarted by returning to step a).

Step d) in the above PPDU exchange represents steady-state unidirectional transmit beamforming operation.

During the PPDU exchange neither the receiving nor the transmitting STA should switch antennas.

10.34.2.3 Bidirectional implicit transmit beamforming

Figure 10-47 shows an example of a PPDU exchange used in bidirectional implicit transmit beamforming, using the Clause 19 PHY. In this example, sounding PPDUs are used that carry MPDUs. STA A initiates the frame exchange, and STA A and STA B alternate in the roles of HT beamformer and HT beamformee.

The PPDU exchange can be summarized as follows:

a) STA A initiates the frame exchange sequence by sending an unsteered PPDU to STA B. The PPDU includes a training request (TRQ= 1) in a +HTC MPDU.

b) STA B sends a sounding PPDU in response to the training request. In addition, this PPDU includes a training request in a +HTC MPDU to enable implicit transmit beamforming in the RD.

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c) On receiving the sounding PPDU, STA A uses the resulting channel estimate to compute steering matrices and uses these matrices to send a steered PPDU back to STA B. This steered PPDU is also a sounding PPDU in response to the training request from STA B.

NOTE 1—Steering matrices with nonorthonormal columns should not be used in transmitting sounding PPDUs for implicit feedback. In general, bidirectional implicit beamforming will not function as described here when the steering matrices have nonorthonormal columns. See 19.3.12.2.

d) On receiving the sounding PPDU, STA B uses the resulting channel estimate to compute steering matrices and uses these matrices to send a steered PPDU back to STA A. The steered PPDU transmitted in step c) and subsequent steered PPDUs transmitted by STA A may include training requests in HTC. In response to each training request, STA B returns a sounding PPDU to STA A, which enables STA A to update its steering vectors. If the steering vectors resulting from step c) or subsequent sounding PPDUs are deemed stale due to delay, the sequence may be restarted by returning to step a).

e) The steered PPDU transmitted in step d) and subsequent steered PPDUs transmitted by STA B may include training requests in HTC. In response to each training request, STA A returns a sounding PPDU to STA B, which enables STA B to update its steering vectors. If the steering vectors resulting from step d) or subsequent sounding PPDUs are deemed stale due to delay, the sequence may be restarted by returning to step a).

Steps d) and e) in the above PPDU exchange represent steady-state bidirectional transmit beamforming operation.

During the PPDU exchange neither the receiving nor the transmitting STA should switch antennas.

NOTE 2—The TRQ protocol used with the beamforming training process is not sufficient to permit STA B to transmit Data frames in the RD. In the example shown in Figure 10-47, STA A would additionally have to follow the rules of the reverse direction protocol (see 10.29).

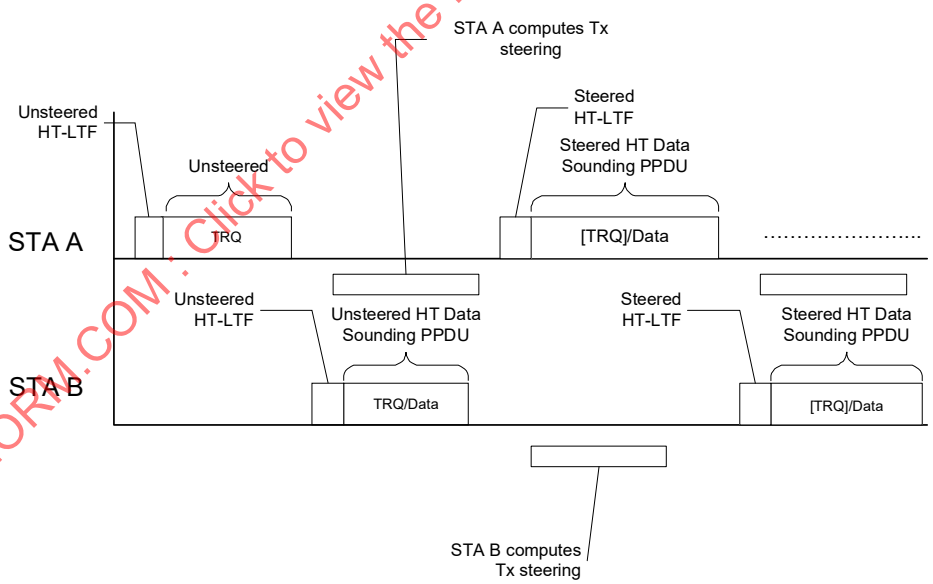

Figure 10-47—Example PPDU exchange for bidirectional implicit transmit beamforming

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10.34.2.4 Calibration

10.34.2.4.1 Introduction

Differences between transmit and receive chains in a STA degrade the inherent reciprocity of the over-the-air time division duplex channel and cause degradation of the performance of implicit beamforming. Calibration acts to remove or reduce differences between transmit and receive chains and enforce reciprocity in the observed baseband-to-baseband channels between two STAs.

A STA acting as an HT beamformer should be calibrated to maximize performance. A STA acting only as an HT beamformee does not need to be calibrated. In order to perform calibration, the STA follows the procedure described below.

The calibration procedure involves the computation of correction matrices that cause the observed channel matrices in the two directions of the link to be transposes of each other and thus renders the resultant channel reciprocal. See 19.3.12.2 for a more detailed description. If it is able to do so, a STA should calibrate upon association.

NOTE—STAs with two or more transmit chains should be calibrated in order to engage in implicit transmit beamforming. STAs with any number of RF chains, including those with a single RF chain, can participate in a calibration exchange as a calibration responder.

10.34.2.4.2 Calibration capabilities

A STA that sets the Implicit Transmit Beamforming Capable subfield of the Transmit Beamforming Capabilities field to 1 shall support calibration and shall set the Calibration subfield of the Transmit Beamforming Capabilities field to 3 (indicating full support of calibration) in HT Capabilities elements that it transmits. A STA that does not set the Implicit Transmit Beamforming Capable subfield of the Transmit Beamforming Capabilities field to 1 may support calibration and shall set the Calibration subfield of the Transmit Beamforming Capabilities field to the value that indicates its calibration capability in the Transmit Beamforming Capabilities field in HT Capabilities elements that it transmits (see Table 9-188), when the Transmit Beamforming Capabilities field exists.

A STA that is capable of initiating calibration (the Calibration subfield of the Transmit Beamforming Capabilities field is equal to 3) shall set the CSI Max Number of Rows Beamformer Supported subfield to an appropriate value, even if the STA sets the Explicit Transmit Beamforming CSI Feedback subfield to the value 0.

In order to support calibration, a STA that advertises that it is capable of responding to a calibration request shall be capable of transmitting a CSI frame in which the value of the Grouping subfield of the MIMO Control field is 0 (no grouping) and the Coefficients Size subfield of the MIMO Control field is 3 (Nb = 8 bits) in response to a CSI feedback request indicated by the CSI/Steering subfield of the HT Control field equal to 1 and the Calibration Position subfield of the HT Control field equal to 3, independently of the advertised values of the Explicit Transmit Beamforming CSI Feedback subfield in the Transmit Beamforming Capabilities field in the HT Capabilities element. A STA that advertises that it is capable of initiating a calibration request shall be capable of receiving a CSI frame in which the value of the Grouping subfield of the MIMO Control field is equal to 0 (no grouping) and the Coefficients Size subfield of the MIMO Control field is equal to 3 (Nb = 8 bits) as a response to CSI feedback request indicated by the CSI/Steering subfield of the HT Control field equal to 1 with the Calibration Position subfield equal to 3, independently of the advertised values of the Explicit CSI Transmit Beamforming Capable subfield in the Transmit Beamforming Capabilities field in the HT Capabilities element.

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A STA may initiate a calibration training frame exchange sequence with another STA if that STA supports calibration. A STA shall not initiate a calibration training frame exchange with another STA if that STA does not support calibration.

If the Receive NDP Capable field is equal to 1, the value of the Calibration field is equal to 1 or 3, and the device supports transmitting sounding PPDUs for which two or more channel dimensions can be estimated (two or more columns of the MIMO channel matrix), then transmission of NDPs shall be supported (and the Transmit NDP Capable bit shall be set to 1).

10.34.2.4.3 Sounding exchange for calibration

Figure 10-48 illustrates the calibration PPDU exchange using sounding PPDUs that contain an MPDU.

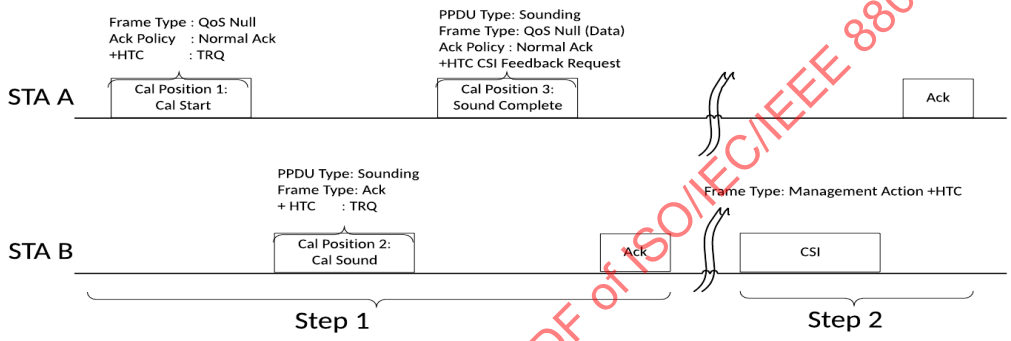

Figure 10-48—Calibration procedure with sounding PPDU containing an MPDU

The calibration procedure begins with a calibration sounding PPDU exchange sequence shown as Step 1 in Figure 10-48. The Calibration Sequence subfield in the HT Control field shall be incremented each time a new calibration procedure is started.

STA A (the calibration initiator) shall transmit a Calibration Start frame (Calibration Position subfield set to 1) with the TRQ field in the HT Control field set to 1. This frame initiates a calibration procedure. It shall be a QoS Null frame with Normal Ack ack policy.

In response, STA B (the calibration responder) shall transmit a Calibration Sounding Response frame (Calibration Position subfield set to 2), a SIFS after the end of the Calibration Start frame, using a sounding PPDU. This step allows STA A to estimate the MIMO channel from STA B to STA A. In the Calibration Sounding Response frame, the Calibration Sequence subfield in HT Control field shall be set to the same value that is indicated in the Calibration Start frame. The Calibration Sounding Response frame shall have a frame type of Ack+HTC, and the TRQ field in the HT Control field in this frame shall be set to 1.

In response, STA A shall transmit a Calibration Sounding Complete frame (Calibration Position subfield set to 3) that contains the CSI/Steering subfield of the HT Control field set to 1, a SIFS after the end of the Calibration Sounding Response frame, using a sounding PPDU. This step allows STA B to estimate the MIMO channel from STA A to STA B. In this Calibration Sounding Complete frame, the Calibration Sequence subfield in the HT Control field shall be set to the same value that is indicated in the Calibration Sounding Response frame. The Calibration Sounding Complete frame shall be a QoS Null+HTC with Normal Ack ack policy.

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A frame in which the Calibration Position subfield is equal to 2 or 3 shall be transmitted in a sounding PPDU (a PPDU for which the SOUNDING parameter is set to SOUNDING). The number of Long Training fields (LTFs) used to obtain MIMO channel estimation that are sent in the sounding PPDU shall be determined by the number of transmit chains (N_{TX}) used in sending these LTFs at the STA transmitting the sounding PPDU. The transmit chains used at the calibration initiator are those for which calibration is required.

The calibration responder may train up to maximum available transmit chains to maximize the quality of the resulting calibration, although the number of space-time streams for data symbols shall be determined by the rule described in 10.6.

When transmitting a sounding PPDU during Step 1 of a calibration procedure, if the Receive Staggered Capability subfield in the Transmit Beamforming Capability field of the HT Capabilities element transmitted by the intended receiver is 0, then,

— If the sounding PPDU is not an NDP, the number of antennas used by the sender shall be less than or equal to the maximum number of space-time streams indicated by the Rx MCS Bitmask subfield of the Supported MCS Set field and the Rx STBC subfield of the HT Capabilities element transmitted by the intended receiver.

— If the sounding PPDU is an NDP, the number of antennas used by the sender shall be less than or equal to the number indicated by the Channel Estimation Capability subfield in the Transmit Beamforming Capability field of the HT Capabilities element transmitted by the intended receiver.

Sounding PPDUs in which the Calibration Position subfield is equal to 2 or 3 shall use the spatial mapping matrices defined in 19.3.12.3. The calibration responder shall not remove the spatial mapping from the CSI to be fed back to the initiator of the frame exchange.

NOTE 1—The calibration initiator of this frame exchange is responsible for accounting for the spatial mapping in both its local channel estimate as well as in the quantized CSI fed back to it.

The row order in the CSI feedback matrix transmitted from STA B shall correspond to the association of the rows of the spatial mapping matrix [see Equation (19-75)] to its transmit antennas. For example, the receive antenna at STA B associated with row i in the CSI feedback matrix in each subcarrier is the same as its transmit antenna associated with row i in the spatial mapping matrix used for transmitting the sounding response with Calibration Position equal to 2.

Figure 10-49 and Figure 10-50 illustrate the calibration PPDU exchange using NDPs.

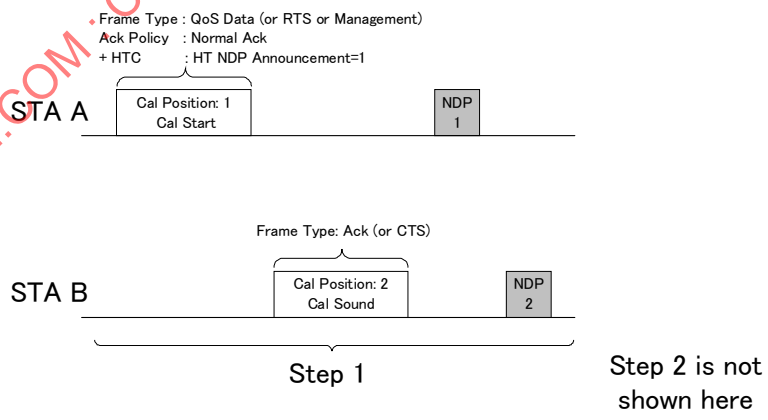

Figure 10-49—Calibration procedure with NDP

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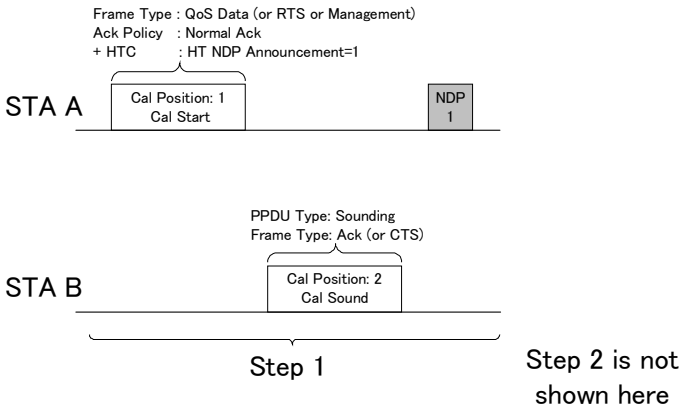

Figure 10-50—Calibration procedure with NDP when STA B supports transmitting sounding PPDUs for which only one channel dimension can be estimated (i.e., a single column of the MIMO channel matrix)

The calibration procedure begins with a calibration sounding PPDU exchange sequence, shown as Step 1 in Figure 10-49 and Figure 10-50, when STA B supports transmitting sounding PPDUs for which only one channel dimension can be estimated (i.e., a single column of the MIMO channel matrix). The Calibration Sequence subfield in the HT Control field shall be incremented each time a new calibration procedure is started.

NDP transmission within a calibration procedure follows the rules defined in 10.36.1. STA A transmits a Calibration Start frame (i.e., with the Calibration Position subfield set to 1) with the HT NDP Announcement subfield set to 1 and CSI/Steering subfield of the HT Control field set to 1. Only the current TXOP holder may set both the Calibration Position and HT NDP Announcement subfields to 1. This frame initiates a calibration procedure.

STA B shall transmit a Calibration Sounding Response frame (i.e., with the Calibration Position subfield set to 2) after a SIFS after the received Calibration Start frame. If STA B supports transmitting sounding PPDUs for which only one channel dimension can be estimated (i.e., a single column of the MIMO channel matrix), this Calibration Sounding Response frame is sent with the SOUNDING parameter of the TXVECTOR set to SOUNDING (see Figure 10-50).

As determined by NDP rules a) or b) in 10.36.1, STA A sends the first NDP as a sounding PPDU a SIFS after receiving the Calibration Sounding Response frame. This step allows STA B to estimate the MIMO channel from STA A to STA B. In the Calibration Sounding Response frame, the Calibration Sequence subfield in HT Control field shall be set to the same value that is contained in the Calibration Start frame. The Calibration Sounding Response frame shall contain an HT Control field, and the type and subtype of the frame are determined by the Calibration Start frame.

As determined by NDP rule d), STA B might transmit a second NDP as a sounding PPDU a SIFS after receiving the first NDP. This second NDP allows STA A to estimate the channel from STA B to STA A.

NOTE 2—STA B does not transmit an NDP when it supports transmitting sounding PPDUs for which only one channel dimension can be estimated (see Figure 10-50).

Otherwise [i.e., if STA B supports transmitting sounding PPDUs for which only one channel dimension can be estimated (single column of the MIMO channel matrix)], the transmission of the sounding PPDU in Calibration Position 2 allows STA A to estimate the channel from STA B to STA A.

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NDP sounding PPDUs shall use the spatial mapping matrices defined in 19.3.13.3. The calibration responder shall not remove the spatial mapping from the CSI to be fed back to the initiator of the frame exchange.

NOTE 3—The calibration initiator of this frame exchange is responsible for accounting for the spatial mapping in both its local channel estimate as well as in the quantized CSI fed back to it.

10.34.2.4.4 CSI reporting for calibration

The remaining message exchange in the calibration procedure is not time critical.

The calibration initiator should not transmit any frames that are part of the calibration sequence shown in Step 1 in Figure 10-48 if either of the response frames from the calibration responder (the frames shown as Calibration Position 2 and Ack in Step 1) is not received correctly within an AckTimeout interval (as defined in 10.3.2.11) after the PHY-TXEND.confirm primitive. If the calibration initiator aborts the calibration sequence, it may restart the calibration sequence with a value of the Calibration Sequence subfield in the Calibration Control subfield of the HT Control field that is different (i.e., incremented) from the value used in the aborted sequence. Within a non-NDP calibration sequence, the calibration responder should not transmit any further frames that are part of the calibration sequence shown in Step 1 if the frame having Calibration Position 3 is not received correctly within an AckTimeout interval (as defined in 10.3.2.11) after the PHY-TXEND.confirm primitive.

When the MIMO channel measurements become available at STA B, STA B shall send one or more CSI frames that contain the CSI report (Step 2 in Figure 10-48). This CSI report shall have full precision, i.e, *Ng*=1 (no grouping) and *Nb*=3 (8 bits). In these CSI frames, the Calibration Sequence subfields in HT Control fields shall be set to the same value that is indicated in the Calibration Sounding Complete frame. These CSI frames shall have a frame type of Management Action +HTC.

STA B should finish transmission of the first CSI frame within aMaxCSIMatricesReportDelay (in milliseconds) after the reception of the frame containing the CSI feedback request or HT NDP announcement.

NOTE—If necessary, the CSI Report field can be split into up to 8 segments as specified in Table 9-55.

A STA that has started but not completed the calibration procedure and that receives some other request that requires the buffering of CSI (such as another calibration initiation frame, MFB request, CSI feedback request for link adaptation, or feedback request for explicit Transmit Beamforming) may ignore the other request.

From the beginning of Step 1 of the calibration procedure and continuing through the end of Step 2 of the calibration procedure, neither the receiving nor the transmitting STA should switch antennas.

10.34.3 Explicit feedback beamforming

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

In this subclause, the terms *HT beamformer* and *HT beamformee* refer to STAs that are involved in explicit feedback beamforming.

An HT beamformer uses the feedback response that it receives from the HT beamformee to calculate a beamforming feedback matrix for transmit beamforming. This feedback response may have one of three formats:

— *CSI*: The HT beamformee sends the MIMO channel coefficients to the HT beamformer.
— *Noncompressed beamforming*: The HT beamformee sends calculated beamforming feedback matrices to the HT beamformer.

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— *Compressed beamforming*: The HT beamformee sends compressed beamforming feedback matrices to the HT beamformer.

The supported formats shall be advertised in the HT beamformee's HT Capabilities element.

NOTE 1—An HT beamformer might discard the feedback response if the TSF time when the PHY-CCA.indication(IDLE) primitive corresponding to the feedback response frame's arrival minus the value from the Sounding Timestamp field in the feedback response frame is greater than the coherence time interval of the propagation channel.

An HT beamformee's responding capabilities shall be advertised in HT Capabilities elements that are transmitted by the HT beamformee. Devices that are capable of acting as an HT beamformee shall advertise one of the following response capabilities in the Explicit Transmit Beamforming CSI Feedback subfield of the Transmit Beamforming Capability field:

— *Immediate*: The HT beamformee is capable of sending a feedback response a SIFS after receiving a sounding PPDU and/or is capable of sending a feedback response aggregated in a PPDU that contains a MAC response within the HT beamformer's TXOP.

— *Delayed*: The HT beamformee is not capable of sending the feedback response within the HT beamformer's TXOP, but it is capable of sending the feedback response in a TXOP that it obtains.

— *Immediate and Delayed*: The HT beamformee is capable of sending a feedback response a SIFS after receiving a sounding PPDU, sending a feedback response aggregated in a PPDU that contains a MAC response within the HT beamformer's TXOP, or sending the feedback response in a TXOP that it obtains.

The sounding frame types supported by the HT beamformee, staggered and/or NDP, are advertised in the HT Capabilities element in frames that are transmitted by the HT beamformee.

A STA that sets any of the Explicit Transmit Beamforming CSI Feedback Capable, Explicit Noncompressed Beamforming Feedback Capable, or Explicit Compressed Beamforming Feedback Capable fields to 1 shall transmit explicit feedback based on the receipt of a +HTC sounding PPDU in which the CSI/Steering subfield has a nonzero value and that does not contain Extension HT-LTFs (HT-ELTFs). This requirement is independent of the values of the Receive Staggered Sounding Capable and the Receive NDP Capable fields.

An HT beamformer shall set the SOUNDING parameter of the TXVECTOR to SOUNDING in the PHY-TXSTART.request primitive corresponding to each PPDU that is used for sounding.

An HT beamformer shall set the response type format indicated in the CSI/Steering subfield of the HT Control field of any sounding frame excluding the NDP and of any PPDU with the NDP Sounding Announcement field equal to 1 to one of the nonzero values (CSI, Compressed Beamforming, or Noncompressed Beamforming) that corresponds to a type that is supported by the HT beamformee.

The receipt of a PHY-RXSTART.indication primitive with the RXVECTOR SOUNDING parameter value equal to SOUNDING indicates a sounding PPDU. A non-NDP request for feedback is a sounding PPDU with a +HTC MPDU that contains a nonzero value of the CSI/Steering subfield and that has the HT NDP Announcement subfield equal to 0.

An NDP request for feedback is the combination of a +HTC MPDU that contains a nonzero value of the CSI/Steering subfield and that has the HT NDP Announcement subfield equal to 1 and the NDP that follows.

An HT beamformee that transmits a feedback frame in response to a sounding PPDU sent by an HT beamformer shall transmit a frame of the type (CSI, Compressed Beamforming, or Noncompressed Beamforming) indicated in the CSI/Steering subfield of the HT Control field transmitted by the HT beamformer.

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The HT beamformee decides on any subcarrier grouping to be used in the explicit Beamforming feedback. The value selected shall be a value supported by the HT beamformer as indicated in the Minimal Grouping subfield of the HT beamformer's HT Capabilities element.

An HT beamformee that sets the Explicit Transmit Beamforming CSI Feedback field of its HT Capabilities element to either 2 or 3 shall transmit Explicit CSI feedback after SIFS or later in the HT beamformer's TXOP as a response to a non-NDP request for feedback in a frame that is appropriate for the current frame exchange sequence following Table 10-26. An HT beamformee that sets the Explicit Noncompressed Beamforming Feedback Capable field of its HT Capabilities element to either 2 or 3 shall transmit Explicit Noncompressed Beamforming feedback after SIFS or later in the HT beamformer's TXOP as a response to a non-NDP request for feedback in a frame that is appropriate for the current frame exchange sequence following Table 10-26.

Table 10-26—Rules for HT beamformee immediate feedback transmission responding to non-NDP sounding

Type of response	Rule
CTS response	If the transmission of a CTS is required in response to the non-NDP request for feedback, the transmission of the feedback response frame shall be delayed until the HT beamformee's next transmission within the TXOP. This feedback response frame may be aggregated in an A-MPDU with an Ack or BlockAck frame.
Acknowledgment response	If the transmission of an Ack or BlockAck frame is required in response to the non-NDP request for feedback, both the feedback response frame and the control response frame may be aggregated in an A-MPDU.
No control response	If the transmission of a control response frame is not required in response to the non-NDP request for feedback, the feedback response frame shall be sent a SIFS after the reception of the sounding PPDU containing the request for feedback.
Later aggregation of feedback and acknowledgment	If the immediate-feedback-capable HT beamformee cannot transmit an aggregated or immediate CSI/Steering response in a SIFS after the end of the received sounding PPDU and the HT beamformee is subsequently required to transmit an Ack or BlockAck frame in the same TXOP, it may transmit the feedback response in an A-MPDU with the Ack or BlockAck frame.

An HT beamformee that sets the Explicit Compressed Beamforming Feedback Capable field of its HT Capabilities element to either 2 or 3 shall transmit Explicit Compressed Beamforming feedback after SIFS or later in the HT beamformer's TXOP as a response to a non-NDP request for feedback in a frame that is appropriate for the current frame exchange sequence following Table 10-26.

An HT beamformee that sets the Explicit Transmit Beamforming CSI Feedback field of its HT Capabilities element to either 2 or 3 shall transmit the Explicit CSI feedback after SIFS or later in the HT beamformer's TXOP as a response to an NDP request for feedback in a frame that is appropriate for the current frame exchange sequence following Table 10-27.

An HT beamformee that sets the Explicit Noncompressed Beamforming Feedback Capable field of its HT Capabilities element to either 2 or 3 shall transmit the Explicit Noncompressed Beamforming feedback after SIFS or later in the HT beamformer's TXOP as a response to an NDP request for feedback in a frame that is appropriate for the current frame exchange sequence following Table 10-27.

An HT beamformee that sets the Explicit Compressed Beamforming Feedback Capable field of its HT Capabilities element to either 2 or 3 shall transmit the Explicit Compressed Beamforming feedback after SIFS or later in the HT beamformer's TXOP as a response to an NDP request for feedback in a frame that is appropriate for the current frame exchange sequence following Table 10-27.

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Table 10-27—Rules for HT beamformee immediate feedback transmission responding to NDP sounding

Type of response	Rule
Control response	If the transmission of a control response frame is required in response to the NDP request for feedback, the control response frame is transmitted a SIFS after reception of the PPDU that elicited the control response, and the feedback response frame may be transmitted a SIFS after the reception of the NDP. — If the feedback response frame is not transmitted a SIFS after the reception of the NDP and the HT beamformee is subsequently required to transmit an Ack or BlockAck frame in the same TXOP, then the feedback response may be aggregated with the Ack or BlockAck frame. — If the feedback response frame is not transmitted a SIFS after the reception of the NDP and is not transmitted with an aggregated Ack or BlockAck frame in the same TXOP, then the feedback response frame is delayed until the HT beamformee's next transmission within the TXOP.
No control response	If the transmission of a control response frame is not required in response to the NDP request for feedback, the feedback response frame may be sent a SIFS after the reception of the NDP. — If the feedback response frame is not transmitted a SIFS after the reception of the NDP and the HT beamformee is subsequently required to transmit an Ack or BlockAck frame in the same TXOP, then the feedback response may be aggregated with the Ack or BlockAck frame. — If the feedback response frame is not transmitted a SIFS after the reception of the NDP and is not transmitted with an aggregated Ack or BlockAck frame in the same TXOP, then the feedback response frame is delayed until the HT beamformee's next transmission within the TXOP.

When the HT beamformee sets the Explicit Transmit Beamforming CSI Feedback field of its HT Capabilities element to either 2 or 3 and the HT beamformer has transmitted an NDP or an non-NDP Explicit Beamforming CSI feedback request in a frame that does not require immediate control response, the HT beamformer shall not transmit the next PPDU to the HT beamformee until PIFS after transmitting the sounding request.

When the HT beamformee sets the Explicit Noncompressed Beamforming Feedback Capable field of its HT Capabilities element to either 2 or 3 and the HT beamformer has transmitted an NDP or an non-NDP Explicit Noncompressed Beamforming feedback request in a frame that does not require immediate control response, the HT beamformer shall not transmit the next PPDU to the HT beamformee until PIFS after the sounding request.

When the HT beamformee sets the Explicit Compressed Beamforming Feedback Capable field of its HT Capabilities element to either 2 or 3 and the HT beamformer has transmitted an NDP or an non-NDP Explicit Compressed Beamforming feedback request in a frame that does not require immediate control response, the HT beamformer shall not transmit the next PPDU to the HT beamformee until PIFS after transmitting the sounding request.

An HT beamformee shall not transmit a CSI, Compressed Beamforming, or Noncompressed Beamforming frame except in response to a request for feedback.

NOTE 2—Error recovery in a TXOP is not affected by sounding. An HT beamformer that is a TXOP holder and that fails to receive an expected response to a sounding PPDU can continue transmission as specified in 10.23.2.8.

An HT beamformee transmitting a feedback response after SIFS or later in the HT beamformer's TXOP shall use an Action No Ack frame or an Action No Ack +HTC frame (defined in 9.3.3.14).

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An HT beamformee transmitting delayed feedback response shall use an Action frame or an Action +HTC frame to send this information within a separate TXOP.

If necessary, the CSI Report field, Noncompressed Beamforming Report field, or Compressed Beamforming Report field may be split into up to 8 frames. The length of each segment shall be equal number of octets for all segments except the last, which may be smaller.

NOTE 3—A STA that has been granted an RDG can act as an HT beamformer during the RDG time period, provided that the RD rules are obeyed.

An HT beamformee that advertises itself as delayed-feedback-capable shall not transmit an immediate feedback response unless it also advertises itself as immediate-feedback-capable.

An HT beamformer may use the following worst-case parameters to estimate the duration of the expected frame that contains the feedback response: lowest rate in basic HT-MCS set, HT-mixed format, no grouping.

An Explicit Feedback Request may be combined with an MRQ. If the response contains a beamforming feedback matrix, the returned MCS shall be derived from the same information that was used to generate this particular beamforming feedback matrix. If the response contains channel coefficients, the returned MCS shall be derived from an analysis of the sounding frame that was used to generate the channel coefficients. The MFB field set to 127 (meaning no feedback) may be used when the HT beamformee is unable to generate the MCS in time for inclusion in the response transmission frame. A CSI-capable STA may be incapable of generating MFB.

Explicit feedback shall be calculated only from a sounding PPDU.

An HT beamformee that transmits a feedback frame of type Compressed Beamforming in response to a sounding PPDU sent by an HT beamformer shall set the *Nr* Index subfield in the MIMO Control field of the feedback frame to indicate the same value as the number of streams in the sounding PPDU.

10.34.4 VHT MU beamforming

An MU beamformer may transmit a VHT MU PPDU with a single nonzero TXVECTOR parameter NUM_STS[p], where $0 \le p \le 3$.

An MU beamformer shall not transmit a VHT MU PPDU with a nonzero TXVECTOR parameter NUM_STS[p], where $0 \le p \le 3$, to a STA whose MU Beamformee Capable field is equal to 0.

When transmitting a VHT MU PPDU, an MU beamformer shall order the per-user arrays of TXVECTOR parameters so that the per-user USER_POSITION array is in ascending order.

10.34.5 Explicit feedback beamforming for CMMG STAs

In this subclause, the terms *CMMG beamformer* and *CMMG beamformee* refer to STAs that are involved in explicit feedback beamforming.

A CMMG beamformer uses the feedback response that it receives from the CMMG beamformee to calculate a beamforming feedback matrix for transmit beamforming. This feedback response has the following format:

— *Compressed beamforming*: The CMMG beamformee sends compressed beamforming feedback matrices to the CMMG beamformer.

The supported formats shall be advertised in the beamformee's CMMG Capabilities element.

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NOTE 1—An HT and CMMG beamformer might discard the feedback response if the TSF time when the PHY-CCA.indication(IDLE) primitive corresponding to the feedback response frame's arrival minus the value from the Sounding Timestamp field in the feedback response frame is greater than the coherence time interval of the propagation channel.

A CMMG beamformee's responding capabilities shall be advertised in CMMG Capabilities elements contained in DMG Beacon, Probe Request, Probe Response, Association Request, Association Response, Action, and Action No Ack frames that are transmitted by the CMMG beamformee. Devices that are capable of acting as a CMMG beamformee shall advertise one of the following response capabilities in the Explicit Compressed Beamforming Feedback Capable subfield of the Transmit Beamforming Capability field:

— *Immediate:* The CMMG beamformee is capable of sending a feedback response an SIFS after receiving a sounding PPDU and/or is capable of sending a feedback response aggregated in a PPDU that contains a MAC response within the CMMG beamformer's TXOP.

— *Delayed:* The CMMG beamformee is not capable of sending the feedback response within the CMMG beamformer's TXOP, but it is capable of sending the feedback response in a TXOP that it obtains.

— *Immediate and Delayed:* The CMMG beamformee is capable of sending a feedback response an SIFS after receiving a sounding PPDU, sending a feedback response aggregated in a PPDU that contains a MAC response within the CMMG beamformer's TXOP, or sending the feedback response in a TXOP that it obtains.

The sounding frame types supported by the CMMG beamformee, staggered and/or NDP, are advertised in the CMMG Capabilities element in frames that are transmitted by the CMMG beamformee.

A STA that sets Explicit Compressed Beamforming Feedback Capable fields to 1 shall transmit explicit feedback based on the receipt of a sounding PPDU in which the CSI/Steering subfield has a nonzero value. This requirement is independent of the values of the Receive Staggered Sounding Capable and the Receive NDP Capable fields.

A CMMG beamformer shall set the SOUNDING parameter of the TXVECTOR to SOUNDING in the PHY-TXSTART.request primitive corresponding to each PPDU that is used for sounding.

A CMMG beamformer shall set the response type format indicated in the CSI/Steering subfield of the CMMG variant HT Control field of any sounding frame excluding the NDP and of any PPDU with the NDP Sounding Announcement field equal to 1 to the value of the type Compressed Beamforming.

The receipt of a PHY-RXSTART.indication primitive with the RXVECTOR SOUNDING parameter value equal to SOUNDING indicates a sounding PPDU. A non-NDP request for feedback is a sounding PPDU that contains a nonzero value of the CSI/Steering subfield and that has the NDP Announcement subfield equal to 0.

An NDP request for feedback is the combination of a CMMG MPDU that contains a nonzero value of the CSI/Steering subfield and that has the NDP Announcement subfield equal to 1 and the NDP that follows.

A CMMG beamformee that transmits a feedback frame in response to a sounding PPDU sent by a beamformer shall transmit a Compressed Beamforming frame.

The CMMG beamformee decides on any subcarrier grouping to be used in the explicit beamforming feedback. The value selected shall be a value supported by the CMMG beamformer as indicated in the Minimal Grouping subfield of the CMMG beamformer's CMMG Capabilities element.

A CMMG beamformee that sets the Explicit Compressed Feedback Capable field of its CMMG Capabilities element to either 2 or 3 shall transmit explicit compressed beamforming feedback after SIFS or later in the beamformer's TXOP as a response to a non-NDP request for feedback in a frame that is appropriate for the current frame exchange sequence following Table 10-28.

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Table 10-28—Rules for CMMG beamformee immediate feedback transmission responding to non-NDP sounding

Type of response	Rule
CTS response	If the transmission of a CTS is required in response to the non-NDP request for feedback, the transmission of the feedback response frame shall be delayed until the CMMG beamformee's next transmission within the TXOP. This feedback response frame may be aggregated in an A-MPDU with an Ack or BlockAck frame.
Acknowledgment response	If the transmission of an Ack or BlockAck frame is required in response to the non-NDP request for feedback, both the feedback response frame and the control response frame may be aggregated in an A-MPDU.
No control response	If the transmission of a control response frame is not required in response to the non-NDP request for feedback, the feedback response frame shall be sent an SIFS after the reception of the sounding PPDU containing the request for feedback.
Later aggregation of feedback and acknowledgment	If the immediate-feedback-capable CMMG beamformee cannot transmit an aggregated or immediate CSI/Steering response in an SIFS after the end of the received sounding PPDU and the CMMG beamformee is subsequently required to transmit an Ack or BlockAck frame in the same TXOP, it may transmit the feedback response in an A-MPDU with the Ack or BlockAck frame.

A CMMG beamformee that sets the Explicit Compressed Beamforming Feedback Capable field of its CMMG Capabilities element to either 2 or 3 shall transmit the explicit compressed beamforming feedback after SIFS or later in the CMMG beamformer's TXOP as a response to an NDP request for feedback in a frame that is appropriate for the current frame exchange sequence following Table 10-29.

Table 10-29—Rules for CMMG beamformee immediate feedback transmission responding to NDP sounding

Type of response	Rule
Control response	If the transmission of a control response frame is required in response to the NDP request for feedback, the control response frame is transmitted an SIFS after reception of the PPDU that elicited the control response, and the feedback response frame may be transmitted an SIFS after the reception of the NDP. — If the feedback response frame is not transmitted an SIFS after the reception of the NDP and the CMMG beamformee is subsequently required to transmit anAck or BlockAck frame in the same TXOP, then the feedback response may be aggregated with the Ack or BlockAck frame. — If the feedback response frame is not transmitted an SIFS after the reception of the NDP and is not transmitted with an aggregated Ack or BlockAck frame in the same TXOP, then the feedback response frame is delayed until the CMMG beamformee's next transmission within the TXOP.
No control response	If the transmission of a control response frame is not required in response to the NDP request for feedback, the feedback response frame may be sent an SIFS after the reception of the NDP. — If the feedback response frame is not transmitted an SIFS after the reception of the NDP and the CMMG beamformee is subsequently required to transmit an Ack or BlockAck frame in the same TXOP, then the feedback response may be aggregated with the Ack or BlockAck frame. — If the feedback response frame is not transmitted an SIFS after the reception of the NDP and is not transmitted with an aggregated Ack or BlockAck frame in the same TXOP, then the feedback response frame is delayed until the CMMG beamformee's next transmission within the TXOP.

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When the CMMG beamformee sets the Explicit Compressed Beamforming Feedback Capable field of its CMMG Capabilities element to either 2 or 3 and the CMMG beamformer has transmitted an NDP or an non-NDP explicit compressed beamforming feedback request in a frame that does not require immediate control response, the CMMG beamformer shall not transmit the next PPDU to the beamformee until PIFS after transmitting the sounding request.

A CMMG beamformee shall not transmit Compressed Beamforming frame except in response to a request for feedback.

NOTE 2—Error recovery in a TXOP is not affected by sounding. A beamformer that is a TXOP holder and that fails to receive an expected response to a sounding PPDU can continue transmission as specified in 10.23.2.4.

A CMMG beamformee transmitting a feedback response after SIFS or later in the beamformer's TXOP shall use an Action No Ack frame defined in 9.3.3.14.

A CMMG beamformee transmitting delayed feedback response shall use an Action frame to send this information within a separate TXOP.

If necessary, the Compressed Beamforming Report field may be split into up to 8 frames. The length of each segment shall be equal number of octets for all segments except the last, which may be smaller.

NOTE 3—A STA that has been granted an RDG can act as a CMMG beamformer during the RDG time period, provided that the RD rules are obeyed.

A CMMG beamformee that advertises itself as delayed-feedback-capable shall not transmit an immediate feedback response unless it also advertises itself as immediate-feedback-capable.

An explicit feedback request may be combined with an MRQ. If the response contains a beamforming feedback matrix, the returned MCS shall be derived from the same information that was used to generate this particular beamforming feedback matrix. If the response contains channel coefficients, the returned MCS shall be derived from an analysis of the sounding frame that was used to generate the channel coefficients. The MFB field set to 127 (meaning no feedback) may be used when the CMMG beamformee is unable to generate the MCS in time for inclusion in the response transmission frame. A CSI-capable STA may be incapable of generating MFB.

Explicit feedback shall be calculated only from a sounding PPDU.

A CMMG beamformee that transmits a feedback frame of type Compressed Beamforming in response to a sounding PPDU sent by a CMMG beamformer shall set the *Nr* Index subfield in the MIMO Control field of the feedback frame to indicate the same value as the number of streams in the sounding PPDU.

10.35 Antenna selection (ASEL)

10.35.1 Introduction

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

ASEL is a time-variant mapping of the signals at the RF chains onto a set of antenna elements when the number of RF chains is smaller than the number of antenna elements. The mapping might be chosen based on instantaneous or averaged CSI. ASEL requires the training of the full size channel associated with all antenna elements, which is obtained by transmitting or receiving sounding PPDUs over all antennas. These sounding PPDUs should be sent within a single TXOP. To avoid channel distortions, these sounding PPDUs shall be transmitted consecutively. The training information is exchanged using the HT Control field. When both

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transmitter and receiver have ASEL capabilities, training of transmit and receive antennas might be done one after another. ASEL supports up to eight antennas and up to four RF chains.

10.35.2 ASEL frame exchange procedure

A STA shall not initiate an ASEL training frame exchange sequence with another STA unless that STA supports ASEL, as determined by the ASEL Capability field (see 9.4.2.55.7).

A STA that is capable of supporting ASEL should set each subfield of the ASEL Capability field of the HT Capabilities element to 1 depending on its capabilities in HT Capabilities elements that it transmits (see 9.4.2.55.7).

A STA that sets the Explicit CSI Feedback Based Tx ASEL Capable subfield of the ASEL Capability field (see 9.4.2.55.7) to 1 shall set the CSI Max Number of Rows Beamformer Supported subfield of the Transmit Beamforming Capabilities field to an appropriate value, even if the STA sets the Explicit Transmit Beamforming CSI Feedback subfield to the value 0.

The frame exchange sequence for transmit ASEL is shown in Figure 10-51, where the term *ASEL transmitter* identifies the STA that is conducting transmit ASEL, and the term *transmit ASEL responder* identifies the STA that provides ASEL feedback. The frame exchange comprises the following steps:

a) (Optional) A transmit ASEL responder may initiate the transmit ASEL training by sending a +HTC frame with the ASEL Command subfield set to Transmit Antenna Selection Sounding Request (TXASSR).

b) The ASEL transmitter sends out consecutive sounding PPDUs separated by SIFS in a TXOP of which it is the TXOP holder with no acknowledgment over different antenna sets, each PPDU containing a +HTC frame with the ASEL Command subfield set to Transmit Antenna Selection Sounding Indication (TXASSI or TXASSI-CSI). Each sounding PPDU is transmitted over one antenna set.

   If the ASEL transmitter allows antenna indices feedback (by setting the ASEL Command subfield to TXASSI), the antenna sets from which the sounding PPDUs are transmitted shall be disjoint. If the ASEL transmitter uses NDP sounding PPDUs for the ASEL sounding, the spatial mapping matrix Q_k shall be the identity matrix starting with the first NDP. If the ASEL transmitter uses non-NDP sounding PPDUs for the ASEL sounding, the spatial mapping matrix Q_k shall be an FFT matrix. An FFT matrix of size N is defined as a square matrix of dimension NxN with entries w_{im}, i=*0,..N–1,* *m=0,..N–1* where $w_{im} = \frac{1}{\sqrt{N}} \times \exp\left(-j2\pi\frac{im}{N}\right)$.

   The ASEL transmitter shall not include TXASSI-CSI in the command field of the sounding frame if the last received value of the Explicit CSI Feedback Capable subfield of the ASEL Capability field (see 9.4.2.55.7) from the receiver was 0.

   NOTE 1—For example, in the case of sounding over all disjointed antenna sets, the number of consecutive sounding PPDUs equals the smallest integer that is greater than or equal to the number of antennas divided by the number of RF chains. These sounding PPDUs need to be sent within a single TXOP in order to minimize the change in the channel during this procedure.

c) The transmit ASEL responder estimates the subchannel corresponding to each sounding PPDU.

d) If the ASEL Command subfield in the sounding frames is equal to TXASSI-CSI, after receiving all of the sounding PPDUs, the transmit ASEL responder shall respond with the full size CSI in a subsequent TXOP. If the ASEL Command subfield in the sounding frames is equal to TXASSI, after receiving all of the sounding PPDUs, the transmit ASEL responder may either respond with the full size CSI in a subsequent TXOP, or conduct ASEL computation and provide the selected antenna indices in a subsequent TXOP.

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1) CSI is transported using the MIMO CSI Matrices frame defined in 9.6.11.5 contained within either an Action No Ack or Action frame. Multiple CSI frames may be required to provide the complete feedback, in which case the value of the Sounding Timestamp field within each of these CSI frames shall correspond to the arrival time of the sounding frame that was used to generate the feedback information contained in the frame.
2) Antenna indices feedback is carried in the Antenna Selection Indices Feedback frame, defined in 9.6.11.8. One octet of the Antenna Selection Indices field is used to carry the selected antenna indices feedback.

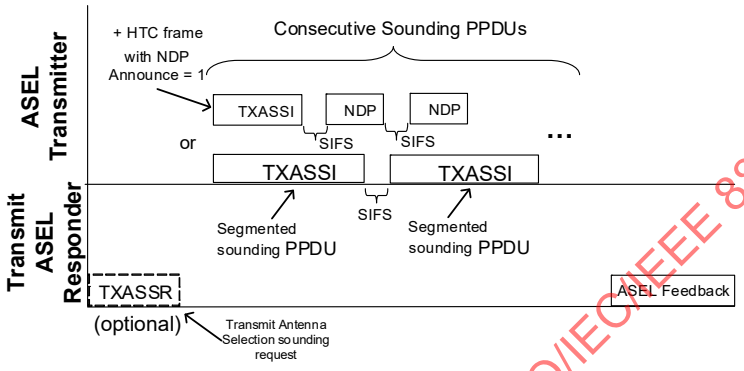

Figure 10-51—Transmit ASEL

If the transmit ASEL responder does not correctly receive all of the sounding PPDUs but has correctly received at least one of the preceding sounding PPDUs, it shall send a +HTC frame with the MAI subfield set to the value ASELI (see Table 9-16), the ASEL Command subfield set to No Feedback Due to ASEL Training Failure or Stale Feedback to indicate the failure of the ASEL training process, and the ASEL Data subfield set to either of the following:

— The integer value corresponding to the number in sequence of the first sounding PPDU that was not properly received, where 0 corresponds to the first sounding PPDU in the ASEL training sequence or
— The value 0

A transmit ASEL responder that determines that the ASEL feedback is stale shall notify the ASEL transmitter by transmitting a +HTC MPDU with the MAI subfield set to ASELI, the ASEL Command subfield set to No Feedback Due to ASEL Training Failure or Stale Feedback, and the ASEL Data subfield set to 0.

If, in response to the transmission of a sequence of sounding PPDUs, the ASEL transmitter receives a +HTC MPDU with the MAI subfield equal to ASELI, the ASEL Command subfield equal to No Feedback Due to ASEL Training Failure or Stale Feedback, and the ASEL Data subfield not equal to 0 to indicate a failed ASEL training frame sequence, the ASEL transmitter may perform any of the following actions:

— Do nothing.
— Restart the failed ASEL training frame sequence from the point of failure by transmitting a +HTC MPDU with the MAI subfield set to ASELI, the ASEL Command subfield set to TXASSR, and the ASEL Data subfield set to a nonzero value to correspond to the command Transmit Antenna Selection Sounding Resumption (a Resumption MPDU), where the ASEL Data subfield value is the order number (from the original training frame sequence) of the first sounding PPDU transmitted in the restarted ASEL training frame sequence and where 0 corresponds to the first sounding PPDU in the original ASEL training sequence.

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— Execute a new ASEL training frame sequence by transmitting a +HTC MPDU with the MAI subfield set to ASELI, the ASEL Command subfield set to TXASSI or TXASSI-CSI, and the ASEL Data subfield set to a nonzero value.

If a transmit ASEL responder receives a +HTC MPDU with the MAI subfield equal to ASELI, the ASEL Command subfield equal to TXASSR, and the ASEL Data subfield not equal to 0 to correspond to the command Transmit Antenna Selection Sounding Resumption (a Resumption MPDU), the transmit ASEL responder shall respond to the training sequence according to the original command value (i.e., TXASSI or TXASSI-CSI) and shall assume a total number of sounding PPDUs that corresponds to the number of sounding PPDUs from the original command frame. The number of sounding frames that follow the Resumption MPDU is equal to the number of sounding PPDUs from the original command frame minus the order number transmitted in the ASEL Data subfield of the Resumption MPDU.

The frame exchange sequence for receive ASEL is shown in Figure 10-52, where the term *ASEL receiver* identifies the STA that is conducting receive ASEL, and the term *ASEL sounding-capable transmitter* identifies the STA sending the consecutive sounding PPDUs used for receive ASEL calculations. The frame exchange comprises the following steps:

— The ASEL receiver transmits a +HTC frame with the MAI subfield set to ASELI, the ASEL Command subfield set to Receive Antenna Selection Sounding Request (RXASSR), and the ASEL Data subfield set to the number of sounding PPDUs required.

NOTE 2—For example, in the case of sounding over all disjointed antenna sets, the number of total consecutive sounding PPDUs or NDPs equals the smallest integer that is greater than or equal to the number of antennas divided by the number of RF chains.

— The ASEL sounding-capable transmitter responds with the corresponding number of sounding PPDUs in its subsequent TXOP. These PPDUs are separated by SIFS. When using non-NDP sounding, each PPDU contains a +HTC frame in which the MAI subfield is set to ASELI, the ASEL Command subfield is set to Receive Antenna Selection Sounding Indication (RXASSI), and the ASEL Data subfield is set to the remaining number of sounding PPDUs to be transmitted. When using NDP sounding, the PPDU that precedes the first NDP contains a +HTC frame in which the NDP Announce field is set to 1, the MAI subfield is set to ASELI, the ASEL Command subfield is set to RXASSI, and the ASEL Data subfield is set to the remaining number of sounding PPDUs to be transmitted.

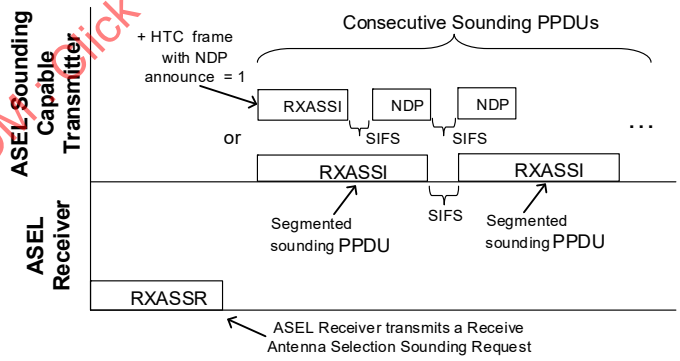

Figure 10-52—Receive ASEL

The ASEL receiver uses different antenna sets to receive these sounding PPDUs, estimates CSI after receiving all these sounding PPDUs, and conducts the ASEL.

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When transmitting the consecutive sounding PPDUs in transmit and receive ASEL exchanges (illustrated in Figure 10-51 and Figure 10-52), the transmitter shall not change the TXPWR_LEVEL_INDEX parameter of the TXVECTOR.

When transmitting a sounding PPDU sent in transmit and receive ASEL exchanges (illustrated in Figure 10-51 and Figure 10-52), if the Receive Staggered Capability subfield of the Transmit Beamforming Capability field of the HT Capabilities element transmitted by the intended receiver is 0, then,

— If the sounding PPDU is not an NDP, the number of antennas used by the sender, as indicated by the ANTENNA_SET parameter in the TXVECTOR, shall be less than or equal to the maximum number of space-time streams indicated by the Rx MCS Bitmask subfield of the Supported MCS Set field and the Rx STBC subfield of the HT Capabilities element transmitted by the intended receiver.

— If the sounding PPDU is an NDP, the number of antennas used by the sender, as indicated by the ANTENNA_SET parameter in the TXVECTOR, shall be less than or equal to the number indicated by the Channel Estimation Capability subfield of the Transmit Beamforming Capability field of the HT Capabilities element transmitted by the intended receiver.

When both transmitter and receiver have ASEL capabilities, the following constraints apply:

— During a transmit ASEL frame exchange, the transmit ASEL responder shall use a subset of antennas that does not change during the reception of all of the sounding PPDUs of the ASEL sounding sequence.

— During a receive ASEL frame exchange, the ASEL sounding-capable transmitter shall use a subset of antennas that does not change during the transmission of all of the sounding PPDUs of the ASEL sounding sequence.

NOTE 3—When a receiver (either a transmit ASEL responder or an ASEL receiver) conducts ASEL computations (for either transmit or receive ASEL), if there is no transmit beamforming conducted at the same time, to achieve the best performance of ASEL, the receiver assumes that the first N_{STS} columns of the same spatial mapping matrix Q_k used for transmitting ASEL sounding PPDUs, where N_{STS} is the number of space-time streams, are applied for the spatial mapping at the ASEL transmitter after the ASEL exchange as in Figure 10-51 and Figure 10-52. To achieve the best performance of ASEL, the ASEL transmitter applies the first N_{STS} columns of the same Q_k for spatial mapping after the ASEL exchange as in Figure 10-51 and Figure 10-52.

10.36 Null data PPDU (NDP) sounding

10.36.1 HT NDP sounding protocol

Sounding may be accomplished using either staggered sounding PPDU or HT NDP, as described in 19.3.13. The MAC rules associated with sounding using HT NDP are described in 10.36.1 to 10.36.4.

An HT STA that has set the Receive NDP Capable field of its HT Capabilities element to 1 during association processes an HT NDP as a sounding PPDU if the destination of the sounding PPDU is determined to match itself as described in 10.36.3 and if the source of the sounding PPDU can be ascertained as described in 10.36.4.

An RXVECTOR LENGTH parameter equal to 0 indicates that an HT PPDU is an HT NDP.

A STA that is a TXOP holder or an RD responder shall not set both the HT NDP Announcement and RDG/More PPDU subfields to 1 simultaneously. The Calibration Position subfield shall not be set to any value except 0 and 1 in any +HTC frame in a PPDU that is also an HT NDP announcement. The Calibration Position subfield shall be set to 0 in any +HTC frame in a PPDU that is an HT NDP announcement that also contains any +HTC frame with the MAI subfield equal to ASELI. The Calibration Position subfield shall be set to 0 in all +HTC frames in a PPDU that is an HT NDP announcement and that contains any +HTC frame with the

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MRQ subfield equal to 1. The TRQ field shall be set to 0 in all +HTC frames in a PPDU that is an HT NDP announcement.

An NDP sequence contains at least one HT NDP and at least one PPDU that is not an NDP. Only one PPDU in the NDP sequence may contain an HT NDP announcement. An NDP sequence begins with an HT NDP announcement. The NDP sequence ends at the end of the transmission of the last HT NDP that is announced by the HT NDP announcement. A STA that transmits the first PPDU of an NDP sequence is the NDP sequence owner. In the NDP sequence, only PPDUs carrying HT NDP and PPDUs carrying single MPDU Control frames may follow the NDP sequence's starting PPDU.

A STA shall transmit only one HT NDP per HT NDP announcement, unless the HT NDP announcement includes a value in the ASEL Data subfield of the ASEL Command subfield of the HTC Control field that is greater than one. Each PPDU in an NDP sequence shall start a SIFS after end of the previous PPDU.

A STA shall not transmit a VHT NDP in a NDP sequence that contains an HT NDP announcement.

A CTS frame that is a +HTC frame shall not contain the HT NDP Announcement subfield set to 1.

NOTE 1—A CTS frame cannot be used for HT NDP announcement: if the CTS frame is a response to an RTS frame, the optional NAV reset timeout that starts at the end of the RTS frame does not include the additional HT NDP and SIFS (see 10.3.2.4). Also, if the CTS were the first frame of an NDP sequence, it would not be possible to determine the destination address of the HT NDP.

A STA shall transmit an HT NDP as follows:

a) A SIFS after sending a PPDU that is an HT NDP announcement and that does not contain an MPDU that requires an immediate response.

b) A SIFS after receiving a correctly formed and addressed immediate response to a PPDU that is an HT NDP announcement and that contains an MPDU that requires an immediate response.

c) A SIFS after transmitting an HT NDP if the HT NDP announcement contains an ASEL Command subfield equal to TXASSI, TXASSI-CSI, or RXASSI and the ASEL Data subfield is equal to a value greater than 0 and if the number of HT NDPs sent before this one is less than the value in the ASEL Data subfield + 1.

   NOTE 2—The total number of sent HT NDPs is equal to the value of in the ASEL Data subfield + 1.

d) A SIFS after receiving an HT NDP from a STA whose HT NDP announcement contained one or more +HTC frames with the Calibration Position subfield equal to 1, when the receiving STA supports transmitting sounding PPDUs for which more than one channel dimension can be estimated (i.e., more than one column of the MIMO channel matrix).

This rule enables the NDP receiver to know that it will receive an HT NDP and can determine the source and destination of the HT NDP. It enables the receiver and transmitter to know when the immediate response and HT NDP will be transmitted relative to the frame containing the HT NDP announcement indication.

A STA that has transmitted an HT NDP announcement in a frame that requires an immediate response and that does not receive the expected response shall terminate the NDP sequence at that point (i.e., the STA does not transmit an HT NDP in the current NDP sequence).

A STA that has received an HT NDP announcement in a +HTC with the Calibration Position equal to 1 or 2, and that does not receive the expected HT NDP shall terminate the NDP sequence at that point (i.e., does not transmit an HT NDP in the current NDP sequence) and not transmit any further frames that are a part of this calibration sequence shown in Step 1 of Figure 10-49.

Feedback information generated from the reception of an HT NDP is transmitted using any of the feedback rules and signaling as appropriate, e.g., immediate or delayed.

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10.36.2 Transmission of an HT NDP

A STA that transmits an HT NDP shall set the LENGTH, SOUNDING, STBC, MCS, and NUM_EXTEN_SS parameters of the TXVECTOR as specified in this subclause.

— LENGTH shall be set to 0.
— SOUNDING shall be set to SOUNDING.
— STBC shall be set to 0.
— MCS shall indicate two or more spatial streams.

The number of spatial streams sounded is indicated by the MCS parameter of the TXVECTOR and shall not exceed the limit indicated by the Channel Estimation Capability field in the Transmit Beamforming Capabilities field transmitted by the STA that is the intended receiver of the HT NDP. The MCS parameter may be set to any value, subject to the constraint of the previous sentence, regardless of the value of the Supported MCS Set field of the HT Capabilities field at either the transmitter or recipient of the HT NDP. A STA shall set the NUM_EXTEN_SS parameter of the TXVECTOR to 0 in the PHY-TXSTART.request primitive corresponding to an HT NDP transmission.

A STA shall not transmit an HT NDP announcement with an RA corresponding to another STA unless it has received an HT Capabilities element from the destination STA in which the Receive NDP Capable field is equal to 1.

10.36.3 Determination of HT NDP destination

The destination of an HT NDP is determined at the NDP receiver by examining the HT NDP announcement as follows:

— The destination of the first HT NDP in the NDP sequence is equal to the RA of any MPDU within HT NDP announcement.
— If Calibration Position subfield is equal to 1 in the HT NDP announcement at the NDP receiver, the destination of the second HT NDP is equal to the TA of that frame. Otherwise, the destination of the second and any subsequent HT NDPs is equal to the destination of the previous HT NDP.

See O.4 for an illustration of these rules.

10.36.4 Determination of HT NDP source

The source of an HT NDP is determined at the NDP receiver by examining the NDP sequences's starting PPDU as follows:

— If any MPDU within the HT NDP announcement contains two or more addresses, the source of the first HT NDP is equal to the TA of that frame.
— Otherwise (i.e., the HT NDP announcement contains one address), the source of the first HT NDP is equal to the RA of the MPDU to which the HT NDP announcement is a response.
— If the Calibration Position subfield is equal to 1 in an MPDU in the HT NDP announcement, the source of the second HT NDP is equal to the RA of that MPDU. Otherwise, the source of the second and any subsequent HT NDPs is equal to the source of the previous NDP.

See O.4 for an illustration of these rules.

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10.36.5 VHT sounding protocol

10.36.5.1 General

Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the *VHT beamformer*, and a STA for which reception is optimized is called a *VHT beamformee*. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.

If dot11VHTSUBeamformerOptionImplemented is true, a STA shall set the SU Beamformer Capable field in the VHT Capabilities element to 1. If dot11VHTSUBeamformeeOptionImplemented is true, a STA shall set the SU Beamformee Capable field in the VHT Capabilities element to 1.

If dot11VHTMUBeamformerOptionImplemented is true, a STA shall set the MU Beamformer Capable field in the VHT Capabilities element to 1. If dot11VHTMUBeamformeeOptionImplemented is true, a STA shall set the MU Beamformee Capable field in the VHT Capabilities element to 1.

If dot11VHTMUBeamformerOptionImplemented is true, a STA shall set dot11VHTSUBeamformerOptionImplemented to true. If dot11VHTMUBeamformeeOptionImplemented is true, a STA shall set dot11VHTSUBeamformeeOptionImplemented to true.

A STA is a VHT SU-only beamformer if it sets the SU Beamformer Capable field to 1 but sets the MU Beamformer Capable field to 0 in transmitted VHT Capabilities elements. A STA is an SU-only beamformee if it sets the SU Beamformee Capable field to 1 but sets the MU Beamformee Capable field to 0 in transmitted VHT Capabilities elements.

If dot11VHTSUBeamformerOptionImplemented is false, a STA shall not act in the role of a VHT beamformer. If dot11VHTSUBeamformeeOptionImplemented is false, a STA shall not act in the role of a VHT beamformee.

For an S1G STA, the S1G sounding protocol is specified in 10.36.5 with “VHT” replaced by “S1G”, except in this sentence.

10.36.5.2 Rules for VHT sounding protocol sequences

A VHT beamformer shall initiate a sounding feedback sequence by transmitting a VHT NDP Announcement frame followed by a VHT NDP after a SIFS. The VHT beamformer shall include in the VHT NDP Announcement frame one STA Info field for each VHT beamformee that is expected to prepare VHT compressed beamforming feedback and shall identify the VHT beamformee by including the VHT beamformee’s AID in the AID12 subfield of the STA Info field. The VHT NDP Announcement frame shall include at least one STA Info field.

NOTE 1—A STA that transmits a VHT NDP Announcement frame to a TDLS peer STA obtains the AID for the peer STA from the TDLS Setup Request or TDLS Setup Response frame.

A VHT beamformer shall not transmit either a VHT NDP Announcement+HTC frame or a Beamforming Report Poll+HTC frame that contains an HT variant HT Control field.

A VHT NDP shall be transmitted only following a SIFS after a VHT NDP Announcement frame. A VHT NDP Announcement frame shall be followed by a VHT NDP after SIFS.

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A VHT beamformer that has not received a VHT Capabilities element from a STA or where the last VHT Capabilities element received from a STA has the SU Beamformee Capable field set to 0 shall not transmit either of the following:

— A VHT NDP Announcement frame addressed to the STA or that includes the STA's AID in one of the STA Info fields
— A Beamforming Report Poll frame addressed to the STA

A VHT beamformer that transmits a VHT NDP Announcement frame to a VHT SU-only beamformee shall include only one STA Info field in the VHT NDP Announcement frame and set the Feedback Type subfield of the STA Info field to SU.

An S1G beamformee with dot11NDPBeamformingReportPollImplemented equal to true shall set the NDP Beamforming Report Poll Supported field in the S1G Capabilities element to 1. Otherwise it shall set the NDP Beamforming Report Poll Supported field in the S1G Capabilities element to 0.

An S1G beamformer may transmit NDP Beamforming Report Poll frames instead of VHT Beamforming Report Poll frames to an S1G beamformee from which it has received a frame containing an S1G Capabilities element with the NDP Beamforming Report Poll Supported field equal to true; otherwise, the S1G beamformer shall not transmit NDP Beamforming Report Poll frames to the S1G beamformee. A non-S1G beamformer or an S1G beamformer working on 1 MHz channel shall not transmit NDP Beamforming Report Poll frames. An S1G non-AP beamformer shall not transmit NDP Beamforming Report Poll frames to a non-AP beamformee.

If the VHT NDP Announcement frame includes more than one STA Info field, the RA of the VHT NDP Announcement frame shall be set to the broadcast address. If the VHT NDP Announcement frame includes a single STA Info field, the RA of the VHT NDP Announcement frame shall be set to the MAC address of the VHT beamformee.

A VHT NDP Announcement frame shall not include two or more STA Info fields with same value in the AID12 subfield.

A VHT beamformer that transmits a VHT NDP Announcement frame to a VHT beamformee that is an AP, mesh STA or IBSS STA, shall include a single STA Info field in the VHT NDP Announcement frame and shall set the AID12 subfield in the STA Info field to 0.

A VHT NDP Announcement frame with more than one STA Info field shall not carry a VHT variant HT Control field, unless all of the STAs listed in the AID12 subfield of the STA Info fields have set +HTC-VHT Capable to 1 in the VHT Capabilities Information field.

A VHT beamformer that transmits a VHT NDP Announcement frame with more than one STA Info field should transmit any Beamforming Report Poll frames used to retrieve VHT compressed beamforming feedback from the intended VHT beamformees in the same TXOP. If the duration of the TXOP that contained the VHT NDP Announcement frame has insufficient duration to accommodate the transmission of all of the feedback reports, the VHT beamformer may poll for the remaining VHT compressed beamforming feedback in subsequent TXOPs.

A VHT beamformer may use the worst case for various parameters to estimate the duration of the expected frame(s) that contain(s) the feedback response(s), such as the lowest rate in basic rate, HT-MCS or VHT-MCS set, no grouping and the highest precision codebook.

NOTE 2—The transmission of the VHT NDP Announcement, VHT NDP, VHT Compressed Beamforming, and Beamforming Report Poll frames is subject to the rules in 10.23.2.8.

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A VHT beamformer that sets the Feedback Type subfield of a STA Info field to MU shall set the Nc Index subfield of the same STA Info field to a value less than or equal to the minimum of both of the following:

— The maximum number of supported spatial streams for receive operation according to the combination of the corresponding VHT beamformee's Rx VHT-MCS Map subfield in the Supported VHT-MCS and NSS Set field and VHT Capabilities Information field

— The maximum number of supported spatial streams according to the Rx NSS subfield value and, when the value of the VHT Extended NSS BW Capable subfield received from the VHT beamformee is 1 and dot11ExtendedNSSSupported is equal to true, the 160/80+80 BW subfield value in the Operating Mode field of the most recently received Operating Mode Notification frame or Operating Mode Notification element with the Rx NSS Type subfield equal to 0 from the corresponding VHT beamformee, as computed according to 10.6.13.1

A non-AP VHT beamformee that receives a VHT NDP Announcement frame from a VHT beamformer with which it is associated or has an established TDLS session and that contains the VHT beamformee's AID in the AID12 subfield of the first (or only) STA Info field and also receives a VHT NDP a SIFS after the VHT NDP Announcement frame shall transmit the PPDU containing its VHT compressed beamforming feedback a SIFS after the VHT NDP. A VHT beamformee that is an AP, mesh STA, or IBSS STA, that receives a VHT NDP Announcement frame with the RA matching its MAC address and the AID12 subfield of the only STA Info field set to 0, and that also receives a VHT NDP a SIFS after the VHT NDP Announcement frame shall transmit the PPDU containing its VHT compressed beamforming feedback a SIFS after the VHT NDP. The TXVECTOR parameter CH_BANDWIDTH of the PPDU containing the VHT compressed beamforming feedback shall be set to indicate a bandwidth not wider than that indicated in the RXVECTOR parameter CH_BANDWIDTH of the received VHT NDP. A STA ignores received VHT NDP Announcement, VHT NDP, and Beamforming Report Poll frames if dot11VHTSUBeamformeeOptionImplemented is false.

A VHT beamformee shall indicate the maximum number of space-time streams it can receive in a VHT NDP in the Beamformee STS Capability subfield of the VHT Capabilities Information field of the VHT Capabilities element. If the beamformee is a non-AP STA, this shall be less than or equal to the maximum total number of space-time streams that the STA can receive in a VHT MU PPDU.

An example of the VHT sounding protocol with a single VHT beamformee is shown in Figure 10-53.

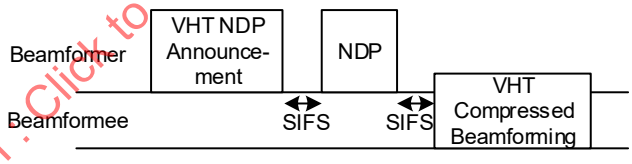

Figure 10-53—Example of the sounding protocol with a single VHT beamformee

A non-AP VHT beamformee that receives a VHT NDP Announcement frame from a VHT beamformer with which it is associated or has an established TDLS session and that contains the VHT beamformee's AID in the AID12 subfield of a STA Info field that is not the first STA Info field shall transmit its VHT compressed beamforming feedback a SIFS after receiving a Beamforming Report Poll with RA matching its MAC address and a nonbandwidth signaling TA obtained from the TA field matching the MAC address of the VHT beamformer. If the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT of the received Beamforming Report Poll frame is valid, the TXVECTOR parameter CH_BANDWIDTH of the PPDU containing the VHT compressed beamforming feedback shall be set to indicate a bandwidth not wider than that indicated by the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT of the Beamforming Report Poll frame; otherwise, the TXVECTOR parameter CH_BANDWIDTH of the PPDU containing VHT compressed beamforming feedback shall be set to indicate a bandwidth not wider than that indicated by the RXVECTOR parameter CH_BANDWIDTH of the Beamforming Report Poll frame.

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An example of the VHT sounding protocol with more than one VHT beamformee is shown in Figure 10-54.

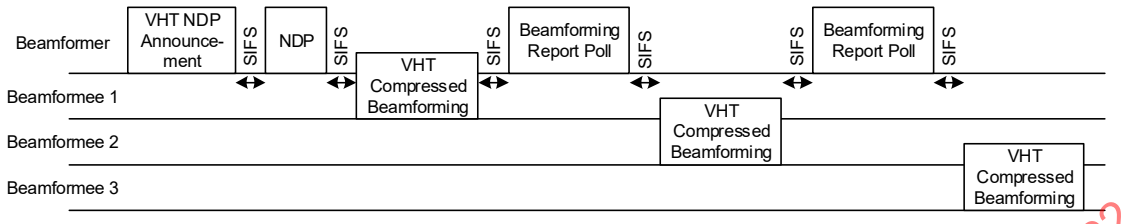

Figure 10-54—Example of the sounding protocol with more than one VHT beamformee

The RA field of the VHT Compressed Beamforming frame(s) of the VHT compressed beamforming feedback shall be set to a nonbandwidth signaling TA obtained from the TA field of the VHT NDP Announcement frame or the Beamforming Report Poll frame to which this VHT compressed beamforming feedback is a response.

If the VHT Beamformee is transmitting VHT Compressed Beamforming frame(s) a SIFS after the VHT NDP, then the VHT Compressed Beamforming frame(s) shall include the VHT Compressed Beamforming Report information and, for the case of MU feedback, the MU Exclusive Beamforming Report information.

A VHT beamformee that transmits a VHT Compressed Beamforming frame shall set the Feedback Type field in the VHT MIMO Control field to the same value as the Feedback Type field in the corresponding STA Info field in the VHT NDP Announcement frame. If the Feedback Type field indicates MU, the STA shall send a VHT Compressed Beamforming frame with the Nc Index field value in the VHT MIMO Control field equal to the minimum of all of the following:

— The Nc Index field value in the corresponding STA Info field in the VHT NDP Announcement Frame
— The maximum number of supported spatial streams for receive operation according to the combination of its Rx VHT-MCS Map subfield in the Supported VHT-MCS and NSS Set field, VHT Capabilities Information field and Operating Mode field (see 10.6.13.1)
— The maximum number of supported spatial streams according to the Rx NSS subfield value and, when the value of the most recently transmitted VHT Extended NSS BW Capable subfield is 1, the 160/80+80 BW subfield value in the Operating Mode field of the most recently transmitted Operating Mode Notification frame or Operating Mode Notification element, as computed according to 10.6.13.1

If the Feedback Type indicates SU, the Nc Index field value in the VHT MIMO Control field is determined by the VHT beamformee.

The Nr Index field in the VHT MIMO Control field shall be set to the same value as the RXVECTOR parameter NUM_STS of the corresponding VHT NDP. The Nc Index field shall not be set to a value larger than the Nr Index value in the VHT MIMO Control field. A VHT beamformee shall set the value of the Channel Width subfield in the VHT MIMO Control field of a VHT Compressed Beamforming frame to the same value as the RXVECTOR parameter CH_BANDWIDTH of the corresponding VHT NDP.

A VHT beamformee shall not include MU Exclusive Beamforming Report information in VHT compressed beamforming feedback if the Feedback Type subfield in the MIMO Control field of the VHT Compressed Beamforming frame(s) indicates SU. A VHT beamformee shall include both VHT Compressed Beamforming Report information and MU Exclusive Beamforming Report information in VHT compressed beamforming feedback if the Feedback Type subfield in the MIMO Control field of the VHT Compressed Beamforming frame(s) indicates MU.

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A VHT beamformee that transmits VHT compressed beamforming feedback shall include neither the VHT Compressed Beamforming Report information nor the MU Exclusive Beamforming Report information, if the transmission duration of the PPDU carrying the VHT Compressed Beamforming Report information and any MU Exclusive Beamforming Report information would exceed the maximum PPDU duration.

The value of the Sounding Dialog Token Number subfield in the VHT MIMO Control field shall be set to the same value as the Sounding Dialog Token Number subfield in the Sounding Dialog Token field in the corresponding VHT NDP Announcement frame.

NOTE 3—The VHT beamformer can use the sounding dialog token in the VHT Compressed Beamforming frame(s) of the VHT compressed beamforming feedback to associate the feedback with a prior VHT NDP Announcement frame and thus compute the delay between sounding and receiving the feedback. The VHT beamformer can use this delay time when making a decision regarding the applicability of the feedback for the link.

NOTE 4—Recovery in the case of a missing response to a VHT NDP Announcement or Beamforming Report Poll frame follows the rules for multiple frame transmission in an EDCA TXOP (see 10.23.2.8).

VHT compressed beamforming feedback comprises the VHT Compressed Beamforming Report information (see Table 9-75) and the MU Exclusive Beamforming Report information (see Table 9-78). Subclause 9.6.22.2 specifies how VHT compressed beamforming feedback is converted into a VHT Compressed Beamforming frame, and it also specifies the rules for the presence or absence of the two fields listed here.

In a frame transmitted by a TVHT STA, the TVHT Compressed Beamforming Report field replaces the VHT Compressed Beamforming Report field.

In a frame transmitted by a TVHT STA, the TVHT MU Exclusive Beamforming Report field replaces the MU Exclusive Beamforming Report field.

10.36.5.3 Rules for fragmented feedback in VHT sounding protocol sequences

VHT compressed beamforming feedback shall be transmitted in a single VHT Compressed Beamforming frame unless the result would be a VHT Compressed Beamforming frame that exceeds the VHT beamformer's maximum MPDU length capability.

NOTE 1—The requirement that the VHT compressed beamforming feedback is transmitted in a single VHT Compressed Beamforming frame implies that the VHT beamformee might have to transmit an MPDU that is bigger than its receive capability.

If VHT compressed beamforming feedback would result in a VHT Compressed Beamforming frame that exceeds the VHT beamformer's maximum MPDU length capability, the VHT compressed beamforming feedback shall be split into up to 8 feedback segments, with each feedback segment sent in a different VHT Compressed Beamforming frame and containing successive portions of the VHT compressed beamforming feedback consisting of the VHT Compressed Beamforming Report information followed by any MU Exclusive Beamforming Report information. Each of the feedback segments except the last shall contain the maximum number of octets allowed by the VHT beamformer's maximum MPDU length capability. The last feedback segment may be smaller. Each feedback segment is identified by the value of the Remaining Feedback Segments subfield and the First Feedback Segment subfield in the VHT MIMO Control field as defined in 9.4.1.48; the other nonreserved subfields of the VHT MIMO Control field shall be the same for all feedback segments. All feedback segments shall be sent in a single A-MPDU and shall be included in the A-MPDU in the descending order of the Remaining Feedback Segments subfield values.

NOTE 2—The feedback segments of a VHT Compressed Beamforming report are not MSDU/MMPDU fragments and can be included in an A-MPDU as described in this subclause.

A VHT beamformer, in its first attempt to retrieve VHT compressed beamforming feedback from a VHT beamformee that is not the one indicated by the first STA Info field, shall transmit a Beamforming Report Poll

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frame to poll all possible feedback segments of the VHT compressed beamforming feedback from the VHT beamformee, by setting all of the bits in the Feedback Segment Retransmission Bitmap field of the Beamforming Report Poll frame to 1.

If a VHT beamformer fails to receive some or all feedback segments of VHT compressed beamforming feedback, the VHT beamformer may, subject to the condition on VHT SU-only beamformees described at the end of this subclause, request a selective retransmission of missing feedback segments by transmitting a Beamforming Report Poll frame with the Feedback Segment Retransmission Bitmap field set as described in 9.3.1.20 to indicate the feedback segments requested for retransmission. If the VHT beamformer fails to receive the feedback segment with the First Feedback Segment field set to 1, the VHT beamformer may request a selective retransmission of missing feedback segments assuming the VHT compressed beamforming feedback is split into 8 feedback segments. The VHT beamformer may also request the retransmission of all feedback segments by setting all of the bits in the Feedback Segment Retransmission Bitmap field of the Beamforming Report Poll frame to 1.

A VHT beamformee that transmits VHT compressed beamforming feedback including the VHT Compressed Beamforming Report information and any MU Exclusive Beamforming Report information in response to a Beamforming Report Poll frame shall either transmit only the feedback segments indicated in the Feedback Segment Retransmission Bitmap field in the Beamforming Report Poll frame excluding the indicated feedback segments that do not exist at the VHT beamformee or transmit all of the feedback segments that exist at the VHT beamformee disregarding the Feedback Segment Retransmission Bitmap field in the Beamforming Report Poll frame.

A VHT beamformer shall not transmit a Beamforming Report Poll frame to a VHT SU-only beamformee unless the VHT beamformer has received at least one feedback segment of the VHT compressed beamforming feedback from the VHT beamformee in the current frame exchange sequence.

In a frame transmitted by a TVHT STA, the TVHT Compressed Beamforming Report field replaces the VHT Compressed Beamforming Report field.

In a frame transmitted by a TVHT STA, the TVHT MU Exclusive Beamforming Report field replaces the MU Exclusive Beamforming Report field.

10.36.6 Transmission of a VHT NDP

A VHT NDP shall use the SU PPDU format as described in 21.1.4. A STA shall transmit a VHT NDP using the following TXVECTOR parameters:

— APEP_LENGTH set to 0
— NUM_USERS set to 1
— NUM_STS indicates two or more space-time streams
— CH_BANDWIDTH set to the same value as the TXVECTOR parameter CH_BANDWIDTH in the preceding VHT NDP Announcement frame
— GROUP_ID and PARTIAL_AID are set as described in 10.19

The number of space-time streams sounded and as indicated by the NUM_STS parameter shall not exceed the value indicated in the Beamformee STS Capability field in the VHT Capabilities element of any intended recipient of the VHT NDP. The NUM_STS parameter may be set to any value, subject to the constraint of the previous sentence, regardless of the value of the Supported VHT-MCS and NSS Set field of the VHT Capabilities element at either the transmitter or recipient of the NDP.

The intended receiver of a VHT NDP is identified by the RA of the immediately preceding VHT NDP Announcement frame.

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The transmitter of a VHT NDP is identified by the TA of the immediately preceding VHT NDP Announcement frame.

10.36.7 Transmission of an S1G NDP

An S1G NDP shall use the 2 MHz short format as described in 23.1.4. An S1G STA transmitting an S1G NDP shall use the following TXVECTOR parameters:

- APEP_LENGTH set to 0 if AGGREGATION is set to AGGREGATED
- PSDU_LENGTH set to 0 if AGGREGATION is set to NOT_AGGREGATED
- NUM_USERS set to 1
- CH_BANDWIDTH set to the same value as the TXVECTOR parameter CH_BANDWIDTH in the preceding VHT NDP Announcement frame carried in an S1G PPDU
- NUM_STS indicates two or more space-time streams
- PARTIAL_AID set as described in 10.21
- NDP_INDICATION set to 0
- RESPONSE_INDICATION set to Long Response

The number of space-time streams sounded as indicated by the NUM_STS parameter shall not exceed the value indicated in the Beamformee STS Capability field in the S1G Capabilities element of any intended recipient of the S1G NDP. The NUM_STS parameter may be set to any value, subject to the constraint of the previous sentence, regardless of the value of the Supported S1G-MCS and NSS Set field of the S1G Capabilities element transmitted by either the transmitter or recipient of the S1G NDP.

The intended receiver of an S1G NDP is identified by the RA of the immediately preceding VHT NDP Announcement frame carried in an S1G PPDU.

The transmitter of an S1G NDP is identified by the TA of the immediately preceding VHT NDP Announcement frame carried in an S1G PPDU.

10.37 Null data PPDU (NDP) sounding for CMMG STAs

10.37.1 NDP rules

Sounding may be accomplished using CMMG NDP, as described in 25.6.8.14. The MAC rules associated with sounding using CMMG NDP are described in 10.37.1 and 10.37.2.

A CMMG STA that has set the Receive NDP Capable field of its CMMG Capabilities element to 1 during association processes a CMMG NDP as a sounding PPDU if the destination of the sounding PPDU is determined to match itself and if the source of the sounding PPDU can be ascertained.

An RXVECTOR LENGTH parameter equal to 0 indicates that the PPDU is a CMMG NDP.

A STA that is a TXOP holder or an RD responder shall not set both the CMMG NDP Announcement and RDG/More PPDU subfields to 1 simultaneously.

An NDP sequence contains at least one CMMG NDP and at least one PPDU that is not an NDP. Only one PPDU in the NDP sequence may contain a CMMG NDP announcement. An NDP sequence begins with a CMMG NDP announcement. The NDP sequence ends at the end of the transmission of the last CMMG NDP that is announced by the CMMG NDP announcement. A STA that transmits the first PPDU of an NDP sequence is the NDP sequence owner. In the NDP sequence, only PPDUs carrying CMMG NDP and PPDUs carrying single MPDU Control frames may follow the NDP sequence's starting PPDU.

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A STA shall transmit only one CMMG NDP per NDP announcement. Each PPDU in an NDP sequence shall start a SIFS after end of the previous PPDU.

NOTE—A CTS frame cannot be used for CMMG NDP announcement: if the CTS frame is a response to an RTS frame, the optional NAV reset timeout that starts at the end of the RTS frame does not include the additional CMMG NDP and SIFS. Also, if the CTS frame were the first frame of an NDP sequence, it would not be possible to determine the destination address of the CMMG NDP.

A STA shall transmit a CMMG NDP as follows:

a) A SIFS after sending a PPDU that is a CMMG NDP announcement and that does not contain an MPDU that requires an immediate response.
b) A SIFS after receiving a correctly formed and addressed immediate response to a PPDU that is a CMMG NDP announcement and that contains an MPDU that requires an immediate response.

This rule enables the NDP receiver to know that it receives a CMMG NDP and can determine the source and destination of the CMMG NDP. It enables the receiver and transmitter to know when the immediate response and CMMG NDP are transmitted relative to the frame containing the CMMG NDP announcement indication.

A STA that has transmitted a CMMG NDP announcement in a frame that requires an immediate response and that does not receive the expected response shall terminate the NDP sequence at that point (i.e., the STA does not transmit a CMMG NDP in the current NDP sequence).

Feedback information generated from the reception of a CMMG NDP is transmitted using any of the feedback rules and signaling as appropriate, e.g., immediate or delayed.

10.37.2 Transmission of a CMMG NDP

A STA that transmits a CMMG NDP shall set the LENGTH, SOUNDING, NSS, and STBC parameters of the TXVECTOR as specified in this subclause.

— LENGTH shall be set to 0.
— SOUNDING shall be set to SOUNDING.
— STBC shall be set to 0.
— NSS indicates two or more spatial streams.

The number of spatial streams sounded is indicated by the NSS parameter of the TXVECTOR and shall not exceed the limit indicated by the Channel Estimation Capability field in the Transmit Beamforming Capabilities field transmitted by the STA that is the intended receiver of the CMMG NDP.

10.37.3 Determination of CMMG NDP destination

The destination of a CMMG NDP is determined at the NDP receiver by examining the CMMG NDP announcement as follows:

— The destination of the first CMMG NDP in the NDP sequence is equal to the RA of any MPDU within the CMMG NDP announcement.
— If Calibration Position subfield is equal to 1 in the CMMG NDP announcement at the NDP receiver, the destination of the second CMMG NDP is equal to the TA of that frame. Otherwise, the destination of the second and any subsequent CMMG NDPs is equal to the destination of the previous CMMG NDP.

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10.37.4 Determination of CMMG NDP source

The source of a CMMG NDP is determined at the NDP receiver by examining the NDP sequences's starting PPDU as follows:

— If any MPDU within the CMMG NDP announcement contains two or more addresses, the source of the first CMMG NDP is equal to the TA of that frame.

— Otherwise (i.e., the CMMG NDP announcement contains one address), the source of the first CMMG NDP is equal to the RA of the MPDU to which the CMMG NDP announcement is a response.

If the Calibration Position subfield is equal to 1 in an MPDU in the CMMG NDP announcement, the source of the second CMMG NDP is equal to the RA of that MPDU. Otherwise, the source of the second and any subsequent CMMG NDPs is equal to the source of the previous NDP.

10.38 Mesh forwarding framework

10.38.1 General

The term *mesh forwarding* refers to forwarding of MSDUs and MMPDUs on paths determined by the mesh path selection between mesh STAs at the link layer. The mesh paths are contained in the forwarding information. The forwarding information, for instance, the lifetime of a mesh path, may be updated as a consequence of mesh forwarding.

The forwarding of MSDUs and MMPDUs within an MBSS is described in 10.38.3, 10.38.4, 10.38.5, and 10.38.8. The forwarding of MSDUs and MMPDUs between the MBSS and the DS at proxy mesh gates is described in 14.11.3.

10.38.2 Forwarding information

Forwarding information is created by the active mesh path selection protocol and is utilized for MSDU/MMPDU forwarding as described in 10.38.3 and 10.38.5.2.

The basic forwarding information to a destination mesh STA consists of the destination mesh STA address, the next-hop address, the precursor list, and the lifetime of this forwarding information.

An entry in the precursor list contains the precursor mesh STA address and the lifetime of this entry. If an existing entry in a precursor list is updated, the lifetime is the maximum of the current and the updated value. If the lifetime of a precursor expires, it will be deleted from the precursor list. Precursors are used to identify legitimate transmitters of individually addressed frames (see 10.38.3.2) and for the notification of link failures (in case of HWMP, see 14.10.11).

The forwarding information shall be considered as valid when the active mesh path selection protocol validates it. When a STA performs MSDU/MMPDU forwarding, it shall use valid forwarding information only.

If a STA finds its forwarding information to a particular destination mesh STA is not validated, it shall consider the corresponding next-hop address as unknown and may take necessary actions to forward any MSDU/MMPDU appropriately. See 10.38.8 and 14.10.9.3 for the HWMP case.

The forwarding information shall be considered as invalid if its lifetime has expired. Also, forwarding information is marked as invalid when certain conditions are met in the processing of mesh path selection elements, e.g., path error processing in HWMP (14.10.11.4).

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The active path selection protocol may define additional parameters in the forwarding information. Details on the additional parameters of the forwarding information constructed by the hybrid wireless mesh protocol (HWMP) are described in 14.10.8.4.

10.38.3 Addressing and forwarding of individually addressed mesh Data frames

10.38.3.1 At source mesh STAs (individually addressed)

MSDUs sent by a mesh STA (as a consequence of an MA-UNITDATA.request primitive with an individual destination address) and destined to another mesh STA in the MBSS shall be transmitted using a frame with the four-address MAC header format [with the Address Extension Mode subfield in the Mesh Control field set to "None" (see Table 9-26)], where the four address fields are set as follows [see row "Mesh Data (individually addressed)" in Table 9-47]:

— Address 1: The address of the next-hop mesh STA (toward the destination mesh STA according to the forwarding information; see 10.38.2).
— Address 2: The address of the transmitter mesh STA.
— Address 3: The address of the destination mesh STA.
— Address 4: The address of the source mesh STA.

MSDUs that are sent by a mesh STA as a consequence of an MA-UNITDATA.request primitive with an individual destination address and are destined to an address that is different from the mesh STA at the end of a mesh path shall be transmitted using a frame with the four-address MAC header format [with the Address Extension Mode subfield in the Mesh Control field set to "Address5&6" (see Table 9-26)], where the Mesh Address Extension subfield in the Mesh Control field carries the addresses of the end stations, as specified in row "Mesh Data (proxied, individually addressed)" of Table 9-47. The additional addresses 5 and 6 are defined as follows:

— Address 5: The address of the destination end mesh STA (may be the same as Address 3 if the destination is the mesh STA at the end of the mesh path).
— Address 6: The address of the source end mesh STA (may be the same as Address 4 if the source is the mesh STA at the beginning of the mesh path).

NOTE—The destination address is distinct from the mesh STA at the end of the mesh path in two cases: 1) when the destination is an external address and 2) when the destination is a mesh STA distinct from the destination mesh STA at the end of the mesh path. The former case is described in 14.11.3. The latter case might occur if a source mesh STA sends the MSDU to another intermediate mesh STA that sends the MSDU on a different mesh path to the destination mesh STA in the MBSS.

The Mesh TTL subfield in the Mesh Control field shall be set to dot11MeshTTL.The MSDUs are forwarded multiple hops, limited by the Mesh TTL value.

The source mesh STA shall set the Mesh Sequence Number subfield in the Mesh Control field to a value from a modulo 2^{32} counter that is incremented by 1 for each new MSDU transmitted with a Mesh Control field and for each new MMPDU transmitted using a Multihop Action frame.

10.38.3.2 At intermediate and destination mesh STAs (individually addressed)

On receipt of an individually addressed mesh Data frame, a mesh STA shall perform the following:

a) The mesh STA shall decipher the frame and check it for authenticity. If it is not from a peer mesh STA, the frame shall be silently discarded.
b) The mesh STA shall check to see whether the MAC address in the Address 3 field is a known destination address; if it is an unknown destination address, the mesh STA may perform any of the following three actions:

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1) Silently discard the frame.
2) Trigger a path discovery procedure depending on the path selection protocol that is currently active in the mesh BSS. For HWMP, see 14.10.9.3 Case A.
3) Inform the mesh STA in Address 2 that the destination is unreachable depending on the path selection protocol that is currently active in the mesh BSS. For HWMP, see 14.10.11.3 Case B.

c) If Address 2 is not one of the precursors for this destination mesh STA (see 10.38.2), the frame shall be discarded.

If the frame is not discarded and one or more MSDUs are collected from the frame, the mesh STA may detect duplicate MSDUs according to 10.38.6 and discard them.

If Address 3 does not match the mesh STA's own address, but is a known individual destination MAC address in the forwarding information then the following actions are taken:

— The lifetime of the forwarding information to the destination (Address 3) is set to its initial value.
— The lifetime of the forwarding information to the source (Address 4) is set to its initial value.
— The lifetime of the precursor list entry for the precursor to the destination (Address 2) is set to the maximum of the initial value and the current value.
— The lifetime of the precursor list entry for the precursor to the source (next hop to the destination) is set to the maximum of the initial value and the current value.
— The Mesh TTL in the corresponding Mesh Control field of the collected MSDU is decremented by 1. If zero has been reached, the MSDU shall be discarded.
— If the MSDU has not been discarded, the mesh STA shall forward the MSDU via a frame with the Address 1 field set to the MAC address of the next-hop mesh STA as determined from the forwarding information (see 10.38.2) and the Address 2 field set to its own MAC address and queue the frame for transmission.

If Address 3 matches the mesh STA's own MAC address, the following actions are taken:

— The lifetime of the forwarding information to the source (Address 4) is set to its initial value.
— The lifetime of the precursor list entry for the precursor to the destination (Address 2) is set to the maximum of the initial value and the current value.
— If the Address Extension Mode subfield in the Mesh Control field is "None" (see Table 9-26), the MA-UNITDATA.indication primitive is passed from the MAC sublayer entity to the LLC sublayer entity or entities.
— If the Address Extension Mode subfield in the Mesh Control field is "Address5&6" (see Table 9-26) and Address 5 is equal to Address 3, the mesh STA is the final destination of the MSDU, and the MA-UNITDATA.indication primitive is passed from the MAC sublayer entity to the LLC sublayer entity or entities.
— If the Address Extension Mode subfield in the Mesh Control field is "Address5&6" (see Table 9-26) and Address 5 is a known destination MAC address in the forwarding information (mesh STA), the mesh STA shall forward the MSDU via a frame as described in 10.38.3.1 with the Address 3 field set to the MAC Address of the Address 5 field.
— If the Address Extension Mode subfield in the Mesh Control field is "Address5&6" (see Table 9-26), the MSDU is forwarded according to 14.11.3.2 in all other cases.

If Address 3 matches the group address, the mesh STA shall perform the procedures as given in 10.38.4.2.

Note that during the forwarding process at intermediate mesh STAs, the content of the MSDU is not changed.

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10.38.4 Addressing and forwarding of group addressed mesh Data frames

10.38.4.1 At source mesh STAs (group addressed)

MSDUs sent by a mesh STA (as a consequence of an MA-UNITDATA.request primitive with a group destination address) shall be transmitted using a group addressed mesh Data frame [with the Address Extension Mode subfield in the Mesh Control field set to "None" (see Table 9-26)] [see row "Mesh Data (group addressed)" in Table 9-47]. An implementation may circumvent the unreliability of group addressed transmissions by using multiple individually addressed mesh Data frames, which are individually acknowledged. In such case, the frame may be converted to individually addressed frames and transmitted as individually addressed mesh Data frames to each peer mesh STA as described in 10.38.3.1 with the Address 3 field set to the group address. The circumstances for choosing this method are outside the scope of the standard.

In group addressed mesh Data frames, the address fields are set as follows:

— Address 1: The group address
— Address 2: The address of the transmitter mesh STA
— Address 3: The address of the source mesh STA

The source mesh STA shall set the Mesh TTL subfield in the Mesh Control field to dot11MeshTTL in order to control the hop count. The MSDUs are forwarded multiple hops, limited by the Mesh TTL value. For example, if the Mesh TTL subfield is 1, MSDUs are delivered only to immediate neighbors.

The source mesh STA shall set the Mesh Sequence Number subfield in the Mesh Control field to a value from a modulo 2^{32} counter that is incremented by 1 for each new MSDU transmitted with a Mesh Control field and for each new MMPDU transmitted using a Multihop Action frame.

Procedures that enhance the reliability or efficiency of group addressed transmissions are outside the scope of this standard.

10.38.4.2 At recipient mesh STAs (group addressed)

On receipt of a group addressed mesh Data frame with Address 1 (DA) equal to the group address, or on receipt of an individually addressed mesh Data frame with Address 3 (Mesh DA) equal to the group address, a mesh STA shall perform the following:

a) The mesh STA shall decipher the frame and check it for authenticity. If it is not from a peer mesh STA, the frame shall be silently discarded.
b) If the frame is not discarded and one or more MSDUs are collected from the frame, the mesh STA may detect duplicate MSDUs according to 10.38.6 and discard them.
c) The mesh STA decrements the Mesh TTL in the Mesh Control field. If the Mesh TTL value has reached zero, the corresponding MSDU shall not be forwarded to other mesh STAs.
d) If the Mesh TTL value has not reached zero and if dot11MeshForwarding is true, the mesh STA shall forward the MSDU via a group address mesh Data frame with the Address 2 field set to its own MAC address.
e) If the Address Extension Mode is "Address4" (see Table 9-26) and the recipient mesh STA is a proxy mesh gate and if the Mesh TTL value has not reached zero and if dot11MeshForwarding is true, the MSDU is forwarded according to 14.11.3.2.

When the SA and the Mesh SA are not identical (the source address is therefore an external address), the MSDU shall be forwarded by using a frame with the three-address MAC header format [with the Address Extension Mode subfield in the Mesh Control field set to "Address4" (see Table 9-26)] as specified in row "Mesh Data (proxied, group addressed)" of Table 9-47. Otherwise, the MSDU shall be forwarded by using a

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frame with the three-address MAC header format [with the Address Extension Mode subfield in the Mesh Control field set to "None" (see Table 9-26)] as specified in row "Mesh Data (group addressed)" of Table 9-47.

An implementation may circumvent the unreliability of group addressed transmissions by using multiple individually addressed mesh Data frames, which are individually acknowledged. In such case, the frame may be converted to individually addressed frames and transmitted as an individually addressed mesh Data frame to each peer mesh STAs as described in 10.38.3.2 with the Address 3 field set to the group address. If the Address Extension Mode subfield in the Mesh Control field in the group addressed mesh Data frame is equal to "Address4" (see Table 9-26), the Address Extension Mode subfield in the Mesh Control field in the individually addressed mesh Data frames is set to "Address5&6" (see Table 9-26), the Address 5 field is set to the group address, and the Address 6 field set to the Source Address contained in the Address 4 field of the group addressed mesh Data frame. The circumstances for choosing this method and the ability to determine all of the addresses of the neighbor peer mesh STAs are beyond the scope of the standard.

If one or more MSDUs collected from the frame have not been discarded, the MA-UNITDATA.indication primitive is passed from the MAC sublayer entity to the LLC sublayer entity or entities.

10.38.5 Addressing of Management frames and MMPDU forwarding

10.38.5.1 General

All MMPDUs except MMPDUs transmitted using Multihop Action frames are transmitted over only one hop to peer mesh STAs.

NOTE—In several cases, the reception and processing of an Action frame leads to the transmission of a new Action frame of the same type that might include an identical or a modified version of the contents from the elements of the received Action frame. This is called *propagation* in contrast to forwarding.

A mesh STA may convert a group addressed Management frame to individually addressed Management frames and transmit them as individually addressed frames to each peer mesh STA, if the frame is intended to be delivered only to its peer mesh STAs. The circumstances for choosing this method are outside the scope of the standard.

10.38.5.2 MMPDU forwarding using individually addressed Multihop Action frames

MMPDUs sent by a mesh STA and destined to another mesh STA in the MBSS using individually addressed Multihop Action frames (see 9.6.17) shall be transmitted using a Management frame with the three-address MAC header format [with the Address Extension Mode subfield in the Mesh Control field set to "Address4" (see Table 9-26)], where the four address fields are set as follows [see row "Multihop Action (individually addressed)" in Table 9-47]:

— Address 1: The address of the next-hop mesh STA (toward the destination mesh STA according to the forwarding information; see 10.38.2.
— Address 2: The address of the transmitter mesh STA.
— Address 3: The address of the destination mesh STA.
— Address 4: The address of the source mesh STA.

The source mesh STA shall set the Mesh TTL subfield in the Mesh Control field to dot11MeshTTL, and set the Mesh Sequence Number subfield in the Mesh Control field to a value from a modulo 2^{32} counter that is incremented by 1 for each new MSDU transmitted with a Mesh Control field and for each new MMPDU transmitted using a Multihop Action frame.

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At intermediate and destination mesh STAs, on receipt of an individually addressed Multihop Action frame, the address matching, the reception procedures, the forwarding information update, and the Mesh TTL decrement are performed as described in 10.38.3.2, and the MMPDU is forwarded according to the forwarding information and the procedures in 10.38.3.2.

At intermediate mesh STAs, frame fields following the Mesh Control field are not required to be examined.

If the Address 3 in the received Multihop Action frame matches the mesh STA's own MAC address or the group address, the mesh STA (destination mesh STA) shall process the content of the MMPDU.

10.38.5.3 MMPDU forwarding using group addressed Multihop Action frames

MMPDUs sent by a mesh STA and destined to all other mesh STAs in the MBSS using group addressed Multihop Action frames (see 9.6.17) shall be transmitted using a Management frame with the three-address MAC header format (with the Address Extension Mode subfield in the Mesh Control field set to "None" (see Table 9-26)], where the three address fields are set as follows [see row "Multihop Action (group addressed)" in Table 9-47]:

— Address 1: The group address
— Address 2: The address of the transmitter mesh STA
— Address 3: The address of the source mesh STA

An implementation may circumvent the unreliability of group addressed transmissions by using multiple individually addressed Multihop Action frames, which are individually acknowledged. In such case, the frame may be converted to individually addressed frames and transmitted as individually addressed Multihop Action frames to each peer mesh STA as described in 10.38.5.2 with the Address 3 field set to the group address. The circumstances for choosing this method are outside the scope of the standard.

The source mesh STA shall set the Mesh TTL subfield in the Mesh Control field to dot11MeshTTL, and set the Mesh Sequence Number subfield in the Mesh Control field to a value from a modulo 2^{32} counter that is incremented by 1 for each new MSDU transmitted with a Mesh Control field and for each new MMPDU transmitted using a Multihop Action frame.

At recipient mesh STAs, on receipt of Multihop Action frame, the address matching, the reception procedures, the forwarding information update, and the Mesh TTL decrement are performed as described in 10.38.4.2, and the MMPDU is forwarded according to the forwarding information and the procedures in 10.38.4.2.

If the Address 1 in the received Multihop Action frame matches the group address, the mesh STA shall process the content of the MMPDU.

Procedures that enhance the reliability or efficiency of group addressed transmissions are outside the scope of this standard.

10.38.6 Detection of duplicate MSDUs/MMPDUs

A mesh STA may receive multiple copies of the same MSDU or MMPDU from different neighbor peer mesh STAs.

The filtering of such duplicates is facilitated through the inclusion of a Mesh Sequence Number subfield in the Mesh Control field in mesh Data frames and Multihop Action frames as specified in 9.2.4.7.3.

The receiving mesh STA shall keep a cache of recently received <Mesh SA, Mesh Sequence Number> tuples. The Mesh Source Address (Mesh SA) is contained in Address 4 for individually addressed mesh

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Data frames and Multihop Action frames. The Mesh Source Address (Mesh SA) is contained in Address 3 for group addressed mesh Data frames.

A mesh STA shall reject an MSDU/MMPDU with a Mesh Control field as a duplicate if it matches a <Mesh SA, Mesh Sequence Number> tuple of an entry in the cache.

The rules in 10.3.2.14 also apply to the filtering of duplicates sent by the same neighbor peer mesh STA.

10.38.7 Mesh STAs that do not forward

A mesh STA that has dot11MeshForwarding equal to false does not forward either MSDUs, or Multihop Action frames. The circumstances in which a mesh STA may be allowed to become a non- forwarding entity and the authority to set dot11MeshForwarding to false are beyond the scope of this standard.

A mesh STA that does not forward is a special case of a mesh STA. Such mechanism depends on whether the path selection protocol provides a mechanism to allow mesh STAs not to participate in forwarding. The HWMP path selection protocol provides such a mechanism; see 14.10.

10.38.8 MSDU forwarding and unknown destination

A source mesh STA in the MBSS might not able to forward an MSDU that it has received as a consequence of an MA-UNITDATA.request primitive with an individual destination address. This is the case if the destination of the MSDU is unknown to the mesh STA. The destination is unknown to a mesh STA if the mesh STA has no valid forwarding information for this destination or if the destination is not in its proxy information as an external STA (see 14.11.4.2). Note that the procedure to determine that an address is unknown depends on the active path selection protocol. It might require an attempt to establish a path to the destination (see 14.8).

If the source mesh STA is not able to forward the MSDU because its destination is unknown, the mesh STA shall assume that the destination is outside the MBSS and shall forward the MSDU to known mesh gates in the MBSS as one or more individually addressed frames according to the procedures for frame addressing and data forwarding of individually addressed frames at source mesh STAs in an MBSS (10.38.3.1). These frame(s) shall be transmitted using the four-address MAC header format [with the Address Extension Mode subfield in the Mesh Control field set to “Address5&6” (see Table 9-26)], where the Mesh Address Extension subfield in the Mesh Control field carries the address of the destination end station, as specified in row “Mesh Data (proxied, individually addressed)” of Table 9-47. The address fields are set as follows:

- Address 1: The address of the next-hop mesh STA (toward the known mesh gate in the MBSS according to the forwarding information; see 10.38.2).
- Address 2: The address of the source mesh STA.
- Address 3: The address of the known mesh STA in the MBSS.
- Address 4: The address of the source mesh STA.
- Address 5: The address of the destination end mesh STA, which is the unknown destination address of the MSDU.
- Address 6: The address of the source mesh STA, which is the same as Address 4.

If there is no mesh gate available, the mesh STA shall silently discard the MSDU.

Discovery of mesh gates by mesh STAs is performed using propagated elements, such as a GANN (14.11.2). Other methods specific to the HWMP path selection protocol are also available, such as the proactive PREQ mechanism (14.10.4.2) or the proactive RANN mechanism (14.10.4.3), when the Gate Announcement subfield in the Flags field in these HWMP elements is set to 1.

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10.39 DMG and CMMG channel access

10.39.1 General

Channel access by a DMG STA is related to beacon interval timing and is coordinated using a schedule. A DMG STA operating as an AP or PCP generates the schedule and communicates it to STAs using DMG Beacon and Announce frames. A non-PCP STA that is a non-AP STA and that receives scheduling information accesses the medium during the scheduled periods using the access rules specific to that period. Medium access rules to establish a BSS are defined in 10.40 and 11.1.4. CMMG STAs follow the same rules of DMG channel access except the specific modification for CMMG STAs as described in 10.39.

10.39.2 Access periods within a beacon interval

Medium time within a DMG or CMMG BSS is divided into beacon intervals. Subdivisions within the beacon interval are called *access periods*. Different access periods within a beacon interval have different access rules. The access periods are described in a schedule that is communicated by the AP or PCP to the non-PCP and non-AP STAs within the BSS. The schedule communicated by the AP or PCP can include the following access periods:

— *BTI:* For DMG STAs, it is an access period during which one or more DMG Beacon frames is transmitted. Not all DMG Beacon frames are detectable by all non-PCP and non-AP STAs (see 10.42.4). Not all beacon intervals contain a BTI. For CMMG STAs, it is an access period during which one or more DMG Beacon frames are transmitted at least in the primary 540 MHz channel. Not all DMG Beacon frames are detectable by all non-PCP and non-AP STAs. A non-PCP STA that is a non-AP STA shall not transmit during the BTI of the BSS of which it is a member.

— *A-BFT:* An access period during which beamforming training is performed with the STA that transmitted a DMG Beacon frame during the preceding BTI (see 10.42.5). The presence of the A-BFT is optional and signaled in DMG Beacon frames.

— *ATI:* A request-response based management access period between the AP or PCP and non-AP and non-PCP STAs (see 10.39.3). The presence of the ATI is optional and signaled in DMG Beacon frames.

— *CBAP:* An access period during which frame exchanges between STAs that use the channel access rules described in 10.39.5.

— *SP:* An access period during which frame exchanges between STAs use the channel access rules described in 10.39.6.2.

The BHI comprises the BTI, A-BFT and ATI. The DTI, in turn, comprises contention based access periods (CBAPs) and scheduled service periods (SPs). There is a single BHI and a single DTI per beacon interval.

Figure 10-55 illustrates an example of access periods within a beacon interval comprising a BTI, an A-BFT, an ATI, and two CBAPs and SPs within the DTI. Any combination in the number and order of SPs and CBAPs can be present in the DTI.

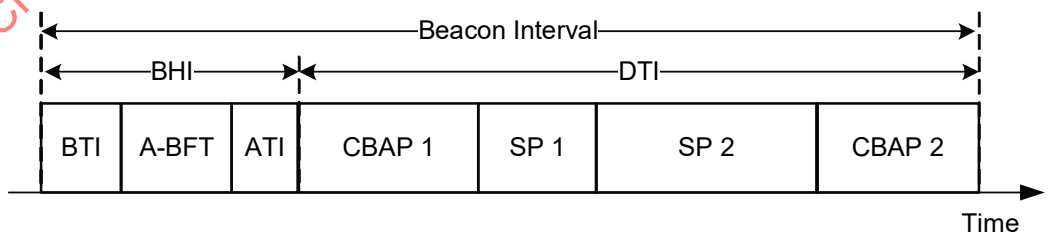

Figure 10-55—Example of access periods within a beacon interval

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For a 1080 MHz CMMG BSS, the DTI can comprise contention-based access periods (CBAPs) and scheduled service periods (SPs), and the bandwidth of the allocation in the DTI can be 540 MHz and 1080 MHz.

Figure 10-56 illustrates an example of access periods within a beacon interval for a 1080 MHz CMMG BSS, comprising a BHI, that may contain BTI, A-BFT, and ATI, and two 540 MHz CBAPs and SPs within the DTI and one 1080 MHz CBAPs and SPs within the DTI. Any combination in the number and order of SPs and CBAPs can be present in the DTI. For a CMMG BSS, the BHI shall be sent on the primary 540 MHz channel and can be sent on the 1080 MHz channel with duplicate format.

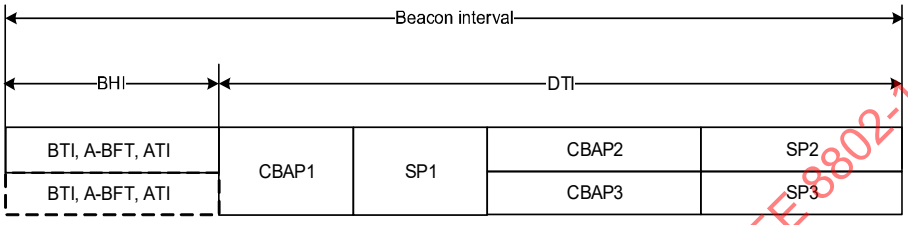

Figure 10-56—Example of access periods within a beacon interval for CMMG STAs

The details of the access protocol within each of the access periods are described in the remaining subclauses of 10.39 and within 10.42.

In the ATI, a non-AP and non-PCP STA shall be ready to receive a transmission from the AP or PCP at least RxAdvanceTime before the expected transmission of a request frame. The destination STA of an SP shall be ready to receive a transmission from the source STA of the SP at least RxAdvanceTime before the start of the SP. A STA that participates in a CBAP shall be ready to receive a transmission within the CBAP at least RxAdvanceTime before the start of the CBAP plus DIFS. In the A-BFT, the AP or PCP should be ready to receive a transmission from a non-AP and non-PCP STA at least RxAdvanceTime before the start of an SSW slot. In all of the preceding rules, RxAdvanceTime is defined as follows:

$$\text{RxAdvanceTime} = \text{Ceil}\left(\left(\frac{C \times T_{DI}}{10^6} + T_P\right),\ T_{TR}\right)$$

where

C is aDMGTSFAccuracy, in ppm

T_{DI} is the time elapsed since a synchronizing reference event, in μs. The synchronizing event is the reception of the Timestamp field from the AP or PCP

T_P is aAirPropagationTime, in μs

T_{TR} is aTSFResolution, in μs

10.39.3 ATI transmission rules

The presence of an ATI in the current beacon interval is signaled by the ATI Present field set to 1 in the current DMG Beacon frame (9.3.4.2). The Next DMG ATI element (9.4.2.135) transmitted in the Announce frame or in the DMG Beacon frame indicates the earliest start time for the next ATI in a subsequent beacon interval and ATI duration.

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An example of an ATI is shown in Figure 10-57.

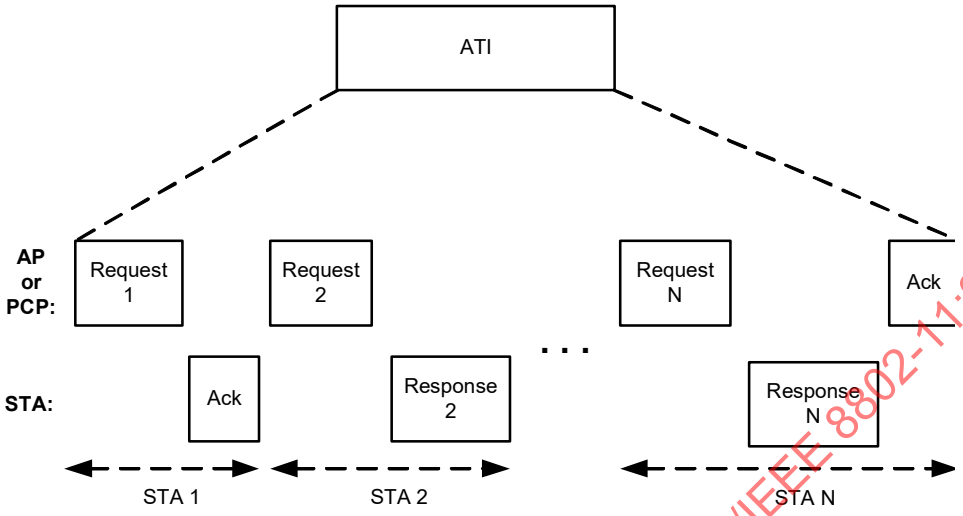

Figure 10-57—Example of frame exchanges during the ATI

During an ATI, request and response frames are exchanged between the AP or PCP and any subset of STAs. The AP or PCP initiates all frame exchanges that occur during the ATI. The ATI shall not start sooner than Max(guard time, MBIFS), where guard time is defined in 10.39.6.5, following the end of the previous A-BFT when an A-BFT is present in the beacon interval or following the end of the previous BTI when an A-BFT is not present but a BTI is present in the beacon interval. The ATI shall not start before TBTT if the ATI is the first period in the beacon interval (the ATI is never the first period in the beacon interval in an infrastructure BSS; see 11.1.2.1). Once the ATI starts, the AP or PCP may start transmission of a request frame immediately or it may delay the transmission of the request frame if the medium is determined by the CCA mechanism to be busy.

For DMG STAs, during each ATI the AP or PCP shall schedule transmissions to a non-AP and non-PCP STA if the non-AP and non-PCP STA Heartbeat field in the STA's DMG Capabilities element within the Association Request frame of the last successful association attempt is 1. If the non-AP and non-PCP STA does not respond to the frame transmitted by the AP or PCP, the AP or PCP shall use the DMG Control modulation class (10.6.7.1) at its next transmission attempt to the non-AP and non-PCP STA. The AP or PCP shall use the DMG Control modulation class for all subsequent transmissions to the non-AP and non-PCP STA until it receives a valid frame from the non-AP and non-PCP STA.

For CMMG STAs, during each ATI the AP or PCP shall schedule transmissions to a non-AP and non-PCP STA if the non-AP and non-PCP STA Heartbeat field in the STA's CMMG Capabilities element within the Association Request frame of the last successful association attempt is 1 and the non-AP and non-PCP STA is in the awake state. If the non-AP and non-PCP STA does not respond to the frame transmitted by the AP or PCP, the AP or PCP shall use the CMMG Control modulation class ((10.6.8.1) at its next transmission attempt to the non-AP and non-PCP STA. The AP or PCP shall use the CMMG Control modulation class for all subsequent transmissions to the non-AP and non-PCP STA until it receives a valid frame from the non-AP and non-PCP STA.

A non-AP and non-PCP STA shall not transmit during the ATI except in response to an individually addressed frame whose TA field contains the AP's or PCP's MAC address and whose RA field contains the STA's MAC address.

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During the ATI a STA shall not transmit frames that are not request or response frames. Request and response frames transmitted during the ATI shall be one of the following:

- A Management frame
- An Ack frame
- A Grant, Poll, RTS or DMG CTS frame when transmitted as a request frame
- An SPR or DMG CTS frame when transmitted as a response frame
- A frame with the Type subfield equal to Data only as part of an authentication exchange to reach an RSNA security association

NOTE 1—The Announce frame is designed to be used primarily during the ATI and can perform functions of a DMG Beacon frame.

The transmission of Poll frames during the ATI follows the rules described in 10.39.7. The Response Offset field within a Poll frame transmitted during the ATI shall be set to 0.

The transmission of Grant frame during the ATI follows the rules described in 10.39.7.3.

Individually addressed request frames transmitted during the ATI shall not be sent using Action No Ack frames.

During the ATI, after an AP or PCP transmits an individually addressed request frame (such as an Announce frame) to a non-AP and non-PCP STA, and the STA receives that frame, the STA shall transmit a response frame addressed to the AP or PCP. The transmission of the response frame shall commence one SIFS after the reception of the request frame. The AP or PCP shall interpret the receipt of the response frame as an acknowledgment of the request frame. Response frames transmitted by non-AP and non-PCP STAs during the ATI shall be individually addressed to the AP or PCP.

NOTE 2—STAs do not transmit a response frame to the AP or PCP when they receive a request frame from the AP or PCP with the RA equal to a group address (see 10.3.6).

The Duration field of a request frame transmitted during the ATI shall be set to cover the remaining duration of the ATI at the end of the request frame transmission. The Duration field of a response frame transmitted during the ATI shall be set to the value of the Duration field within the previously received request frame minus SIFS and minus the duration of the response frame transmission.

When a transmission by a STA is expected by an AP or PCP and a SIFS elapses without its receipt, the AP or PCP may either repeat its individually addressed transmission to that STA or, as early as one PIFS after the end of its previous transmission, transmit a frame to any other STA.

NOTE 3—If acknowledgment is required, the AP or PCP transmits an Ack frame to acknowledge the reception of a response frame during the ATI (see Figure 10-57).

Multiple request and response frame exchanges between the AP or PCP and a STA might occur during a single ATI.

For CMMG STAs, the bandwidth of a response frame transmitted during the ATI shall be set to the same as previously received request frame.

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10.39.4 DTI transmission rules

During the DTI, a STA may initiate a frame exchange (following the DMG channel access rules for DMG STAs and following the CMMG channel access rules for CMMG STAs) if any of the following conditions are met:

a) During a CBAP for which the STA is identified or included as source or destination (10.39.6.3, 10.39.7, and 10.39.8)

b) During an SP for which the STA is identified as source or destination (10.39.6.2 and 10.39.7)

and shall not initiate a frame exchange if none of these conditions are met. A STA initiating data transfer shall check that the transaction, including acknowledgments, completes before the end of the CBAP or SP in which it was initiated. Also, a CMMG STA initiating data transfer shall use a bandwidth no larger than the allocated channel bandwidth of the CBAP or SP in which it was initiated.

When the entire DTI is allocated to CBAP (that is, the CBAP Only field is 1 in the DMG Parameters field for DMG STAs, or the CBAP Only field is 1 in the CMMG Parameters field for CMMG STAs), for DMG STAs, the ATI Present field within the DMG Beacon frame containing the DMG Parameters field shall be set to 0, and for CMMG STAs the ATI Present field within the DMG Beacon frame containing the CMMG Parameters field shall be set to 0.

A DMG or CMMG STA shall be capable of processing Grant frames. A non-AP and non-PCP DMG or CMMG STA shall be capable of processing Poll frames and the Extended Schedule element. An AP or PCP shall be capable of processing SPR frames transmitted by a non-AP and non-PCP STA and responding to an SPR frame with a Grant frame.

The DMG low-power SC mode (20.6) may be used only within SPs that have the LP SC Used subfield within the Extended Schedule element equal to 1 and shall not be used otherwise. A STA supports the DMG low-power SC mode if the Low-Power SC Mode Supported subfield within its DMG Capabilities element is 1. A STA that supports the DMG low-power SC mode shall not initiate a frame exchange using the DMG low-power SC mode unless the STAs identified in the RA field of all MPDUs contained within the PPDU support the DMG low-power SC mode. A STA can use the procedure described in 11.28.1 to discover the capabilities of another STA.

A STA that receives a Grant frame and that has the Grant Ack Supported field equal to 1 in the STA's DMG Capabilities element shall respond with a Grant Ack frame SIFS after reception of the Grant frame. In the transmitted Grant Ack frame, the STA shall copy the Source AID, Destination AID, and Beamforming Training fields from the Grant frame that the Grant Ack frame is being sent in response to. A STA that receives a group addressed Grant frame shall not respond with Grant Ack frame. A STA that receives a Grant frame and that does not have the Grant Ack Supported field equal to 1 in the STA's DMG Capabilities element shall not respond with a Grant Ack frame.

10.39.5 Contention based access period (CBAP) transmission rules

The definition of contention based transmission rules used within a CBAP is provided in 10.3 and in 10.23. This subclause specifies additional rules applicable to the CBAP.

A STA shall not initiate a frame exchange within a CBAP unless at least one of the following conditions is met:

— The value of the CBAP Only field is equal to 1 and the value of the CBAP Source field is equal to 0 within the DMG Parameters field of the DMG Beacon frame that allocates the CBAP

— The STA is an AP or PCP and the value of the CBAP Only field is equal to 1 and the value of the CBAP Source field is equal to 1 within the DMG Parameters field of the DMG Beacon frame that allocates the CBAP

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— The value of the Source AID field of the CBAP is equal to the broadcast AID
— The STA's AID is equal to the value of the Source AID field of the CBAP
— The STA's AID is equal to the value of the Destination AID field of the CBAP

If a STA's AID is equal to the value of the Source AID field of a CBAP allocation or if a STA performs in the role of AP or PCP and both the CBAP Only and CBAP Source fields are equal to 1 in the DMG Beacon frame that allocates a CBAP, the STA may initiate a frame transmission within the CBAP immediately after the medium is determined to be idle for one PIFS.

A BF initiator (10.42) should not initiate an SLS phase within a CBAP if there is not enough time within the CBAP to complete the SLS phase.

A STA shall not extend a transmission frame exchange sequence that started during a CBAP beyond the end of that CBAP. A STA that initiates a sequence shall check that the frame exchange sequence, including any control frame responses, completes before the end of the CBAP.

Operation of the EDCAF is suspended at the end of a CBAP and is resumed at the beginning of the following CBAP. When the EDCAF is being suspended, the values of the backoff and NAVs shall remain unchanged until the start of the following CBAP. A TXOP may be obtained by a DMG STA winning an instance of EDCA contention (see 10.23.2).

At the beginning of a TXOP with a TXOP responder that has the Heartbeat field in the TXOP responder's DMG Capabilities element equal to 1 for DMG STAs or has the Heartbeat field in the TXOP responder's CMMG Capabilities element equal to 1 for CMMG STAs, the following rules apply:

— For DMG STAs, the TXOP holder shall transmit a frame to the TXOP responder using the DMG Control modulation class before it uses any other modulation class for transmission if the time elapsed since the last frame received from the TXOP responder is larger than or equal to the Heartbeat Elapsed Time value computed using the Heartbeat Elapsed Indication field within the TXOP responder's DMG Capabilities element.
— For DMG STAs, the TXOP holder may transmit a frame using a modulation class other than the DMG Control modulation class at the start of the TXOP if the time elapsed since the last frame received from the TXOP responder is shorter than the Heartbeat Elapsed Time value computed using the Heartbeat Elapsed Indication field within the TXOP responder's DMG Capabilities element.
— For CMMG STAs, the TXOP holder shall transmit a frame to the TXOP responder using the CMMG Control modulation class before it uses any other modulation class for transmission if the time elapsed since the last frame received from the TXOP responder is larger than or equal to the Heartbeat Elapsed Time value computed using the Heartbeat Elapsed Indication field within the TXOP responder's CMMG Capabilities element.
— For CMMG STAs, the TXOP holder may transmit a frame using a modulation class other than the CMMG Control modulation class at the start of the TXOP if the time elapsed since the last frame received from the TXOP responder is shorter than the Heartbeat Elapsed Time value computed using the Heartbeat Elapsed Indication field within the TXOP responder's CMMG Capabilities element.

The frame sent by the STA at the beginning of the TXOP may be an RTS frame or a DMG CTS-to-self frame.

Within a CBAP a STA with multiple DMG antennas should use only one DMG antenna in its frame transmission, CCA and frame reception, except if it is the initiator or responder in an SLS (10.42). The algorithm to select a DMG antenna and switch the active DMG antenna is implementation dependent. Within CBAPs a STA that changed to a different DMG antenna in order to transmit should perform CCA on

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that DMG antenna until a frame is detected by which it can set its NAV, or until a period of time equal to the dot11DMGNavSync has transpired, whichever is earlier.

10.39.6 Channel access in scheduled DTI

10.39.6.1 General

An AP or PCP schedules each allocation with a specified start time from the TSF and with a fixed duration. An allocation can be an SP, where ownership of channel time is granted to a single STA, or a CBAP, where STAs can compete for channel access. The start time of each allocation is based on the TSF of the AP or PCP.

The AP or PCP may schedule SPs or CBAPs only during the DTI of a beacon interval, following the end of an allocated BTI, A-BFT, and ATI when any of these periods are present in the beacon interval.

The schedule of the DTI of a beacon interval shall be communicated through the Extended Schedule element. The AP or PCP transmits the Extended Schedule element in either or both an Announce frame or a DMG Beacon frame. The Extended Schedule element shall contain the scheduling information of all allocations in the DTI. The same Allocation field shall not appear more than once in the Extended Schedule element transmitted in a beacon interval. The content of the Extended Schedule element communicated in a beacon interval shall not change if transmitted more than once in the beacon interval, except that if the STA transmitting the Extended Schedule element is a PCP with multiple DMG antennas then the value of the PCP Active field of CBAP allocations within the Extended Schedule element might change when this element is transmitted through different DMG antennas. The AP or PCP should schedule SPs for a STA such that the scheduled SPs do not overlap in time with the traffic scheduling constraints indicated by this STA in the Traffic Scheduling Constraint Set field of the associated DMG TSPEC element.

When scheduling a nonpseudo-static allocation or changing the start time of an existing pseudo-static allocation that has a non-AP and non-PCP STA as a source DMG STA or as a destination DMG STA of the allocation, an AP or PCP shall set the start time of the allocation to no less than aMinAllocationDeliveryTime after the last Extended Schedule element containing this allocation is transmitted by the AP or PCP.

NOTE—This rule does not apply to the case when an AP or PCP schedules a new pseudo-static allocation.

When receiving an Extended Schedule element containing a new pseudo-static allocation in which it is expected to participate, a non-AP and non-PCP STA ignores the allocation if the value of the TSF at the time the frame containing the Extended Schedule element is received is greater than the value of the TSF at the start of the pseudo-static allocation; this allocation is called an *obsolete allocation*. The value of the TSF at the start of the pseudo-static allocation is constructed using the value of the Allocation Start Time field within the Allocation field for the pseudo-static allocation.

An SP or CBAP allocation within an Extended Schedule element may comprise one or more individual allocations. The start time of each individual allocation of an SP or CBAP is given by

$$(A_{start} + (i - 1) \times A_{period})$$

where

A_{start} is the value of the Allocation Start field for the SP or CBAP
A_{period} is the value of the Allocation Block Period field for the SP or CBAP
i is an integer greater than 0 and less than or equal to the value of the Number of Blocks field for the SP or CBAP

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The end of the i^{th} individual SP or CBAP allocation is computed by adding the start time of the i^{th} individual allocation to the value of the Allocation Block Duration field for the corresponding SP or CBAP allocation.

For CMMG STAs, an SP or CBAP allocation within an Extended Schedule element may be a 540 MHz allocation or a 1080 MHz allocation; the channel and bandwidth of the SP or CBAP allocation are indicated in the Extended Schedule element.

If the PCP Active subfield in the Allocation field for an allocation within an Extended Schedule element is 1, the PCP shall be in the receive state for the duration of that allocation, except when transmitting during that allocation. The AP shall set the PCP Active field to 1 for every allocation within an Extended Schedule element transmitted by the AP.

10.39.6.2 Service period (SP) allocation

The AP or PCP shall set the AllocationType subfield to 0 in an Allocation field within an Extended Schedule element to indicate an SP allocation.

An SP allocation that is not an obsolete allocation is assigned to the source DMG STA identified in the Source AID subfield in an Allocation field within the Extended Schedule element. The source DMG STA shall initiate the frame exchange sequence that takes place during the SP at the start of the SP, except when the source DMG STA intends to establish a DMG protected period in which case the rules described in 10.39.6.6 shall be followed before the source DMG STA initiates the frame exchange in the SP. The SP allocation identifies the TC or TS for which the allocation is made; however, the type of traffic transmitted is not restricted to the specified TC or TS (11.4.1).

An SP is assigned to the source CMMG STA identified in the Source AID subfield in an Allocation field that is not an obsolete allocation within the Extended Schedule element. The source CMMG STA shall initiate the frame exchange sequence that takes place during the SP at the start of the SP, except when the source CMMG STA intends to establish a CMMG protected period in which case the rules described in 10.39.6.6 shall be followed before the source CMMG STA initiates the frame exchange in the SP. The SP allocation identifies the TC or TS for which the allocation is made; however, the type of traffic transmitted is not restricted to the specified TC or TS (11.4.1).

Except when transmitting a frame as part of the SP recovery procedure (10.39.6.7) or transmitting a response to the source DMG STA or transmitting a PPDU as part of an RD response burst (10.29), the STA identified by the Destination AID field in the Extended Schedule element should be in the receive state for the duration of the SP in order to receive transmissions from the source DMG STA. If the Destination AID field of the scheduled SP is equal to the broadcast AID and if the Source AID field of the scheduled SP is not equal to the broadcast AID, then all STAs on the PBSS/infrastructure BSS should be in the receive state in order to receive transmissions from the source DMG STA for the duration of the SP. Subclause 10.39.7 describes the rules for when the scheduled SP has both the Source and Destination AID fields equal to the broadcast AID.

Only a STA identified as the source DMG STA or destination DMG STA of an SP may transmit during the SP, except when the rules in 10.39.7, 10.39.8, or 10.39.9 are used.

At the beginning of an SP (except when the source DMG STA intends to establish a DMG protected period, see 10.39.6.6) before the source DMG STA initiates the frame exchange in the SP, a source DMG STA shall transmit a frame to the destination DMG STA using the DMG Control modulation class before it uses any other modulation class for transmission if the Heartbeat field in the destination DMG STA's DMG Capabilities element is 1. The frame sent by the source STA may be an RTS frame or a DMG CTS-to-self frame. The frame sent by the source STA may be an SSW frame or a BRP PPDU if the source STA is performing beamforming (10.6.7.5).

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At the beginning of an SP in a CMMG band, except when the source CMMG STA intends to establish a CMMG protected period (see 10.39.6.6) before the source CMMG STA initiates the frame exchange in the SP, a source CMMG STA shall transmit a frame to the destination CMMG STA using the CMMG Control modulation class before it uses any other modulation class for transmission if the Heartbeat field in the destination CMMG STA's CMMG Capabilities element is 1. The frame sent by the source STA may be an RTS frame or a DMG CTS-to-self frame. The frame sent by the source STA may be an SSW frame or a BRP PPDU if the source STA is performing beamforming (10.6.8.5).

The first frame transmitted by a destination DMG STA to the source DMG STA in an SP shall use the DMG Control modulation class if the Heartbeat field in the source DMG STA's DMG Capabilities element is 1. Subject to the rules specified in 10.6, subsequent frames transmitted by the destination DMG STA within the SP may use a different modulation class.

At the beginning of an SP, a destination CMMG STA shall transmit a frame to the source CMMG STA using the CMMG Control modulation class before it uses any other modulation for transmission if the Heartbeat field in the source CMMG STA's CMMG Capabilities element is 1 and the frame sent by the destination CMMG STA is the unsolicited DMG DTS as first frame in the SP of the STA performing CMMG protected period.

Any MAC entity coordinated by an MM-SME that belongs to an MMSL cluster identified by the Source AID and Destination AID that are equal to, respectively, the Source AID and Destination AID of the Allocation field that is not an obsolete allocation in the Extended Schedule element that allocates the SP may transmit during the SP, if the STA sent an MMS element to the peer STA and the BeamLink Cluster field within the MMS element is 1.

The AP or PCP may create SPs in its beacon interval with the source and destination AID subfields within an Allocation field set to 255 to prevent transmissions during specific periods in the beacon interval.

The AP or PCP shall set the Beamforming Training subfield to 1 in the Allocation field for an SP within an Extended Schedule element to indicate that the source DMG STA of this SP initiates beamforming training with the destination DMG STA at the start of that SP. The source DMG STA and destination DMG STA of the SP shall perform beamforming training as described in 10.42.

If the PCP Active subfield is 0 in the Allocation field for an SP within an Extended Schedule element, neither the destination DMG STA of the SP nor the source DMG STA of the SP shall transmit to the PCP during the SP if none of the STAs are the PCP.

In no case shall the source or destination DMG STA extend a transmission frame exchange sequence that started during an SP beyond the end of that SP. A STA that initiates a sequence shall check that the frame exchange sequence, including any control frame responses, completes before the end of the SP.

When scheduling two adjacent SPs, the AP or PCP should allocate the SPs separated by at least aDMGPPMinListeningTime if one or more of the source or destination DMG STAs participate in both SPs.

Except for frames used for beamforming as described in 10.42, the source of an SP may retransmit a frame PIFS after the end of the frame transmission in case a response frame is expected from the destination DMG STA and a SIFS elapses without receipt of the expected transmission.

The source DMG STA can relinquish the remainder of an SP to the destination DMG STA by sending a Grant frame to the destination DMG STA (10.39.7.3).

10.39.6.3 Contention based access period (CBAP) allocation

The AP or PCP shall set the AllocationType subfield to 1, the Source AID subfield to the broadcast AID or to the AID of the source of the CBAP, and the Destination AID subfield to the broadcast AID or to the AID

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of the destination of the CBAP in an Allocation field within an Extended Schedule element to indicate a CBAP allocation.

All CBAPs are allocated by the AP or PCP, except when allocated by a non-AP and non-PCP STA with the transmission of a Grant frame following an SP truncation (10.39.8). Multiple CBAPs may be present in a beacon interval, with the location and duration of each determined by the AP or PCP and announced in the Extended Schedule element. When only one CBAP is present and no other allocations exist for the DTI, then the AP or PCP shall announce the presence of the CBAP by setting the CBAP Only field to 1 in the DMG Parameters field of the DMG Beacon. If at least one non-CBAP allocation is present, or more than one CBAP is present, or no allocations are present within a DTI, then the AP or PCP shall set the CBAP Only field to 0 in the DMG Parameters field in the DMG Beacon frame transmitted during the BTI. The AP or PCP shall set the CBAP Only field to 0 in the DMG Parameters field within a transmitted DMG Beacon frame if the DMG Beacon frame contains at least one Extended Schedule element.

When the entire DTI is allocated to CBAP through the CBAP Only field in the DMG Parameters field, then that CBAP is pseudo-static and exists for dot11MaxLostBeacons beacon intervals following the most recently transmitted DMG Beacon frame that contained the indication, except if the CBAP is canceled by the transmission by the AP or PCP of a DMG Beacon frame with the CBAP Only field of the DMG Parameters field equal to 0 or an Announce frame with an Extended Schedule element. A guard time (10.39.6.5) precedes a CBAP that is allocated through the CBAP Only field equal to 1.

Channel access during a CBAP shall follow the rules described in 10.39.5.

10.39.6.4 Pseudo-static allocations

An SP or CBAP allocation is pseudo-static if the Pseudo-static field in the Allocation control field for the SP or CBAP is 1, or when the Extended Schedule element is not used and the CBAP Only field within the DMG Parameters field of the DMG Beacon frame is 1 (10.39.5). A pseudo-static SP or CBAP recurs at the same relative offset to TBTT and with the same duration in up to dot11MaxLostBeacons beacon intervals following the last received Extended Schedule element containing the pseudo-static allocation or DMG Beacon frame with the CBAP Only field equal to 1.

A STA might fail to receive up to (dot11MaxLostBeacons–1) Extended Schedule elements or DMG Beacon frame with the CBAP Only field equal to 1 in consecutive beacon intervals and still may access the channel during the pseudo-static SP or CBAP. The STA shall cease transmission during a pseudo-static allocation if it fails to receive an Extended Schedule element or DMG Beacon frame with the CBAP Only field equal to 1 for dot11MaxLostBeacons consecutive beacon intervals.

The AP or PCP may change the offset relative to TBTT or the duration of a pseudo-static allocation by transmitting a modified Allocation field in an Extended Schedule element before dot11MaxLostBeacons beacon intervals from the last transmitted Extended Schedule element. The AP or PCP may delete a pseudo-static allocation by transmitting an Extended Schedule element that does not include an allocation field containing that allocation's TID, source AID, and destination AID before the completion of dot11MaxLostBeacons beacon intervals from the last transmitted Extended Schedule element. In either case, the AP or PCP should not schedule a new allocation that overlaps with the previous pseudo-static allocation for a minimum of dot11MaxLostBeacons beacon intervals unless both the new and previous allocation are for a CBAP or the new allocation identifies the same source DMG STA as the original pseudo-static allocation.

If the destination DMG STA of a pseudo-static allocation receives an Extended Schedule element with an Allocation field that indicates a change in the schedule of the pseudo-static allocation, the STA should enter receive state during the new pseudo-static allocation and may enter receive state during the previous allocation to account for the time it can take the source DMG STA of the allocation to receive the updated schedule.

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10.39.6.5 Guard time

Guard time is the time between the end of one allocation and the start of the following allocation, provided these allocations are not under spatial sharing (11.30). For the purpose of guard time insertion, an allocation is defined as an SP, a CBAP, and a BTI or A-BFT or ATI that is immediately followed by a CBAP allocated through the CBAP Only field (10.39.6.3). Guard times are used to keep transmissions in adjacent allocations from colliding. Figure 10-58 shows an example of the insertion of the guard time such that the allocations are separated by at least the guard time, in case the STAs participating in the adjacent allocations drift toward each other's allocation.

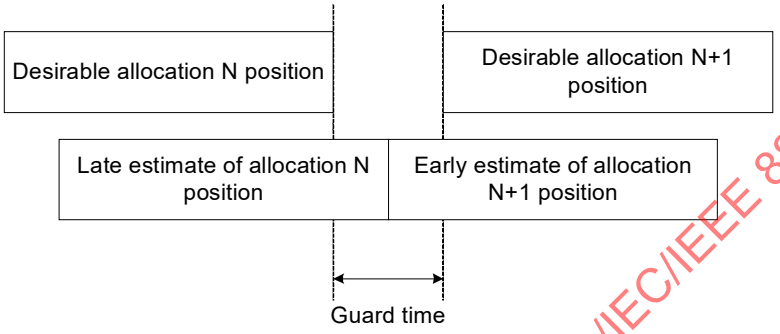

Figure 10-58—The guard time

The AP or PCP shall insert a sufficient guard time between adjacent allocations so that transmissions in adjacent allocations do not overlap in time. For each of the adjacent allocations, guard times are calculated based on the worst case drift and the maximum allowed number of lost DMG Beacons. The AP or PCP shall insert a guard time (T_{guard}) between adjacent allocations that is not shorter than

$$T_{guard} = \text{Ceil}\left(\frac{((A_i + 1) \times C \times D_i) + ((A_{i+1} + 1) \times C \times D_{i+1})}{10^6} + SIFS + T_P, T_{TR}\right)$$

where

A_i is the value of MLB allocation i, and the value of A_i for each allocation depends on whether the allocation is pseudo-static. A_i is 0 for a nonpseudo-static allocation and is equal to dot11MaxLostBeacons if the allocation is pseudo-static

C is aDMGTSFAccuracy, in ppm

D_i is the time elapsed since a synchronizing reference event, in µs. The synchronizing event is the reception of the Timestamp field from the AP or PCP. For a pseudo-static allocation, D_i is equal to the beacon interval

$SIFS$ is aSIFSTime, in µs

T_P is aAirPropagationTime, in µs, which accounts for the propagation delay between the STAs participating in the adjacent allocations

T_{TR} is aTSFResolution, in µs

10.39.6.6 DMG and CMMG protected period

10.39.6.6.1 Introduction

Communicating STA pairs of neighboring PBSS/infrastructure BSS might be granted SPs that potentially create interference for neighbor PBSS/infrastructure BSS STA pairs. SPs within a PBSS/infrastructure BSS

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can also experience such interference when spatial diversity conditions change. The intent of DMG protected period is to minimize such interference by allowing any pair of STAs to protect their SP and thereby limit the transmission of frames during the DMG protected period to not more than one pair of potentially interfering pairs of communicating stations.

In the CMMG protected period that has 540 MHz or 1080 MHz bandwidth, the STA can use dynamic bandwidth operation to negotiate a bandwidth that can be used in this SP.

A DMG protected period can be created by the source DMG STA during an SP, and shall be created by the source DMG STA if at least one of the following conditions is met:

— The source DMG STA is the AP or PCP of the BSS, the ECAPC Policy Enforced subfield within the DMG Parameters field of the last DMG Beacon frame transmitted by the source DMG STA is equal to 1, and the Protected Period Enforced field within the ECAPC Policy Detail field of the last ECAPC Policy element transmitted by the source DMG STA is equal to 1.

— The source DMG STA is not the AP or PCP of the BSS, the ECAPC Policy Enforced subfield within the DMG Parameters field of the last DMG Beacon frame received by the source DMG STA from the AP or PCP of the BSS is equal to 1, and the Protected Period Enforced field within the ECAPC Policy Detail field of the last ECAPC Policy element received by the source DMG STA from the AP or PCP of the BSS is equal to 1.

Both the source DMG STA and destination DMG STA of an SP are owners of the DMG protected period. During any DMG protected period, both stations can receive frames from the other participant.

A CMMG protected period can use the dynamic bandwidth operation during an SP if the bandwidth of the SP that indicated in the Extended Schedule element is 1080 MHz.

A DMG STA that creates a DMG protected period during an SP in which it is a source DMG STA or a destination DMG STA moves to and stays in listening mode during time interval that starts before the start of the SP and remains in the listening mode until it is allowed to use the SP. The actual duration of the time the STA stays in the listening mode is limited by the aDMGPPMinListeningTime parameter. The intent of the listening mode is that the STA listens to other STAs that may have an SP that overlaps with the SP where the STA is a source DMG STA or a destination DMG STA. The NAV mechanism is used to indicate the time occupancy and if the STA is in the listening mode, it updates its NAVs. If the NAVs are not equal to 0, the STA does not use the time of the SP in which it is a source DMG STA or a destination DMG STA. If none of the NAVs has a nonzero value at the start of the SP, the STA is allowed to leave the listening mode and use the SP. If at least one of the NAVs has a nonzero value at the start of the SP, the STA is allowed to leave the listening mode and to use the time remaining in the SP after all NAVs become or already have value zero.

A CMMG STA that creates a CMMG protected period during an SP in which it is a source CMMG STA or a destination CMMG STA moves to and stays in listening mode during time interval that starts before the start of the SP and remains in the listening mode until it is allowed to use the SP. The actual duration of the time the STA stays in the listening mode is limited by the aCMMGPPMinListeningTime parameter. The intent of the listening mode is that the CMMG STA listens to other CMMG STAs that may have an SP that overlaps with the SP where the CMMG STA is a source CMMG STA or a destination CMMG STA. The NAV mechanism is used to indicate the time and frequency occupancy, and the CMMG STA in the listening mode updates NAV timers. If the NAV timers are not equal to 0 for the corresponding channel bandwidth, the CMMG STA does not use the time and the band of the SP in which it is a source CMMG TA or a destination CMMG STA. If none of the NAV timers has a nonzero value at the start of the SP, the DMG STA is allowed to leave the listening mode and use the SP. If at least one of the NAV timers has a nonzero value at the start of the SP, the DMG STA is allowed to leave the listening mode and to use the time remaining in the SP after all NAV timers become or already have value zero.

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Listening mode is a mode of operation during which a DMG STA is in receiving state and meets at least one of the following conditions:

a) Its receiving antenna are in the quasi-omni mode.
b) Its receiving antenna are directed to the peer STA for which this DMG STA is either the destination or source DMG STA.

A DMG protected period is established through an RTS/DMG CTS handshake. The DMG CTS can be sent in a CMMG PHY format and can be sent in 540 MHz or 540 MHz duplicated mode. To create a DMG protected period, the source DMG STA of an SP sends an RTS, and the recipient STA responds with a DMG CTS. If the recipient STA responds with a DMG CTS, then a DMG protected period is established; otherwise, no DMG protected period has been established. In all cases of DMG protected period establishment, the same antenna configurations that are used by the STAs that establish the DMG protected period are used for the exchange of frames during the DMG protected period.

10.39.6.6.2 DMG and CMMG protected period establishment and maintenance

A DMG STA that attempts to create a DMG protected period during an SP shall transition to listening mode not less than aDMGPPMinListeningTime before the attempt and shall remain in listening mode for at least aDMGPPMinListeningTime before making the attempt.

A CMMG STA that attempts to create a CMMG protected period shall transition to listening mode on a channel that the bandwidth is indicated in the Extended Schedule element for this SP.

A DMG STA shall not issue an RTS frame to establish a DMG protected period if any of its NAVs is not equal to 0.

A CMMG STA shall not issue an RTS frame to establish a CMMG protected period on a channel if any of its NAV timers corresponding to this channel are not equal to 0. A CMMG STA may issue an RTS frame to establish a CMMG protected period on a channel of the bandwidth of the channel is less than the SP allocated channel bandwidth and all of its NAV timers that correspond to this channel are 0.

A DMG STA that transmits an RTS frame to establish a DMG protected period during an SP in which it is a source DMG STA shall not transmit the RTS frame outside of the SP and the value of the Duration field of the RTS frame shall not exceed the duration of the portion of the SP that remains following the RTS frame transmission.

A CMMG STA that transmits an RTS frame to establish a CMMG protected period during an SP in which it is a source CMMG STA shall not transmit the RTS frame outside of the SP, and the value of the Duration field of the RTS frame shall not exceed the duration of the portion of the SP that remains following the RTS transmission. And a CMMG STA that transmits an RTS frame to establish a CMMG protected period during an SP in which it is a source CMMG STA shall not transmit an RTS frame that has a bandwidth that is larger than the allocated bandwidth.

In order to maintain STAs that are not aware of the establishment of the DMG protected period because they have begun listening to the medium after the establishment of a DMG protected period, a STA that established a DMG protected period should transmit additional RTSs. An additional RTS frame should be sent at the end of every (aDMGPPMinListeningTime – aRTSTimeoutTime) interval during the DMG protected period if the duration of the RTS/DMG CTS exchange is less than the time remaining in the SP.

A DMG STA that transmitted an RTS frame that established a DMG protected period shall use the same antenna configuration as was used for the transmission of the RTS frame during transmission of Data frame(s) during the DMG protected period.

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A DMG STA should transition to listening mode not less than aDMGPPMinListeningTime before the start of an SP in which it is the destination DMG STA.

During an SP in which it is the destination DMG STA, a DMG STA that receives a valid RTS frame with the RA equal to the recipient DMG STA MAC address and the TA corresponding to the source DMG STA of the SP shall respond with a DMG CTS frame if the recipient DMG STA has been in listening mode for aDMGPPMinListeningTime at the start of the reception of the RTS frame and none of its NAVs has a nonzero value.

During an SP in which it is the destination CMMG STA, a CMMG STA that receives a valid RTS frame addressed to it and the TA corresponding to the source CMMG STA of the SP shall not respond with a DMG CTS frame on the channel if at the start of the reception of the RTS frame the recipient CMMG STA has a nonzero value in at least one of its NAV timers corresponding to this channel.

During an SP in which it is the destination DMG STA, a DMG STA that receives a valid RTS frame with the RA equal to the recipient DMG STA MAC address and the TA corresponding to the source DMG STA of the SP shall not respond with a DMG CTS frame if at the start of the reception of the RTS frame the recipient DMG STA has a nonzero value in at least one of its NAVs or the recipient DMG STA has not been in listening mode for at least aDMGPPMinListeningTime.

During an SP in which it is the destination DMG STA, a DMG STA that receives a valid RTS frame with the RA equal to the recipient DMG STA MAC address and the TA corresponding to the source DMG STA of the SP may respond with a DMG DTS frame if at the start of the reception of the RTS frame the recipient DMG STA has a nonzero value in at least one of its NAVs.

A DMG STA may transmit a DMG DTS frame after the expiration of the aRTSTimeoutTime time following the start of an SP in which it is the destination DMG STA, if any of its NAVs has a nonzero value at that time and no RTS has been received from the source DMG STA of the SP and the STA has been in listening mode for aDMGPPMinListeningTime immediately preceding the start of transmission of the DMG DTS frame. The destination DMG STA shall not transmit a DMG DTS frame if any portion of the DMG DTS frame would be transmitted outside of the SP.

The value in the Duration field of a DMG DTS frame shall be calculated by subtracting the DMG DTS frame transmission time from the NAV in the destination DMG STA that has the largest value at the time of the start of the transmission of the DMG DTS frame. The NAV-DA and NAV-SA fields shall be set to the MAC addresses that identify the NAV in the destination DMG STA that was used to determine the Duration field value of the DMG DTS frame.

During an SP in which it is the destination DMG STA, a DMG STA that receives a valid RTS frame with the RA equal to the recipient DMG STA MAC address and the TA corresponding to the source DMG STA of the SP may respond with a DMG DTS frame if at the start of the reception of the RTS frame the recipient DMG STA has not been in listening mode for at least aDMGPPMinListeningTime. The value of the Duration field of the DMG DTS frame sent by the recipient DMG STA shall include the difference of aDMGPPMinListeningTime and the elapsed time since the recipient DMG STA has been in listening mode, and the NAV-SA and the NAV-DA fields of the DMG DTS frame shall contain the recipient DMG STA MAC address.

A destination DMG STA that responds to an RTS frame with a DMG CTS or DMG DTS frame shall transmit the response frame a SIFS after the end of the received RTS frame. A destination DMG STA that transmits either a DMG CTS or a DMG DTS frame shall use the same antenna configuration for the subsequent transmission of Ack frames and Data frames within the SP as is used for the transmission of the DMG CTS or DMG DTS frame.

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The source DMG STA of an SP can send a CF-End frame to the destination DMG STA of the SP to truncate a DMG protected period. Regardless of whether this CF-End frame is sent, a CF-End frame is also sent to the AP or PCP (see 10.39.8).

10.39.6.6.3 CDMG protected period establishment and maintenance

In addition to establishing a DMG protected period on its current operating channel, a CDMG STA might create another DMG protected period on an overlapping channel to avoid the potential interference from the overlapping channel. This subclause describes rules for establishing and maintaining a CDMG protected period for a pair of CDMG STAs.

A CDMG AP or PCP shall set the Protected Period subfield within the Extended Schedule element sent to the source and destination STAs to indicate whether the protected period is to be created and on which channels the protected period should be created for an SP allocation. The CDMG AP or PCP should determine the time and frequency overlapping status of an SP scheduled by itself with other SPs or CBAPs scheduled by other APs or PCPs according to the schedule information of the neighboring APs or PCPs and itself. The CDMG AP or PCP can obtain the schedule information of the neighboring APs or PCPs by receiving DMG Beacon frames directly if it is within an AP or PCP cluster, or by receiving interference reports included in the Cluster Report elements or DMG TSPEC elements transmitted by STAs within the BSS.

If a CDMG AP or PCP determines that there exists at least one SP or CBAP scheduled by a neighboring AP or PCP that is overlapping in both time and frequency with an SP allocated by the CDMG AP or PCP and cannot determine that the neighboring SP or CBAP does not interfere with its allocated SP based on the received interference report (10.39.6.6.6) from STAs, the CDMG AP or PCP shall set the Protected Period subfield to a nonzero value for the allocated SP to indicate that the source and destination CDMG STAs are required to establish a protected period for the SP. Otherwise, the CDMG AP or PCP shall set the Protected Period subfield to 0 to indicate that the source and destination CDMG STAs do not have to establish a protected period for the SP.

If a potentially interfering SP or CBAP is allocated on the current operating channel, the AP or PCP shall set the Protected Period subfield within the Allocation Control field to 1. The source and destination CDMG STAs shall follow the rules defined in 10.39.6.6.1 to establish a DMG protected period on its current operating channel.

If the source CDMG STA and destination CDMG STA are operating on a 1.08 GHz channel and a potentially interfering SP or CBAP is allocated on the overlapping 2.16 GHz channel, the CDMG AP or PCP shall set the Protected Period subfield to 2. The source CDMG STA and destination CDMG STA shall create a CDMG protected period on both the current operating 1.08 GHz channel and the overlapping 2.16 GHz channel.

If the source CDMG STA and destination CDMG STA are operating on a 2.16 GHz channel and a potentially interfering SP or CBAP is allocated on the overlapped low frequency 1.08 GHz channel, the CDMG AP or PCP shall set the Protected Period subfield to 2 to indicate that the source CDMG STA and destination CDMG STA create a DMG protected period on both the current operating 2.16 GHz channel and the low frequency 1.08 GHz channel.

If the source CDMG STA and destination CDMG STA are operating on a 2.16 GHz channel and a potentially interfering SP or CBAP is allocated on the overlapped high frequency 1.08 GHz channel, the CDMG AP or PCP shall set the Protected Period subfield to 3 to indicate that the source CDMG STA and destination CDMG STA create a DMG protected period on both the current operating 2.16 GHz channel and the high frequency 1.08 GHz channel.

If creating a CDMG protected period on two channels is required, the source and destination STAs shall listen to the current channel first and transition to and stay in listening mode following the rules specified in 10.39.6.6.1. If both the results of the PHY layer carrier sensing (CS) and the virtual carrier sensing show that

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the current channel is idle, the source STA and destination STA shall perform a RTS/DMG CTS handshake on the current channel. Once the first RTS/DMG CTS handshake is completed, the source STA and destination STA shall perform another RTS/DMG CTS handshake on the second channel after a SIFS. After the second RTS/DMG CTS handshake is done, the source STA and destination STA shall switch back to their operating channel and transmit data following a SIFS. An example of creating a CDMG protected period through two RTS/DMG CTS handshakes for CDMG STAs operating on a 1.08 GHz channel is shown in Figure 10-59.

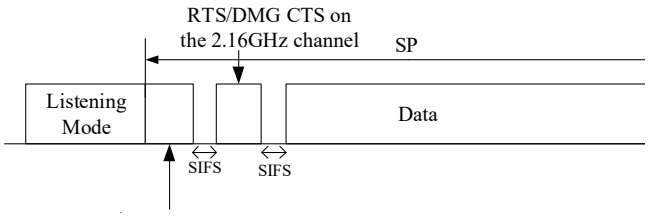

Figure 10-59—An example of creating a CDMG protected period on two channels for CDMG STAs

If an RTS/DMG CTS frame exchange on the 1.08 GHz channel failed, the CDMG STA shall not transmit the subsequent RTS frame on the 2.16 GHz channel after SIFS from the end of the expected CTS frame on the 1.08 GHz channel as shown in Figure 10-59.

In order to maintain protection from STAs that are not aware of the establishment of the CDMG protected period because they have begun listening to the medium after the establishment of a CDMG protected period, a CDMG STA that established a CDMG protected period should transmit additional RTS frames on the channels that are the same as the channels used when establishing the CDMG protected period. The source STA should initiate an additional two RTS/DMG CTS handshakes on the two channels at the end of every (aDMGPPMinListeningTime – aRTSTimeoutTime) interval during the CDMG protected period if the duration of the two RTS/DMG CTS handshakes exchange is less than the time remaining in the SP.

A CDMG AP or PCP can merge the time interval of listening mode when creating a CDMG protected period and the channel measurement time during SPSH (see 11.30) by using the Protected Period subfield and the Directional Channel Quality Request element. If the AP or PCP determines two SPs allocated for two pairs of CDMG STAs within the BSS should both be created with protected period, the AP or PCP may transmit a Directional Channel Quality Request element to the two pairs of STAs based on allocation positions of the SPs for the two pairs of STAs. The directional channel measurement time interval indicated by the Directional Channel Quality Request element of one pair of STAs should cover the listening mode that begins at the start of the SP of this pair of STAs. Thus, the two pairs of STAs can direct their received antennae to their peer STAs involved in the same SP to perform channel monitoring required for establishing the protected period and perform the directional channel quality measurement required by the SPSH mechanism simultaneously. The AP or PCP may use the received Directional Channel Quality Report elements after the listening mode for subsequent SPSH with time overlapping SPs for the two pairs of STAs after the beginning of the next beacon interval.

10.39.6.6.4 Dynamic and static bandwidth operation during CMMG protected period

If the CMMG STA that sending the RTS frame to establish a CMMG protected period during an SP in which it is a source CMMG STA is capable of dynamic bandwidth operation (see 10.3.2.8), the STA shall set the TXVECTOR parameter DYN_BANDWIDTH to Dynamic. Otherwise, the STA shall set the TXVECTOR parameter DYN_BANDWIDTH to Static.

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During an SP, a CMMG STA that is the destination CMMG STA in the SP and that is addressed by an RTS frame in a CMMG PPDU that has the RXVECTOR parameter DYN_BANDWIDTH equal to Static behaves as follows:

— If the NAV indicates idle and CCA has been idle for all the channel width indicated by the RTS frame's RXVECTOR parameter CH_BANDWIDTH, then the STA shall respond with a DMG CTS frame carried in a CMMG PPDU after a SIFS. The DMG CTS frame's TXVECTOR parameter CH_BANDWIDTH shall be set to the same value as the RTS frame's RXVECTOR parameter CH_BANDWIDTH.
— Otherwise, the STA shall not respond with a CTS frame.

During an SP, a CMMG STA that is the destination CMMG STA of the SP and that is addressed by an RTS frame in a CMMG PPDU that has the RXVECTOR parameter DYN_BANDWIDTH equal to Dynamic behaves as follows:

— If the NAV indicates idle in the primary 540 MHz channel, then the STA shall respond with a DMG CTS frame carried in a CMMG PPDU after a SIFS. The DMG CTS frame's TXVECTOR parameter CH_BANDWIDTH shall be set to 540 MHz if the CCA on the secondary 540 MHz channel is detected as busy and shall be set to 1080 MHz if the CCA on the secondary 540 MHz channel is detected as idle and the channel width indicated in the RTS frame's RXVECTOR parameter CH_BANDWIDTH is 1080 MHz.
— Otherwise, the STA shall not respond with a CTS frame.

10.39.6.6.5 NAV update in DMG and CMMG protected period

STAs in the listening mode shall update their NAVs according to the procedures described in 10.39.10.

NOTE—Support of multiple NAVs as defined in 10.39.10 is not limited to be used in the listening mode only and is also used in any case a NAV update is performed.

When an SP terminates, either through time allocation expiration or truncation, then the source DMG STA of that SP may reset any NAV to 0 that has an associated MAC variable NAV_DTSCANCELABLE with a value of true.

10.39.6.6.6 Interference report

A STA that receives an RTS and/or DMG CTS frame that updates the NAV and that overlaps in time with an SP where the STA is destination or source may report the overlap to the AP or PCP by sending a DMG ADDTS Request frame variant (9.6.3.3.2) and including in the DMG TSPEC element (9.4.2.133) the indication of interference in the Traffic Scheduling Constraint Set field (Figure 9-570). Transmission of the DMG ADDTS Request frame variant shall follow the rules defined in 11.4, with the following exceptions.

The Allocation ID subfield of the DMG TSPEC element shall identify the allocation during which the interference was detected. One ADDTS Request frame is generated and transmitted for each allocation during which interference is detected.

The Traffic Scheduling Constraint Set field of the DMG TSPEC element may contain one or more Constraint subfields. Each Constraint subfield provides information separately for each overlapping NAV event. The following NAV events should be reported:

a) Nonzero NAV at start of SP
b) Extension of NAV during the SP, including extension of an initial nonzero NAV and transitioning of the NAV from zero to nonzero value during the SP
c) Truncation of the NAV during the SP

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The TSCONST Start Time field is set to the TSF value at which the NAV event is detected. For event a) above, the TSCONST Start Time field shall be set to the start of the SP. For event b) above, the TSCONST Start Time field shall be set to the time the NAV was updated or initialized to the value reported in the TSCONST Duration field. For event c) above, the TSCONST Start Time field shall be set to the time the NAV was reset.

The TSCONST Duration field shall be set to the NAV value at the TSCONST Start Time, which is the value zero for event c).

The TSCONST Period shall be set to 0 indicating that the field is not applicable.

The Interferer MAC Address shall be set to the NAVDST of the NAV from which the TSCONST Start Time was derived (10.39.10).

CMMG STAs shall also include the Interferer Channel Bandwidth subfield in the report, and the Interferer Channel Bandwidth subfield shall be set to the CH_BANDWIDTH of the NAV timer.

All values conveyed in the Traffic Scheduling Constraint Set field shall refer to the allocation identified by the value of the Allocation ID subfield of the TSPEC.

The value of other fields within the DMG TSPEC element shall comply with the rules specified in 11.4.

Use of the information conveyed in the Traffic Scheduling Constraint Set field is outside the scope of this standard.

10.39.6.7 Service period recovery

When a non-AP and non-PCP STA fails to receive the Extended Schedule element for a beacon interval, the non-AP and non-PCP STA has no knowledge of the nonpseudo-static SPs allocated during the beacon interval that indicate it is the source DMG STA; therefore, it fails to transmit during those SPs. If the destination of the nonpseudo-static SP is an AP or PCP and it does not receive any frames from the source non-AP and non-PCP STA for the dot11SPIdleTimeout interval from the start of the SP, the AP or PCP may truncate the SP and use the mechanism described in 10.39.7 to reallocate the remaining duration of the SP to the source DMG STA of the SP or other STAs provided that it was a truncatable SP. If the SP is not a truncatable SP, the PCP may stay in awake state or may switch to doze state. If the non-AP and non-PCP STA failed to receive the Extended Schedule element from the AP or PCP for that beacon interval, it may switch to doze state or may direct its receive antenna toward the AP or PCP to receive a grant during nonpseudo-static SPs or CBAPs in the current beacon interval.

An AP or PCP may reclaim the entire time allocated in an SP between two non-AP and non-PCP STAs if the following two conditions are met:

— The SP is announced within an Extended Schedule element transmitted during the ATI.
— The AP or PCP does not receive a response frame from at least one of the source and destination non-AP and non-PCP STAs of that SP as part of the ATI exchange (10.39.3).

In either case described in this subclause, the AP or PCP may reallocate the reclaimed SP time as a CBAP, SP, or take no further action. Otherwise, if none of these conditions apply, no time may be reclaimed.

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10.39.7 Dynamic allocation of service period

10.39.7.1 General

Dynamic allocation of service period is employed to allocate channel time during scheduled SPs and CBAPs. The procedure includes an optional Polling Period (PP) phase and a Grant Period (GP) phase. Service periods allocated using this mechanism do not persist beyond a beacon interval. Persistent allocations are created using the allocation mechanisms described in 11.4.

The PP Available field in the STA Availability element (9.4.2.132) indicates whether a STA participates in the PP phase of the dynamic allocation of service period mechanism. A STA that participates in PP phase of the dynamic allocation of service periods responds to Poll frames during the PP. A STA that participates in dynamic allocation of service periods uses the time allocated through Grant frames during the GP to transmit frames. A STA may set the PP Available field in a transmitted STA Availability element to 0 to indicate that the STA does not respond to Poll frames during the PP and the GP.

NOTE—A STA can receive a Grant frame in periods of the beacon interval other than the GP, in which case the STA uses the time allocated through the Grant frame.

The AP or PCP shall not transmit Poll frames to a STA whose PP Available field in the STA Availability element is 0. The AP or PCP shall not dynamically allocate a service period to a STA that is in a D-BI (11.2.7). An AP or PCP may transmit Poll frames to a STA from which the AP or PCP has not received a STA Availability element with the PP Available field from the STA equal to 0.

An AP or PCP may dynamically allocate Service Periods during a scheduled SP for which both the source and destination AID fields are set to the broadcast AID by setting the Truncatable subfield to 1 within the Allocation field corresponding to the scheduled SP.

If a non-AP and non-PCP STA is neither source nor an individually addressed destination during a truncatable SP and the non-AP and non-PCP STA participates in dynamic allocation of service periods and the non-AP and non-PCP STA is in an A-BI, then the non-AP and non-PCP STA should be in the awake state for the duration of the truncatable SP.

A non-AP and non-PCP STA that participates in dynamic allocation of service periods shall be in the awake state for dot11MinPPDuration from the start of each truncatable SP for which both the source and the destination AID fields are set to the broadcast AID and that occurs within each A-BI of that STA. Following the expiration of dot11MinPPDuration, the non-AP and non-PCP STA should remain in the awake state until the end of the truncatable SP.

A STA shall be in the awake state for dot11MinPPDuration from the start of each scheduled CBAP that occurs within each A-BI of that STA. A STA that enters the doze state at any time during a CBAP and then returns to the awake state later during that same CBAP shall perform CCA until a frame is detected by which it can set its NAV, or until a period of time equal to the ProbeDelay has expired before it initiates a transmission.

As described in 10.39.8, a STA that participates in dynamic allocation of service periods and that is neither source nor destination during a truncatable SP can be in the receive state with its receive antennas configured in a quasi-omni antenna pattern for the duration of the truncatable SP.

A STA that receives a Grant frame with an SP allocation for which it is either source or destination shall not transmit longer than the time granted to it.

Any STA coordinated by an MM-SME that belongs to an MMSL cluster identified by the Source AID and Destination AID that are equal to, respectively, the Source AID and Destination AID of the Dynamic

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Allocation Info field in the Grant frame may transmit during the allocation, if the STA sent an MMS element to the peer STA and the BeamLink Cluster field within the MMS element is 1.

An example of dynamic allocation of service period is shown in Figure 10-60.

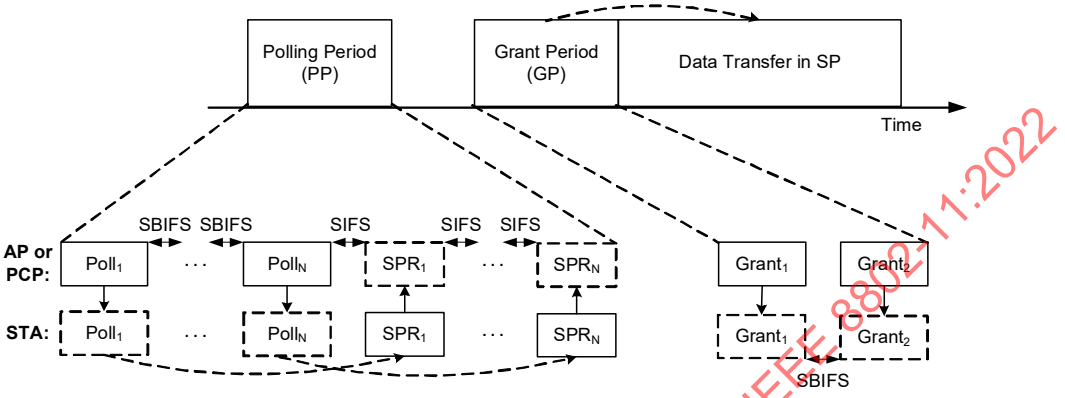

Figure 10-60—Example of dynamic allocation of service period mechanism

10.39.7.2 Polling period (PP)

An AP or PCP that uses a PP to dynamically allocate an SP within the DTI shall commence the PP at a time instant indicated by at least one of the following:

— Any time during a scheduled SP for which the source AID and destination AID are equal to the broadcast AID, excluding any time that has been allocated dynamically

— Any time during a TXOP within a scheduled CBAP for which the destination AID is equal to the broadcast AID, excluding any time that has been allocated dynamically

— Any time during the relinquished channel time following an SP truncation, excluding any time that has been allocated dynamically

The AP or PCP shall not transmit a frame during a PP if any portion of that frame would extend beyond the end of the originally scheduled SP or CBAP.

During the PP, the AP or PCP may transmit individually addressed Poll frames to STAs to solicit SPR frames from those STAs. The Duration field within each Poll frame i out of a total of n ($0 < i \leq n$) transmitted Poll frames in the PP shall be calculated as defined by Equation (10-18).

$$D_i = D_{i,n} + O_m + \text{Ceil}(\text{TXTIME}(\text{SPR}_m), T_{TR}) \quad (10\text{-}18)$$

where

$D_{i,n}$ is the duration of the remaining poll transmissions, in μs, given by

$$D_{i,n} = \text{Ceil}\left(\sum_{k=i+1}^{n} \text{TXTIME}(\text{Poll}_k) + SBIFS + A_k + S, T_{TR}\right)$$

O_m is the offset of SPR transmission m, in μs

SPR_m is SPR transmission m

T_{TR} is aTSFResolution, in μs

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The AP or PCP expects an SPR frame in response to each transmitted Poll frame (i.e., m=n). The position of each SPR frame in the sequence of SPR frames is indicated as j. Thus, j=1 refers to the first SPR frame transmission in the sequence of SPR frames, and j=m refers to the last SPR frame transmission in the sequence of SPR frames. Based on this, the Response Offset field within each Poll frame i transmitted in the PP shall be calculated as follows:

$$Response\ Offset_i = D_{i,n} + O_j$$

where

$D_{i,n}$ is the duration of the remaining poll transmissions, defined in Equation (10-18).
Poll_k is Poll transmission k
$SBIFS$ is aSBIFSTime, in μs
A_k is the antenna switching time, in μs, which is 0 if the AP or PCP uses the same antenna to transmit frame k and frame k+1 and is equal to dot11AntennaSwitchingTime otherwise
S is aSBIFSAccuracy, in μs
T_{TR} is aTSFResolution, in μs
O_j is the offset of SPR transmission j, given by

$$O_j = \begin{cases} SIFS, & j = 1 \\ O_{j-1} + \text{Ceil}(\text{TXTIME}(\text{SPR}_j) + SIFS, T_{TR}), & 2 < j \le m \end{cases}$$

$SIFS$ is aSIFSTime, in μs, the time interval between the end of the last Poll frame transmitted by the AP or PCP and the expected start time of the first SPR frame by the non-AP and non-PCP STA
SPR_j is an SPR transmission j

NOTE—The calculation of O_j guarantees that no less than SIFS or SIFS+dot11AntennaSwitchingTime is provided for the AP or PCP to switch antennas when receiving an SPR from different STAs.

A STA that receives an individually addressed Poll frame shall respond to the AP or PCP with a single directional and individually addressed SPR frame at the time offset from the end of the Poll frame indicated in the Response Offset field within the received Poll frame. The Duration field within the SPR frame shall be set to the value of the Duration field contained in the received Poll frame, minus the value of the Response Offset field contained in the received Poll frame, minus the time taken to transmit the SPR frame.

The PP ends at a time equal to the end of the last Poll frame transmission plus the value of the Response Offset field in that Poll frame plus the expected duration of the SPR transmission that is expected in response to that Poll frame plus SIFS.

10.39.7.3 Grant period (GP)

An AP or PCP that intends to dynamically allocate an SP within the DTI shall commence a GP at a time instant indicated by at least one of the following:

— SIFS following the end of a PP if the PP is present
— Any time during a scheduled SP for which the source AID and destination AID are equal to the broadcast AID if a PP does not precede the GP, excluding any time that has been allocated dynamically
— Any time during a TXOP within a scheduled CBAP for which the destination AID is equal to the broadcast AID, excluding any time that has been allocated dynamically
— Any time during the relinquished channel time following an SP truncation if a PP does not precede the GP, excluding any time that has been allocated dynamically

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The AP or PCP shall not transmit a frame during a GP if any portion of that frame would extend beyond the end of the originally scheduled SP or CBAP, or beyond the end of an immediately following SP if that SP has the broadcast AID as both source and destination AID, whichever is later.

A non-AP and non-PCP STA may switch to doze state if it does not receive a Grant frame from the AP or PCP within dot11MinPPDuration from the start of the scheduled SP for which the source AID and destination AID are set to the broadcast AID.

To commence the GP, the AP or PCP shall transmit Grant frames to notify the source DMG STA and destination DMG STA about a dynamically allocated service period, or the AP or PCP shall transmit Grant frames to notify the source CMMG STA and destination CMMG STA about a dynamically allocated service period. The AP or PCP should transmit the last Grant frame within a GP to the source of the dynamically allocated SP if the source of the dynamically allocated SP is not the AP or PCP. In each transmitted Grant frame, the AP or PCP shall set the Duration field within the Grant frame to a time that covers the duration of all remaining Grant frame and Grant Ack frame transmissions, if any, plus all appropriate IFSs (10.3.2.3). In addition, the source AID and destination AID fields shall be set to the source and destination, respectively, of the dynamically allocated SP, the AllocationType field set to indicate the channel access mechanism during the allocation, and the Allocation Duration field set to a value that if added to the value of the Duration field does not overlap in time with another SP that has either the source AID or destination AID different from the broadcast AID. An allocation that is indicated in this manner begins at the time that is equal to the PHY-TXEND.indication primitive of the Grant frame plus the value from the Duration field of the Grant frame.

The Dynamic Allocation Info field within Grant frames transmitted as part of the same GP shall be the same.

NOTE—This means the AP or PCP can create only one allocation per GP.

During an SP between a source DMG STA and a destination DMG STA, the source DMG STA may transmit a Grant frame to the destination DMG STA to relinquish the remainder of the SP to the destination DMG STA. In the Allocation Info field of the transmitted Grant frame, the source DMG STA shall set source AID field to the AID of the destination DMG STA, the destination AID field to the AID of the source DMG STA, the AllocationType field set to indicate SP, and the Allocation Duration field set to a value of 32 768 as defined in 9.5.2. The Duration field in the Grant frame shall be set to the time remaining in the SP minus TXTIME (Grant frame) minus aSIFSTime. Upon transmission of the Grant frame with the Beamforming Training field equal to 0, for the remainder of the SP the roles of source DMG STA and destination DMG STA are swapped between the STAs.

During an SP between a source CMMG STA and a destination CMMG STA, the source CMMG STA may transmit a Grant frame to the destination CMMG STA to relinquish the remainder of the SP to the destination CMMG STA. In the Allocation Info field of the transmitted Grant frame, the source CMMG STA shall set the Source AID field to the AID of the destination CMMG STA, the Destination AID field to the AID of the source CMMG STA, the AllocationType subfield to indicate SP, the Allocation Duration field to the time remaining in the SP minus the time taken to transmit the Grant frame, and the Allocation Channel Band field to the same channel and bandwidth as the original SP. The Duration field in the Grant frame shall be set to the value of the Allocation Duration field. Upon transmission of the Grant frame, for the remainder of the SP, the roles of source CMMG STA and destination CMMG STA are swapped between the STAs.

During a TXOP between a TXOP holder and a TXOP responder, the TXOP holder may transmit a Grant frame to the TXOP responder to relinquish the remainder of the TXOP to the TXOP responder. In the transmitted Grant frame, the TXOP holder shall set source AID field to the AID of the TXOP responder, the destination AID field to the AID of the TXOP holder, the AllocationType field set to indicate CBAP, and the Allocation Duration field set to a value of 32 768 as defined in 9.5.2. For CMMG STAs, the Channel Band field shall be set to the same channel and bandwidth as the original TXOP. The Duration field in the Grant frame shall be set

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to the time remaining in the TXOP minus TXTIME (Grant frame) minus aSIFSTime. Upon transmission of the Grant frame with the Beamforming Training field equal to 0, for the remainder the TXOP the roles of TXOP holder and TXOP responder are swapped between the STAs.

A STA that receives a Grant frame shall not update its NAV if the value of either the source AID or destination AID fields in the Grant frame are equal to the STA's AID.

The AP or PCP may grant a dynamic allocation of service period to a STA that does not transmit an SPR frame during the PP.

10.39.8 Dynamic truncation of service period

10.39.8.1 DMG dynamic truncation of service period

A STA truncates an SP to release the remaining time in the SP. The STA can use the CF-End frame to truncate the SP at the peer STA, to reset NAV in third party STAs and to return to the AP or PCP the time left in the SP, thus allowing the AP or PCP to grant any portion of the released time as part of an SP to any other STA or to allocate any portion of it as a CBAP. The STA can use the Grant frame to release any part of the time left in the SP as a CBAP.

A STA that is neither source nor destination during a truncatable SP may participate in dynamic allocation of service period by being in the receive state with its receive antenna configured in a quasi-omni antenna pattern for the duration of the truncatable SP. If both the source and destination AID fields of a truncatable SP are set to the broadcast AID, a non-AP and non-PCP STA may direct its receive antenna to its AP or PCP for the duration of the truncatable SP if the non-AP and non-PCP STA does not participate in a frame exchange and the truncatable SP is not dynamically allocated to the non-AP and non-PCP STA.

Only the source DMG STA of an SP may truncate the SP, except that the destination DMG STA may truncate the SP if it does not receive an expected transmission from the source DMG STA at the start of the SP as defined in 10.39.6.7.

Only the source CMMG STA of an SP may truncate the SP, except that the destination CMMG STA may truncate the SP if it does not receive an expected transmission from the source CMMG STA at the start of the SP as defined in 10.39.6.7.

In order to advertise the availability of truncatable SP time for reuse through AP or PCP dynamic allocation, a non-AP and non-PCP STA shall transmit an CF-End frame to the AP or PCP. A STA is not required to truncate an SP if a portion of the SP is unused.

In order to enable CBAP access during the time released through SP truncation, the STA shall broadcast a Grant frame with the Source AID and Destination AID set to broadcast AID, the AllocationType field set to indicate CBAP and the Duration field set to the time needed to transmit the Grant frame(s) (the Duration field in a Grant frame does not include duration of that frame) plus SIFS and plus the time needed to transmit the following CF-End frame and the response CF-End frame, if required and appropriate IFS (10.3.2.3) values. The Allocation Duration field shall be set to a value that is not greater than the result of the subtraction of the value in the Duration field from the time remaining in the SP. The CBAP that is indicated in this manner begins at the time that is equal to the PHY-TXEND.indication primitive of the Grant frame plus the value from the Duration field of the Grant frame and continues for the time indicated in the Allocation Duration field of the Grant frame.

The STA shall not transmit the Grant frame and shall not transmit the CF-End frame to the AP or PCP if the SP is not indicated as truncatable.

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After transmission of the CF-End frame to the AP or PCP or after broadcasting a Grant frame, the STA shall transmit a CF-End frame to the peer STA of the SP. The CF-End frame releases any time remaining in the SP at the recipient and resets the NAV in third party STAs. The NAV is reset only if the RA and TA of the CF-End frame match the addresses of the frame that established the NAV (see 10.39.10). The recipient STA may transmit a CF-End frame SIFS after the reception if the Duration field of the received frame is not equal to 0 and the transmission does not extend beyond the end of the originally scheduled SP.

A STA shall not initiate SP truncation if there is not enough time left in the SP to complete the frame exchange required for truncation of the SP.

After the truncation is completed, the AP or PCP may dynamically allocate any portion of the relinquished channel time that has not been allocated to a CBAP through a transmitted Grant frame (10.39.7).

10.39.8.2 CDMG dynamic truncation of service period

A CDMG STA truncates an SP to release the remaining time in the SP. The dynamic truncation of SP includes two types of truncation. The first type of truncation is that the STA can return to the AP or PCP the time left in the SP, thus allowing the AP or PCP to grant any portion of the released time as part of an SP to any other STA or to allocate any portion of it as a CBAP. The second type of truncation is that the STA can use the Grant frame to release any part of the time left in the SP as a CBAP.

A CDMG STA supports the DMG dynamic truncation of SP as described in 10.39.8.1. Unlike the DMG dynamic truncation of SP, the SP truncation type shall be determined by the CDMG AP or PCP when allocating an SP.

A CDMG AP or PCP shall determine whether an SP is truncatable and which truncation type is adopted by setting the Truncatable subfield and the Truncation Type subfield within the Allocation Control field when allocating an SP for the source CDMG STA and destination CDMG STA. If the Truncatable subfield of the Extended Schedule element is equal to 1, the CDMG STA may truncate the SP to release any part of the time left in the SP in accordance with the truncation type indicated by the received Truncation Type subfield.

A CDMG AP or PCP should determine the Truncatable subfield and the Truncation Type subfield according to the allocation type requirements of the STAs in its BSS, in order to satisfy the channel access requirements of the STAs using the potential released time of SPs. If the remaining time in the SP released as a CBAP might cause interference to other STAs during SPSH, the CDMG AP or PCP shall set the Truncatable subfield to 1 and the Truncation Type subfield to 0 for the SPs that are under SPSH state to indicate that the CDMG STA returns the time left in the SP to the AP or PCP; otherwise, the CDMG AP or PCP may set the Truncatable subfield to 1 and the Truncation Type subfield to 1. The CDMG AP or PCP may also set the Truncation Type subfield to 0 for an SP in order to mitigate interference to other STAs of a adjacent BSS based on the schedule information of the adjacent BSS.

A CDMG PCP may sleep in a truncatable SP that the time left in this SP is released as a CBAP by the CDMG STA by setting the Truncation Type subfield to 1 and the PCP Active field to 0. If both the Truncatable subfield and the Extendable subfield are set to 0, or if the Truncatable subfield is equal to 1 and the Truncation Type subfield is equal to 1, the CDMG PCP can set the PCP Active subfield to 0.

10.39.9 Dynamic extension of service period

A non-AP and non-PCP STA uses dynamic extension of SP to extend the allocated time in the current SP. The additional time can be used to support variable bit rate traffic, for retransmissions or for other purposes. The SPR frame is sent by a non-AP and non-PCP STA to the AP or PCP to request additional SP time in the current beacon interval.

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Except in response to a Poll frame from the AP or PCP, a non-AP and non-PCP STA shall not transmit an SPR frame within an SP if the current SP is not extendable (see 9.4.2.131).

Only the source DMG STA and destination DMG STA of an SP can transmit an SPR frame during that SP.

If the AP or PCP is not the source of an extendable SP, it should be in the receive state and with its receive antennas configured in a quasi-omni antenna pattern for the duration of the extendable SP.

To request an extension of the current SP, a non-AP and non-PCP STA shall transmit an SPR frame to the AP or PCP. The non-AP and non-PCP STA shall not request extension of the current SP if there is not enough time left in the SP to complete the frame exchange required for the SP extension. In the transmitted SPR frame, the STA shall set the RA field to the address of the AP or PCP, the Duration field to the time left in the SP (not including the SPR transmission time), and the Allocation Duration field to the additional amount of time requested by the STA following the end of the current SP.

The AP or PCP may grant the request for an extension of an SP only if the following SP has the broadcast AID as both source and destination AID, and the duration of the following SP is larger than the value of the Allocation Duration field in the received SPR frame. To grant an extension request, the AP or PCP shall transmit a Grant frame with the RA field set to the value of the TA in the received SPR frame, the Duration field set to the value of the Duration field received in the SPR frame minus SIFS and minus the duration of this Grant frame transmission, and the Allocation Duration field set to the amount of additional time granted by the AP or PCP. If a Grant Ack frame is transmitted following reception of the Grant frame, the frame shall be configured as specified in 10.39.4.

To decline a request for an extension of an SP, the AP or PCP shall transmit a Grant frame with the RA field set to the value of the TA in the received SPR frame, the Duration field set to the value of the Duration field received in the SPR frame minus SIFS and minus the duration of this Grant frame transmission, and the Allocation Duration field set to 0.

The extension request is successful if the non-AP and non-PCP STA receives from the AP or PCP a Grant frame with a nonzero value of the Allocation Duration field SIFS after the SPR. SIFS after the reception of a Grant frame from the AP or PCP with a nonzero value of the Allocation Duration field, the non-AP and non-PCP STA shall transmit a Grant frame to the partner STA of the SP with the Duration field set to the value of the Duration field of the Grant frame received from the AP or PCP minus the duration of this Grant frame transmission minus SIFS, and the Allocation Duration field set to the value of the Allocation Duration field of the Grant frame received from the AP or PCP.

An AP or PCP may extend an SP for which it is the source DMG STA by transmitting a Grant frame to the destination DMG STA of the SP. The Grant frame indicates extension of the SP. The Duration field in the transmitted Grant frame shall be set to the remaining time in the SP. The Allocation Duration field of the Grant frame shall be set to the additional channel time allocated by the AP or PCP following the end of the SP. If a Grant Ack frame is transmitted following reception of the Grant frame the frame shall be configured as specified in 10.39.4.

10.39.10 Updating multiple NAVs

If a DMG STA supports multiple NAVs, the number of available NAVs within the STA shall be not less than aMinNAVTimersNumber. Each NAV is identified by a pair of MAC addresses, NAVSRC and NAVDST, and has associated MAC variables NAV_RTSCANCELABLE, NAV_DTSCANCELABLE and NAV_CHANNEL the last of which is used only by CMMG STAs. The MAC variable NAV_CHANNEL indicates the channel on which the Duration field is received, and it is a channel index that contains channel bandwidth information. Each STA also maintains a MAC variable UPDATE_OPTIONAL. When a STA is enabled for operation, all NAVs shall have NULL values for their NAVSRC and NAVDST identifiers, the value of NAV_RTSCANCELABLE shall be false, the value of NAV_DTSCANCELABLE shall be false,

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the value of NAV_CHANNEL shall be NULL only for CMMG STAs, and each NAV shall have the value 0. NAV address pairs correspond to the NAV-SA and NAV-DA fields in DMG DTS frames and correspond to the RA and TA fields of all other received frames that are used to update the NAV. Receipt of any frame can cause an update to the NAV whose identifying address pair corresponds to the specified address fields of the received frame according to the rules in this subclause.

DMG STAs receiving any valid frame shall perform the following NAV update operation expressed using the following pseudocode:

```
NAV_TIMER_UPDATE(received_frame):

    UPDATE_OPTIONAL ← false

    If (received_frame = DMG DTS) {
        UPDATE_OPTIONAL ← true
    }

    If (received_frame(RA) ≠ This STA MAC address || UPDATE_OPTIONAL = true) {
        If (received_frame = DMG DTS) {
            R_DST ← received_frame(NAV-DA)
            R_SRC ← received_frame(NAV-SA)
        } else if (received_frame = Ack) {
            R_DST ← received_frame(RA)
            R_SRC ← 0
        } else {
            R_DST ← received_frame(RA)
            R_SRC ← received_frame(TA)
        }

        R_DUR ← received_frame(DUR)

        N_TIMER ← -1

        // Searching for a matching NAV
        For (x ← 0; x < aMinNAVTimersNumber; x++) {
            If (received_frame = Ack || NAVSRC(x)=R_DST) {
                If(NAVDST(x) = R_DST) {
                    N_TIMER ← x
                    Break
                }
            } else if (NAVSRC(x) = R_SRC && (NAVDST(x) = R_DST
                                || NAVDST(x) = 0) ||
                (NAVSRC(x)=0 && NAVDST(x) = R_DST) ||
                (NAVDST(x)=R_SRC && NAVSRC(x)=R_DST)) {
                N_TIMER ← x
                Break
            }
        }

        // No NAV has been found that matches the addresses
        If (N_TIMER < 0) {
```

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```
                    For (x ← 0; x < aMinNAVTimersNumber; x++) {
                        If (NAVSRC(x) = NULL && NAVDST(x) = NULL
                            || NAV(x) = 0) {
                            NAVSRC(x) ← R_SRC
                            NAVDST(x) ← R_DST
                            N_TIMER ← x
                            Break
                        }
                    }
                }

                // Existing NAV found
                If (N_TIMER ≥ 0) {
                    If (UPDATE_OPTIONAL = false
                        && R_DUR > NAV(N_TIMER) ) {
                        NAV(N_TIMER) ← R_DUR
                        If (received_frame = RTS) {
                            NAV_RTSCANCELABLE(N_TIMER) ← true
                        } else {
                            NAV_RTSCANCELABLE(N_TIMER) ← false
                        }
                    } else if (UPDATE_OPTIONAL = true && R_DUR > NAV(N_TIMER)) {
                        If ((implementation decision to update = true) ||
                        (received_frame(RA) = This STA MAC address &&
                        This STA MAC address = source DMG STA MAC address for current SP))
                        ) {
                            NAV_DTSCANCELABLE(N_TIMER) ← true
                            NAV(N_TIMER) ← R_DUR
                        }
                    }
                }

            } else {
                No change to NAV
            }

END OF NAV_TIMER_UPDATE
```

CMMG STAs receiving any valid frame shall perform the following NAV update operation expressed using the following pseudocode:

```
NAV_TIMER_UPDATE(received_frame):

        UPDATE_OPTIONAL ← false

        If (received_frame = DMG DTS) {
            UPDATE_OPTIONAL ← true

        }
        If (received_frame(RA) ≠ This STA MAC address || UPDATE_OPTIONAL = true) {
            If (received_frame = DMG DTS) {
```

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```
                R_DST ← received_frame(NAV-DA)
                R_SRC ← received_frame(NAV-SA)
                R_CHANNEL ← received_frame(CHANNEL BANDWIDTH)
        } else if (received_frame = Ack) {
                R_DST ← received_frame(RA)
                R_SRC ← 0
                NAV_CHANNEL ← received_frame(CHANNEL BANDWIDTH)
} else {
        R_DST ← received_frame(RA)
        R_SRC ← received_frame(TA)
}
        R_DUR ← received_frame(DUR)
        N_TIMER ← –1
// Searching for a matching NAV timer
For (x = 0; x < aMinNAVTimersNumber; x++) {
        If (received_frame = Ack || NAVSRC(x)=R_DST) {
                If(NAVDST(x) = R_DST) {
                        N_TIMER ← x
                        Break
                }
                } else if (NAVSRC(x) = R_SRC && (NAVDST(x) = R_DST|| NAVDST(x) = 0)
                ||(NAVSRC(x)=0 && NAVDST(x) = R_DST) ||
                (NAVDST(x)=R_SRC && NAVSRC(x)=R_DST)) {
                        N_TIMER ← x
                        Break
                }
        }
        // No NAV timer has been found that matches the addresses
        If (N_TIMER < 0) {
                For (x = 0; x < aMinNAVTimersNumber; x++) {
                        If (NAVSRC(x) = NULL && NAVDST(x) = NULL
                        || NAV(x) = 0) {
                                NAVSRC(x) ← R_SRC
                                NAVDST(x) ← R_DST
                                NAV_CHNNAL(x) ← R_CHANNEL
                                N_TIMER ← x
                                Break
                        }
                }
        }
        // Existing NAV timer found
        If (N_TIMER ≥ 0) {
                If (UPDATE_OPTIONAL = false) {
                        NAV(N_TIMER) ← R_DUR
                        NAV_CHNNAL(N_TIMER) ← R_CHANNEL
                        If (received_frame = RTS) {
                                NAV_RTSCANCELABLE(N_TIMER) ← true
                        } else {
                                NAV_RTSCANCELABLE(N_TIMER) ← false
```

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```
                    }
                } else if (UPDATE_OPTIONAL = true) {
                    If ((implementation decision to update = true) ||
                    (received_frame(RA) = This STA MAC address &&
                    This STA MAC address = source DMG STA MAC address for current
                    SP))) {
                        NAV_DTSCANCELABLE(N_TIMER) ← true
                        NAV(N_TIMER) ← R_DUR
                        NAV_CHNNAL(N_TIMER) ← R_CHANNEL
                        }
                    }
                }
            } else {
                No change to NAV timers
            }
END OF NAV_TIMER_UPDATE
```

A STA that has updated a NAV as a result of the reception of an RTS may reset its NAV(s) as follows. After the NAV update for a duration of NAVTimeout period (10.3.2.4), the STA shall monitor the channel to determine if a PHY-RXSTART.indication primitive is received from the PHY. If such an event has not occurred during this time period, then the STA may reset to 0 any NAV whose NAV_RTSCANCELABLE value is true.

After each NAV is updated, it counts down until it reaches 0 or is reset to 0.

If a STA receives a valid CF-End frame response with RA and TA values that match the NAVSRC and NAVDST values, in any order, for any NAV, then the STA shall set the associated NAV to the value of the Duration field in the received CF-End frame. If one of NAVSRC or NAVDST of a NAV is 0 and the corresponding NAVDST or NAVSRC, respectively, of the NAV match the RA or the TA value of the received valid CF-End frame, then the STA shall set the associated NAV to the value of the Duration field in the received CF-End frame.

If one of NAVSRC or NAVDST of a NAV is 0 and the nonzero NAVDST or NAVSRC of the NAV match either the RA or the TA value of a received valid frame, the NAVSRC or NAVDST that is 0 shall be set to the RA or TA that does not match the nonzero NAVSRC or NAVDST.

10.39.11 Opportunistic transmission in alternative channel for CDMG STAs

When dot11OpportunisticTransmissionsImplemented is true, an AP or PCP is capable of supporting the scheduling of opportunistic data transmission between two or more non-AP and non-PCP CDMG STAs that support such opportunistic transmission in a channel that is not the BSS's operating channel. The channel for such opportunistic transmission is termed the alternative channel while the BSS's operating channel is termed the dedicated channel as a contrast in this subclause. The spectrum access in the alternative channel is divided into three phases: monitor phase, transmission phase, and suspension phase. Scheduled transmission in the alternative channel shall start with the monitor phase, and then the three phases rotate cyclically until all the scheduled transmissions in the alternative channel are completed as illustrated in Figure 10-61.

The monitor phase shall last for at least aMaxBIDuration. During the monitor phase, a CDMG STA that is scheduled to operate in the alternative channel shall listen for the transmission of DMG Beacon frames in the alternative channel. If a CDMG STA receives one or more valid DMG Beacon frames with a BSSID different from its own, it shall abandon transmission during the transmission phase.

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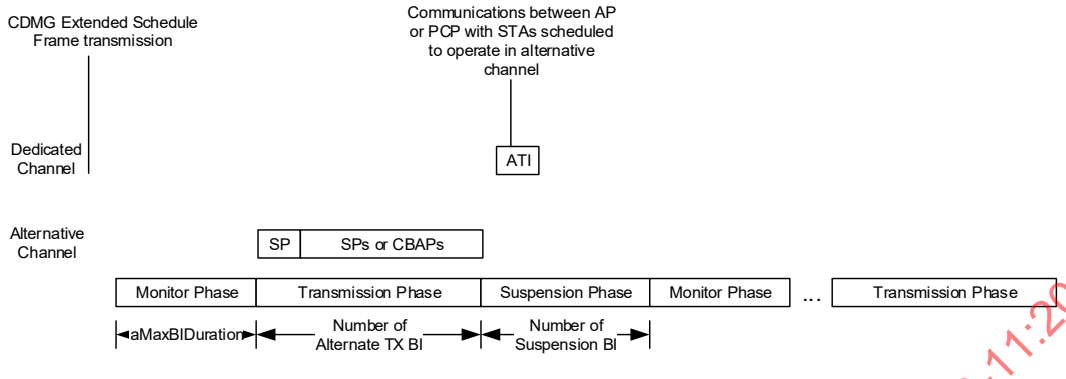

Figure 10-61—Opportunistic transmission in alternative channels for CDMG STAs

During the transmission phase, a CDMG STA may transmit frames according to the DTI transmission rules (10.39.4). A CDMG STA may continue to listen for the transmission of DMG Beacon frames in the alternative channel during the transmission phase when the CDMG STA is not transmitting. If a CDMG STA is not the source or destination STA in an access period, it may switch to the dedicated channel to receive the DMG Beacon frame or Announce frame send out by the AP or PCP to maintain synchronization with the AP or PCP.

During the suspension phase, a CDMG STA that is scheduled to operate in the alternative channel shall switch to the dedicated channel and be ready to receive transmission from the AP or PCP in the dedicated channel. The CDMG STA may receive the DMG Beacon frame or Announce frame transmitted by the AP or PCP to maintain synchronization with the AP or PCP during the suspension phase. If a CDMG STA receives a DELTS frame from the AP or PCP during the suspension phase, the CDMG STA should cease opportunistic transmission in the alternative channel.

The schedule of the transmission in the alternative channel is communicated through the CDMG Extended Schedule element (9.4.2.221). The AP or PCP shall transmit the CDMG Extended Schedule element in the Announce frame and/or DMG Beacon frame. The CDMG Extended Schedule element shall contain the scheduling information of all allocations in the alternative channel. The Number of Alternate TX BI field in the CDMG Extended Schedule element indicates the number of beacon intervals that makes up the transmission phase. The Number of Suspension BI field in the CDMG Extended Schedule element indicates the number of beacon intervals that makes up the suspension phase.

The access periods in the alternative channel may be scheduled to be either CBAPs or SPs but the first access period shall be an SP. The CBAPs in the alternative channel may be used by the AP or PCP to send more CDMG STAs to operate in the alternative channel after the initial setup. The source CDMG STA of the first SP in the alternative channel shall transmit a DMG Beacon frame at the start of the first transmission phase in the alternative channel and after every aMaxBIDuration within the transmission phase if the duration of the transmission phase exceeds aMaxBIDuration.

The AP or PCP should send a DMG CTS-to-self frame in the ATIs (10.39.3) during the suspension phase to each of the CDMG STAs scheduled to operate in the alternative channel. If a CDMG STA receives one or more DMG Beacon frames with a BSSID different from its own during the monitor phase, the CDMG STA shall respond with a DELTS frame to the AP or PCP with the Reason Code field set to the value defined in 9.4.1.7 that indicates the alternative channel is occupied upon reception of a DMG CTS-to-self frame from the AP or PCP during the ATI. If a transmission link in the alternative channel cannot be established during the transmission phase, the CDMG STA shall respond with a DELTS frame to the AP or PCP with the Reason Code field set to 67 to indicate that the transmission link establishment in alternative channel is failed. If the AP or PCP received a DELTS frame with the Reason Code field (9.4.1.7) set to 68 in an ATI, the AP or PCP shall

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transmit a DELTS frame to each of the CDMG STAs scheduled to operate in the alternative channel in the same ATI.

A CDMG AP or PCP may allocate a pair of STAs to perform SLS on an alternative channel. A CDMG STA may reuse the transmit sector indicated by the Sector Select field obtained from the operating channel, which is the primary channel on an alternative channel with the same channel width, and vice versa. If an SPR frame with the Beamforming Training subfield equal to 1 is received from a CDMG initiator STA, the CDMG AP or PCP may configure a channel for the initiator and the responder designated by the initiator to perform BF training according to the AllocationType subfield in the SPR frame. The SPR frame contains channel allocation request in the AllocationType subfield and BF Control field for the initiator and responder that form a BF pair. If the NoPrimaryChannel subfield in the BF Control field is equal to 1 and the Beamforming Training subfield is equal to 1 in the SPR frame, the CDMG AP or PCP can allocate SPs on an alternative channel using the CDMG Extended Schedule element included in a DMG Beacon frame or an Announce frame for the initiator and the responder; otherwise, the CDMG AP or PCP should allocate SPs on the current operating channel. If the CDMG AP or PCP receives SPR frames from multiple pairs of initiators and responders, the CDMG AP or PCP may allocate time overlapping SPs on designated channels with different channel numbers for different pairs of STAs to perform an SLS.

10.40 DMG and CMMG AP or PCP clustering

10.40.1 General

An AP or PCP may use the AP or PCP clustering mechanism to improve spatial sharing and interference mitigation with other co-channel DMG BSSs. An AP or PCP may use the AP or PCP clustering mechanism to improve spatial sharing and interference mitigation with other co-channel CMMG BSSs. There are two types of clustering:

— Decentralized AP or PCP clustering that involves a single S-AP or S-PCP in the BSA of the S-AP or S-PCP

— Centralized AP or PCP clustering where there can be multiple S-APs in the BSA of any one S-AP, and all S-APs are coordinated via a single centralized coordination service set

AP or PCP clustering allows an AP or PCP that is a member of a cluster to schedule transmissions in nonoverlapping time periods with respect to other members of the same cluster since the AP or PCP can receive DMG Beacon and Announce frames containing the Extended Schedule element of other APs and PCPs that are members of the cluster and can also receive the Extended Schedule element from another BSS through associated non-AP and non-PCP STAs (10.40.4).

A STA is decentralized AP or PCP clustering capable if it sets the Decentralized AP or PCP Clustering field to 1 within the DMG AP Or PCP Capability Information field in the DMG Capabilities element. A STA is decentralized AP or PCP clustering capable if it sets the Decentralized AP or PCP Clustering field to 1 within the CMMG AP Or PCP Capability Information field in the CMMG Capabilities element. A STA is centralized AP or PCP clustering capable if it sets the Centralized AP or PCP Clustering field to 1 within the DMG AP Or PCP Capability Information field in the DMG Capabilities element. A STA is centralized AP or PCP clustering capable if it sets the Centralized AP or PCP Clustering field to 1 within the CMMG AP Or PCP Capability Information field in the CMMG Capabilities element. The AP or PCP employs the Clustering Control field and ECAPC Policy Enforced field defined in 9.3.4.2 to configure the use of AP or PCP Clustering. A decentralized AP or PCP clustering capable or centralized AP or PCP clustering capable AP or PCP that transmits the Clustering Control field is decentralized clustering enabled or centralized clustering enabled, respectively.

An AP or PCP cluster includes one S-AP or S-PCP and zero or more member APs and PCPs. Decentralized clustering enabled APs and PCPs operating on the same channel may form a decentralized AP or PCP cluster. The Cluster ID of the decentralized AP or PCP cluster shall be set to the MAC address of the S-AP

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or S-PCP. Centralized clustering enabled APs and PCPs operating on the same channel as a S-AP form a centralized AP or PCP cluster as described in 10.40.2.2. The Cluster ID of the centralized AP or PCP cluster shall be set to the MAC address of the S-AP.

A clustering enabled AP or PCP that is not a member of any cluster shall set the Cluster Member Role subfield to 0 in transmitted frames that contain the Clustering Control field.

Each AP or PCP that is a member of an AP or PCP cluster shall include the Clustering Control field in each DMG Beacon frame it transmits.

For each cluster, there exists a set of ClusterMaxMem Beacon SPs. The n^{th} Beacon SP, Beacon SP_n, begins at $ClusterTimeOffset_{n-1}$ μs following the TBTT of the S-AP or S-PCP, where

$ClusterTimeOffset_{n-1} = 1024 \times (dot11BeaconPeriod/ClusterMaxMem) \times (n–1)$

and n=2, 3,…, *ClusterMaxMem*

The $ClusterTimeOffset_{n-1}$ and Beacon SP_n where n equals one is reserved for the S-AP or S-PCP.

An AP or PCP that is a member of an AP or PCP cluster shall transmit its DMG Beacon frame during one of the Beacon SPs as specified in 10.40.2.

The maximum size of the Beacon SP Duration field transmitted by a S-AP or S-PCP shall be the beacon interval of the S-AP or S-PCP divided by ClusterMaxMem.

10.40.2 Cluster formation

10.40.2.1 Decentralized AP or PCP cluster formation

A clustering enabled AP or PCP starts a decentralized AP or PCP cluster by becoming an S-AP or S-PCP, subject to the absence of existing clusters as described below and in 10.40.2.2. A decentralized clustering enabled AP or PCP becomes an S-AP or S-PCP of a decentralized AP or PCP cluster by transmitting a DMG Beacon frame at least once every aMinBTIPeriod beacon intervals that has the ECAPC Policy Enforced subfield in the DMG Parameters field set to 0 and that includes a Clustering Control field with the Beacon SP Duration subfield set to dot11BeaconSPDuration, the Cluster ID subfield set to the S-AP or S-PCP MAC address, and the Cluster Member Role subfield set to the value for an S-AP or S-PCP. The value of ClusterMaxMem subfield shall be chosen to keep the result of (beacon interval length/ClusterMaxMem) as an integer number of microseconds.

A decentralized clustering enabled AP or PCP that receives a DMG Beacon frame with the ECAPC Policy Enforced subfield in the DMG Parameters field set to 0 from an S-AP or S-PCP on the channel the AP or PCP selects to establish a BSS shall monitor the channel for DMG Beacon frame transmissions during each Beacon SP for an interval of length at least aMinChannelTime. A Beacon SP is empty if no DMG Beacon frames is received during the Beacon SP over an interval of length aMinChannelTime. The AP or PCP shall not become a member of the cluster if no Beacon SP is determined to be empty during aMinChannelTime, in which case, subject to the requirements described in 10.40.2.2, then the AP or PCP may become the S-AP or S-PCP of a new cluster, or may cease its activity on this channel and may attempt operation on a different channel.

A decentralized clustering enabled AP or PCP that operates its BSS on a channel on which it discovered an S-AP or S-PCP within a decentralized AP or PCP cluster and at least one empty Beacon SP shall transmit its DMG Beacon frame during an empty Beacon SP. By transmitting its DMG Beacon frame during an empty Beacon SP and by setting the clustering control field appropriately as described in 9.3.4.2, the AP or PCP becomes a member AP or member PCP.

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The member AP or member PCP shall select a beacon interval length that is equal to the beacon interval length of its S-AP or S-PCP.

The member AP or member PCP shall transmit its DMG Beacon frame with the ECAPC Policy Enforced field set to 0, the Beacon SP Duration subfield set to the value of the Beacon SP Duration subfield contained in the S-AP or S-PCP DMG Beacon, the Cluster ID subfield set to the MAC address of the S-AP or S-PCP, the Cluster Member Role subfield set to the member AP or member PCP value, and the ClusterMaxMem subfield set to the value of the ClusterMaxMem field contained in the S-AP or S-PCP DMG Beacon.

An AP or PCP with a value of Cluster Member Role that is not zero shall schedule a Beacon SP that is allocated for DMG Beacon frame transmission of other cluster member APs and PCPs within the decentralized AP or PCP cluster at each of $ClusterTimeOffset_n$, at any time the AP or PCP transmits its own DMG Beacon. The minimum size of the Beacon SP should be equal to the value of the Beacon SP Duration subfield within the S-AP or S-PCP DMG Beacon.

An S-AP or S-PCP and a member AP or member PCP of a decentralized AP or PCP cluster should not transmit or schedule transmissions during a Beacon SP that is not its own Beacon SP.

Figure 10-62 illustrates, for three APs and PCPs, the Beacon SPs of the S-AP or S-PCP and member APs and PCPs of a decentralized AP or PCP cluster.

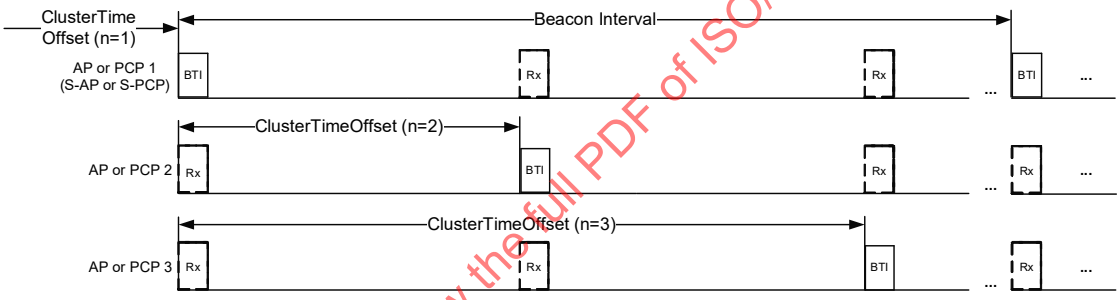

Figure 10-62—Decentralized AP or PCP clustering for 3 APs and PCPs

10.40.2.2 Centralized AP or PCP cluster formation

In order to become an S-AP, a centralized clustering enabled STA that is stationary with respect to its local environment shall successfully perform both the following steps in order:

- Configuration step
- Verification step

Once these steps have been performed successfully, the STA has become an S-AP.

- *Configuration step*: The configuration step is defined to be successful if the following occur:
  - The STA obtains the MAC address of the CCSR; and
  - The STA obtains an ECAPC Policy Detail field, beacon interval, ClusterMaxMem, Beacon SP Duration, TXSS CBAP Offset, TXSS CBAP Duration, TXSS CBAP MaxMem, TSF synchronization parameters, Cluster Time Offset availability information, and a nonempty list of excluded channels for the intended operating class of the STA from the CCSR; and
  - Either channel 2 is an allowed channel in the current regulatory domain and the list of excluded channels includes channel 2, or channel 2 is not an allowed channel in the current regulatory domain; and

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- The beacon interval/ClusterMaxMem is an integer number of microseconds; and
- At least one of beacon interval/TXSS CBAP MaxMem or TXSS CBAP MaxMem/beacon interval is an integer.

Otherwise, the configuration step is defined to be unsuccessful. If the configuration step is unsuccessful, then the STA can attempt to resolve the problem or quit attempting to start a centralized AP or PCP cluster. The method by which the STA obtains the configuration information from the CCSR is not defined in this standard.

- *Verification step*: The verification step is defined to be the following procedure:
  - The centralized clustering enabled STA monitors the channel for DMG Beacon frames over an interval of at least aMinChannelTime.
  - During this monitoring period, for each distinct Cluster ID received in a DMG Beacon frame that has the ECAPC Policy Enforced field set to 1 in the DMG Parameters field and Cluster Member Role set to 1 (S-AP or S-PCP of the cluster) or 2 (a member AP or member PCP of the cluster), the centralized clustering enabled STA determines if an S-AP with a MAC address equal to the Cluster ID belongs to the same CCSS as the centralized clustering enabled STA, via i) attempting to receive an Announce frame from the S-AP that transmitted the DMG Beacon frame according to the channel access rules described in 10.39 in order to solicit an ECAPC Policy element or ii) any other means. Any such DMG Beacon frame whose transmitter cannot be determined in this way to belong to the same CCSS as the centralized clustering enabled STA is defined to be from another ECAPC.

  The verification step is defined to be unsuccessful if, at the end of the monitoring period, there are one or more received DMG Beacon frames that are from another ECAPC. Otherwise, the verification step is defined to be successful.

If a centralized clustering enabled STA receives at least one DMG Beacon frame that has the ECAPC Policy Enforced field set to 1 and from a member AP, S-AP, or member PCP of another ECAPC during the monitoring period and the STA is not an ECAPC policy blind AP or PCP, the STA

- Shall cease its activity on this channel and may attempt operation on a different channel, or
- If one of the received DMG Beacon frames was sent by an S-AP, may elect to unenroll from its current CCSS and join the cluster of the S-AP as a member AP or member PCP.

If a centralized clustering enabled STA receives at least one DMG Beacon frame that has the ECAPC Policy Enforced field set to 1 from an S-AP from the same CCSS during the monitoring period and the STA is not an ECAPC policy blind AP or PCP, the STA may elect either to unenroll from its current CCSS and join the cluster of the S-AP as a member AP or member PCP or to continue and become an S-AP in the CCSS.

In order to become an S-AP in a centralized AP or PCP cluster, a centralized clustering enabled STA shall take the following actions:

- Set dot11ChannelUsageImplemented to true
- Start a BSS as an AP
  - On a channel that is not listed as excluded by the CCSR, and
  - At the start time and with the beacon interval configured by the CCSR
- Include in transmitted DMG Beacon frames
  - The ECAPC Policy Enforced field set to 1 in the DMG Parameters field, and
  - A Clustering Control field with the ClusterMaxMem subfield set to the values configured by the CCSR, the Beacon SP Duration subfield set to the value most recently configured by the CCSR, the Cluster ID subfield set to the S-AP MAC address, and the Cluster Member Role subfield set to 1 (S-AP or S-PCP of the cluster).

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An S-AP in a centralized AP or PCP cluster shall set the ECAPC Policy Enforced subfield in the DMG Parameters field to 1 for the lifetime of the BSS.

An S-AP within a centralized AP or PCP cluster shall include the ECAPC Policy element in (Re)Association Response, Announce, and Information Response frames with the ECAPC Policy Detail, TXSS CBAP Offset, and TXSS CBAP Duration fields set to the respective values most recently configured by the CCSR for the S-AP, the TXSS CBAP MaxMem subfield set to the policy configured by the CCSR, the CCSR ID subfield set to the MAC address of the CCSR, and bits in the Available Cluster Time Offset Bitmap subfield set to 0 to indicate the Cluster Time Offsets that are determined to be already in use, excluding the recipient if sent within an individually addressed frame. The means by which a Cluster Time Offset is determined to be in use are unspecified. Bits in the Available Cluster Time Offset Bitmap subfield for other Cluster Time Offsets shall be set to 1.

An AP or PCP that

— receives a DMG Beacon frame that has the ECAPC Policy Enforced subfield in the DMG Parameters field set to 1 from an S-AP on a channel and
— does not receive at least one DMG Beacon frame that has the ECAPC Policy Enforced subfield in the DMG Parameters field set to 1 from S-AP on every channel supported by the AP or PCP in the Operating Class within the next aMinChannelTime and
— is not an ECAPC policy blind AP or PCP

shall either join the cluster of the S-AP as a member AP or member PCP if centralized clustering enabled or cease its activity on this channel and may attempt operation on a different channel. S-APs within a CCSS report the channels unused by the ECAPC via the Channel Usage procedures (see 11.21.15).

An AP or PCP within a decentralized AP or PCP cluster that

— receives a DMG Beacon frame that has the ECAPC Policy Enforced subfield in the DMG Parameters field set to 1 from an S-AP and
— does not receive at least one DMG Beacon frame that has the ECAPC Policy Enforced subfield in the DMG Parameters field set to 1 from an S-AP on every channel supported by the AP or PCP in the Operating Class within the next aMinChannelTime (i.e., does not become a ECAPC policy blind AP) and
— is not already an ECAPC policy blind AP or PCP

shall quit the decentralized AP or PCP cluster before the next TBTT + beacon interval length, then the AP or PCP shall either join the cluster of the S-AP as a member AP or member PCP if centralized AP or PCP clustering enabled or cease its activity on this channel and may attempt operation on a different channel.

An AP or PCP that receives at least one DMG Beacon frame that has the ECAPC Policy Enforced subfield in the DMG Parameters field set to 1 sent by an S-AP on every channel supported by the AP or PCP in the Operating Class within the most recent aMinChannelTime ignores the ECAPC Policy Enforced subfield (i.e., treats this subfield as though equal to 0) in DMG Beacon frames received from S-APs for 300 × aMinChannelTime. During this period, the AP or PCP is called an *ECAPC policy blind AP or PCP*.

NOTE—An AP or PCP within a decentralized AP or PCP cluster does not cease DMG Beacon frame transmission when quitting a decentralized AP or PCP cluster. Hence, data communication is unaffected while performing these procedures.

A centralized clustering enabled AP or PCP that attempts to join the centralized AP or PCP cluster of an S-AP as a member AP or member PCP shall be a STA coordinated by an MM-SME that also coordinates a second non-AP and non-PCP STA, and shall successfully perform the following steps in order:

— The AP or PCP shall monitor the channel for DMG Beacon frames during each Beacon SP over an interval of length at least aMinChannelTime. A Beacon SP_n is empty if no DMG Beacon frame is received during the Beacon SP_n over an interval of length aMinChannelTime.

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— The second non-AP and non-PCP STA shall attempt to associate with the S-AP and thereby receive an Announce frame from the S-AP. The contents of the Announce frame are passed to the AP or PCP.
— Upon receiving an Announce frame that includes the ECAPC Policy element, the AP or PCP shall select a Cluster Time Offset index from the intersection of a) the Cluster Time Offset indices of the empty Beacon SPs with b) the indices indicated by the Available Cluster Offset Bitmap field in the ECAPC Policy element. If the intersection is empty, the AP or PCP shall select a Cluster Time Offset index of an empty Beacon SP. The selected Cluster Time Offset index is passed to the second non-AP and non-PCP STA.
— The second non-AP and non-PCP STA shall respond to the Announce frame with an Information Response frame that includes the Cluster Time Offset element containing the Cluster Time Offset Index set to the selected index.
— The AP or PCP shall operate its BSS at the selected Cluster Time Offset on the channel of the S-AP and include the AP or PCP clustering control field in transmitted DMG Beacon frames.

The AP or PCP shall not become a member of the centralized AP or PCP cluster if no Beacon SP is determined to be empty during aMinChannelTime or if the second non-AP and non-PCP STA did not associate to the S-AP, in which case the AP or PCP may attempt to join the cluster of another S-AP or cease its activity on this channel and may attempt operation on a different channel.

A member AP or member PCP within a centralized AP or PCP cluster shall select a beacon interval that is equal to the beacon interval of the S-AP of the cluster.

The member AP or member PCP within a centralized AP or PCP cluster shall transmit its DMG Beacon frames with the ECAPC Policy Enforced subfield in the DMG Parameters field set to 1, the Beacon SP Duration subfield in the Clustering Control field set to the value of the Beacon SP Duration subfield contained in the most recently received S-AP DMG Beacon, the Cluster ID subfield set to the MAC address of the S-AP, the Cluster Member Role subfield set to 2 (a member AP or member PCP of the cluster), and the ClusterMaxMem subfields set to the value of the ClusterMaxMem field contained in the S-AP DMG Beacon.

A member AP or member PCP within a centralized AP or PCP cluster shall include the ECAPC Policy element in (Re)Association Response, Announce, and Information Response frames with the ECAPC Policy Detail, TXSS CBAP Offset, and TXSS CBAP Duration fields set to the most recently received respective field from the S-AP of the cluster, the TXSS CBAP MaxMem field set to the value of the TXSS CBAP MaxMem field received from the S-AP of the cluster, with the CCSR ID set to the MAC address of the CCSR field received from the S-AP of the cluster, and with the Available Cluster Time Offset Bitmap field reserved.

At any time an AP or PCP within a centralized AP or PCP cluster transmits a DMG Beacon frame, the AP or PCP shall schedule a Beacon SP that reserves time for BHI transmission by other APs and PCPs within the centralized AP or PCP cluster at each in use $\text{ClusterTimeOffset}_{n-1}$ as indicated by the most recently transmitted (if S-AP) or received (if member AP or member PCP) Available Cluster Time Offset Bitmap. The minimum size of the Beacon SP shall be equal to the value of the Beacon SP Duration subfield within the DMG Beacon frame of the S-AP of the centralized AP or PCP cluster. A member AP, S-AP, or member PCP of a centralized AP or PCP cluster shall not transmit or schedule transmissions during a Beacon SP of another member AP, S-AP, or member PCP.

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10.40.3 Cluster maintenance

10.40.3.1 General cluster maintenance

The TBTT of the S-AP or S-PCP provides a timing reference for the Beacon SPs of the member APs and PCPs. Timing synchronization among the member APs and PCPs facilitates equitable sharing of the common medium among the member APs and PCPs. As long as a member AP or member PCP periodically receives DMG Beacons from the S-AP or S-PCP, the member AP or member PCP is able to maintain synchronization with the S-AP or S-PCP and hence the other member APs and PCPs.

10.40.3.2 Decentralized AP or PCP cluster maintenance

In the case when the S-AP or S-PCP of a decentralized AP or PCP cluster is lost, or appears to a member AP or member PCP to have been lost, another AP or PCP needs to become the S-AP or S-PCP of the decentralized AP or PCP cluster in order to allow the remaining member APs and PCPs to maintain synchronization with the cluster. The creation of a new S-AP or S-PCP is called *S-AP or S-PCP handover*. After an S-AP or S-PCP handover, the cluster might continue to function as before, except with altered membership, or the cluster might no longer exist, or there might be one or more new clusters.

A member AP or member PCP of the decentralized AP or PCP cluster shall start an S-AP or S-PCP handover if, within a time period of 4×aMinBTIPeriod beacon intervals, it does not receive a DMG Beacon frame with the ECAPC Policy Enforced field set to 0, with the value of the Cluster ID field equal to the Cluster ID of the cluster of which the AP or PCP is a member and with the Cluster Member Role field set to the S-AP or S-PCP value. This is the first cluster monitoring period. During the next step in the S-AP or S-PCP handover, the member AP or member PCP performs another cluster monitoring period. A cluster monitoring period is a time period of 4×aMinBTIPeriod beacon intervals during which the AP or PCP listens for DMG Beacons while continuing to transmit DMG Beacons using its current Beacon SP_n.

NOTE 1—A decentralized clustering enabled AP or PCP does not cease DMG Beacon frame transmission during Cluster Monitoring and S-AP or S-PCP handover. Hence, data communication is unaffected while performing these procedures.

If, during a cluster monitoring period, the member AP or member PCP receives a DMG Beacon frame with the value of Cluster Member Role set to the S-AP or S-PCP value, the member AP or member PCP shall follow the rules in 10.40.2 to become a member AP or member PCP of the cluster corresponding to the detected S-AP or S-PCP or cease operation on the channel; in either case, the cluster monitoring period is terminated.

If, during a cluster monitoring period, the AP or PCP receives no DMG Beacons with the value of Cluster Member Role set to the S-AP or S-PCP value and one or more DMG Beacons with the ECAPC Policy Enforced field set to 0 and with Cluster ID equal to the Cluster ID of its last S-AP or S-PCP, then at the end of the cluster monitoring period the AP or PCP compares the MAC addresses of all such received DMG Beacons with its own MAC address. If its MAC address is the lowest, the AP or PCP shall become an S-AP or S-PCP according to the rules in 10.40.2. If its MAC address is not the lowest, the AP or PCP shall perform a new cluster monitoring period. If the number of cluster monitoring periods performed by the AP or PCP exceeds dot11MaxNumberOfClusteringMonitoringPeriods, the AP or PCP may cease cluster maintenance and initiate cluster formation as described in 10.40.2.

If, during a cluster monitoring period, the AP or PCP does not receive a DMG Beacon frame that contains the value of S-AP or S-PCP in the Cluster Member Role field and does not receive a DMG Beacon frame with the ECAPC Policy Enforced field set to 0 and with Cluster ID equal to the Cluster ID of the cluster of which it is currently a member, then at the end of the cluster monitoring period the AP or PCP may become an S-AP or S-PCP according to the rules of 10.40.2, or it may cease its activity on this channel and may attempt operation on a different channel.

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NOTE 2—An assumption to allow the establishment of an S-AP or S-PCP in this case is that the APs and PCPs cannot hear each other's DMG Beacons. How a STA decides to switch the channel or to establish an S-AP or S-PCP is implementation dependent.

If, during a cluster monitoring period, the member AP or member PCP of a decentralized AP or PCP cluster receives no DMG Beacons from clustering enabled STAs, then the AP or PCP shall establish itself as an S-AP or S-PCP according to the rules in 10.40.2.

If an S-AP or S-PCP of a decentralized AP or PCP cluster detects the presence of a S-AP or S-PCP of another decentralized AP or PCP cluster on the same channel, it should schedule a Beacon SP for the DMG Beacon frame transmission of the other S-AP or S-PCP if the MAC address of the other S-AP or S-PCP is lower than the MAC address of this S-AP or S-PCP. The S-AP or S-PCP with higher MAC address should become a member AP or member PCP of the cluster corresponding to the S-AP or S-PCP with the lower MAC address according to the rules in 10.40.2.

10.40.3.3 Centralized AP or PCP cluster maintenance

A STA, while operating as an S-AP, remains stationary with respect to its local environment.

An S-AP within a centralized AP or PCP cluster, upon a change of the Beacon SP Duration field or the ECAPC Policy element configured by the CCSR, shall update the Clustering Control field sent in subsequent frames and shall send individually addressed Announce or Information Response frames to other STAs within the BSS in order notify them of the changes.

When a member AP or member PCP is coordinated by an MM-SME and the member AP or member PCP elects to change its S-AP within a centralized AP or PCP cluster, then a second non-AP and non-PCP STA coordinated by the MM-SME of the member AP or member PCP should disassociate from the previous S-AP, and the member AP or member PCP shall perform the steps described in 10.40.2.2 that allow a clustering enabled AP or PCP to join the centralized AP or PCP cluster of an S-AP as a member AP or member PCP.

When a member AP or member PCP is coordinated by an MM-SME and the member AP or member PCP elects to change its Cluster Time Offset within a centralized AP or PCP cluster, then the member AP or member PCP shall pass the updated Cluster Time Offset to a second non-AP and non-PCP STA coordinated by the MM-SME of the member AP or member PCP, and the second non-AP and non-PCP STA shall send an Information Response frame that includes a Cluster Time Offset element containing the Cluster Time Offset Index set to the updated index to the S-AP of the centralized AP or PCP cluster.

A member AP or member PCP within a centralized AP or PCP cluster, upon a change of the Clustering Control field received from its S-AP, shall update the Clustering Control field sent in subsequent frames. Upon a change of the ECAPC Policy Detail field received from its S-AP, a member AP or member PCP within a centralized AP or PCP cluster shall update the ECAPC Policy element sent in subsequent frames and send individually addressed Announce or Information Response frames to other STAs within the BSS in order to notify them of the changes. The member AP or member PCP within the centralized AP or PCP cluster shall attempt to receive a DMG Beacon frame from its S-AP at least once every dot11DMGEcssPolicyDetailUpdateDurationMax TUs.

In the case when a member AP or member PCP of a cluster has not received DMG Beacon frames from its S-AP for a duration exceeding 4×aMinBTIPeriod beacon intervals, and the member AP or member PCP intends to continue to operate a BSS on the channel, the AP or PCP shall either

a) Stop the current BSS then become an S-AP within the CCSS as described in 10.40.2.2; or

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b) Monitor the channel for DMG Beacon frames for an interval of length at least aMinChannelTime. During this period
   1) If one or more DMG Beacon frames are received with the ECAPC Policy Enforced field set to 1 in the DMG Parameters field and the Cluster Member Role set to 1 (S-AP or S-PCP of cluster) from one or more S-APs and the AP or PCP is not an ECAPC policy blind AP or PCP, then the AP or PCP shall join a selected S-AP as a cluster member as described in 10.40.2.2;
   2) Otherwise, if the AP or PCP is an ECAPC policy blind PCP or AP, then it may join a selected S-AP as a cluster member;
   3) Otherwise, if, after the period elapses, no DMG Beacon frames are received with the ECAPC Policy Enforced field in the DMG Parameters field set to 1 and the Cluster Member Role set to 1 (S-AP or S-PCP of cluster) and if the AP or PCP is decentralized AP or PCP clustering capable, then the AP or PCP shall attempt to join a decentralized AP or PCP cluster if present as described in 10.40.2.1. If the AP or PCP is not decentralized AP or PCP clustering capable or a decentralized AP or PCP cluster is not present, then the AP or PCP shall set its Cluster Member Role to 0 (not currently participating in a cluster).

c) In all three cases, the AP or PCP
   1) Shall set the ECAPC Policy Enforced bit to 0 and shall not include the ECAPC Policy element in (Re)Association Response, Announce, or Information Response frames and
   2) Should send individually addressed Announce or Information Response frames to other STAs within the BSS to notify them of the changes.

10.40.3.4 Centralized AP or PCP cluster MAC requirements

If the most recent ECAPC Policy element transmitted by a member AP, S-AP, or member PCP includes the BHI Enforced field set to 1, the member AP, S-AP, or member PCP shall complete the BTI, A-BFT, and ATI for each subsequent beacon interval before TBTT + (8×Beacon SP duration). The most recently transmitted (if an S-AP) or received (if a member AP, member PCP, or non-AP and non-PCP STA) value of Beacon SP Duration is used.

If the most recent ECAPC Policy element transmitted by a member AP, S-AP, or member PCP has the TXSS CBAP Enforced field set to 1, the member AP, S-AP, or member PCP shall complete each of its TXSSs in the DTI within one or more TXSS CBAPs.

If the most recent ECAPC Policy element, received by a non-AP and non-PCP STA in a BSS from the member AP, S-AP, or member PCP of the BSS, has the TXSS CBAP Enforced field set to 1, then the non-AP and non-PCP STA shall perform each of its TXSSs in the DTI within one or more TXSS CBAPs. If the non-AP and non-PCP STA is the source DMG STA of an SP and if the non-AP and non-PCP determines that it needs to perform a TXSS before continuing to transmit to the destination DMG STA of the SP, then the non-AP and non-PCP STA should truncate the SP (see 10.39.8). If the non-AP and non-PCP STA is the source CMMG STA of an SP and if the non-AP and non-PCP STA determines that it needs to perform a TXSS before continuing to transmit to the destination CMMG STA of the SP, then the non-AP and non-PCP STA should truncate the SP.

A TXSS CBAP shall last from T_{Start} to T_{End}, as defined below, excluding any time that overlaps a BHI or an SP that has source and destination DMG AIDs set to 255 (such as for a Beacon SP). A TXSS CBAP shall last from TStart to TEnd, as defined below, excluding any time that overlaps a BHI or an SP that has source and destination CMMG AIDs set to 255 (such as for a Beacon SP).

$$T_{Start} = T_{TBTT} + 8 \times T_o + \frac{(n-1) \times 1024 \times T_{BI}}{N}, 1 \le n \le N$$

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$$T_{End} = T_{TBTT} + 8 \times T_o + \frac{(n-1) \times 1024 \times T_{BI}}{N} + 8 \times T_d, 1 \le n \le N$$

where

T_{TBTT} is the TBTT
T_o is the TXSS CBAP Offset, in microseconds
T_d is the TXSS CBAP Duration, in microseconds
T_{BI} is the beacon interval, in TU
N is TXSS CBAP MaxMem

The most recently transmitted (if an S-AP) or received (if a member AP, member PCP, or non-AP and non-PCP STA) value of TXSS CBAP Offset and TXSS CBAP Duration fields are used.

The TXSS CBAP is available to all STAs in an ECAPC. A STA may also use the TXSS CBAP for sending frames not related to transmit sector sweeping. Transmission rules during a TXSS CBAP are defined in 10.39.5.

NOTE—Frames, such as Data frames, sent in a TXSS CBAP when the TXSS CBAP Enforced field is set to 1 might experience erratically higher interference than frames sent at other times due to the TXSSs of other nearby STAs.

Additional centralized AP or PCP cluster requirements are defined in 10.39.6.6 and 11.1.3.3.

10.40.4 Cluster report and rescheduling

A clustering enabled AP or PCP that receives an Extended Schedule element from another clustering enabled AP or PCP may reschedule SPs and CBAPs in its beacon interval, or move the BTI (11.1.3.3), in an attempt to mitigate any interference with the transmissions indicated in the received Extended Schedule element. The AP or PCP can create SPs in its beacon interval with the source and destination AID set to 255 to prevent transmissions during specific periods in the beacon interval (10.39.6.2).

A non-AP and non-PCP STA that is a member of a BSS and that receives a DMG Beacon frame should send a Cluster Report element to its AP or PCP if the received DMG Beacon frame meets all of the following conditions:

- The DMG Beacon frame is not from the STA's AP or PCP.
- The DMG Beacon frame contains the Clustering Control field.
- Either
  - The value of the Cluster ID field within the Clustering Control field is different from the MAC address of the STA's AP or PCP; or
  - The value of the Cluster ID field within the Clustering Control field is the same as the MAC address of the STA's AP or PCP, the TBTTs of the two BSSs are less than dot11BeaconPeriod/(2×ClusterMemMax) apart in time, and the ECAPC Policy Enforced field in the DMG Beacon frame received most recently from the STA's AP or PCP is equal to 1.

The non-AP and non-PCP STA shall not send a Cluster Report element to its AP or PCP if the received DMG Beacon frame does not meet the preceding conditions.

A Cluster Report element meeting the conditions above shall be transmitted in an Announce or Information Response frame sent to the STA's AP or PCP. Within the transmitted Cluster Report element, the STA shall set the Cluster report subfield to 1. The STA shall set the Clustering Control field within a transmitted Cluster Report element to the corresponding field values within the Clustering Control of the received DMG Beacon, shall set the Reported BSSID field to the BSSID field of the received DMG Beacon, and shall set the Reference Timestamp field to indicate the DMG Beacon frame reception time. The STA shall set the

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Schedule present subfield to 1 if the Extended Schedule field is present in the transmitted Cluster Report element; otherwise, it shall set Schedule present subfield to 0. The STA shall set the TSCONST present subfield to 1 if the Traffic Scheduling Constraint Set field is present in the transmitted Cluster Report element; otherwise, it shall set TSCONST present subfield to 0.

The STA shall set the ECAPC Policy Enforced field in the Cluster Report Control field to the value of the ECAPC Policy Enforced field in the received DMG Beacon. The STA should attempt to receive an Announce frame from the AP or PCP that transmitted the DMG Beacon frame according to the channel access rules described in 10.39 in order to solicit an ECAPC Policy element. If the STA obtains an ECAPC Policy element from the AP or PCP that transmitted the DMG Beacon, the STA shall set the ECAPC Policy Present subfield to 1 and include the ECAPC Policy element in the transmitted Cluster Report element; otherwise, the STA shall set ECAPC Policy Present subfield to 0 and not include the ECAPC Policy element in the transmitted Cluster Report element. If present, the Extended Schedule Element field within the Cluster Report element shall be set to the corresponding field values within the Extended Schedule element of the received DMG Beacon. If present, the Traffic Scheduling Constraint Set field shall be set to indicate periods of time with respect to the TBTT of the beacon interval of the BSS the STA participates where the transmitting STA experiences poor channel conditions, such as due to interference.

If the received DMG Beacon frame contains more than one Extended Schedule element entry, the STA shall repeat the aforementioned procedure and transmit a Cluster Report element corresponding to each Extended Schedule element entry.

Upon receiving a Cluster Report element from a non-AP and non-PCP STA with the Cluster report field set to 1, a clustering enabled AP or PCP may reschedule SPs and CBAPs in its beacon interval, move the BTI if the clustering enabled AP or PCP is an S-AP or S-PCP in a decentralized AP or PCP cluster, or change the Cluster Time Offset if the clustering enabled AP or PCP is a member AP or member PCP, or perform other actions, in an attempt to mitigate any interference with the transmissions indicated in the received Cluster Report element. The clustering enabled AP or PCP may also create SPs in its beacon interval with the source and destination AID set to 255 to prevent transmissions during specific periods in the beacon interval.

A member AP or member PCP within a centralized AP or PCP cluster should report new interference information and may report all interference information to the S-AP of the cluster

- When the member AP or member PCP receives one or more of the following:
  - A DMG Beacon frame from another AP or PCP in another centralized AP or PCP cluster within the same CCSS or another CCSS
  - A Cluster Report element with the Cluster Report field set to 1 from a non-AP and non-PCP STA within the same BSS characterizing an AP or PCP in another centralized AP or PCP cluster within the same CCSS or another CCSS; and
- If at least dot11DMGEcssClusterReportDurationMin TUs have elapsed since the last report.

The report should aggregate the information received from all sources and minimize duplication. The member AP or member PCP passes the report to a second non-AP and non-PCP STA coordinated by the MM-SME of the member AP or member PCP, and the second non-AP and non-PCP STA sends the report in an Information Response frame that includes one or more Cluster Report elements to the S-AP of its centralized AP or PCP cluster. If the member AP or member PCP does not elect to change its Cluster Time Offset at this time, the second non-AP and non-PCP STA includes a Cluster Time Offset element with an unchanged Cluster Time Offset Index field.

Via unspecified means, the S-AP might aggregate received DMG Beacon frames and Cluster Report elements and send the aggregate to the CCSR. Upon receiving this information, the CCSR might reconfigure the TSF offsets of an S-AP, reconfigure the ECAPC Policy Detail of an S-AP, update the Cluster Time Offset availability information provided in an individually addressed frame by an S-AP to a member AP or member PCP, or perform other actions.

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10.40.5 Decentralized AP or PCP cluster request

A non-AP and non-PCP STA that is a member of a BSS may transmit a Cluster Report element to its AP or PCP to request that decentralized AP or PCP clustering be enabled in the BSS. The non-AP and non-PCP STA can make this request if, for example, the device containing the non-AP and non-PCP STA intends to initialize another co-channel BSS (11.1) in which it performs the role of AP or PCP and, when performing this role, it wishes to become a member AP or member PCP of the decentralized AP or PCP cluster formed by its current AP or PCP.

To request AP or PCP clustering to be enabled in the BSS, the STA shall transmit a Cluster Report element with the Cluster request subfield set to 1 to its AP or PCP. Upon receiving a Cluster Report element with the Cluster request subfield set to 1, the AP or PCP should form and maintain decentralized AP or PCP clustering in the BSS according to the procedures described in 10.40.2 and 10.40.3. In doing that, the AP or PCP should set the minimum duration of the Beacon SP to be equal to the Beacon SP duration.

If the non-AP and non-PCP STA does not receive a DMG Beacon frame from its AP or PCP with decentralized AP or PCP clustering enabled after dot11ClusterEnableTime following the transmission to its AP or PCP of a Cluster Report element with the Cluster request subfield set to 1, the non-AP and non-PCP STA may transmit an Announce frame including the last Extended Schedule element transmitted by the AP or PCP. If the Announce frame is transmitted, it shall use MCS 0, and the TA field shall be set to the broadcast address. If a DMG STA receives an Announce frame with the TA field set to the broadcast address and with the BSSID field different from the BSSID of its BSS, the STA may send a Cluster Report element containing the Extended Schedule element within the received Announce frame to its AP or PCP, which might be used by the AP or PCP to reschedule SPs in portions of the beacon interval that are nonoverlapping in time with the SPs contained in the Extended Schedule element reported by the STA. if a CMMG STA receives an Announce frame with the TA field set to the broadcast address and with the BSSID field different from the BSSID of its BSS, the STA may send a Cluster Report element containing the Extended Schedule element within the received Announce frame to its AP or PCP, which might be used by the AP or PCP to reschedule SPs in portions of the beacon interval that are nonoverlapping in time with the SPs contained in the Extended Schedule element reported by the STA.

If a non-AP and non-PCP STA becomes a member AP or member PCP of the clustering enabled by its current AP or PCP, the non-AP and non-PCP STA can synchronize scheduled CBAP allocations, if any, between the BSS in which it performs the role of AP or PCP and the BSS of its current AP or PCP. The non-AP and non-PCP STA can disallow STAs in the BSS in which it plays the role of AP or PCP from transmitting during the Beacon SPs of the cluster it is a part of, and this can be done by allocating an SP time-overlapping with each Beacon SP such that each allocated SP has both the source AID and destination AID fields within the Extended Schedule element set to the AID of the non-AP and non-PCP STA.

10.41 CDMG AP or PCP clustering

10.41.1 General

A CDMG AP or PCP may use the CDMG AP or PCP clustering mechanism to improve spatial sharing and interference mitigation with other co-channel DMG or CDMG BSSs.

A clustering enabled AP or PCP that is operating on a 2.16 GHz or 1.08 GHz channel and transmitting DMG Beacon frames with the DBC Option subfield of the Dynamic Bandwidth Control element set to 1 (10.64.2.2) is able to start a decentralized AP or PCP cluster or a centralized AP or PCP cluster on a 2.16 GHz channel following the rules as described in 10.40.

A clustering enabled AP or PCP that is operating on a 1.08 GHz channel and transmitting DMG Beacon frames with the DBC Option subfield of the Dynamic Bandwidth Control element set to 0 (10.64.2.2) is able to start an

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AP or PCP cluster on a 1.08 GHz channel. Starting an AP or PCP cluster on a 1.08 GHz channel shall follow the rules defined in 10.40 and in this subclause.

If an AP or PCP cluster starts on a 1.08 GHz channel, the S-AP or S-PCP shall not only transmit its DMG Beacon frame during the first Beacon SP (10.40.1) on this 1.08 GHz channel but also transmit the DMG Beacon frame during the notification period (NP) of each allocated quiet period (QP) on the corresponding 2.16 GHz common channel as described in 10.64. Moreover, according to the rules in 10.64, the S-AP or S-PCP shall set its beacon interval on the 2.16 GHz common channel as an integer multiple of the beacon interval on the 1.08 GHz channel in terms of TUs, and the maximum length of beacon interval on the 1.08 GHz channel can be given as the same length of the beacon interval on the 2.16 GHz channel.

The member AP or member PCP of a cluster starting on a 1.08 GHz channel shall not allocate QP on the 2.16 GHz common channel to transmit its DMG Beacon frame if there is no legacy non-AP and non-PCP DMG STA within its BSS or it does not involve in a synchronization pair with another AP or PCP operating in the adjacent 1.08 GHz channel. Otherwise, the member AP or member PCP shall transmit its DMG Beacon frame during its NP of the allocated QP on the 2.16 GHz common channel, similar to the S-AP or S-PCP.

10.41.2 Cluster formation

10.41.2.1 Decentralized CDMG AP or PCP cluster formation

A decentralized clustering enabled AP or PCP starts a decentralized AP or PCP cluster on a 1.08 GHz channel by becoming an S-AP or S-PCP, subject to the absence of existing clusters on this 1.08 GHz channel as described below and in 10.40.2.1.

The S-AP or S-PCP of an AP or PCP cluster starting on a 1.08 GHz channel shall set the DMG Parameters field and the Clustering Control field following the rules defined in 10.40.2.1 and also set the first bit of the Clustering Status subfield contained in the Dynamic Bandwidth Control element to 1.

A decentralized clustering enabled AP or PCP that receives a DMG Beacon frame from an S-AP or S-PCP on either a 2.16 GHz channel or a 1.08 GHz channel shall know the exact channel on which this S-AP or S-PCP selects to start a cluster through the Channel Splitting subfield, Clustering Status subfield, and the Channel Number field contained in the Dynamic Bandwidth Control element.

If an existing AP or PCP cluster is operating on a 2.16 GHz channel, the decentralized clustering enabled AP or PCP shall monitor the corresponding 2.16 GHz channel and then follow the procedures defined in 10.40.2.1 to become a member AP or member PCP of this cluster.

If the decentralized clustering enabled AP or PCP receives a DMG Beacon frame containing the Clustering Control field from an S-AP or S-PCP on a 1.08 GHz channel, the AP or PCP shall monitor the corresponding 1.08 GHz channel during each Beacon SP according to the received cluster synchronization and control information to listen whether the Beacon SPs are occupied by other member APs or member PCPs. If an empty Beacon SP is discovered, the AP or PCP shall follow the same procedures defined in 10.40.2.1 to become a member AP or member PCP of this cluster.

A decentralized clustering enabled AP or PCP shall not become a member of a cluster starting on a 1.08 GHz channel if no Beacon SP is determined to be empty during aMinChannelTime, in which case, subject to the requirements described in 10.40.2.1, then the AP or PCP may become the S-AP or S-PCP of a new cluster, or may cease its activity on this 1.08 GHz channel, or may request to operate on the unoccupied adjacent 1.08 GHz channel within the 2.16 GHz common channel (10.64.2.3), and, if desired, attempt operation on a different 2.16 GHz or 1.08 GHz channel.

The AP or PCP of a decentralized AP or PCP cluster shall not transmit or schedule transmissions during a Beacon SP that is not its own Beacon SP and a QP duration that is not its own QP.

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Figure 10-63 illustrates an example of a decentralized AP or PCP cluster starting on the 1.08 GHz channel 35 while the adjacent 1.08 GHz channel 36 is unoccupied. The S-AP or S-PCP and member AP 3 or member PCP 3 with a BSS in which there is at least one DMG STA transmit DMG Beacon frames during the NPs of the allocated QPs on the 2.16 GHz channel 2 and their own Beacon SPs on channel 35, respectively. Other member APs or member PCPs transmit DMG Beacon frames only during their own Beacon SPs on channel 35.

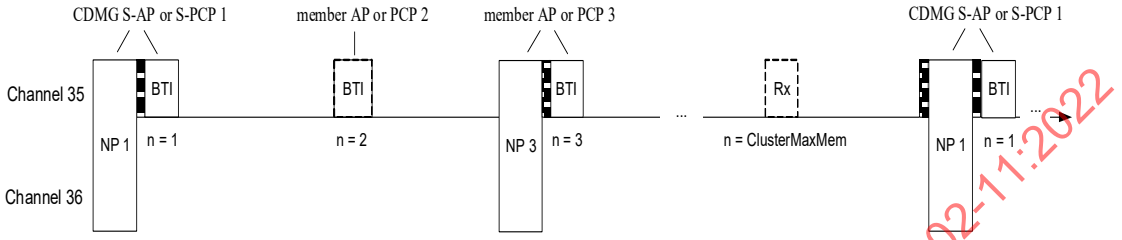

Figure 10-63—Example of a decentralized AP or PCP cluster on a 1.08 GHz channel

Figure 10-64 illustrates an example of two decentralized AP or PCP clusters starting on the two adjacent 1.08 GHz channel 35 and channel 36, respectively. Two S-APs or S-PCPs form a synchronization pair under the first mode of DBC mechanism(10.44) and transmit DMG Beacon frames during their own NPs of the allocated QPs on the 2.16 GHz channel 2 and the Beacon SPs on the 1.08 GHz channel 35 and channel 36. Other member APs or member PCPs APs transmit DMG Beacon frames only during their own Beacon SPs on the corresponding 1.08 GHz channels.

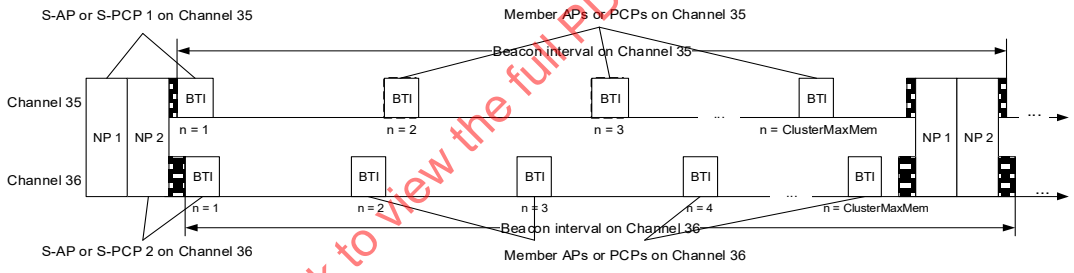

Figure 10-64—Example of decentralized clusters for two APs or PCPs of a synchronization pair

The member AP or member PCP operating on a 1.08 GHz channel shall select a beacon interval length on the 1.08 GHz channel that is equal to the beacon interval length of its S-AP or S-PCP on the same channel.

The AP or PCP operating on the 1.08 GHz channel should determine its beacon interval on the 2.16 GHz channel to be equal to the beacon interval of the S-AP or S-PCP on the 2.16 GHz channel according to the cluster synchronization and control information of the S-AP or S-PCP. The AP or PCP operating on the 1.08 GHz channel should continue transmitting the DMG Beacon frames on the 2.16 GHz channel during the beacon SP according to the beacon interval on the 2.16 GHz channel. The AP or PCP operating on the 1.08 GHz channel shall switch back to the 1.08 GHz channel to transmit DMG Beacon frames during the BTI on the 1.08 GHz channel according to the beacon interval on the 2.16 GHz channel.

If a member AP or member PCP does not involve in a synchronization pair with another AP or PCP (10.64.2.3), it shall set the beacon interval length on the 2.16 GHz channel as an integer multiple of its beacon interval length on the 1.08 GHz channel. Otherwise, if the member AP or member PCP is involved in a synchronization pair with another AP or PCP operating in the adjacent 1.08 GHz channel, it shall adjust its

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beacon interval length on the 2.16 GHz channel as an integer multiple of its beacon interval length on the 1.08 GHz channels and also notify the neighboring AP or PCP that is involved in the synchronization pair to adjust the beacon interval on the 2.16 GHz channel to the same value through a DMG BSS Parameter Change element within the DMG Beacon frame transmitted in its NP of the allocated QP on the 2.16 GHz common channel following the rules in 11.31.4 In this case, subject to the requirement described in 10.64, the neighboring AP or PCP may further adjust its beacon interval on the 1.08 GHz channel as an integer factor of the new beacon interval length on the 2.16 GHz channel in units of TUs. The procedures of the adjusting beacon interval and CDMG SBBI for AP or PCP 1 and AP or PCP 2 that is involved in a synchronization pair should be as follows:

a) If the AP or PCP 1 detected an empty Beacon SP on the 1.08 GHz channel, AP or PCP 1 shall change the current beacon interval length beacon interval 1 to beacon interval 2 on the 2.16 GHz channel to align the beginning of the first BTI on the 1.08 GHz channel after beacon interval 2 duration with the beginning of the empty Beacon SP.

b) Determine whether the ratio of beacon interval 2 divided by CDMG SBBI of the S-AP or S-PCP is an integer. If the ratio of beacon interval 2 divided by CDMG SBBI of the S-AP or S-PCP is an integer, the AP or PCP 1 shall adjust CDMG SBBI 1 to equal the CDMG SBBI of the S-AP or S-PCP. Otherwise, the AP or PCP 1 shall change its beacon interval length beacon interval 2 to beacon interval 3 on 2.16 GHz channel during its next NP 1 and set its CDMG SBBI 1 to the CDMG SBBI of S-AP or S-PCP during the BTI to make the ratio of beacon interval 3 divided by CDMG SBBI of the S-AP or S-PCP an integer. For both cases, the AP or PCP 1 shall notify the AP or PCP 2 of the new beacon interval 2 or beacon interval 3 during the first QP at the end of beacon interval 2 or beacon interval 3, where the QP comprises the NP and a guard interval (GI) used for channel switching, and the AP or PCP 2 should also adjust its SBBI 2 to make the ratio of beacon interval 2 or beacon interval 3 divided by CDMG SBBI 2 an integer.

c) The AP or PCP 1 transmits the DMG Beacon frame including the Clustering Control field during the empty Beacon SP on the 1.08 GHz channel to join the intended 1.08 GHz cluster as a member AP or member PCP.

An example of adjusting beacon interval and CDMG SBBI for step a) and b) is illustrated in Figure 10-65. For step a) and step b), changing beacon interval on the 2.16 GHz channel or changing SBBI on the 1.08 GHz channel is completed by AP or PCP 1 by negotiation with AP or PCP 2 in a notification period (NP) that comprises NP1 and NP2. AP or PCP 1 transmits the DMG Beacon frame to AP or PCP 2 in NP1, and AP or PCP 2 transmits the DMG Beacon frame to AP or PCP 1 in NP2.

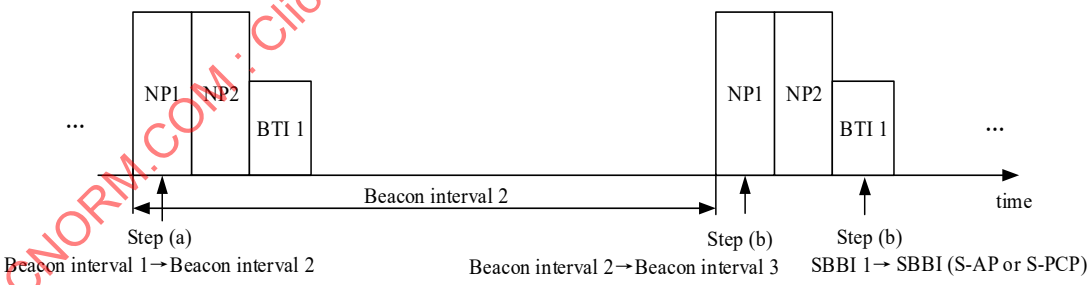

Figure 10-65—Example of joining the CDMG AP or PCP cluster for a CDMG AP or PCP involved in a synchronization pair with another AP or PCP

A synchronized AP or PCP is a CDMG AP or PCP that is operating on a 1.08 GHz channel but still transmitting its DMG Beacon frames on the relevant 2.16 GHz channel with the AP or PCP Role subfield of the Dynamic Bandwidth Control element (9.4.2.220) set to 1 and synchronizing with the synchronizing AP or PCP on the relevant 2.16 GHz channel.

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A synchronizing AP or PCP is a CDMG AP or PCP that is operating on a 1.08 GHz channel but still transmitting its DMG Beacon frames on the relevant 2.16 GHz channel with the AP or PCP Role subfield of the Dynamic Bandwidth Control element (9.4.2.220) set to 0 and providing synchronization service to a synchronized AP or PCP on the relevant 2.16 GHz channel.

If an AP or PCP involved in a synchronization pair is a synchronized AP or PCP and intends to join to a co-channel AP or PCP cluster, it shall set the AP or PCP Role subfield within the Dynamic Bandwidth Control element to 0 to exchange the role with the synchronizing AP or PCP before joining the co-channel cluster. When the AP or PCP Role subfield is changed, the synchronized AP or PCP shall include the Cluster Switch Announcement element in the DMG Beacon frame to indicate the time that the AP or PCP role exchange occurs.

If an AP or PCP that is involved in a synchronization pair intends to join a discovered cluster or intends to start a cluster on the 2.16 GHz common channel, it should send a Cluster Switch Announcement element included in the DMG Beacon frame during its NP to notify the peer AP or PCP involved in the synchronization pair to monitor the common 2.16 GHz channel and join the cluster on 2.16 GHz channel if an empty Beacon SP can be found. After the Cluster Switch Announcement element is transmitted, the AP or PCP should cease transmission during its NP.

When a decentralized clustering enabled AP or PCP operating on 1.08 GHz channel receives a DMG Beacon frame that contains the Clustering Control field in the Cluster Switch Announcement element from its neighboring AP or PCP of a synchronization pair to indicate the presence of a cluster on the 2.16 GHz common channel, it may monitor this 2.16 GHz channel to become a member AP or member PCP following the procedures described in 10.40.2.1.

When a decentralized clustering enabled AP or PCP operating on a 1.08 GHz channel still experiences poor channel conditions after performing all the actions in an attempt to mitigate any interference, it may broadcast one or more Cluster Probe elements using the DMG Beacon frame or Probe Request frame to detect the presence of a cluster actively on the 2.16 GHz common channel during its NPs, SPs, or CBAPs. In addition to transmitting Cluster Probe elements included in DMG Beacon frames on the 2.16 GHz common channel during NPs, the AP or PCP operating on a 1.08 GHz channel may reserve multiple SPs during DTI and switch to the 2.16 GHz channel during each of the SPs to transmit Cluster Probe elements included in Probe Request frames on the 2.16 GHz common channel.

For an AP or PCP that is operating on a 1.08 GHz channel and is involved in a synchronization pair, the AP or PCP may transmit Cluster Probe elements on the common 2.16 GHz channel, using Probe Request frames during its reserved SPs or using DMG Beacon frames during its NPs. The SPs for receiving a Probe Response frame from S-PCP or S-AP can be scheduled in the NP of the next beacon interval on the 2.16 GHz channel or in a DTI. The peer AP or PCP that is involved in the synchronization pair shall also reserve the same SPs with destination AIDs set to 255 to listen for a Probe Response frame and to avoid interferences to the SPs used for cluster probe.

The S-AP or S-PCP that is operating on the 2.16 GHz common channel and receives a Cluster Probe element shall respond with one or more Probe Response frames including an Extended Cluster Report element in each SP scheduled according to the Cluster Probe element to indicate its presence by including the cluster synchronization and control information of the S-AP or S-PCP in the Extended Cluster Report element. The Cluster Probe element contains timing information for the CDMG S-AP or S-PCP operating on the 2.16 GHz channel to transmit the Probe Response frame for the Cluster Probe element. This element defines a sequence of SPs that are scheduled in a DTI or the next NP by both the cluster probe requesting AP or PCP and responder AP or PCP for receiving and transmitting the response frames. The multiple SPs are reserved corresponding to the SPs during which the Cluster Probe elements are transmitted.

After receiving a Probe Response frame from an S-AP or S-PCP operating on the 2.16 GHz common channel, during at least one of the reserved SPs in a DTI, the decentralized clustering enabled AP or PCP operating

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on 1.08 GHz channel may switch to the 2.16 GHz common channel, by using the cluster synchronization and control information in the Extended Cluster Report element in the Probe Response frame of the S-AP or S-PCP operating on the 2.16 GHz channel, and attempt to discover an empty Beacon SP. If an empty Beacon SP exists, then the AP or PCP may transmit DMG Beacon frames during the empty Beacon SP to become a member AP or member PCP of this cluster following the procedures described in 10.40.2.1.

If two APs or PCPs involved in a synchronization pair both receive an Extended Cluster Report element and discover an empty Beacon SP during their reserved SPs at the same time, the AP or PCP that first transmits a Cluster Switch Announcement element during NP should join the empty Beacon SP with priority, and the peer AP or PCP should monitor the 2.16 GHz channel for another aMinChannelTime to find another empty Beacon SP.

If the decentralized clustering enabled AP or PCP on the 1.08 GHz channel does not receive any Probe Response frame from an S-AP or S-PCP during the reserved SPs on the 2.16 GHz channel in the whole DTI, it may reschedule multiple SPs whose positions are adjusted stochastically in the following DTI.

10.41.2.2 Centralized CDMG AP or PCP cluster formation

In order to become an S-AP, a centralized clustering enabled CDMG STA that is operating on a 2.16 GHz channel or a 1.08 GHz channel and is stationary with respect to its local environment shall successfully perform both the configuration step and verification step in order and take the actions following the rules as described in 10.40.2.2.

If at least one DMG Beacon frame that has the ECAPC Policy Enforced field set to 1 and is sent by an S-AP or member AP or member PCP from another ECAPC is received during the monitoring period, the centralized clustering enabled CDMG STA shall follow the rules as described in 10.40.2.2.

The remaining available channels for a centralized CDMG AP or PCP cluster are channels 3, 37, and 38. Channels 2, 35, and 36 are the channels upon which the S-AP is excluded from operating. The channels 3, 37, and 38 that interfere with each other form a channel set. The channel set available for a centralized CDMG AP or PCP cluster is channel {3, 37, 38}.

The functions of a CDMG CCSR shall cover the channel set. The CDMG CCSR shall provide coordination services for all the S-APs operating on the channels of the channel set {3, 37, 38} within the CCSS to mitigate interference. The CDMG CCSR should provide an S-AP with the cluster information of other S-APs. Thus, each S-AP operating on a channel within the channel set can obtain the same cluster information from the CDMG CCSR.

After receiving a DMG Beacon frame including cluster information transmitted by an S-AP, a centralized clustering enabled AP or PCP that intends to become a member AP or member PCP shall successfully perform the following steps in order:

a) The AP or PCP shall monitor the channel for DMG Beacon frames during each Beacon SP over an interval of length at least aMinChannelTime to find an empty Beacon SP and measure the status of each Beacon SP and the signal quality (RCPI and RSNI) of the received DMG Beacon frames based on the received cluster information of the S-AP. The AP or PCP can determine the timing start point of each Beacon SP over a beacon interval of the S-AP based on the Next BTI Offset field, the Reported BI Duration field, and the Reported Clustering Control field. Thus, the AP or PCP can measure each Beacon SP over a beacon interval of the S-AP based on the timing start point of each Beacon SP over a beacon interval and obtain the status of each Beacon SP and signal quality over a beacon interval.

b) If an empty Beacon SP is discovered, the second non-AP and non-PCP STA shall attempt to associate with the S-AP and thereby receive an Announce frame from the S-AP. The contents of the Announce frame are passed to the AP or PCP. All the centralized cluster information of the S-AP(s)

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operating on the channels in the same channel set except the current S-AP shall be included in the Announce frame. The cluster information of the other S-AP(s) can be conveyed in the Extended Cluster Report elements.

c) The CDMG AP or PCP should determine whether to join the current S-AP's cluster or other S-AP(s)'s cluster based on the signal quality, the states of Beacon SPs during a beacon interval indicated by the Available Cluster Offset Bitmap field in the ECAPC Policy element of the S-AP or the member APs or member PCPs of the current S-AP's cluster, and other S-AP(s)'s cluster information. If the AP or PCP elects to join the current cluster, it proceeds to step d); otherwise, the AP or PCP monitors the channels for DMG Beacon frames during each Beacon SP of all the centralized clusters over an interval of length at least aMinChannelTime using the cluster information from the current S-AP. The CDMG AP or PCP may identify a new intended cluster based on the signal quality of the DMG Beacon frames or the Available Cluster Offset Bitmap field in the ECAPC Policy element of the other clusters, if the intersection of 1) the Cluster Time Offset indices of the empty Beacon SPs with 2) the indices indicated by the Available Cluster Offset Bitmap field shows more common nonempty Beacon SPs. The second non-AP and non-PCP STA shall disassociate with the current S-AP and associate with the S-AP of the intended cluster, receive the Announce frame from the S-AP, and pass the contents of the Announce frame to the AP or PCP.

d) Upon receiving an Announce frame that includes the ECAPC Policy element, the AP or PCP shall select a cluster time offset index from the intersection of the cluster time offset indices of the empty Beacon SPs with the indices indicated by the Available Cluster Offset Bitmap field in the ECAPC Policy element. If the intersection is empty, the AP or PCP shall select a cluster time offset index of an empty Beacon SP. The selected cluster time offset index is passed to the second non-AP and non-PCP STA.

e) The second non-AP and non-PCP STA shall respond to the Announce frame with an Information Response frame that includes the Cluster Time Offset element containing the Cluster Time Offset Index field set to the selected index.

f) The AP or PCP shall join the cluster of S-AP at the selected cluster time offset on the channel of the S-AP and transmit DMG Beacon frames with the AP or PCP Clustering Control field.

After joining the centralized AP or PCP cluster, the CDMG member AP or member PCP shall transmit its DMG Beacon frames and include the ECAPC Policy element in (Re)Association Response, Announce, and Information Response frames following the rules as described in 10.40.2.2.

10.41.3 Cluster maintenance

10.41.3.1 General cluster maintenance

Regardless of whether a cluster starts on a 2.16 GHz channel or a 1.08 GHz channel, the member AP or member PCP is able to maintain synchronization with the S-AP or S-PCP and other member APs or member PCPs through receiving DMG Beacon frames from the S-AP or S-PCP on this channel.

If an AP or PCP cluster starts on a 1.08 GHz channel and the AP or PCP of this cluster involves in a synchronization pair with another AP or PCP operating in the adjacent 1.08 GHz channel at the same time, this pair of APs or PCPs shall also maintain synchronization according to the rules described in 10.64 unless one of them ceases its BSS.

10.41.3.2 Decentralized CDMG AP or PCP cluster maintenance

In the case when the S-AP or S-PCP of a decentralized AP or PCP cluster on a 1.08 GHz channel is lost, or appears to a member AP or member PCP to have been lost, the S-AP or S-PCP handover procedures shall follow the rules in 10.40.3.2. In addition, the new S-AP or S-PCP shall also transmit the DMG Beacon frame during its NP of the allocated QP on the 2.16 GHz common channel as described in 10.64.5, even if there is no

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legacy non-AP and non-PCP DMG STA within its BSS or it does not involve in a synchronization pair with another AP or PCP operating in the adjacent 1.08 GHz channel.

If the S-AP or S-PCP of a decentralized AP or PCP cluster detects the presence of the S-AP or S-PCP of another decentralized AP or PCP cluster through receiving a DMG Beacon frame on either a 2.16 GHz channel or a 1.08 GHz channel or receiving a Probe Response frame including the Extended Cluster Report element on a 2.16 GHz channel with the DBC Present field set to 1 and the Channel Splitting subfield set to 1, it should become a member AP or member PCP of the other cluster on the corresponding channel according to the procedures described in 10.41.2 if the values of its Adjacent Channel Occupancy subfield, Clustering Status subfield, and the Synchronizing AP or PCP MAC Address subfield in the Dynamic Bandwidth Control element are higher than those of the other S-AP or S-PCP.

If the S-AP or S-PCP of a decentralized AP or PCP cluster detects the presence of the S-AP or S-PCP of another decentralized AP or PCP cluster through receiving a DMG Beacon frame on either a 2.16 GHz channel or a 1.08 GHz channel or receiving a Probe Response frame including the Extended Cluster Report element on a 2.16 GHz channel with the DBC Present field set to 1 and the Channel Splitting subfield set to 0, it should become a member AP or member PCP of the other cluster on the corresponding channel according to the procedures described in 10.41.2 if its Channel Splitting subfield is 1 or its Channel Splitting subfield is 0, but the MAC Address is higher than that of the other S-AP or S-PCP.

If the S-AP or S-PCP of a decentralized AP or PCP cluster detects the presence of the DMG S-AP or S-PCP of another decentralized AP or PCP cluster through receiving a DMG Beacon frame on a 2.16 GHz channel with the DBC Present field set to 0, it should become a member AP or member PCP of the other cluster on this 2.16 GHz channel according to the procedures described in 10.40.2 if its MAC address is higher than that of the other DMG S-AP or S-PCP.

If the S-AP or S-PCP operating on a 1.08 GHz channel detects the presence of the S-AP or S-PCP of another decentralized AP or PCP cluster starting on the 2.16 GHz common channel and intends to become a member AP or member PCP of the other cluster, it may transmit a DMG Beacon frame containing the Cluster Switch Announcement element to its member APs or member PCPs before it switches to the 2.16 GHz common channel. After that, the S-AP or S-PCP may continue transmitting DMG Beacon frames on the 1.08 GHz channel within a time period of (aMinBTIPeriod × BI + aMinChannelTime) to maintain the time reference for the cluster, where BI is the Reported BI Duration field in the Cluster Switch Announcement element. Then it shall monitor the 1.08 GHz channel for DMG Beacon frames within the next time interval of (aMinChannelTime + CDMG SBBI), where CDMG SBBI is its beacon interval on the 1.08 GHz channel.

If no DMG Beacon frames are received over the monitoring period, the S-AP or S-PCP shall cease operation on the 1.08 GHz channel. Otherwise, it may use the cluster coordination mechanism described in 10.41.3.3 to mitigate interference between the cluster operating on the 1.08 GHz channel and the cluster operating on the 2.16 GHz common channel.

Upon receiving a DMG Beacon frame including a Cluster Switch Announcement element on a 1.08 GHz channel, a member AP or member PCP should switch to the corresponding 2.16 GHz common channel to become a member AP or member PCP of the cluster operating on this 2.16 GHz channel following the procedure described in 10.40.2.1. If the AP or PCP cannot detect the presence of the S-AP or S-PCP of another decentralized AP or PCP cluster operating on the 2.16 GHz channel or cannot discover an empty Beacon SP, it should switch back to the former 1.08 GHz channel. After that, the decentralized clustering enabled AP or PCP may monitor this 1.08 GHz channel and follow the same procedures defined in 10.40.2.1 to become a member AP or member PCP of the cluster corresponding to the former S-AP or S-PCP or start an S-AP or S-PCP handover process according to 10.40.3.2.

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10.41.3.3 Cluster coordination

The cluster coordination mechanism allows a CDMG S-AP or S-PCP of a decentralized cluster operating on the 1.08 GHz channel to be a member AP (or member PCP) or S-AP (or S-PCP) of a decentralized cluster operating on the 2.16 GHz channel simultaneously by transmitting and receiving DMG Beacon frames within both clusters. By this means, cluster synchronization and control information can be exchanged to mitigate interference and improve spatial sharing.

In the case when a decentralized clustering enabled CDMG AP or PCP using cluster coordination mechanism, it shall maintain schedule information for both clusters (i.e., beacon intervals, Beacon SPs or SPs) to switch alternatively between the 1.08 GHz channel and 2.16 GHz channel. For example, it should switch to the 2.16 GHz channel prior to a Beacon SP allocated on the 2.16 GHz channel and transmit or receive the DMG Beacon frames.

The decentralized clustering enabled CDMG AP or PCP using cluster coordination mechanism should schedule at least one SP within the cluster operating on the 2.16 GHz channel that has the source and destination DMG AIDs set to 255 and the AllocationType subfield set to 2 indicating the Beacon SP of the synchronization CDMG AP or PCP of the cluster operating on the 1.08 GHz channel. In addition, it may schedule more SPs indicating other nonempty Beacon SPs of the cluster operating on the 1.08 GHz channel.

As being an S-AP or S-PCP of the cluster operating on the 1.08 GHz channel, the AP or PCP using coordination mechanism shall adjust its TBTT to avoid overlapping with any Beacon SP of the cluster operating on the 2.16 GHz channel. In addition, it should schedule multiple SPs within the cluster operating on the 1.08 GHz channel that has the source and destination DMG AIDs set to 255 and the AllocationType subfield set to 0 indicating the schedule information of a nonempty Beacon SP_n of the cluster operating on the 2.16 GHz channel.

If a member AP or member PCP of a cluster operating on the 1.08 GHz channel receives an Extended Schedule element from an S-AP or S-PCP with the same cluster ID that includes at least one Allocation field with the AllocationType subfield set to 0 and the source and destination AIDs set to 255, it may switch to the 2.16 GHz channel according to the schedule information in an attempt to receive a DMG Beacon frame.

10.41.3.4 Centralized CDMG AP or PCP cluster maintenance

In the case when the S-AP or S-PCP of a centralized AP or PCP cluster on a 1.08 GHz channel is lost, or appears to a member AP or member PCP to have been lost, the S-AP handover procedures shall follow the rules in 10.40.3.3. In addition, the new S-AP or S-PCP shall also transmit a DMG Beacon frame during its NP of the allocated QP on the 2.16 GHz common channel as described in 10.64.5, even if there is no legacy non-AP and non-PCP DMG STA within its BSS or it does not involve in a synchronization pair with another AP or PCP operating on the adjacent 1.08 GHz channel.

If a CDMG CCSR detects that a new S-AP that is joining the CCSS is a DMG AP or a CDMG AP operating on the 2.16 GHz channel and there is at least one S-AP operating on a 1.08 GHz channel in its CCSS, the CDMG CCSR shall announce the cluster information (including the cluster ID, cluster synchronization and control information, and the channel number of the new S-AP operating on the 2.16 GHz common channel) to each S-AP operating on 1.08 GHz channel to facilitate the detection of the presence of the new S-AP for the S-APs operating on 1.08 GHz channel.

If a CDMG S-AP operating on a 1.08 GHz channel receives the cluster information of the new S-AP operating on 2.16 GHz channel from the CCSR, it should measure the state and the signal quality of each Beacon SP and determine whether to join the centralized cluster of the new S-AP based on the state or signal quality of each Beacon SP.

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The S-AP shall broadcast the cluster information of the new S-AP to all the member APs or member PCPs in its centralized cluster using the Extended Cluster Report element indicated in the DMG Beacon frame. The member APs or member PCPs on the 1.08 GHz channels should determine whether to join the centralized cluster of the new S-AP based on the cluster information and the monitoring results of the new S-AP operating on the 2.16 GHz channel.

If an S-AP or a member AP or member PCP operating on a 1.08 GHz channel decides to join the centralized cluster of the new S-AP operating on a 2.16 GHz channel, the S-AP or member AP or member PCP shall transmit a Cluster Switch Announcement element to all its cluster members using the DMG Beacon frame to broadcast the cluster information and its cluster switching determination to all the member APs or member PCPs in the centralized cluster. The remaining member APs or member PCPs can update the Available Cluster Offset Bitmap field by using the Cluster Switch Announcement element transmitted by a member AP or member PCP.

10.41.3.5 Centralized CDMG AP or PCP cluster MAC requirements

Centralized CDMG AP or PCP cluster MAC requirements shall follow the rules described in 10.40.3.4.

10.41.4 Cluster report and rescheduling

Regardless of whether an AP or PCP cluster starts on a 2.16 GHz channel or a 1.08 GHz channel, a CDMG STA shall follow the rules defined in 10.40.4 for the cluster report and rescheduling.

When an AP or PCP operating on a 1.08 GHz channel still experiences poor channel conditions after performing all the actions in an attempt to mitigate any interference, it may send an Information Request frame to one of the non-AP and non-PCP STAs within its BSS to monitor the corresponding 2.16 GHz common channel for a cluster monitoring period defined in 10.40.3.2. The non-AP and non-PCP STA operating on a 1.08 GHz channel that receives a DMG Beacon frame on the 2.16 GHz common channel shall report the monitoring results through sending a Cluster Report element contained in an Announce frame or Information Response frame to the AP or PCP if the received DMG Beacon frame meets the conditions given in 10.40.4.

Upon receiving a Cluster Report element included in the Announce frame from a non-AP and non-PCP STA operating on the 1.08 GHz channel with the Cluster Report field equal to 1 and the Cluster Channel Number field equal to 0, a decentralized cluster enabled AP or PCP operating on a 1.08 GHz channel may reserve multiple SPs on the 1.08 GHz channel to identify whether there is an empty Beacon SP. The AP or PCP may reschedule SPs and CBAPs in its beacon interval, or move the BTI if the clustering enabled AP or PCP is an S-AP or S-PCP in a decentralized AP or PCP cluster, or change the cluster time offset if the clustering enabled AP or PCP is a member AP or member PCP, or perform other actions, in an attempt to mitigate any interference from the transmissions as indicated in the received Cluster Report element. The AP or PCP may also create SPs in its beacon interval with the source and destination AIDs set to 255 to eliminate transmissions during specific periods in the beacon interval. In addition, the AP or PCP operating on a 1.08 GHz channel can reserve multiple SPs in a DTI based on the clustering synchronization and control information included in the Cluster Report element, monitoring the Beacon SPs on the 2.16 GHz channel, to identify whether there is an empty Beacon SP of the decentralized cluster operating on the channel indicated by the Cluster Channel Number field.

Upon receiving a Cluster Report element from a non-AP and non-PCP STA with the Cluster Report field set to 1 and the Cluster Channel Number field set to 0, a clustering enabled AP or PCP that is an S-AP or S-PCP or a member AP or member PCP may switch to the corresponding 2.16 GHz common channel and discover an empty Beacon SP to become a member AP or member PCP of this cluster following the procedures described in 10.41.3.2. The AP or PCP should also broadcast a DMG Beacon frame containing the Cluster Switch Announcement element to other APs or PCPs of the same cluster before it switches to the 2.16 GHz common channel.

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10.41.5 Decentralized AP or PCP cluster request

Regardless of whether a BSS starts on a 2.16 GHz channel or a 1.08 GHz channel, a CDMG STA shall follow the rules defined in 10.40.4 for the cluster request.

To request AP or PCP clustering to be enabled in the BSS, the STA shall transmit a Cluster Report element with the Cluster Request subfield set to 1 to its AP or PCP. Upon receiving a Cluster Report element with the Cluster Request subfield set to 1, the AP or PCP should form and maintain decentralized AP or PCP clustering in the BSS according to the procedures described in 10.40.2, 10.40.3, 10.41.2, and 10.41.3.

10.41.6 Spatial sharing in a CDMG AP or PCP cluster

This subclause describes mechanisms to enable spatial sharing and interference mitigation among CDMG infrastructure BSSs or PBSSs in a coordinated OBSS environment, i.e., in a CDMG AP or PCP clustering environment. By utilizing the schedule information of SP allocation in other BSSs in an AP or PCP cluster, an AP or PCP acquires and shares channel measurement results of STAs within its BSS by requesting STAs in its BSS to perform directional channel measurement during SPs of other BSSs. Therefore, APs or PCPs in different BSSs can allocate SPs in overlapping time periods in the same channel and achieve spatial sharing among BSSs.

If the SPSH in CDMG Cluster subfield in the CDMG Capabilities element of a CDMG AP or PCP is 1 and one of the Decentralized Cluster field and the Centralized Cluster field is 1, then the CDMG AP or PCP supports spatial sharing mechanism among BSSs in the AP or PCP cluster.

A CDMG STA that supports spatial sharing, as indicated by the SPSH in CDMG Cluster subfield set to 1 in the STA's CDMG Capabilities element, shall support the directional channel quality measurements described in 9.4.2.21.15 and 9.4.2.21.16.

The SP spatial sharing among BSSs in an AP or PCP cluster contains two phases: SPSH measurement phase and SP spatial sharing phase. The goal of setting an SPSH measurement phase is to allow APs or PCPs to find pairs of links in different BSSs that can coexist. Spatial reuse is not allowed in SPSH measurement phase. Only one pair of STAs participate directional channel quality measurement.

A CDMG S-AP or S-PCP that supports SPSH among BSSs should indicate whether all the member APs or member PCPs in a cluster are in the SPSH measurement phase or in the SP spatial sharing phase by setting the SPSH Measurement Enabled subfield in the Clustering Control field of the DMG Beacon frame to 1 or by setting the Clustering SPSH Enabled field within the Clustering Interference Assessment element to 1. The SPSH Measurement field is set to 1 to indicate that SPSH measurement phase starts. Each member AP or member PCP that supports SPSH among BSSs should request STAs in its BSS to perform directional channel quality measurement during SPs of other BSSs in the same cluster, as described in 11.11. The CDMG AP or PCP should send directional channel quality request to STAs in the same BSS and receive directional channel quality report from the STAs. The period of the directional channel quality measurement is indicated by the Channel Quality Measurement Duration subfield within the Clustering Interference Assessment element. The AP or PCP can obtain the interference information that indicates link(s) in its BSS experience interference from at least one link of other BSS within the AP or PCP cluster through channel measurement of STAs. The AP or PCP can determine the channel quality across STAs within multiple BSSs and implement spatial sharing based on the results of the measurements performed by the STAs associated with the AP or PCP. The S-AP or S-PCP should periodically set the SPSH Measurement Enabled subfield, generating and sending the indicated information of interference measurement.

In the SPSH measurement phase, each member AP or member PCP that supports SPSH among BSSs in an AP or PCP cluster shall schedule SPs in nonoverlapping period according to the clustering mechanism, as described in 10.40 and 10.41. If one link in a BSS is transmitting data, link(s) in other BSSs keeps in directional

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channel measurement state. The determination of the interference from the measured link (existing SP) to the candidate SP is implementation dependent and beyond the scope of this standard.

Each member AP or member PCP in a cluster may record the information that links in other BSSs do not interfere with the link(s) in its BSS through channel measurement of STAs, and include the information in SPSH Report elements that are sent to other AP(s) or PCP(s) through DMG Beacon frames. Each member AP or member PCP can obtain interference information that indicates interference experienced by at least one link of other BSS(s) from link(s) of its BSS, after receiving the SPSH Report element from other APs or PCPs in the same cluster. Each AP or PCP is able to obtain a database of links that may perform SPSH, but the definition of the database is beyond the scope of this standard.

After SPSH measurement, the S-AP or S-PCP shall set the SPSH Measurement Enabled subfield in the Clustering Control field of the DMG Beacon frame to 0, indicating that BSSs in the cluster are allowed to conduct spatial sharing in overlapping SPs in SP spatial sharing phase.

In the SP spatial sharing phase, each AP or PCP in the cluster should schedule SPs to achieve spatial sharing according to the received SP allocation information that indicates scheduled SP allocation for link(s) of other BSS(s) in the same AP or PCP cluster and according to the interference information from link(s) of other BSS(s) to its BSS and the interference information from link(s) of its BSS to link(s) of other BSS(s) obtained in SPSH measurement phase. The SP allocation information is obtained by receiving the Extended Schedule element in the DMG Beacon frame of other AP(s) or PCP(s) in the AP or PCP cluster. The scheduled link(s) of the AP's or PCP's BSS and link(s) of other BSS(s) should not interfere with each other during the same SP.

If an AP or PCP discovers that a link in its BSS and a link in another BSS in the same cluster do not interfere with each other, then the AP or PCP can schedule overlapping SPs for the two links.

Through sending and receiving the SPSH Report element, an AP or PCP should schedule an overlapping candidate SP only after sharing the spatial reuse information including noninterfering links corresponding to the scheduled SPs and candidate SPs with a neighbor AP or PCP. If an AP or PCP cannot know the interference information between links in neighboring BSSs and its BSS, it should not conduct SP spatial sharing.

Figure 10-66 illustrates an example of the resulting SP schedule for the spatial sharing among three BSSs in a cluster.

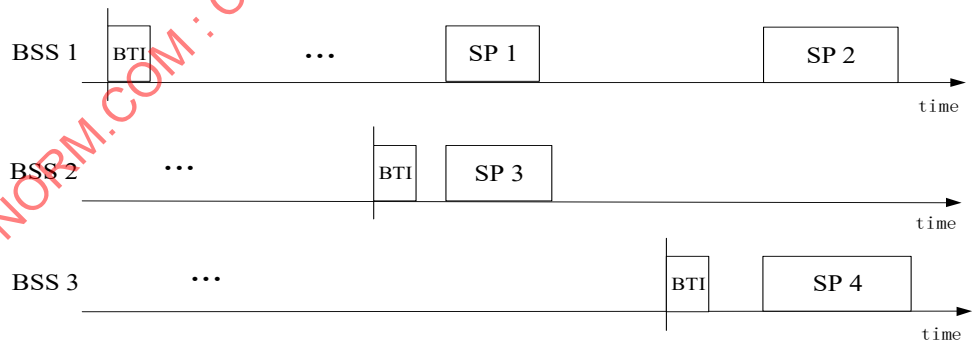

Figure 10-66—Example of spatial sharing with interference mitigation among multiple BSSs

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10.42 DMG beamforming

10.42.1 General

Beamforming (BF) is a mechanism that is used by a pair of STAs to achieve the necessary DMG link budget for subsequent communication. BF training is a bidirectional sequence of BF frame transmissions that uses sector sweep and provides the necessary signaling to allow each STA to determine appropriate antenna system settings for both transmission and reception. After the successful completion of BF training, BF is said to be established. A BF frame is an SSW frame, a DMG Beacon frame, an SSW-Feedback frame, an SSW-Ack frame or a BRP frame. Figure 10-67 gives an example of the beamforming training procedure.

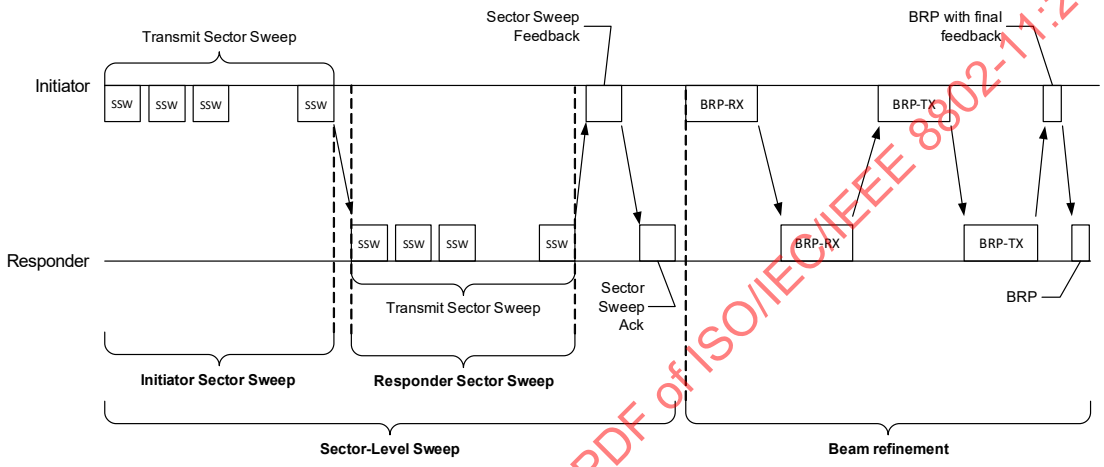

Figure 10-67—An example of beamforming training

In this subclause, the STA that initiates BF training through the transmission of a BF frame is referred to as the *initiator*, and the recipient STA of the BF frame that participates in BF training with the initiator is referred to as the *responder*. For BF training that occurs within the A-BFT allocation, the AP or PCP is the initiator and a non-AP and non-PCP STA becomes the responder. For BF training that occurs during an SP allocation, the source DMG STA of the SP is the initiator and the destination DMG STA of the SP becomes the responder. For BF training during a CBAP allocation, the TXOP holder is the initiator and the TXOP responder is the responder and the value of the Duration field in the transmitted BF frames does not limit the duration of the BF training procedure. The duration of the BF training procedure is specified in 10.42.6.2 and 10.42.6.4.

The link from the initiator to the responder is referred to as the *initiator link*, and the link from the responder to the initiator is referred to as the *responder link*.

BF training starts with a SLS from the initiator. A beam refinement protocol (BRP) may follow, if requested by either the initiator or the responder. The purpose of the SLS phase is to enable communications between the two participating STAs at the DMG control mode rate or higher MCS. Normally, the SLS phase provides only transmit BF training. The purpose of the BRP phase is to enable receive training and enable iterative refinement of the AWV of both transmitter and receiver at both participating STAs. If one of the participating STAs chooses to use only one transmit antenna pattern, receive training may be performed as part of the SLS.

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Any BF information obtained by an initiator or a responder during a BF training attempt shall be considered invalid if either or both of the following conditions are satisfied:

a) The SLS phase was not completed within dot11MaxBFTime beacon intervals from the start of the SLS phase.

b) The BRP phase, if initiated, was not completed within dot11MaxBFTime beacon intervals from the start of the BRP phase.

A STA shall abort an SLS if the SLS is not completed within dot11MaxBFTime beacon intervals from the start of the SLS, and shall abort a BRP if the BRP is not completed within dot11MaxBFTime beacon intervals from the start of the BRP.

A STA can have one or more DMG antennas. A DMG antenna can be used to create sectors through which a STA can transmit or receive frames. The number of sectors per DMG antenna shall not be greater than 64. The total number of sectors across all DMG antennas in a STA shall not be greater than 128.

Table 10-30 shows the mandatory and optional procedures in the beamforming mechanism described in this subclause.

Table 10-30—Mandatory and optional procedures in the Beamforming mechanism

Beamforming item		Support mandatory	Notes
SLS phase (10.42.2, 10.42.6.2)		Yes	A DMG STA is capable to participate in an SLS with any other STA as described in 10.42.2 and 10.42.6.2.
Beamforming in BTI (10.42.4)		Yes	When operating as an AP or PCP, a DMG STA is capable to perform beamforming in the BTI as described in 10.42.4.
Beamforming in A-BFT (10.42.5)		Yes	When operating as an AP or PCP, a DMG STA is capable to perform beamforming in the A-BFT as described in 10.42.5.
BRP setup subphase (10.42.3.2)		Yes	A DMG STA is capable to negotiate BRP settings with any other STA as described in 10.42.3.2.
MIDC subphase (10.42.6.3)	MID subphase	No	A DMG STA does not have to be capable to perform MID as described in 10.42.6.3.
	BC subphase	No	A DMG STA does not have to be capable to perform BC as described in 10.42.6.3.
BRP phase (10.42.3, 10.42.6.4)	Feedback = BS-FBCK	Yes	A DMG STA is capable to perform the BRP with any other STA as described in 10.42.3 and 10.42.6.4 and is capable to return the BS-FBCK.
	Feedback = Channel measurement	No	A DMG STA is capable to perform the BRP with any other STA as described in 10.42.3 and 10.42.6.4, but does not have to be capable to return channel measurements.
Beam tracking (10.42.7)	Feedback = BS-FBCK	Yes	A DMG STA is capable of responding to a receive beam tracking request. A DMG STA is capable of responding to a transmit beam tracking request with the BS-FBCK.
	Feedback = Channel measurement	No	A DMG STA is capable of responding to a receive beam tracking request. A DMG STA does not have to be capable of responding to a transmit beam tracking request with channel measurements.

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An SLS between an initiator and a responder is successful for the initiator if, after the completion of the SLS, the initiator receives a response to a frame transmitted to the responder using the sector and antenna selected during the SLS. The SLS is successful for the responder if, after the completion of the SLS, the responder receives a response to a frame transmitted to the initiator using the sector and antenna selected during the SLS.

In this subclause, the last negotiated Total Number of Sectors field, Number of RX DMG Antennas field, and RXSS Length field held by the initiator with respect to the responder refer to the last value of the corresponding field received by the initiator from the responder and that the SLS between the initiator and responder using this value was successful for the initiator. Similarly, the last negotiated Total Number of Sectors field, Number of RX DMG Antennas field, and RXSS Length field held by the responder with respect to the initiator refer to the last value of the corresponding field received by the responder from the initiator and that the SLS between the responder and initiator using this value was successful for the responder.

Until an SLS is successful between an initiator and a responder, the last negotiated Total Number of Sectors field, Number of RX DMG Antennas field, and RXSS Length field used by the initiator with respect to the responder refer to the value of these fields in the responder's DMG Capabilities element, and the last negotiated Total Number of Sectors field, Number of RX DMG Antennas field, and RXSS Length field used by the responder with respect to the initiator refer to the value of these fields in the initiator's DMG Capabilities element.

If an MMSL cluster capable STA has successfully transmitted to a peer STA an MMS element with the BeamLink Cluster field set to 1, then all MAC entities coordinated by the same MM-SME as the MMSL cluster capable STA shall use a single beamformed link for the MMSL cluster. Also, the MAC address used by the MMSL cluster capable STA to initiate the beamforming procedure shall remain the same until the completion of the beamforming procedure.

A CMMG STA shall follow the DMG beamforming rules as described in 10.42 where a BF frame transmitted by a CMMG STA is contained in a CMMG PPDU.

A CDMG STA shall follow the DMG beamforming rules as described in 10.42, including the rules of CDMG enhanced beam tracking as described in 10.42.9.

10.42.2 Sector-level sweep (SLS) phase

10.42.2.1 General

The SLS phase can include as many as four components: an initiator sector sweep (ISS) to train the initiator link as described in 10.42.2.2, a responder sector sweep (RSS) to train the responder link as described in 10.42.2.3, an SSW feedback procedure as described in 10.42.2.4, and an SSW ack procedure as described in 10.42.2.5.

An initiator shall begin the SLS phase by transmitting the frames of the ISS.

A responder shall not begin transmitting the frames of an RSS before the ISS is successfully completed (as defined in 10.42.1), except when the ISS occurs in the BTI (10.42.5).

An initiator shall not begin an SSW feedback procedure before the RSS phase is successfully completed (as defined in 10.42.1), except when the RSS occurs in the A-BFT.

A responder shall not begin an SSW ack procedure with an initiator in the A-BFT. A responder shall begin an SSW ack procedure with an initiator immediately following the successful completion (as defined in 10.42.1) of the SSW feedback procedure with the initiator.

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During the SLS phase the only BF frames an initiator may transmit are the DMG Beacon frame, the SSW frame, and the SSW-Feedback frame. During the SLS phase the only BF frames a responder may transmit are the SSW frame and the SSW-Ack frame.

If during the SLS the initiator and responder each execute a TXSS, then at the end of the SLS phase both the initiator and the responder possess their own transmit sector. If either the ISS or the RSS employs a receive sector sweep, then the responder or the initiator, respectively, possesses its own receive sector.

The following rule applies to all channel access in DMG BSSs. A STA shall not transmit a frame as part of a sector sweep comprising at least two sectors if a response is expected within SIFS from the STA identified in the RA field of the transmitted frame.

A STA shall not change its transmit power during a sector sweep.

A frame transmitted as part of a sector sweep does not include training fields. A STA shall set the TRN_LEN parameter of the TXVECTOR to 0 for a frame transmitted as part of a sector sweep.

Two examples of the SLS phases are shown in Figure 10-68 and Figure 10-69.

In Figure 10-68 the initiator has many sectors, the responder has only one transmit sector, and receive sector sweep is used at the responder sector sweep (the responder is transmitting all responder SSW frames through the same transmit sector, and the initiator is switching receive antennas at the same time).

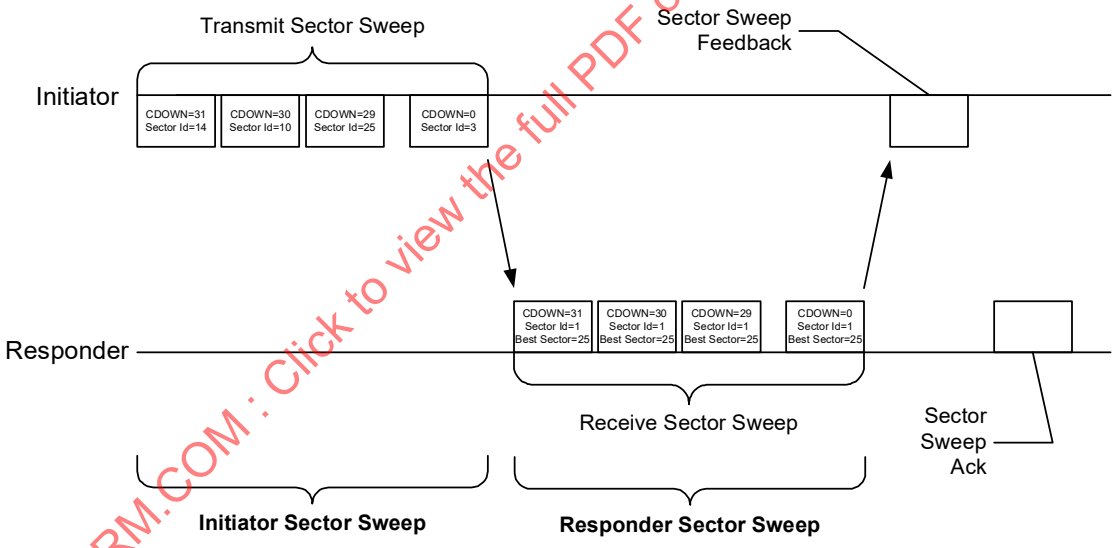

Figure 10-68—An example of SLS

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In Figure 10-69 the initiator has many transmit sectors, and the responder has one transmit sector. In this case, receive training for the initiator is performed in the BRP phase.

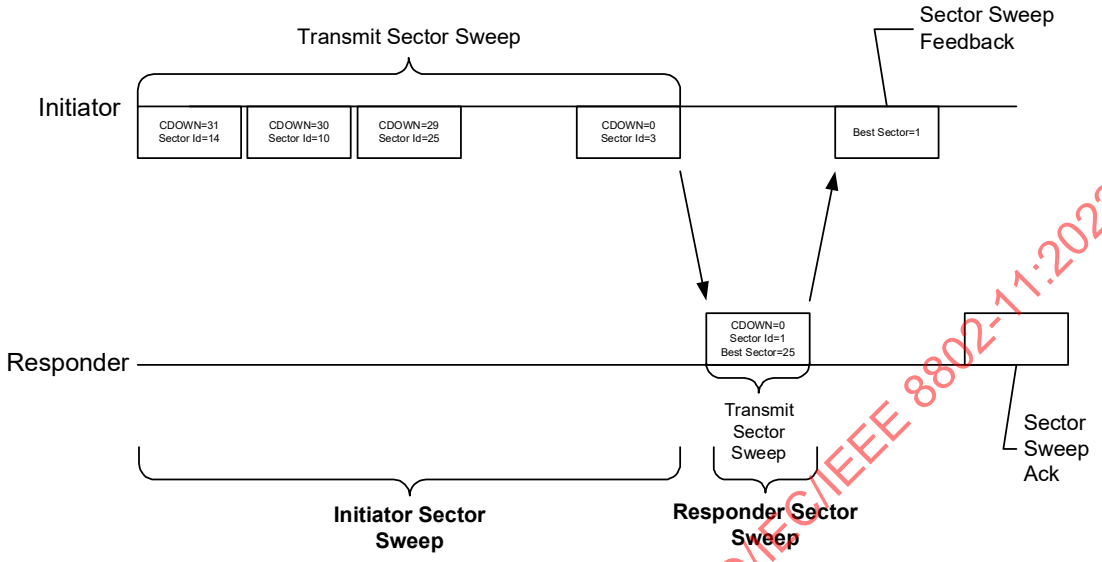

Figure 10-69—An example of SLS

10.42.2.2 Initiator sector sweep (ISS)

10.42.2.2.1 General

An ISS comprises either an initiator TXSS or an initiator RXSS.

An initiator RXSS may be performed in an ISS when the initiator chooses to use only one transmit antenna pattern across each of its DMG antennas.

An initiator may employ either DMG Beacon frames or SSW frames in the ISS. If the initiator begins an ISS with the transmission of a DMG Beacon frame, it shall use the DMG Beacon frame for all subsequent transmissions during the ISS. Conversely, if the initiator begins an ISS with the transmission of an SSW frame, it shall use the SSW frame for all subsequent transmissions during the ISS. A responder never begins an ISS.

The initiator shall set the Direction subfield in the Sector Sweep field to 0 within each DMG Beacon and SSW frame transmitted during an ISS.

The initiator shall set the Total Sectors in ISS subfield within the SSW Feedback field to the total number of sectors that it is using in the ISS. The total is computed as the sum of all sectors employed on all antennas in the ISS multiplied by the number of the responder's receive DMG antennas. For example, if 4 sectors are used on antenna 0, 3 sectors on antenna 1, 5 sectors on antenna 2, and the responder has two receive DMG antennas, then the Total Sectors in ISS subfield is set to 24.

10.42.2.2.2 Initiator TXSS

When the IsInitiatorTXSS field for a specific SP is 1 in a received Extended Schedule element (see 9.4.2.131) or Grant frame (see 9.3.1.12) and the Beamforming Training field of the BF Control field for that SP in the same Extended Schedule element or Grant frame is 1, then the SP contains an initiator TXSS,

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and the initiator shall start an initiator TXSS at the start of the next SP as indicated by the received Extended Schedule element or Grant frame.

During the BTI, the initiator shall start an initiator TXSS (see also 10.42.4).

During a CBAP, an initiator may obtain a TXOP with an initiator TXSS or use an existent TXOP for the initiator TXSS. If transmission of a Grant frame to the responder is used to initiate the TXSS, the Beamforming Training and IsInitiatorTXSS fields of the BF Control field is set to 1. If a Grant Ack frame is transmitted by the responder, it shall comply with 10.39.4. In the Grant Ack frame, the responder shall set the Beamforming Training field to 1. The initiator starts the initiator TXSS SIFS after transmission of the Grant frame or after the reception of the Grant Ack frame if the Grant Ack Supported field in the responder's DMG Capabilities element is 1 or PIFS interval after the transmission the Grant frame otherwise.

During an initiator TXSS, the Sector ID field in each BF frame shall be set to a value that uniquely identifies the transmit antenna sector employed when the BF frame is transmitted. The CDOWN field in each transmitted frame shall contain the total number of transmissions remaining until the end of the initiator TXSS, including any LBIFS if required, such that the last BF frame transmission of the initiator TXSS has the CDOWN field set to 0. Each transmitted BF frame shall be separated by a time interval equal to SBIFS, unless the allocation ends as described in 10.42.6. This is indicated in Figure 10-70.

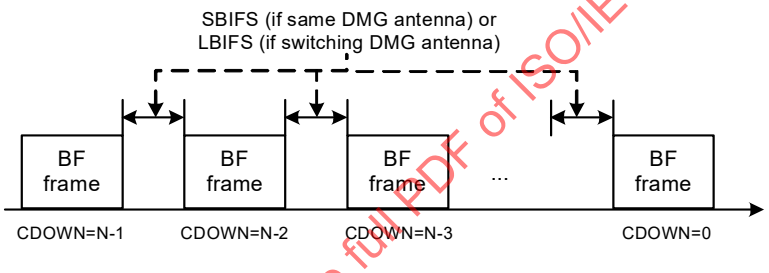

Figure 10-70—Initiator TXSS or initiator RXSS

If the initiator has more than one DMG antenna, the initiator transmits the BF frame through a number of sectors equal to the value of the last negotiated Total Number of Sectors field that was transmitted by the initiator to the responder. In each transmitted BF frame, the initiator shall set the Sector ID and DMG Antenna ID fields to uniquely identify the sector and the DMG antenna ID, respectively, the initiator is using for the frame transmission and shall set the CDOWN field to the total number of transmissions remaining from all of the initiator's DMG antennas.

If an ISS is outside the BTI and if the responder has more than one DMG antenna, the initiator repeats its initiator sector sweep for the number of DMG antennas indicated by the responder in the last negotiated Number of RX DMG Antennas field that was transmitted by the responder. Repetitions of the initiator sector sweep are separated by an interval equal to LBIFS. In this case CDOWN indicates the number of sectors until the end of transmission from all initiator's DMG antennas to all responder's DMG antennas. At the start of an initiator TXSS, the responder should have its first receive DMG antenna configured to a quasi-omni pattern and should not change its receive antenna configuration for a time corresponding to the value of the last negotiated Total Number of Sectors field transmitted by the initiator multiplied by the time to transmit a single SSW frame, plus appropriate IFSs (10.3.2.3). After this time, the responder may switch to a quasi-omni pattern in another DMG antenna.

The initiator TXSS ends at the end time of the BF frame from the initiator with the CDOWN field set to 0. If the responder is unable to receive this frame, the responder shall assume that the initiator TXSS has completed at the expected end time of this frame.

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10.42.2.2.3 Initiator RXSS

An initiator RXSS may be requested only when an initiator is aware of the capabilities of a responder, which includes the RXSS Length field. An initiator can obtain the capabilities of a responder using the Information Request and Response procedure as described in 11.28.1.

When the IsInitiatorTXSS field for a specific SP in a received Extended Schedule element or Grant frame is 0 and the Beamforming Training field of the BF Control field for that SP in the same Extended Schedule element or Grant frame is 1, then the SP shall contain an initiator RXSS, and the initiator shall start an initiator RXSS at the start of the next SP described by the received Extended Schedule element or Grant frame.

The initiator never performs an initiator RXSS during the BTI.

During a CBAP, an initiator shall not obtain a TXOP with an initiator RXSS. When transmission of a Grant frame to the responder is used to initiate the RXSS the Beamforming Training field set to 1 and the IsInitiatorTXSS field set to 0. If a Grant Ack frame is transmitted by the responder it shall comply with 10.39.4. In the Grant Ack frame, the responder shall set the Beamforming Training field to 1. The initiator starts the initiator RXSS SIFS after transmission of the Grant frame or after the reception of the Grant Ack frame if the Grant Ack Supported field in the responder's DMG Capabilities element is 1 or PIFS after the transmission the Grant frame otherwise.

If the initiator uses more than one transmit sector or more than one transmit DMG antenna to perform beamforming with the responder, the initiator shall perform an initiator TXSS with the responder before participating in an initiator RXSS with the responder.

During the initiator RXSS the initiator shall transmit from the DMG antenna and sector that were selected during the preceding TXSS with the responder the number of BF frames indicated by the responder in the last negotiated RXSS Length field transmitted by the responder. Each transmitted BF frame shall be transmitted with the same fixed antenna sector or pattern. The initiator shall set the Sector ID and DMG Antenna ID fields in each transmitted BF frame to a value that uniquely identifies the single sector through which the BF frame is transmitted. The initiator shall set the CDOWN field in each transmitted BF frame to contain the total number of transmissions remaining to the end of the initiator RXSS, such that the last BF frame transmission of the initiator RXSS has the CDOWN field set to 0. Each transmitted BF frame shall be separated by a time interval equal to SBIFS, except if the allocation ends as described in 10.42.6. This is indicated in Figure 10-70.

During an initiator RXSS, the responder should have its receive antenna array configured to sweep RXSS Length sectors, including any LBIFS if required, while attempting to receive SSW frames from the initiator.

The initiator RXSS ends at the end time of the SSW frame from the initiator with the CDOWN field set to 0. If the responder is unable to receive this frame, the responder shall assume that the initiator RXSS has completed at the expected end time of this frame.

10.42.2.3 Responder sector sweep (RSS)

10.42.2.3.1 General

An RSS comprises either a responder TXSS or a responder RXSS.

A responder RXSS may be performed in an RSS when the responder chooses to use only one transmit antenna pattern across each of its DMG antennas.

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The responder initiates an RSS with the transmission of an SSW frame, which is the only frame allowed during an RSS.

The responder shall set the Direction subfield in the Sector Sweep field to 1 within each SSW frame transmitted during an RSS.

10.42.2.3.2 Responder TXSS

If the DMG Beacon frame immediately preceding an A-BFT contained a value of one in the IsResponderTXSS subfield of the Beacon Interval Control field, then the A-BFT is a responder TXSS A-BFT.

When the IsResponderTXSS field for a specific SP in a received Extended Schedule element or Grant frame is 1 and the Beamforming Training field of the BF Control field for that SP in the same Extended Schedule element or Grant frame is 1, then the SP contains a responder TXSS, and the responder shall initiate a TXSS following the completion of the ISS in the SP described by the received Extended Schedule element or Grant frame.

When the RXSS Length field within an SSW frame used to obtain a TXOP during a CBAP is 0, the responder shall initiate a TXSS following the completion of the ISS in the TXOP described by the received SSW frame.

During a responder TXSS, the responder shall set the Sector ID and the DMG Antenna ID fields in each transmitted SSW frame to a value that uniquely identifies the sector through which the SSW frame is transmitted. The initial value of CDOWN is set to the total number of sectors in the responder (covering all DMG antennas) multiplied by the number of DMG antennas at the initiator minus one. The responder shall set the CDOWN field in each transmitted SSW frame to contain the total number of transmissions remaining to the end of the responder TXSS, including any LBIFS if required, such that the last SSW frame transmission of the responder TXSS has the CDOWN field set to 0. The responder shall transmit from its DMG antennas in increasing order of DMG antenna ID. Each transmitted SSW frame shall be separated by an interval of time equal to SBIFS. Transmissions are not separated by SBIFS if the allocation ends as described in 10.42.4 and 10.42.6 or if the end of an SSW slot is reached as described in 10.42.5 or when the responder completed a full sweep of all its transmit sectors and is ready to transmit to another DMG antenna of the initiator. In the latter case, the next transmission is separated from the previous transmission by LBIFS. This is indicated in Figure 10-71.

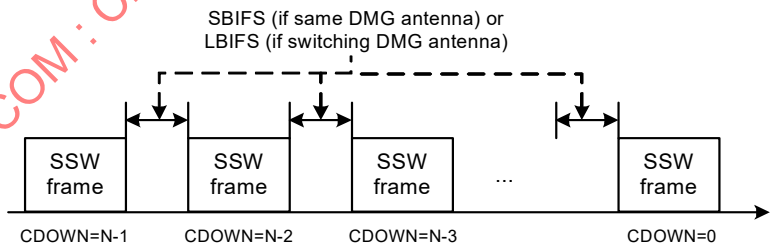

Figure 10-71—Responder TXSS or responder RXSS

A responder that has more than one DMG antenna and has set the value of the DMG Antenna Reciprocity field in its DMG Capabilities element to 0 transmits sequentially through all of the sectors of all of its DMG antennas. A responder that has more than one DMG antenna and has set the value of the DMG Antenna Reciprocity field in the responder's DMG Capabilities element to 1 transmits through the DMG antenna from which it had the best reception in the initiator sector sweep. The length of the sector sweep to each of the initiator's DMG antennas is not dependent on the value of the DMG Antenna Reciprocity field.

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A responder that has only one DMG antenna should transmits through all its sectors, regardless of the setting of the DMG Antenna Reciprocity field.

The responder shall set the Sector Select field and the DMG Antenna Select field in each transmitted SSW frame to the value of the Sector ID field and DMG Antenna ID field, respectively, of the frame received with the best quality during the ISS. The determination of which frame is received with best quality is implementation dependent and beyond the scope of this standard. The responder shall set the SNR Report field to the SNR measured for the frame indicated by the Sector Select field and DMG Antenna Select field.

If the initiator has more than one DMG antenna, the responder repeats its responder sector sweep for the number of DMG antennas indicated by the initiator in the last negotiated Number of RX DMG Antennas field transmitted by the initiator. At the start of a responder TXSS, the initiator should have its receive antenna array configured to a quasi-omni antenna pattern in one of its DMG antennas for a time corresponding to the value of the last negotiated Total Number of Sectors field transmitted by the responder multiplied by the time to transmit a single SSW frame, plus any appropriate IFSs (10.3.2.3). After this time, the initiator may switch to a quasi-omni pattern in another DMG antenna.

The responder TXSS ends at the end time of the SSW frame from the responder with the CDOWN field set to 0. If the initiator is unable to receive this frame, the initiator shall assume that the responder TXSS has completed at the expected end time of this frame.

10.42.2.3.3 Responder RXSS

If the DMG Beacon frame immediately preceding an A-BFT contained a value of zero in the IsResponderTXSS subfield of the Beacon Interval Control field within the DMG Beacon, then the A-BFT is a responder RXSS A-BFT.

When the IsResponderTXSS field for a specific SP in a received Extended Schedule element or Grant frame is 0 and the Beamforming Training field of the BF Control field for that SP in the same Extended Schedule element or Grant frame is 1, then the SP contains a responder RXSS, and the responder shall initiate an RXSS following the completion of the ISS in the SP described by the received Extended Schedule element or Grant frame.

When the RXSS Length field within an SSW frame used to obtain a TXOP during a CBAP is nonzero, the responder shall initiate an RXSS following the completion of the ISS in the TXOP described by the received SSW frame.

If the responder chooses to use more than one transmit sector or more than one transmit DMG antenna to perform beamforming with the initiator, the responder shall perform a responder TXSS with the initiator before participating in a responder RXSS with the initiator.

During the responder RXSS, the responder shall transmit the number of SSW frames indicated by the initiator in the initiator's most recently transmitted RXSS Length field (non-A-BFT) or FSS field (A-BFT) from the DMG antenna and sector that were selected during the preceding TXSS with the initiator. The responder shall set the Sector ID and DMG Antenna ID fields in each transmitted frame to a value that uniquely identifies the sector and DMG antenna, respectively, through which the BF frame is transmitted. The responder shall set the CDOWN field in each transmitted SSW frame to contain the total number of transmissions remaining until the end of the responder RXSS, such that the last SSW frame transmission of the responder RXSS has the CDOWN field equal to 0. Each transmitted SSW frame shall be separated by an interval of time equal to SBIFS, except if the allocation ends as described in 10.42.6 or if the end of an SSW slot is reached as described in 10.42.5. This is indicated in Figure 10-71.

The responder shall set the Sector Select field and the DMG Antenna Select field in each transmitted SSW frame to the value of the Sector ID field and the DMG Antenna ID field, respectively, of the frame received

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with the best quality during the ISS. The determination of which frame is received with best quality is implementation dependent and beyond the scope of this standard.

At the start of a responder RXSS, the initiator should have its receive antenna array configured to sweep over RXSS Length sectors, including any LBIFS if required, when it attempts to receive frames from the responder until the completion of the responder RXSS.

The responder RXSS ends at the end time of the SSW frame from the responder with the CDOWN field set to 0. If the initiator is unable to receive this frame, the initiator shall assume that the responder RXSS has completed at the expected end time of this frame.

10.42.2.4 Sector sweep (SSW) feedback

An SSW feedback procedure occurs following each RSS.

During an SSW feedback procedure, the initiator shall transmit an SSW-Feedback frame to the responder.

During an SSW feedback procedure, the responder should have its receive antenna array configured to a quasi-omni antenna pattern in the DMG antenna through which it received with the highest quality during the ISS, or to the best antenna configuration it has found during RXSS if RXSS has been performed during the ISS, and should not change its receive antenna configuration when it communicates with the initiator until the expected end of the SSW feedback procedure.

When responder TXSS was performed during the preceding RSS, the initiator shall set the Sector Select field and the DMG Antenna Select field in the SSW-Feedback frame it transmits to the value of the Sector ID field and DMG Antenna ID field, respectively, of the frame received with the best quality during the responder TXSS. The determination of which frame is received with the best quality is implementation dependent and beyond the scope of this standard. In addition, the initiator shall set the SNR Report field to the SNR measured for the frame received by the sector and DMG antenna indicated by the Sector Select field and DMG Antenna Select field. The SSW-Feedback frame shall be transmitted through the sector identified by the value of the Sector Select field and DMG Antenna Select field received from the responder during the preceding responder TXSS.

When responder RXSS was performed during the preceding RSS, the Sector Select field and the DMG Antenna select field in the transmitted SSW-Feedback frame are reserved. The initiator shall set the SNR Report field to the SNR measured on the frame on the receive sector designated by the RSS. The SSW-Feedback frame shall be transmitted through the sector identified by the value of the Sector Select field received from the responder during its most recently completed RSS with the initiator.

The initiator may include transmit training as part of the beam refinement phase by setting the TX-TRN-REQ field to 1 in the SSW Feedback frame and setting the L-RX field to indicate the length of the training sequence it requests the responder to use in the beam refinement phase. The initiator may carry out the MIDC subphase as part of the beam refinement by setting the BC-REQ field to 1 (to request a BC subphase) and setting the MID-REQ field to 1 (to request an MID subphase); in this case, the L-RX field shall be set to indicate the number of receive AWVs the initiator uses during the MID subphase.

If the responder receives an SSW-Feedback frame from the initiator before it completes the RSS with the initiator such as described in 10.42.5, the responder may cease the RSS.

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10.42.2.5 SSW ack

When present, the SSW ack procedure occurs following an SSW feedback procedure.

When a responder TXSS is performed during an RSS, the responder shall transmit an SSW-Ack frame to the initiator to perform an SSW ack procedure. The SSW-Ack frame shall be transmitted through the sector identified by the value of the Sector Select field and the DMG Antenna Select field received from the initiator in the last SSW-Feedback frame.

When an RXSS was performed during an RSS, an SSW-Ack frame shall be sent by the responder to the initiator. The SSW-Ack frame should be sent using the DMG antenna indicated in the DMG Antenna Select field in the last SSW-Feedback frame.

The responder may include transmit training as part of the beam refinement phase by setting the TX-TRN-REQ field to 1 in the SSW-Ack frame and setting the L-RX field to indicate the length of the training sequence it requests the initiator to use in the beam refinement phase, as described in 9.3.4. The responder may carry out a MID subphase by setting the MID-REQ bit to 1 in the BRP Request field of the SSW frame. In this case, it shall also set the L-RX field to indicate the number of receive AWVs it uses during the MID subphase. The responder may carry out a BC subphase by setting the BC-REQ bit to 1. If the initiator has set either the MID-REQ or the BC-REQ fields to 1 in the SSW-Feedback frame, the responder may set the MID-Grant or the BC-Grant fields to 1, or both, to grant the requests.

At the start of an SSW ack procedure, the initiator should have its receive antenna array configured to a quasi-omni antenna pattern using the DMG antenna through which it received with the highest quality during the RSS, or the best receive sector if an RXSS has been performed during the RSS, and should not change its receive antenna configuration while it attempts to receive from the responder until the expected end of the SSW ack procedure.

10.42.3 Beam Refinement Protocol (BRP) phase

10.42.3.1 General

BRP is a process in which a STA trains its RX and TX antenna array(s) and improves its TX antenna configuration and RX antenna configuration using an iterative procedure. BRP may be used regardless of the antenna configuration a STA supports.

The BRP phase is composed of a BRP setup subphase, a Multiple sector ID Detection (MID) subphase, a Beam Combining (BC) subphase, a subset of the previous subphases, and one or more beam refinement transactions. BRP setup allows STAs to exchange beam refinement capability information and to request the execution of the other BRP subphases. MID and BC (collectively, the MIDC subphase) are optionally used to find better initial AWVs for iterative beam refinement than might have been found by SLS due to imperfect quasi-omni receive antenna patterns. In MID, a quasi-omni transmit pattern is tested against a number of receive AWVs; this reverses the scanning roles from the transmit sector sweep. In BC, a small set of transmit and receive AWVs are tested in pairwise combinations, thus avoiding the use of quasi-omni patterns. Finally, given the starting point from SLS or MIDC, STAs can explore a broader set of transmit and receive AWVs using a request/response exchange referred to as a *beam refinement transaction*.

The BRP setup subphase may be skipped if the BRP phase does not include a MID or BC subphase. MID and BC subphases can be skipped if either STA indicates that the subphase is not needed by setting the MID-REQ and BC-REQ fields to 0 or by setting the MID-Grant and BC-Grant fields to 0. The beam refinement transaction can be skipped if both sides indicate that the transaction is not needed by setting the L-RX and TX-TRN-REQ fields to 0.

The BRP setup subphase is defined in 10.42.3.2.

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The MID subphase is composed of either an R-MID subphase or an I-MID subphase or both, which are composed of one or more transmissions of BRP-RX PPDUs (20.9.2.2), followed by feedback contained in the next BRP frames from the initiator and responder.

The BC subphase is composed of either an R-BC subphase or an I-BC subphase or both, which are composed of transmission of BRP-RX PPDUs to select a beam, followed by feedback.

A beam refinement transaction is a set of BRP frames consisting of beam refinement requests and responses. A beam refinement request can be either a transmit beam refinement request or a receive beam refinement request or both.

A transmit beam refinement request (TX-TRN-REQ field within the BRP Request field set to 1) indicates the need for transmit antenna array training by the transmitting STA. The BRP PPDU that has the TX-TRN-REQ set to 1 (or the next BRP PPDU from this STA) shall include transmit training (TRN-T) subfields appended to it. The STA responding to the BRP PPDU shall include feedback based on measurements it performed during the reception of the BRP PPDU. The feedback type is dictated by the FBCK-TYPE field within the DMG Beam Refinement element contained in the BRP PPDU.

A receive beam refinement request (L-RX field within the BRP Request field greater than zero) indicates the need of the receive antenna array training for the transmitting STA. The responding STA shall respond with a BRP PPDU with receive training (TRN-R) subfields appended to it.

Requests and responses can be combined in the same frame. As an example, the same frame can be both a transmit beam refinement request and a receive beam refinement request. The same frame can also be used as receive beam refinement response and a receive beam refinement request. See the example in Figure 10-72.

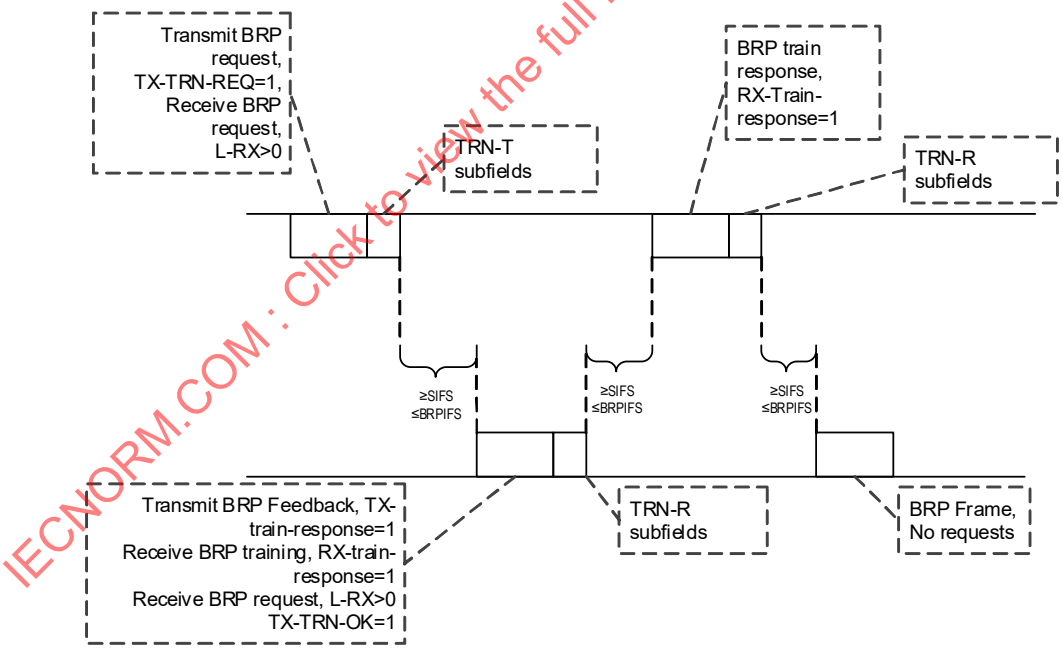

Figure 10-72—Example of beam refinement transaction

A beam refinement response is separated from a preceding beam refinement request by at least a SIFS and at most a BRPIFS provided sufficient time is available for the complete transmission of those frames within the SP allocation or TXOP. Similarly, a beam refinement request, if any, is separated from a preceding beam

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refinement response by at least a SIFS and at most a BRPIFS provided sufficient time is available for the complete transmission of the beam refinement request within the SP allocation or TXOP.

When performing BRP, if a responding STA requires longer than SIFS to transmit a BRP frame as a response for beam refinement training request from a requesting STA, the responding STA should keep the IFS not longer than SIFS by transmitting one or more PPDUs to the requesting STA.

When the beam refinement occurs within the same allocation as the SLS, the SLS initiator is the beam refinement initiator. If the beam refinement occurs in a separate allocation, the STA that transmits the first beam refinement request is the beam refinement initiator. The other STA is the beam refinement responder.

A beam refinement transaction is complete when one of the following conditions is met:

a) The initiator determines that it does not need further training and it has received a BRP frame with no training requests from the beam refinement responder.

b) A duration equal to BRPIFS plus aSlotTime has elapsed since the last transmission from the beam refinement initiator to the refinement responder without a response from the beam refinement responder.

In Figure 10-72, the first PPDU (from the initiator) has TX-TRN-REQ=1, the L-RX field has a value greater than zero and TRN-T subfields are appended to the PPDU. The second PPDU (from the responder) has a value greater than zero in the L-RX field, the TX-train-response field set to 1, the RX-train-response field set to 1, and TRN-R subfields are appended to the PPDU. The last PPDU (from the initiator) has RX-train-response set to 1 and TRN-R subfields are appended to the PPDU.

10.42.3.2 BRP setup subphase

The BRP setup subphase is used to exchange the intent and capabilities to conduct some or all of the subphases and beam refinement transactions in a subsequent BRP phase. The BRP setup subphase is used to set up the MIDC subphase, but can also be used to set up beam refinement transactions.

The BRP setup subphase shall be used in the following cases:

— When the RSS part of the SLS phase occurred in an A-BFT, in which case the SSW-Ack frame was not part of the SLS.

— When the initiator set the MID-REQ or BC-REQ fields in the SSW-Feedback frame to 1 or the responder set the MID-REQ or BC-REQ fields in the SSW-Ack frame to 1.

— When the initiator intends to include MID or BC or both subphases, independent of a preceding SLS phase.

The BRP setup subphase starts with the initiator sending a BRP PPDU with the Capability Request subfield set to 1 and with the remaining subfields within the BRP Request field set according to the initiator's need for an MID subphase, a BC subphase, and a beam refinement subphase. The BRP setup subphase can also start when the responder grants a MID-REQ or BC-REQ through the SSW-Ack frame or when the responder requests MID or BC in the SSW-Ack frame. Upon receiving a BRP PPDU with the Capability Request subfield set to 1, the responder shall respond with a BRP PPDU with the subfields within the BRP Request field set to indicate the presence of an MID subphase, a BC subphase and a beam refinement subphase. This process is repeated until the responder transmits to the initiator a BRP PPDU with the Capability Request subfield set to 0 and the initiator sends as a response a BRP PPDU with the Capability Request subfield also set to 0. The BRP PPDU from the initiator that initiates the termination of the BRP setup subphase can be the first BRP PPDU of the BRP phase, either as part of beam refinement or as part of a MID or BC subphase.

A DMG STA (either initiator or responder) requests MID and BC subphases (see 10.42.6.3.2) by setting both the MID-REQ and BC-REQ subfields to 1 in the BRP Request field of an SSW-Feedback, SSW-Ack or

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BRP frame. It shall also set the L-RX subfield in the BRP Request field to the number of RX AWV settings it needs in each BRP-RX PPDU during the MID subphase. The peer STA grants the request by setting the MID-Grant and BC-Grant subfields to 1 in the BRP Request field within the next SSW-Ack or BRP frame transmitted to the requesting DMG STA. If either the MID or BC were not granted by the peer STA, the MID and BC subphases shall not occur.

A DMG STA (either initiator or responder) requests an MID only subphase (see 10.42.6.3.3) by setting the MID-REQ subfield to 1 in the BRP Request field of an SSW-Feedback, SSW-Ack or BRP frame. The STA shall also set the L-RX subfield in the BRP Request field to the number of RX AWV settings it needs in each BRP-RX PPDU during the MID-subphase. The peer STA grants the request by setting the MID-Grant subfield to 1 in the BRP Request field within the next SSW-Ack or BRP frame transmitted to the requesting DMG STA. The Capability Request subfield and request subfields (TX-TRN-REQ, L-RX, MID-REQ, BC-REQ) within the granting frame shall be set to 0.

If the MID-REQ was granted, the requesting STA shall transmit a BRP frame with the SNR Present and Sector ID Order Present subfields set to 1 and with the Number of Measurements field in the FBCK-TYPE field indicating the number of SNR measurements from the last SLS phase. In the Channel Measurement Feedback element, the requesting STA sets the SNR subfields to the SNRs corresponding to the TX sectors received during the SLS phase. In the Sector ID Order subfield, the requesting STA lists the sector IDs of the received sectors. The Capability Request field within the BRP frame shall be set to 0. The MID subphase starts with the transmission of a BRP PPDU from the peer STA after the reception of the list of sectors. A STA that has granted a MID only request shall not request MID or BC in the response PPDU. The STA may request MID or BC in the last PPDU it transmits to the requesting STA as part of the MID. The MID only subphase shall not occur if it was not granted by the peer STA.

A DMG STA (either initiator or responder) requests a BC only subphase (see 10.42.6.3.4) by setting the BC-REQ subfield to 1 in the BRP Request field of an SSW-Feedback, SSW-Ack, or BRP frame. The peer STA (either a responder or initiator) grants the request by setting the BC-Grant subfield to 1 in the BRP Request field within the next SSW-Ack or BRP frame transmitted to the requesting STA. The BC subphase shall not occur if the peer STA does not grant the request.

A DMG STA indicates that beam refinement transactions (10.42.6.4.2) occur by setting the L-RX field to a value greater than 0 to indicate the need for receive beam refinement or by setting the value of the TX-TRN-REQ field to 1 to indicate the need for transmit beam refinement or by setting both. The beam refinement transactions shall occur if at least one of these conditions is met.

If the initiator has requested an MID subphase by setting the MID-REQ subfield or the BC-REQ subfield to 1 and the responder rejected by setting in the response the MID-Grant subfield or the BC-Grant subfield to 0, respectively, the initiator should send a BRP frame with the MID-REQ field set to 0 and the L-RX field set to indicate the number of TRN-R subfields the initiator requests for use in the BRP transaction.

If the responder has requested an MID subphase by setting the MID-REQ subfield or the BC-REQ subfield to 1 and the initiator rejected by setting in the response the MID-Grant or the BC-Grant subfields to 0, the initiator should send a BRP frame with the Capability Request subfield set to 1. The responder shall respond with a BRP frame with the MID-REQ field set to 0 and the L-RX field set to indicate the number of TRN-R subfields the responder requests for use in the BRP transaction.

Beam refinement transactions shall occur following a MIDC subphase when one or both of the following conditions are met at the last BRP frame transmitted by either the initiator or responder as part of the MID or BC subphases:

a) Either the initiator or the responder set the L-RX field to a value greater than 0.
b) Either the initiator or responder has set the value of the TX-TRN-REQ field to 1.

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If within the appropriate IFS the initiator does not receive a response from the responder to a PPDU transmitted to the responder, the initiator may retransmit the PPDU.

After the BRP setup subphase, beamforming training shall immediately continue to the next phase (i.e., either MIDC subphase or the beam refinement transactions). Examples of BRP setup subphase procedures are illustrated in Figure 10-73 and Figure 10-74 as well as in Figure 10-78, Figure 10-79, and Figure 10-85.

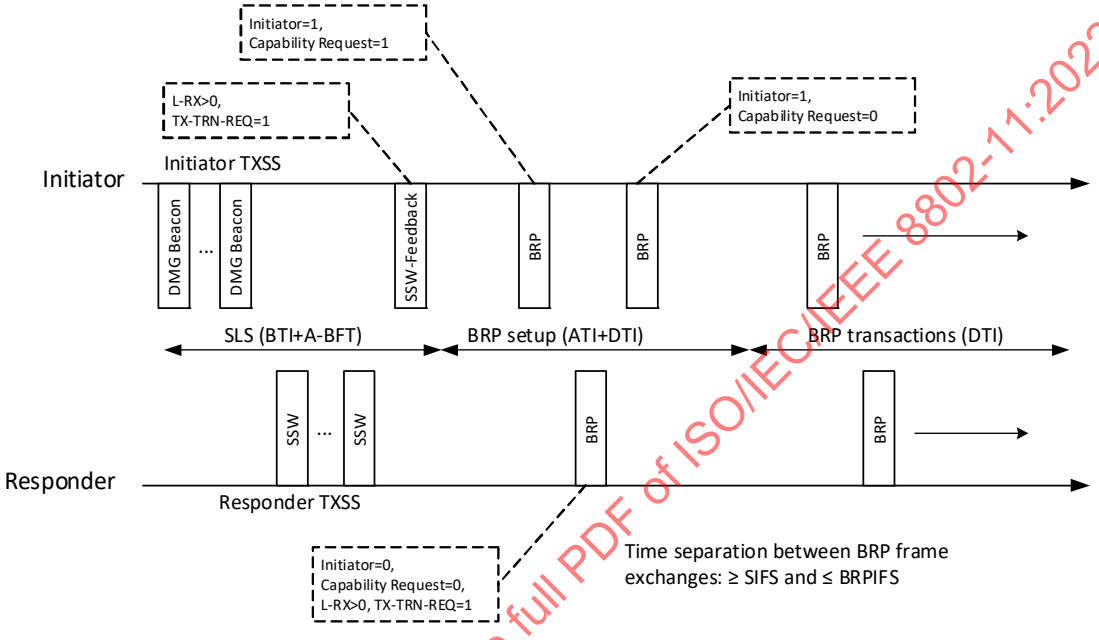

Figure 10-73—Example of BRP setup subphase procedure (SLS in BTI and A-BFT)

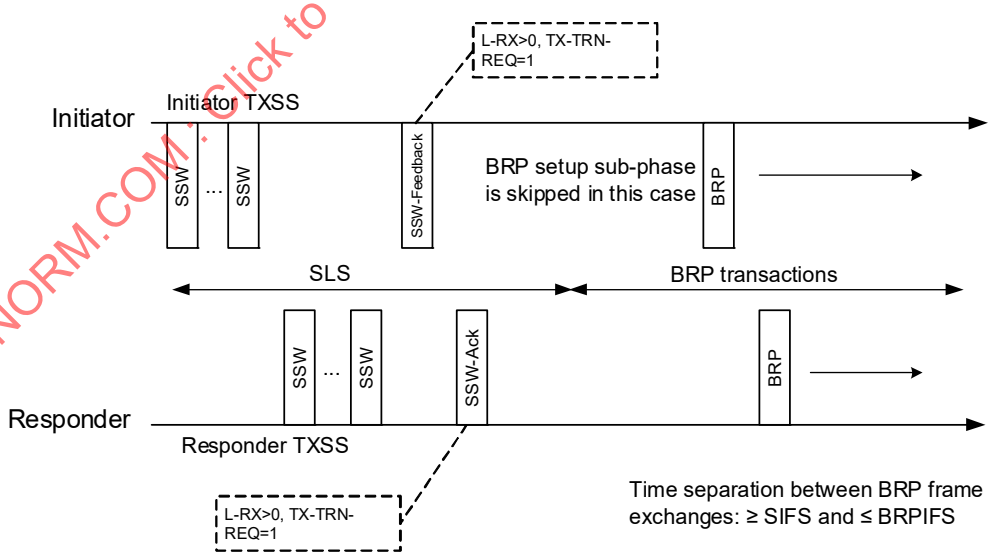

Figure 10-74—Example of skipping the BRP setup subphase (SLS in DTI)

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10.42.4 Beamforming in BTI

In the BTI, the AP or PCP performs an initiator TXSS as the first part of the SLS with the transmission of at least one DMG Beacon frame. The AP or PCP does not transmit SSW frames in the BTI (10.42.2.2.1).

The AP or PCP may fragment the initiator TXSS over multiple consecutive BTIs by not transmitting a DMG Beacon frame through all sectors available to the AP or PCP in a single BTI. In a BTI with a fragmented initiator TXSS, the AP or PCP shall transmit DMG Beacon frames with the Fragmented TXSS field set to 1. Otherwise, the AP or PCP shall set the Fragmented TXSS field to 0. The AP or PCP shall not change the duration of the next BTI if at least one of the DMG Beacon frames transmitted in the current BTI have the Fragmented TXSS field set to 1. The CDOWN field shall be set to the total number of transmissions remaining to the end of the initiator TXSS, such that the last DMG Beacon frame transmission of the initiator TXSS has the CDOWN field set to 0 (i.e., in a fragmented TXSS, the value of the CDOWN field covers the total number of transmissions remaining in the fragmented TXSS). The TXSS Span field shall be set to the total number of beacon intervals it takes the AP or PCP to complete the entire TXSS phase. The Duration field within each transmitted DMG Beacon frame shall be set to the time remaining until the end of the current BTI.

When an AP or PCP has more than one DMG antenna, the TXSS shall cover all of the sectors in all DMG antennas. The TXSS Span field indicates the total number of beacon intervals it takes the AP or PCP to cover all sectors in all DMG antennas. The value of the TXSS Span field shall be lower than dot11MaximalSectorScan. The AP or PCP shall not change DMG antennas within a BTI. The AP or PCP has a regular schedule of transmitting through each DMG antenna (see 10.42.5.4).

NOTE—If an unassociated responder receives a DMG Beacon frame in the BTI with a fragmented initiator TXSS, the responder may start a responder TXSS in the following A-BFT, or it may scan for the number of beacon intervals indicated in a received TXSS Span field in order to cover a complete initiator TXSS and find a suitable TX sector from the AP or PCP.

Each subfield in the Beacon Interval Control field and DMG Parameters field of each DMG Beacon frame transmitted by the AP or PCP shall retain the same value from start to completion of a TXSS phase.

10.42.5 Beamforming in A-BFT

10.42.5.1 Allocation of A-BFT

The AP or PCP shall allocate an A-BFT period MBIFS following the end of a BTI that included a DMG Beacon frame transmission with Next A-BFT equal to 0.

Following the end of a BTI, the AP or PCP shall decrement the value of the Next A-BFT field by 1 provided it is not equal to 0 and shall announce this value in the next BTI. The AP or PCP may increase the Next A-BFT field value following a BTI in which the Next A-BFT field was equal to 0. A STA shall consider that a BTI is completed at the expiration of the value within the Duration field of the last DMG Beacon frame received in that BTI.

All DMG Beacon frames transmitted within the number of beacon intervals specified within the most recently updated TXSS Span field have the same value for each subfield within the Beacon Interval Control field (11.1.3.3).

10.42.5.2 Operation during the A-BFT

Beamforming training in the A-BFT consists of the RSS and SSW feedback procedures of the SLS between the AP or PCP and a STA.

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In the A-BFT, the AP or PCP is the initiator and the STA is the responder in the RSS part of the SLS (10.42.2.3). The BRP phase shall not be performed within the A-BFT. A STA shall not transmit in the A-BFT of a beacon interval if it does not receive at least one DMG Beacon frame during the BTI of that beacon interval.

A DMG STA that receives a DMG Beacon frame with the Discovery Mode field equal to 1 may transmit in the A-BFT following the BTI where the DMG Beacon frame is received if at least one of the following conditions is met:

— The CC Present field within the received DMG Beacon frame is equal to 1 and the STA's MAC address is equal to the value of the A-BFT Responder Address subfield within the received DMG Beacon frame.

— The CC Present field within the received DMG Beacon frame is equal to 1, the value of the A-BFT Responder Address subfield within the received DMG Beacon frame is a group address of a group to which the STA belongs, and the responding STA's role matches the role identified by the value of the BSS Type subfield within the received DMG Beacon frame and the "Responding STA role" column of Table 9-69.

— The CC Present field within the received DMG Beacon frame is equal to 0.

If none of these conditions is met following the reception of a DMG Beacon frame with the Discovery Mode field equal to 1, the STA shall not transmit in the A-BFT.

The A-BFT is slotted and the length of the A-BFT is an integer multiple of the sector sweep slot time. The structure of the A-BFT is shown in Figure 10-75. The AP or PCP shall announce the size of the A-BFT in the A-BFT Length subfield of the Beacon Interval Control field (9.3.4.2). The first SSW slot begins at the start of the A-BFT, and the following SSW slots are adjacent and nonoverlapping. An SSW slot (Figure 10-76) is a period of time within the A-BFT that can be used by a responder to transmit at least one SSW frame. An SSW slot has a duration of aSSSlotTime. aSSSlotTime is defined to be

aSSSlotTime = aAirPropagationTime + aSSDuration + MBIFS + aSSFBDuration + MBIFS

where

aAirPropagationTime	accounts for the propagation delay between the initiator and the responder
aSSDuration (11.37)	provides time for a responder to transmit up to the number of SSW frames announced in the FSS subfield of the Beacon Interval Control field in the DMG Beacon
aSSFBDuration	provides time for the initiator to perform an SSW feedback procedure (see 11.37)

The initiator shall set the FSS subfield of the Beacon Interval Control field in the DMG Beacon frame to a value that is no less than aSSFramesPerSlot. See Figure 10-75.

If the IsResponderTXSS subfield of the Beacon Interval Control field is equal to 1, the A-BFT shall be used to perform a responder TXSS. Otherwise, the A-BFT shall be used to perform a responder RXSS. In the case of a responder RXSS, the same slotted structure described above is used and the responder shall transmit the number of SSW frames announced in the FSS field in the DMG Beacon. If the AP or PCP allocates the A-BFT as a responder RXSS, it should set the value of the FSS field within the Beacon Interval Control to the number of receive sectors supported by the AP or PCP. The AP or PCP shall allocate the A-BFT as a responder TXSS at least once every dot11ABFTRTXSSSwitch beacon intervals in which an A-BFT is present.

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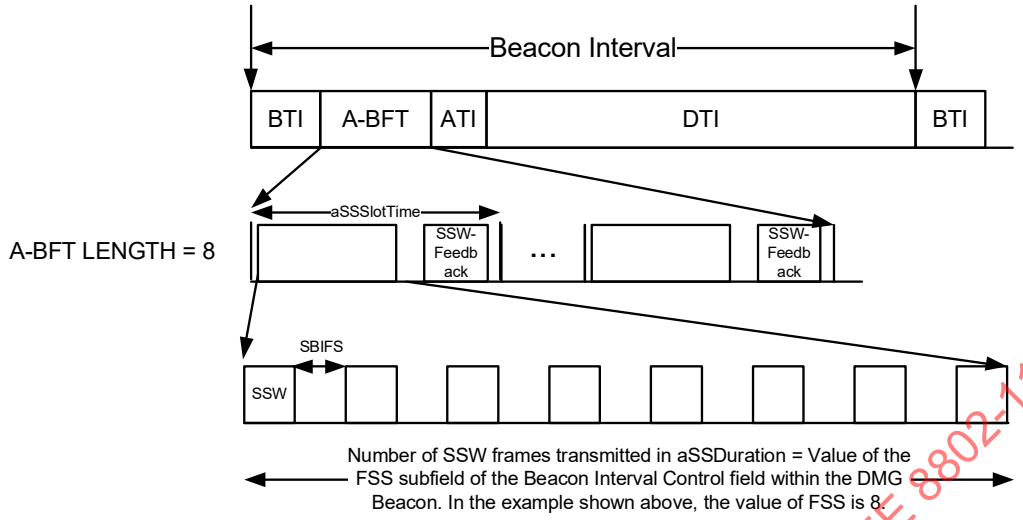

Example of A-BFT with length 8 and with each SSW slot accommodating 8 SSW frames. A possible contention between 3 STAs is shown in the figure below: STAs A, B and C are competing for access. All STAs choose a random value between [0,7]. STA A chooses value = 2, while STAs B and C choose value = 5, which might result in a collision.

Figure 10-75—A-BFT structure

At the start of each A-BFT, the responder(s) shall invoke a random backoff procedure to initiate or resume an RSS as follows. The random backoff procedure begins at the start of the A-BFT with the responder selecting a backoff count as a random integer drawn from a uniform distribution [0, A-BFT Length), i.e., 0 to A-BFT Length – 1, where A-BFT Length is the value of the A-BFT Length field in the last received DMG Beacon. The responder shall decrement the backoff count by one at the end of each SSW slot, even if the CS function at the responder indicates the medium busy condition for that SSW slot. The responder may initiate the RSS only at the start of the SSW slot for which the backoff count is 0 at the beginning of the SSW slot. See Figure 10-76.

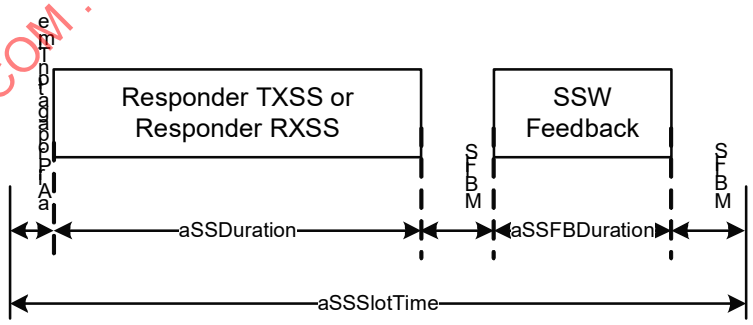

Figure 10-76—SSW slot (aSSSlotTime) definition

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The responder shall transmit no more SSW frames within an SSW slot than indicated in the value of the FSS subfield in the DMG Beacon. If the responder has more SSW frames to transmit as part of the RSS, but is not allowed to send any more SSW frames in the current SSW slot, then the responder may resume the RSS at the start of the following SSW slot provided that the A-BFT has not ended. If the responder cannot complete the RSS before the end of the A-BFT, it may use the same backoff procedure described above to resume the RSS at the next A-BFT for which the value of the IsResponderTXSS field is the same as the current A-BFT.

The initiator shall initiate an SSW feedback procedure to a responder (10.42.2.4) at a time such that the beginning of the first symbol of the SSW-Feedback frame on the WM occurs at aSSFBDuration + MBIFS before the end of the SSW slot. A responder that transmitted at least one SSW frame within an SSW slot shall be in quasi-omni receive mode for a period of aSSFBDuration ending MBIFS before the end of the SSW slot. The initiator may initiate an SSW feedback procedure to the responder at an SSW slot even if the responder did not complete RSS within that SSW slot. If the initiator transmits an SSW-Feedback under this circumstance, it can transmit an Announce frame to the responder in an ATI. Following the reception of the Announce frame, the responder can respond with an SPR frame requesting time for the responder to continue with the RSS. Alternatively, the responder can transmit an SPR frame to the AP or PCP in accordance with the channel access rules.

The information contained in an SSW-Feedback frame is based on the SSW frames received during the SSW slot in which the SSW-Feedback frame was transmitted. To communicate with each other following an SLS, an initiator and responder should use the information contained within the SSW-Feedback frame that had the highest value in its SNR Report field and was transmitted or received, respectively, as part of the most recent SLS between the initiator and responder.

A responder that receives an SSW-Feedback frame from the initiator during an A-BFT that was allocated with a DMG Beacon frame with Discovery Mode equal to 1 should not attempt to access the following aMaxABFTAccessPeriod A-BFT allocations to redo beamforming with the initiator, unless in the BTI preceding the A-BFT the responder receives a DMG Beacon frame that has the Discovery Mode field equal to 1, the CC Present field equal to 1 and the value of the A-BFT Responder Address subfield equal to the responder's MAC address. This allows other STAs the opportunity to successfully contend for A-BFT access and perform beamforming with the initiator.

The responder may attempt to restart the RSS within the same A-BFT if it does not receive an SSW-Feedback frame from the initiator by the end of the SSW slot in which it completes the RSS. To do this, the responder shall invoke the random backoff procedure beginning at the start of the SSW slot following the completion of the RSS. The responder shall select a backoff count as a random integer drawn from a uniform distribution [0, A-BFT Length), i.e., 0 to A-BFT Length – 1, where A-BFT Length is the value of the A-BFT Length field in the last received DMG Beacon. The responder shall decrement the backoff count by one at the end of each SSW slot, even if the CS function at the responder indicates the medium busy condition for that SSW slot. The responder may restart the RSS at the start of the SSW slot for which the backoff count is 0 at the beginning of the SSW slot provided the A-BFT still has SSW slots available.

At the end of an A-BFT the responder shall cancel a backoff procedure that was started during the A-BFT, but has not been completed at the end of the A-BFT. As described above, the responder invokes a random backoff procedure at the start of each A-BFT.

Each STA maintains a counter, FailedRSSAttempts, of the consecutive number of times the STA initiates RSS during A-BFTs but does not receive an SSW-Feedback frame as a response. If FailedRSSAttempts exceeds dot11RSSRetryLimit, the STA shall select a backoff count as a random integer drawn from a uniform distribution [0, dot11RSSBackoff), i.e., 0 to dot11RSSBackoff – 1. The responder shall decrement the backoff count by one at the end of each A-BFT period in the following beacon intervals. The responder may reinitiate RSS only during an A-BFT when the backoff count becomes zero. The STA shall set FailedRSSAttempts to 0 upon receiving an SSW-Feedback frame during the A-BFT.

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In an A-BFT, the responder shall not initiate an SSW ack procedure (10.42.2.5) in response to an SSW-Feedback frame from the initiator. The SSW ack procedure occurs within the DTI of a beacon interval (10.42.6.2); it does not occur otherwise.

If the AP or PCP receives an SSW frame from the responder during the RSS with the Poll Required field within the SSW frame equal to 1 and the TDDTI field within the AP's or PCP's DMG Capabilities element is 1, the AP or PCP shall allocate time for the responder and the AP or PCP to communicate during the ATI or within an SP of the DTI of at least one of the following aMinBTIPeriod beacon intervals beginning with the beacon interval in which the SSW frame was received. This can be done through the Extended Schedule element or the transmission of a Poll or Grant frame addressed to the responder, and the allocated time can be used for at least one of association, authentication, and service period request.

After transmitting an SSW-Feedback frame to the responder, the initiator shall send a BRP frame with the Capability Request subfield within the BRP Request field set to 1 and addressed to the responder. The BRP frame shall be sent in one of the following aMinBTIPeriod beacon intervals beginning with the beacon interval in which the RSS phase with the responder was last completed. The BRP frame shall be transmitted at MCS 0 using the sector identified by the Sector Select field received from the responder during the RSS.

In an ATI after the completion of the SSW feedback procedure, a responder should have its receive antenna configured to a quasi-omni antenna pattern in the DMG antenna in which it received the best sector from the initiator during the preceding ISS in order to receive an Announce, Grant, or BRP frame (with the Capability Request subfield within the BRP Request field set to 1) from the initiator, while the initiator should configure its transmit DMG antenna to the value of the Sector Select and the DMG Antenna Select fields received from the responder during the preceding RSS. If the responder does not receive an Announce or Grant frame from the initiator with the RA equal to the responder's MAC address until aMinBTIPeriod beacon intervals after the beacon interval in which the SLS phase with the initiator was last attempted, it may retry BF with the initiator in the A-BFT.

NOTE—Due to the multiple access nature of RSS in the A-BFT, the AP or PCP might not receive the best sector for communication with the STA. The AP or PCP might schedule an SP to perform BF again with the STA to find the best sector for communication with the STA.

10.42.5.3 STA Beamforming after A-BFT

The initiator shall either initiate BRP execution with the responder in the next CBAP or shall schedule time in the DTI for BRP execution with the responder if the initiator needs BRP training or the responder indicated a need for training (by setting any of the L-RX, TX-TRN-REQ, MID-REQ, or BC-REQ fields to a nonzero value) as a response to an SSW-Feedback or BRP frame with Capability Request subfield within the BRP Request field set to 1.

The responder may initiate BRP in a CBAP by sending a BRP frame with any of the training request fields (i.e., L-RX, TX-TRN-REQ, MID-REQ, BC-REQ) set to 1.

To schedule time in the DTI for BRP execution with a responder, the initiator may use any of the following methods:

1) Allocate an SP with the Beamforming Training subfield set to 1 in the Allocation field within an Extended Schedule element. The source of the SP shall be the initiator and the destination of the SP shall be the responder. The Extended Schedule element is carried in DMG Beacon or Announce frames, as defined in 10.39.4. The source AID of the allocation shall be set to the AID of the initiator. The destination AID of the allocation shall be set to the AID of the responder or the broadcast AID.
2) Allocate a CBAP in which the initiator or responder may start beamforming training with each other. The CBAP allocation is announced in an Extended Schedule element carried in a DMG Beacon or an Announce frame, as defined in 10.39.4. The source AID of the CBAP shall be

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set to the AID of the initiator or to the broadcast AID. The destination AID of the CBAP may be set to the AID of the responder or to the broadcast AID.

3) Use a Grant frame to allocate either a CBAP or an SP in which the initiator or responder may start beamforming with each other. In the Grant frame, the initiator shall set the RA field to the MAC address of the responder and the TA field to the MAC address of the initiator. In the Dynamic Allocation Info field of the Grant frame, the AllocationType field shall be set to indicate CBAP or SP, the source AID field shall be set to the AID of the initiator, the destination AID field shall be set to the AID of the responder or the broadcast AID, and the Allocation Duration field shall be set to the expected duration of the BRP phase.
4) Allocate a DTI as CBAP only as defined in 10.39.4.

At least one of the above allocations shall occur during one of the following aMinBTIPeriod beacon intervals beginning with the beacon interval in which the SLS phase with the responder was last completed.

The duration of the allocation, as specified in the Allocation Block Duration (see 9.4.2.131), shall cover at least the expected duration of the BRP phase.

If the initiator receives at least one SSW frame from a responder within an A-BFT but did not transmit an SSW-Feedback frame to the responder within that A-BFT, the initiator may schedule time in the DTI to perform the ISS and RSS. To do that, the initiator may use one of the methods above. The Allocation Block Duration field shall be set to cover at least the ISS and RSS.

The initiator may transmit an Announce frame to the responder during the ATI to announce a CBAP allocation in the beacon interval. If the responder receives the Announce frame with a CBAP allocation, the responder may contend for a TXOP during a CBAP to perform the BRP execution with the initiator or continue the RSS with the initiator.

Any Announce or Grant frame the initiator sends to a responder after initiating beamforming with the responder in the A-BFT but before beamforming with the responder is completed shall be transmitted at MCS 0 using the sector identified by the Sector Select field received from the responder in the RSS.

The execution of the beamforming procedure in an allocation in the DTI is described in 10.42.6.

10.42.5.4 Beamforming in A-BFT with multiple DMG antennas

An AP or PCP shall receive through a quasi-omni antenna pattern from a single DMG antenna throughout an A-BFT unless RXSS is used in the A-BFT, in which case it switches through antenna patterns as described in 10.42.5.2.

An AP or PCP shall have an A-BFT every *k* beacon intervals, where *k* is the value indicated by the N BIs A-BFT subfield in the Beacon Interval Control field. In an A-BFT, the AP or PCP shall receive in a quasi-omni antenna pattern using the DMG antenna indicated by the value of the DMG Antenna ID subfield within the SSW field transmitted in the DMG Beacon. An AP or PCP with multiple DMG antennas has a regular schedule of receiving through each DMG antenna corresponding to the DMG antenna in which a DMG Beacon frame is transmitted through. The AP or PCP shall switch RX DMG antenna every *l* allocations, where *l* is the value of the N A-BFT in Ant subfield within the Beacon Interval Control field.

In each DMG Beacon, the A-BFT Count subfield in the Beacon Interval Control field indicates the number of A-BFTs that have passed since the AP or PCP last switched RX DMG antennas.

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10.42.6 Beamforming in DTI

10.42.6.1 General

An initiator and responder may perform BF training within an SP or CBAP.

An initiator shall determine the capabilities of the responder prior to initiating BF training with the responder if the responder is associated. A STA may obtain the capabilities of other STAs through the Information Request and Information Response frames (11.28.1) or following a STA's association with the PBSS/infrastructure BSS. The initiator should use its own capabilities and the capabilities of the responder to compute the required allocation size and TXOP duration to perform BF training and BF training related timeouts.

An initiator may request the AP or PCP to schedule an SP to perform BF training with a responder by setting the Beamforming Training subfield in the BF Control field of the DMG TSPEC element or SPR frame to 1. The AP or PCP shall set the Beamforming Training subfield to 1 in the Allocation field of the Extended Schedule element if the Beamforming Training subfield in the BF Control field of the DMG TSPEC element or SPR frame that generated this Allocation field is equal to 1. The AP or PCP should set the Beamforming Training subfield in an Allocation field of the Extended Schedule element to 0 if this subfield was equal to 1 when the allocation was last transmitted by the AP or PCP in an Extended Schedule element and if, since that last transmission, the AP or PCP did not receive a DMG TSPEC element for this allocation with the Beamforming Training subfield equal to 1.

10.42.6.2 SLS phase execution

For BF training in the DTI, both the initiator and responder shall use the SSW frame for the ISS and RSS.

The initiator shall begin an ISS (10.42.2.2) at the start of an SP allocation or TXOP with an initiator TXSS, except in the case of an SP allocation that has the IsInitiatorTXSS field for this SP is equal to 0 in which case the initiator shall begin an ISS with an initiator RXSS.

If the responder has more than one DMG antenna, the initiator shall repeat its ISS k+1 times, where k is the value indicated by the responder in the last negotiated Number of RX DMG Antennas field transmitted by the responder. Repetitions of the ISS are separated by an interval equal to LBIFS. The value of the CDOWN field within SSW frames transmitted in the ISS indicates the number of sectors until the end of transmissions from all of the initiator's DMG antennas to all of the responder's DMG antennas. The ISS phase shall not be fragmented across multiple allocations.

The RSS comprises a responder TXSS unless the allocation is an SP and the IsResponderTXSS field for this SP is equal to 0 or the allocation is a CBAP and the RXSS Length field within the SSW frame received by the responder during the ISS is nonzero. The responder shall begin an RSS (10.42.2.3) MBIFS following the completion of an ISS, provided the responder received an SSW frame from the initiator during the ISS and there is sufficient time in the allocation for the responder to transmit all SSW frames necessary to complete the RSS phase. The responder shall not begin or continue the RSS phase in a different allocation from the allocation that contained the ISS phase.

NOTE—The responder can begin an RSS if there is not sufficient time in the allocation to complete the RSS phase. The RSS phase does not continue in a subsequent allocation in this case.

The initiator shall begin an SSW feedback procedure (10.42.2.4) MBIFS following the completion of an RSS, provided the initiator received an SSW frame from the responder during the RSS and there is sufficient time left in the allocation to complete the SSW feedback procedure followed by an SSW ack procedure (10.42.2.5) from the responder in an MBIFS. If there is not sufficient time left in the allocation for the

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completion of the SSW feedback and SSW ack procedures, the initiator may begin the SSW feedback procedure in the following allocation between the initiator and the responder.

The responder shall begin an SSW ack procedure (10.42.2.5) to the initiator an MBIFS following the reception of an SSW-Feedback frame from the initiator.

The initiator may restart the SSW feedback procedure up to dot11BFRetryLimit times if it does not receive an SSW-Ack frame from the responder an MBIFS following the completion of the SSW feedback procedure. The initiator shall restart the SSW feedback procedure PIFS following the expected end of the SSW-Ack frame by the responder, provided there is sufficient time left in the allocation for the initiator to begin the SSW feedback procedure followed by an SSW ack procedure from the responder in an MBIFS. If there is not sufficient time left in the allocation for the completion of the SSW feedback and SSW ack procedures, the initiator may restart the SSW feedback procedure in the following allocation between the initiator and the responder.

Once started, the initiator and responder shall complete the SLS phase before any additional frame exchange takes place between these STAs.

10.42.6.3 Multiple sector ID capture (MIDC) subphase

10.42.6.3.1 General

In practice, the quasi-omni RX antenna patterns used in the SLS phase might exhibit imperfections that lead to an incorrect choice of the best TX sector and consequently a sub-optimal starting point for beam refinement in the BRP phase. To remedy this, a multiple sector ID capture (MIDC) subphase may be used. Instead of selecting the starting point for the beam refinement transactions (i.e., the best TX sector) based on information obtained with quasi-omni RX antenna patterns from the SLS phase, the MIDC subphase enables the use of additional information based on the trial of multiple transmit and receive sectors.

The MIDC subphase can be implemented in two ways. The first option is to conduct a trial between a small set of transmit and receive AWV settings with wide (e.g., quasi-omni) antenna patterns. The second option is to carry out a trial between a small set of TX sectors and a set of RX AWV settings, chosen by the receiver in an implementation dependent manner, that maximizes the probability of determining the RX AWVs that best match the chosen set of TX sectors. Note that this may involve using a set of RX AWVs that correspond to the "full set" of RX sectors (from the SLS phase). The set of TX sectors are chosen from a TX sector sweep with a quasi-omni RX antenna pattern. With either option, the end result from the MIDC subphase can be the better starting point transmit and receive sector pair for further beam refinement.

For the first option above, the MIDC subphase consists of a MID subphase and a BC subphase. This is further elaborated upon in 10.42.6.3.2, and a sample time allocation is illustrated in Figure 10-77. For the second option, the MIDC subphase consists only of a MID subphase. This is further elaborated upon in 10.42.6.3.3, and a sample time allocation is illustrated in Figure 10-78.

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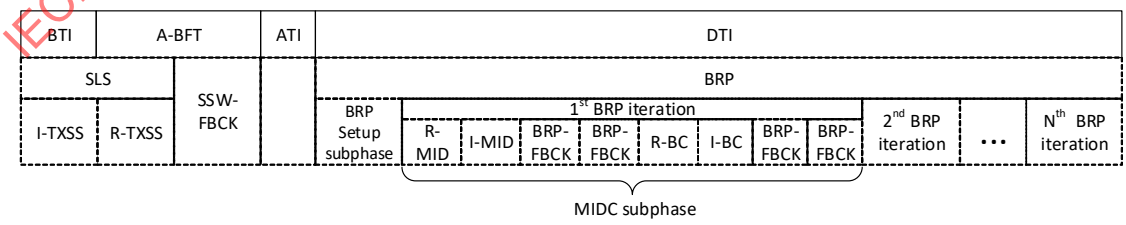

Figure 10-77—Example of time allocation for the MIDC subphase with MID and BC subphases

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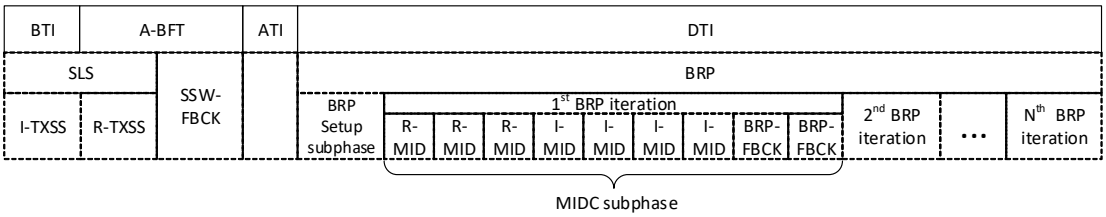

Figure 10-78—Example of time allocation for the MIDC subphase with the MID subphase only

Prior to the beginning of the MIDC subphase, a BRP setup subphase is carried out as specified in 10.42.3.2. This subphase enables the two DMG STAs involved to negotiate whether and how the MIDC subphase is carried out.

In 10.42.6.3 the following terminology is used:

— Nbeam: the value of the Number of Beams subfield of the FBCK-TYPE field.

— Nbeam(Link Type,Antenna Type): represents a combination of Nbeam, Link Type (I for Initiator, R for Responder), and Antenna Type (TX for Transmitter, RX for Receiver).

— Number of Measurements: the value of the Number of Measurements subfield of the FBCK-TYPE field.

Examples of how the MIDC subphase is set up, depending on whether beamforming is initiated in the BTI and A-BFT or in the DTI, are illustrated in Figure 10-79 and Figure 10-80, respectively. Note that the MIDC subphase is applicable only when both the initiator and the responder have the ability to switch among their sectors.

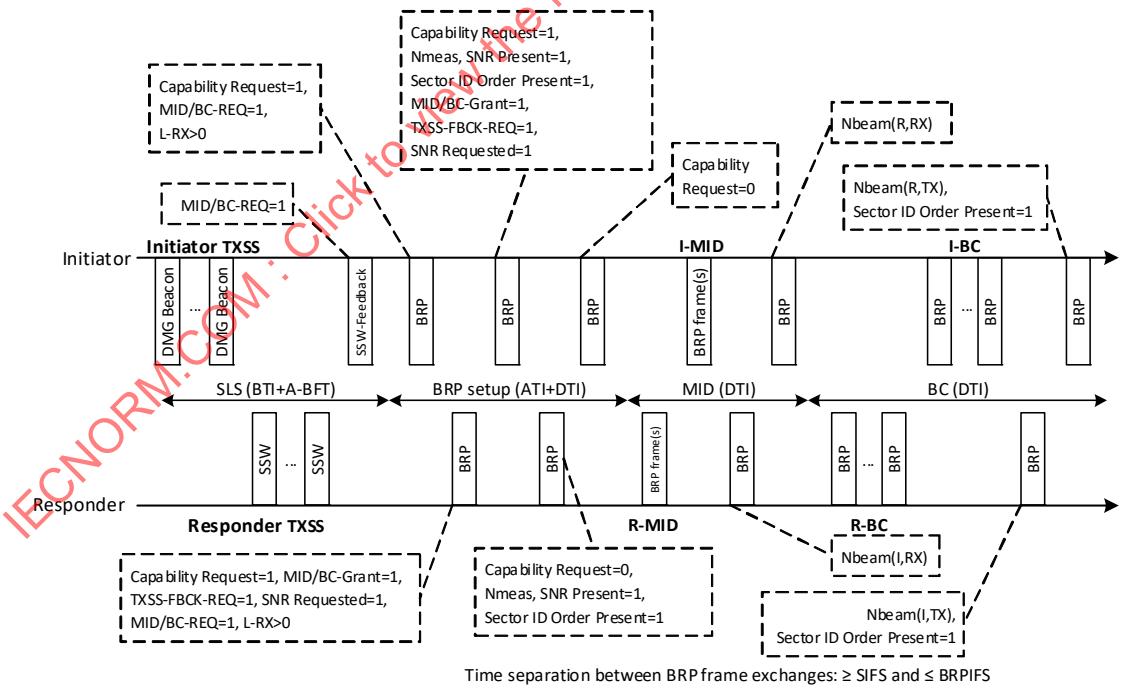

Figure 10-79—Example of using BRP setup subphase to set up subsequent MIDC subphase in A-BFT and DTI

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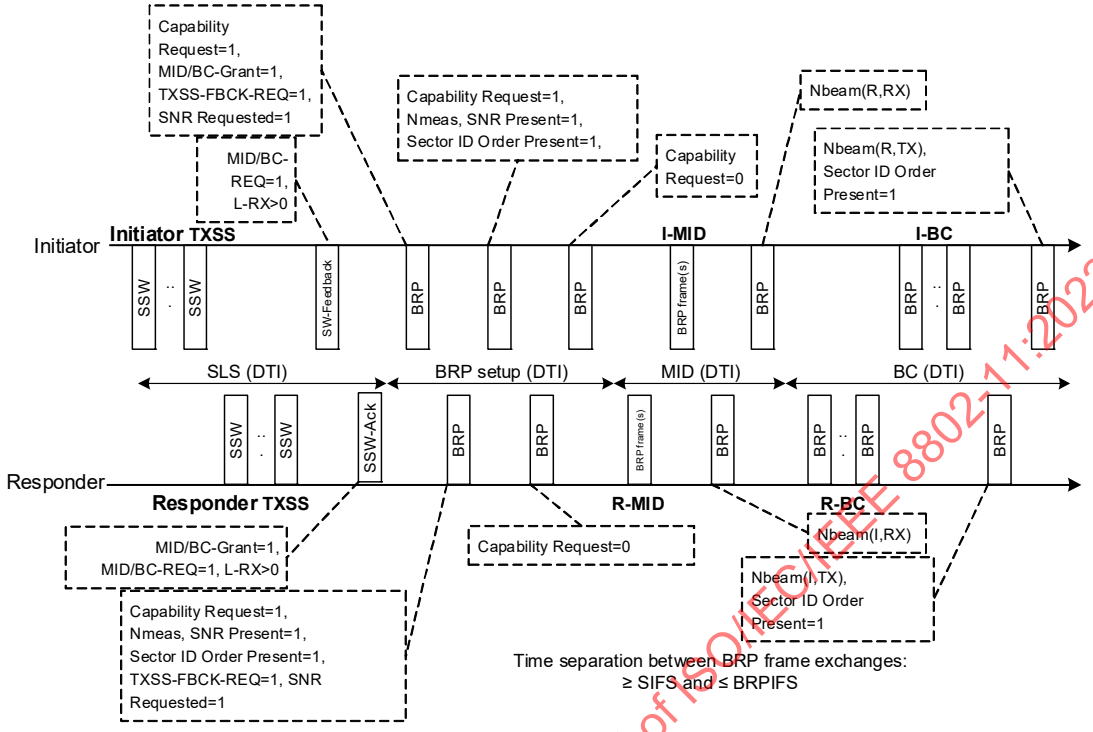

Figure 10-80—Example of using BRP setup subphase to set up subsequent MIDC subphase in DTI

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10.42.6.3.2 MIDC subphase with MID and BC subphases

The MIDC subphase can be implemented such that small subsets of TX sector IDs and RX AWVs are first chosen, followed by trials between these subsets to determine the optimal starting TX sector ID and RX AWV pair. The set of TX sectors is chosen from an a priori TX sector sweep with a quasi-omni RX antenna pattern (in the SLS phase). To enable the selection of the RX sectors, and the subsequent trial between the transmit and receive sectors, the MIDC subphase consists of an MID subphase and a BC (or beam combining) subphase. In the MID subphase, a wide TX beam (e.g., quasi-omni) is used while the receiver sweeps through its choice of AWV settings to determine the set of RX AWVs with the highest link quality. This is followed by the BC subphase, which involves testing the multiple RX AWVs together with multiple TX AWVs.

This is conceptually illustrated in Figure 10-81. Note that the consecutive numbering of TX sector IDs (e.g., TX sector ID1, TX sector ID2, …) or RX AWVs is just used for representation purposes. It is used to indicate the subset of TX sector IDs without placing any restrictions on how these sector IDs are selected (i.e., consecutive numbering of TX sector IDs does not mean that the selected TX sector IDs should be those that are consecutively numbered).

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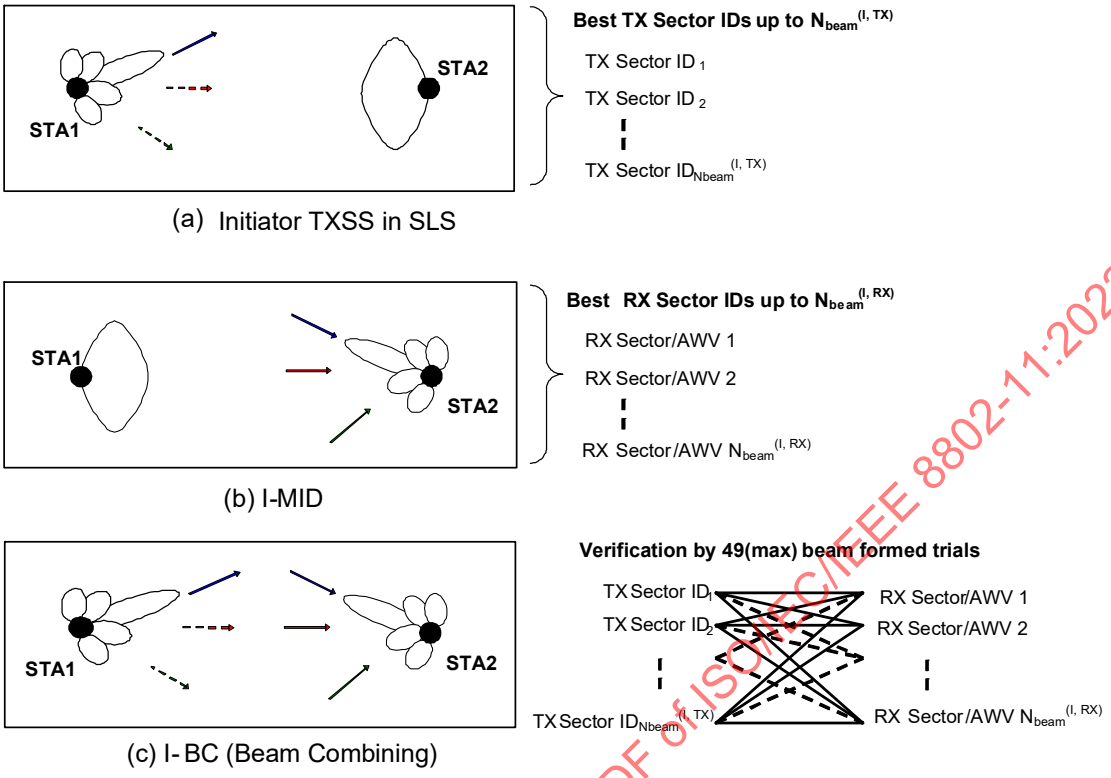

Figure 10-81—Conceptual flow of sample MIDC subphase execution with MID and BC subphases for initiator link

a) *Setting up the MID and BC subphases*: To request a MIDC subphase with the MID and the BC subphases, the initiator shall transmit an SSW-Feedback or BRP frame with the MID-REQ and the BC-REQ fields set to 1 in the BRP Request field. The responder may grant this request by setting the MID-Grant and the BC-Grant fields to 1 in the BRP Request field within the next SSW-Ack or BRP frame transmitted to the initiator. The R-MID and R-BC subphases are performed if the request is granted and are not performed otherwise.

The responder shall transmit an SSW-Ack or BRP frame to request a MIDC subphase, with the I-MID and I-BC subphases. It shall do so by setting the MID-REQ and the BC-REQ fields to 1 in the BRP Request field within the transmitted frame. The initiator may grant this request by setting the MID-Grant and the BC-Grant fields to 1 in the BRP Request field within the next BRP frame transmitted to the responder. The I-MID and I-BC subphases are performed if the request is granted and are not performed otherwise.

If all of R-MID, R-BC, I-MID, and I-BC subphases are performed, the MID subphases are performed before the BC subphases. Within the MID subphase, R-MID is performed before I-MID. Within the BC subphase, R-BC is performed before I-BC (see Figure 10-77 and Figure 10-78).

In addition to the MID-REQ, BC-REQ, MID-Grant and BC-Grant fields, the responder (and/or initiator) needs to obtain the number of RX AWV settings to be appended to BRP-RX PPDUs in the R/I-MID subphase. To do this, the initiator (and/or responder) should use the L-RX field in the BRP Request field to convey this information. Similarly, the responder (and/or initiator) needs to obtain the IDs and SNRs of the TX sectors received during the SLS phase for use in the R-BC and I-BC subphases. To do this, the responder (and/or initiator) shall send a BRP PPDU with the TXSS-FBCK-REQ subfield and SNR Requested subfield set to 1 in the FBCK-REQ field of the DMG

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Beam Refinement element. In response, the initiator (and/or responder) should send a BRP frame with both the SNR Present subfield and the Sector ID Order Present subfield set to 1. The Number of Measurements subfield in the FBCK-TYPE field is set to indicate the number of sectors received during the last SLS for which an SNR measurement is included. In the Channel Measurement field, the initiator (or responder) should set the SNR subfield to the SNRs corresponding to the TX sectors trialled during the SLS phase. In the Sector ID subfield, it should list the sector IDs of the received sectors. The responder (and/or initiator) should then use the SNR information, and any additional information such as angular separation between sectors, to determine the TX sectors for use in the BC subphase. The responder (or initiator) shall inform the initiator (or responder) of the number of TX sectors using the Number of Beams subfield in the FBCK-TYPE field during the BRP setup subphase. After the R/I-MID subphases, the same field is used to exchange information about the number of RX AWVs to be trialled during the BC subphase.

b) *Executing the MID subphase*: If R-MID was requested and granted during the SLS and/or subsequent BRP setup subphase, then after the BRP setup subphase, the R-MID shall be initiated by the responder sending a BRP frame with TRN-R subfields (as requested in the BRP setup subphase). This PPDU may be transmitted using a wide pattern, approaching an omni transmit pattern, or using a sector antenna pattern. The receiver may use the TRN-R subfields for receive training.

   If the MID Extension field in the PPDU is equal to 1, the responder shall transmit another BRP-RX PPDU, which may be transmitted using another transmit pattern. It may continue transmitting BRP-RX PPDUs as long as the MID Extension field in all of them is equal to 1. The last BRP-RX PPDU transmitted by the responder shall have the MID Extension field set to 0.

   If the initiator does not receive a BRP-RX PPDU within BRPIFS after transmitting the last PPDU of the BRP setup subphase, it may retransmit the last PPDU of the BRP setup subphase.

   After the initiator receives a BRP-RX PPDU with the MID Extension field set to 0, it shall respond with a BRP frame with the appropriate feedback. This BRP frame should be sent using the best TX sector as determined in the SLS phase, while the responder should use a quasi-omni pattern to receive this frame. The feedback included in this BRP frame is the number of RX AWVs to be tested in the subsequent R-BC subphase using the Number of Beams subfield in the FBCK-TYPE field.

   If I-MID was granted in addition to R-MID, the initiator shall send a BRP frame with TRN-R subfields (as requested in the BRP setup subphase). The initiator shall continue to send BRP PPDUs if the MID Extension was set to 1 as in the R-MID.

   After the responder receives a BRP-RX PPDU with the MID Extension set to 0, it shall respond by sending a BRP frame with feedback. This BRP frame should be sent using the best TX sector as determined in the SLS phase, while the initiator should use a quasi-omni pattern to receive this frame. The feedback included in this BRP frame is the number of RX AWVs to be tested in the subsequent I-BC subphase using the Number of Beams subfield in the FBCK-TYPE field. The initiator shall respond with a BRP frame with the TX-TRN-OK field set to 1 as an acknowledgment. The R-BC subphase then follows.

   If I-MID does not follow R-MID, the BC subphase follows immediately.

c) *Executing the BC subphase*: The execution of an I-BC subphase is used as an example. In an I-BC subphase, the initiator shall transmit Nbeam(I,TX) BRP-RX frames using the number of TX sectors specified during the BRP setup subphase. Each BRP-RX frame shall be appended with Nbeam(I,RX) TRN-R subfields, and shall include the Sector ID subfield of the TX sector used. While receiving these TRN-R subfields, the responder shall switch through the RX AWVs selected during the prior I-MID subphase. To conclude the I-BC subphase, the responder shall feed back to the initiator a BRP frame with (a) the BS-FBCK field set to the TX sector ID of the BRP-RX PPDU received with the highest link quality, and (b) the ordered list of transmit sectors (based on received link quality during the I-BC) using the Sector ID Order subfield in the Channel Measurement Feedback element. This BRP frame should be sent using the best TX sector as determined in the SLS phase, while the initiator should use a quasi-omni pattern to receive this frame. The complete procedure is illustrated in Figure 10-82, while Figure 10-83 depicts the beam combining subphase.

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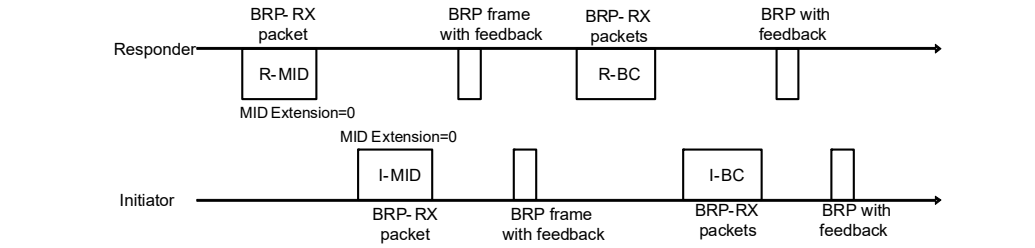
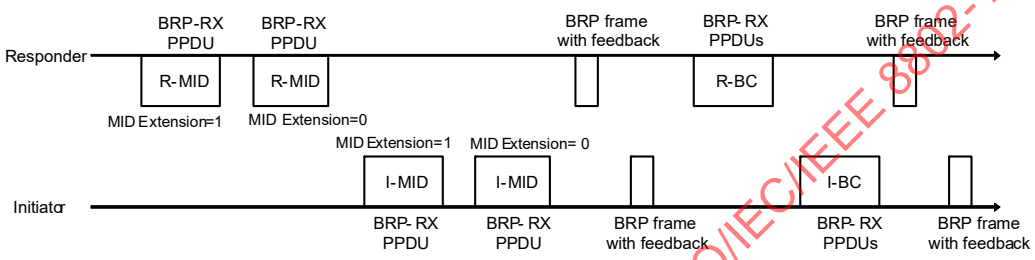
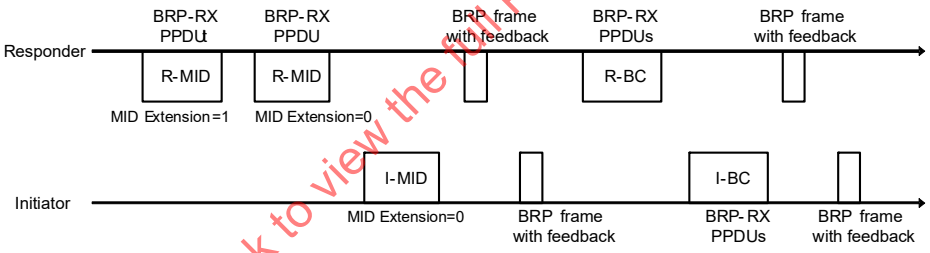


(a) Normal process: one MID and BC for each initiator and responder link
(the initiator and responder use a quasi-omni TX pattern)



(b) The MID for both the initiator and responder are repeated twice:
each TX beam is wider than a TX sector, but narrower than a quasi-omni pattern and covers a different direction



(c) The MID for the initiator is repeated twice:
each TX beam is wider than a TX sector, but narrower than a quasi-omni pattern and covers a different direction

Figure 10-82—Examples of using MID Extension field during execution of MID subphase

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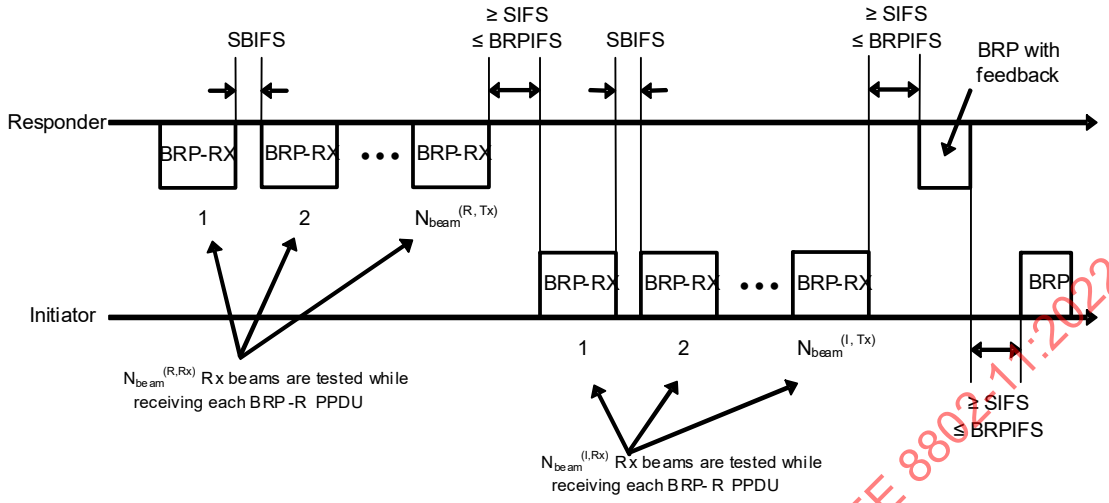

Figure 10-83—Beam combining

10.42.6.3.3 MIDC subphase with MID subphase only

The MIDC subphase may also be implemented such that multiple TX sectors, obtained from the TXSS in the SLS phase, are used instead of wide TX beams. Here, the receiver employs multiple RX AWVs for each TX sector chosen by the transmitter. Based on this joint trial of transmit and receive AWVs, the optimal starting transmit and receive AWV pair is chosen for further refinement in the BRP phase. In this case, the MIDC subphase consists only of the MID subphase. This is conceptually illustrated in Figure 10-84.

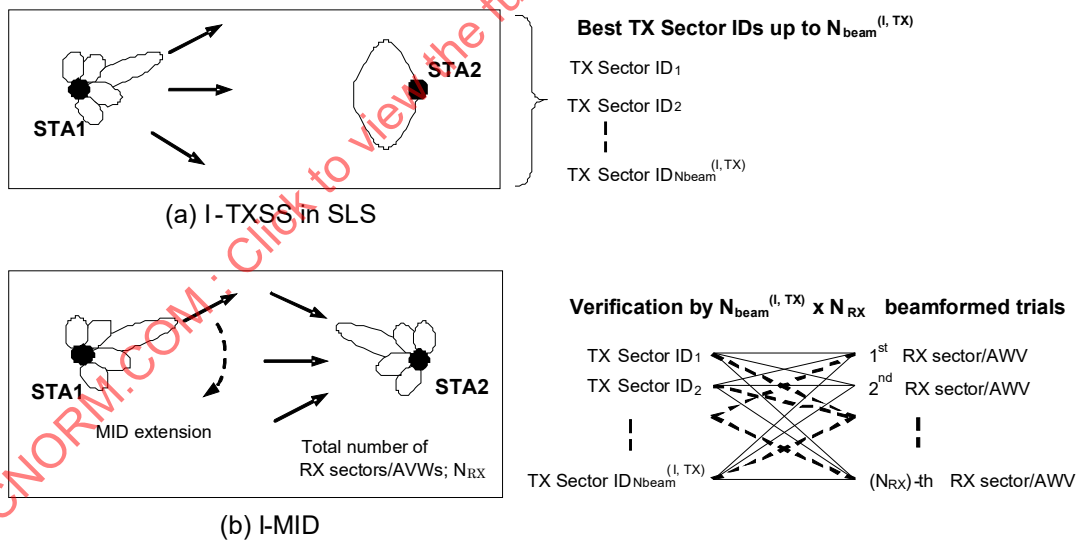

Figure 10-84—Conceptual flow of sample MIDC subphase execution with only MID subphase for initiator link

a) *Setting up the MID subphase*: The procedure of setting up the MID-subphase is described in 10.42.3.2.

In the example of Figure 10-85, the initiator transmits an SSW-Feedback frame with the MID-REQ subfield set to 1 and the BC-REQ subfield set to 0 in the BRP Request field, thus requesting an

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MIDC with only the R-MID subphase. The responder grants the MID-REQ by setting the MID-Grant subfield to 1 in the SSW-Ack frame. The initiator then sends a frame with the SNR Present and Sector ID Order Present subfields both set to 1, the Number of Measurement subfield in the FBCK-TYPE field indicating the number of SNR measurements from the last SLS phase, and the SNR and Sector ID subfields with the SNRs measured during the SLS phase and the list of received sectors, respectively. The L-RX subfield is set according to the number of training fields the initiator needs in each PPDU as part of the R-MID. The responder then starts the R-MID process by transmitting BRP-RX PPDUs.

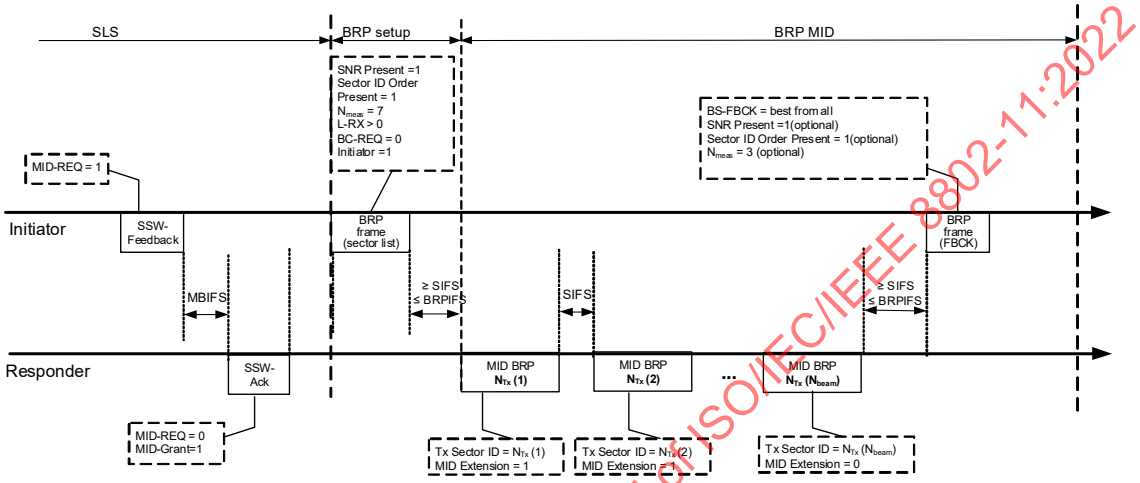

Figure 10-85—Example of using BRP setup subphase to set up subsequent R-MID subphase

b) *Executing the MID subphase*: The execution of the MID subphase for the responder link (i.e., R-MID) is used as an example. Execution of the MID subphase for the initiator link (i.e., I-MID) is similar, except for a change in the direction of the corresponding frames. In an R-MID subphase, the responder shall transmit one BRP-RX PPDU each from one of the chosen TX sectors. In each PPDU, it shall indicate the sector ID of the TX sector used using the Sector ID field in the BRP Request field. Each transmitted BRP-RX PPDU should be appended with multiple TRN-R subfields such that the initiator can train its receiver antenna during the R-MID subphase. The initiator shall train its receiver antenna by cycling through its choice of RX AWVs while receiving the TRN-R subfields. The initiator shall indicate to the responder the number of TRN-R subfields to be appended using the *L-RX* field in the BRP Request field during the SLS phase or the BRP setup subphase. For all BRP-RX PPDUs except the last one, the responder shall also set the MID Extension field to 1.

In the R-MID subphase, the initiator shall send a BRP frame with feedback. This BRP frame should be sent using the best TX sector as determined in the SLS phase, while the responder should use a quasi-omni pattern to receive this frame. The feedback included in this BRP frame should be (a) the BS-FBCK field set to the TX sector ID of the BRP-RX PPDU received with the highest link quality, and (b) the ordered list of transmit sectors (based on received link quality during the R-MID) using the Sector ID Order subfield.

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10.42.6.3.4 MIDC subphase with BC subphase only

An MIDC subphase with only the BC subphase is carried out when the MID and BC subphases have been carried out earlier. In this case, the initiator and responder keep track of the transmit and receive sectors, for use in the BC subphase, from earlier iterations. Since the best transmit and receive sectors (in terms of link quality) are kept track of, this information can be used to deal with link blockage events. STAs can utilize

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only the chosen set of TX sectors in the SLS phase to reduce beamforming training time, and jump to the BC subphase directly without executing the MID subphase. In this manner, fast recovery is possible when some of the backup links are available after partial blockage around the STA.

To carry out the MIDC subphase with the BC subphase only, the MID-REQ field is set to 0 and the BC-REQ field is set to 1 in SSW-Feedback or SSW-Ack or BRP frames, and the BC-Grant field is set to 1 in the following SSW-Ack or BRP frame. The BC subphase can include an I-BC and/or an R-BC (10.42.6.3.2).

10.42.6.4 BRP phase execution

10.42.6.4.1 General

Beam refinement is a request/response based process. A STA requests receive beam refinement training by sending a BRP frame with a nonzero value in the L-RX field. The STA that receives the BRP frame shall respond with a BRP PPDU (20.9.2.2) including as many TRN-R subfields as indicated in the value of the L-RX field within the received BRP frame and with the RX-train-response field in the DMG Beam Refinement element set to 1.

A STA requests transmit beam refinement training by sending a BRP frame as follows. In the BRP Request field, the TX-TRN-REQ field is set to 1, and the FBCK-REQ field indicates the feedback type. The Sector ID Order Requested subfield in the FBCK-REQ field shall be set to 0. In the TXVECTOR, the PPDU_TYPE parameter is set to TRN-T-PACKET, and the TRN_LEN parameter indicates the number of AGC and TRN-T subfields appended to the PPDU.

The responding STA shall reply to the transmit beam refinement training with a BRP frame containing a DMG Beam Refinement element with the TX-TRN-OK field and TX-train-response field both set to 1 and the BS-FBCK field set to indicate the TRN-T subfield on which the responding STA received the best signal (the determination of best signal is implementation dependent). The FBCK-TYPE field shall be set to according to the format of the Channel Measurement Feedback element, if one is included in the frame. If the SNR Present and Channel Measurement Present subfields of this FBCK-TYPE field are set to 0, the Channel Measurement Feedback element shall not be included. The number of taps indicated in the FBCK-TYPE field shall be less than or equal to the number of taps indicated in the FBCK-REQ field of the request frame.

If a STA requests transmit beam refinement training, but does not send TRN-T subfields, the responding STA shall reply with a BRP frame containing a DMG Beam Refinement element with the TX-TRN-OK field set to 1. In this case (i.e., when the TX-train-response field is equal to 0), the responding STA shall set L-RX field to 0. The requesting STA shall then transmit a BRP PPDU with TRN-T subfields. The responding STA shall then respond with a BRP frame with the TX-train-response field set to 1 and the BS-FBCK and Channel Measurement Feedback element as above.

Beam refinement can be performed following SLS (10.42.6.4.3). If the responder receives an SSW-Feedback frame from the AP or PCP in an A-BFT, the AP or PCP allocates an SP for the beam refinement if required (see 10.42.5.3). A STA may transmit a BRP PPDU to another STA whenever the STA transmits a frame to that STA, provided that the transmitting STA knows that the recipient STA's receive antennas are directed to it or are in a quasi-omni antenna pattern.

A STA shall set the Initiator field to 1 within a DMG Beam Refinement element if the previous received frame was not a BRP frame, or the last PPDU the STA transmitted was a BRP frame with the Initiator field set to 1.

A STA that has transmitted a BRP frame with the Initiator field set to 1 and has not received a response BRPIFS after the transmission may retransmit the frame.

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A STA may request a TXSS sector list feedback by sending a BRP frame with the TXSS-FBCK-REQ field set to 1, the SNR Requested subfield within the FBCK-REQ field set to 1 and the remaining subfields within the FBCK-REQ field set to 0. The responding STA shall respond with a BRP frame with the SNR Present subfield within the FBCK-TYPE field set to 1 and Sector ID Order Present subfield set to 1, with a list of sector IDs indicating the sector IDs of the received SSW frames or DMG Beacon frames, and with the SNR values with which those frames were received in the last TXSS. The Number of Measurements subfield in the FBCK-TYPE field is set to indicate the number of sectors received during the last SLS for which an SNR measurement is included.

A STA shall not set the TXSS-FBCK-REQ and the TX-TRN-REQ fields to 1 in the same BRP frame.

Two or more BRP frames shall not be aggregated in the same A-MPDU. A BRP frame may be aggregated with another frame in the same A-MPDU only if the other frame is a single Ack, BA or QoS Null frame.

The Duration field within each BRP frame is set to the time remaining until the end of the current allocation, when transmitted within an SP. Otherwise it is set to the time remaining until the end of the TXOP.

10.42.6.4.2 Beam refinement transaction

A beam refinement transaction is a set of BRP frames composed of request and responses.

A beam refinement transaction starts with the beamforming initiator STA sending a BRP frame with the Initiator field set to 1.

A beam refinement responder is a STA that receives a BRP frame (which is directed to it) with the Initiator field set to 1.

A beam refinement transaction participant shall respond to a BRP frame with a BRP frame.

If the beam refinement transaction initiator received a BRP frame from the responder with no training requests, the initiator may terminate the transaction by not transmitting any further BRP PPDUs.

Figure 10-86, Figure 10-87, and Figure 10-88 show examples of beam refinement transactions.

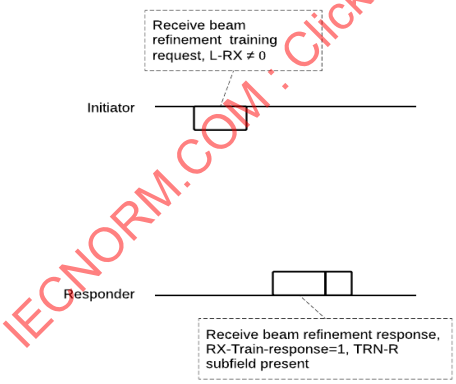

Figure 10-86—Example beam refinement transaction (receive training)

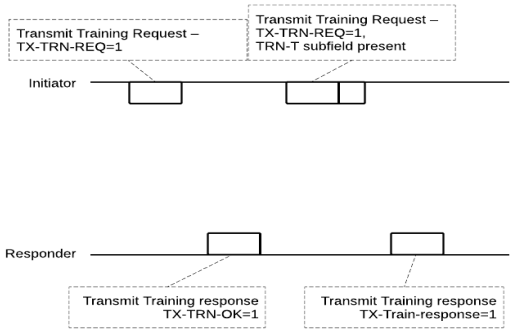

Figure 10-87—Example beam refinement transaction (transmit training)

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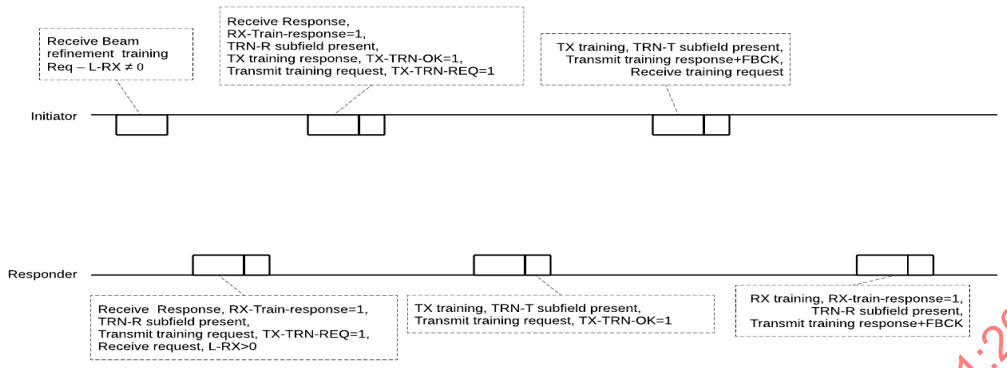

Figure 10-88—Example beam refinement transaction (combination of receive and transmit training)

10.42.6.4.3 Beam refinement transaction after SLS

If either L-RX or TX-TRN-REQ is nonzero within the BRP Request field in the SSW-Ack frame of the most recent SLS phase execution, no MID or BC was granted during the BRP setup subphase, and no beam refinement transaction has been done since the most recent SLS phase execution, then the initiator shall initiate the beam refinement transaction with the responder by sending a BRP frame to the responder. If the value of the L-RX field is greater than 0 in the SSW-Ack frame, the first BRP frame the initiator transmits to the responder is a BRP-RX frame. If the value of the L-RX field is 0 and the value of the TX-TRN-REQ field is 1, the first BRP frame the initiator transmits to the responder shall have either the TX-TRN-OK field set to 1 or the L-RX field greater than 0.

10.42.6.4.4 Antenna configuration setting during a beam refinement transaction

A STA that has requested beam refinement receive training shall, except when receiving TRN-R subfields, set its receive antenna configuration to the best known receive antenna configuration based on previous beam refinement receive training or RXSS. If the STA has not received a BRP frame since the last SLS and the SLS did not include an RXSS, the STA should set its receive antenna configuration to a quasi-omni antenna pattern in the DMG antenna through which the STA received the best sector during the SLS.

A STA that receives a beam refinement transmit training request shall send the response frame and then set its antenna configuration to the best known receive antenna configuration based on previous beam refinement receive training or RXSS, except if both the initiator STA and responder STA support the Other_AID subfield as indicated through the Supports Other_AID field set to 1 within the STA's DMG Capabilities element and the value of the Other_AID subfield within the BRP Request field is different from 0, in which case the STA sets its antenna configuration to the best known receive antenna configuration for receiving from the STA with AID equal to the value of the Other_AID subfield within the BRP Request field. If the STA has not received a BRP frame since the last SLS and the SLS did not include an RXSS, the STA should set its antennas to a quasi-omni antenna pattern.

In a BRP-RX PPDU, all TRN-R subfields shall be transmitted using the same TX AWV configuration as the preamble and data fields of the PPDU, except if both the transmitting and receiving STAs support the Other_AID subfield as indicated through the Supports Other_AID field set to 1 within the STA's DMG Capabilities element and the value of the Other_AID subfield within the BRP Request field is different from 0, in which case the TRN-R subfields shall be transmitted using the best known TX AWV

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configuration for transmitting to the STA with AID equal to the value of the Other_AID subfield within the BRP Request field.

A STA that sets to 1 the Antenna Pattern Reciprocity subfield in the DMG STA Capability Information field in the DMG Capabilities element it transmits and that receives a BRP-RX PPDU from a peer STA that also sets to 1 the Antenna Pattern Reciprocity subfield in the DMG STA Capability Information field of the peer's DMG Capabilities element it transmits shall use the same AWV that was configured with the BRP-RX PPDU in subsequent transmissions and receptions with the peer STA during the DTI. This allows STAs that use reciprocity to shorten the beamforming training time.

A STA that sets to 1 the Antenna Pattern Reciprocity subfield in the CMMG Capabilities Info field in the CMMG Capabilities element it transmits and that receives a BRP-RX PPDU from a peer STA that also sets to 1 the Antenna Pattern Reciprocity subfield in the CMMG Capabilities Info field in the CMMG Capabilities element it transmits shall use the same AWV that was configured with the BRP-RX PPDU in subsequent transmissions and receptions with the peer STA during the DTI. This allows STAs that use reciprocity to shorten the beamforming training time.

10.42.7 Beam tracking

A STA (beam tracking initiator) may request a peer STA (beam tracking responder) to provide receive beam tracking training signals to the initiator on the next PPDU transmitted by the responder. The initiator does this by setting, in a transmitted PPDU, the TXVECTOR parameter BEAM_TRACKING_REQUEST to BEAM-TRACKING-REQUESTED, TRN_LEN to the number of requested TRN subfields as described in 20.9.2.2.3 and PPDU_TYPE to TRN-R. Otherwise, the BEAM_TRACKING_REQUEST parameter shall be set to BEAM-TRACKING-NOT-REQUESTED.

A beam tracking responder that receives a PPDU with the BEAM_TRACKING_REQUEST parameter in the RXVECTOR set to BEAM-TRACKING-REQUESTED and the PPDU_TYPE in the RXVECTOR set to TRN-R shall follow the rules described in 20.9.2.2 and shall include a beam refinement AGC field and TRN-R subfields appended to the next PPDU that is transmitted to the initiator in the same allocation and that employs an MCS index greater than 0. The value of the TRN_LEN parameter in the TXVECTOR of that PPDU shall be equal to the value of the TRN_LEN parameter in the RXVECTOR of the PPDU from the initiator. A responder may ignore a request for beam tracking within an allocation if it has no PPDUs with an MCS index greater than 0 to transmit to the initiator within the allocation.

A beam tracking initiator requesting transmit beam tracking shall set the BEAM_TRACKING_REQUEST parameter in the TXVECTOR to BEAM-TRACKING-REQUESTED, PPDU_TYPE to TRN-T, TRN_LEN to the number of TRN Units as described in 20.9.2.2.3, and append an AGC field and TRN-T subfields to the PPDU. A beam tracking initiator shall not initiate transmit beam tracking if the beam tracking responder has indicated lack of support by setting the DMG STA Beam Tracking Time Limit field to zero. The beam tracking responder may aggregate the feedback inside an A-MPDU in a frame sent from the responder to the initiator according to the rules specified in 10.42.6.4.1. The initiator may allocate time for the feedback through a reverse direction grant, provided the reverse direction protocol is supported by both the initiator and responder. The feedback type shall be the same as the feedback type in the last BRP frame that was transmitted from the initiator to the responder with TX-TRN-REQ equal to 1. If the responder has never received a BRP frame from the initiator with TX-TRN-REQ equal to 1, the responder shall respond with all subfields of the FBCK-TYPE field equal to 0 and set the BS-FBCK field to the index of the TRN-T subfield that was received with the best quality.

A beam tracking initiator may also request a beam tracking responder to perform receive beam tracking by setting the TXVECTOR parameter BEAM_TRACKING_REQUEST to BEAM-TRACKING-NOT-REQUESTED, the TRN_LEN parameter to a nonzero value, the PPDU_TYPE parameter to TRN-R, and append an AGC field and TRN-R subfields to the transmitted PPDU.

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A beam tracking responder that receives a PPDU with the BEAM_TRACKING_REQUEST parameter in the RXVECTOR equal to BEAM-TRACKING-NOT-REQUESTED, the TRN_LEN parameter in RXVECTOR having a nonzero value and the PPDU_TYPE parameter in the RXVECTOR equal to TRN-R, shall follow the rules described in 20.9.2.2 and may use the beam refinement AGC field and TRN-R subfields appended to the received PPDU to perform receive beam training.

Figure 10-89 illustrates a beam tracking frame exchange sequence when the beam tracking initiator requests TRN-R subfields, while Figure 10-90 illustrates a beam tracking frame exchange sequence when the beam tracking initiator requests TRN-T subfields.

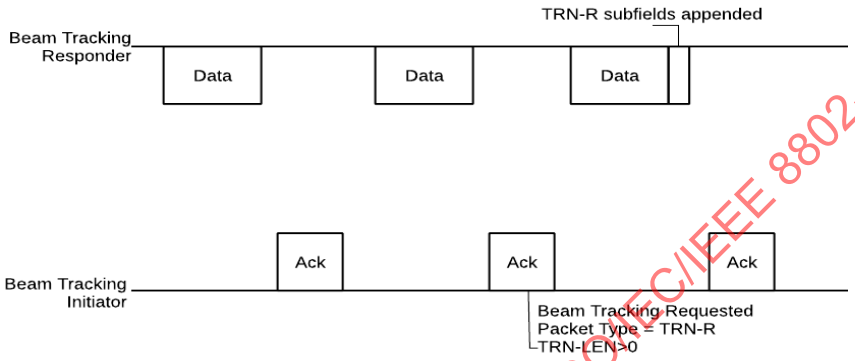

Figure 10-89—Example of beam tracking procedure with initiator requesting TRN-R

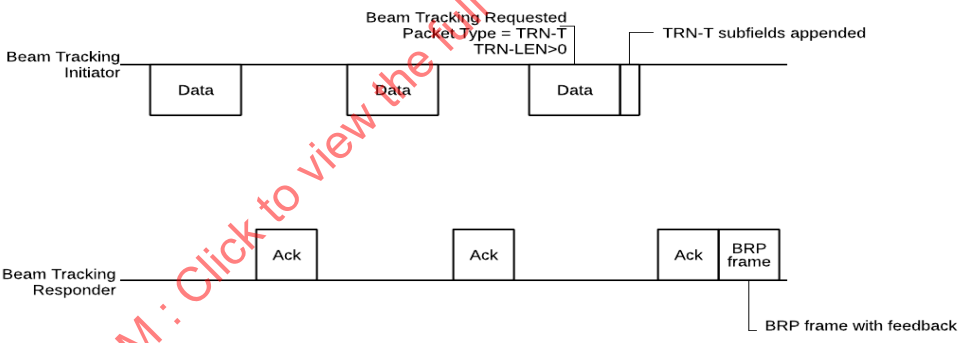

Figure 10-90—Example of beam tracking procedure with initiator requesting TRN-T

A beam tracking initiator may transmit to the beam tracking responder a PPDU requesting transmit beam tracking if at least one of the following conditions is met:

— The time since the last PPDU it transmitted to the beam tracking responder that requested transmit beam tracking is greater than the beam tracking time limit plus BRPIFS.

— A BRP frame with the channel measurement feedback from the beam tracking responder has been received.

If the beam tracking initiator does not receive the expected feedback from the beam tracking responder within a time period that is less than the beam tracking time limit of the last request, the beam tracking request has failed.

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If the initiator receives the expected feedback from the responder within a time period that is greater than or equal to the beam tracking time limit of the last request, the initiator should ignore it.

The time of arrival of the beam tracking responder's feedback is indicated by the PHY-RXEND.indication primitive of PPDU that contains the BRP MMPDU.

The time of transmit completion of the beam tracking initiator's PPDU is indicated by the PHY-TXEND.confirm primitive.

The beam tracking responder shall not transmit a BRP frame with feedback to the beam tracking initiator if the time period between PHY-RXEND.indication primitive of the PPDU that contains the beam tracking request and of PHY-TXEND.confirm primitive of the response BRP frame is longer than the beam tracking time limit.

The beam tracking time limit is based on the values of the DMG STA Beam Tracking Time Limit field received from the peer STA in the DMG Capabilities element and the dot11BeamTrackingTimeLimit. The beam tracking time limit is determined according to Table 10-31.

Table 10-31—Beam tracking time limit determination

DMG STA Beam Tracking Time Limit field from peer STA - denoted A	dot11BeamTrackingTime Limit - denoted B	A vs. B	Beam tracking time limit
0	0	NA	Transmit beam tracking is not supported
>0	0	NA	
0	>0	NA	
>0 and < 65 535	>0 and < 65 535	A ≥ B	A
>0 and < 65 535	>0 and < 65 535	A < B	B
65 535	>0 and < 65 535	NA	B
>0 and < 65 535	65 535	NA	A
65 535	65 535	NA	Default dot11BeamTrackingTimeLimit value

NOTE 1—If the beam tracking responder has not included the DMG STA Beam Tracking Time Limit field in the DMG Capabilities element, the beam tracking initiator cannot tell whether the procedure failed. Retransmission is therefore implementation dependent.

NOTE 2—The signaling that beam tracking is not supported by setting the DMG STA Beam Tracking Time Limit field to zero is deprecated.

10.42.8 State machines

Figure 10-91 depicts an example state machine of the SLS phase for the initiator, and Figure 10-92 illustrates an example state machine of the SLS phase for the responder. These state machines describe the behavior of the initiator and responder during BF and are applicable for any period of the beacon interval where BF is performed.

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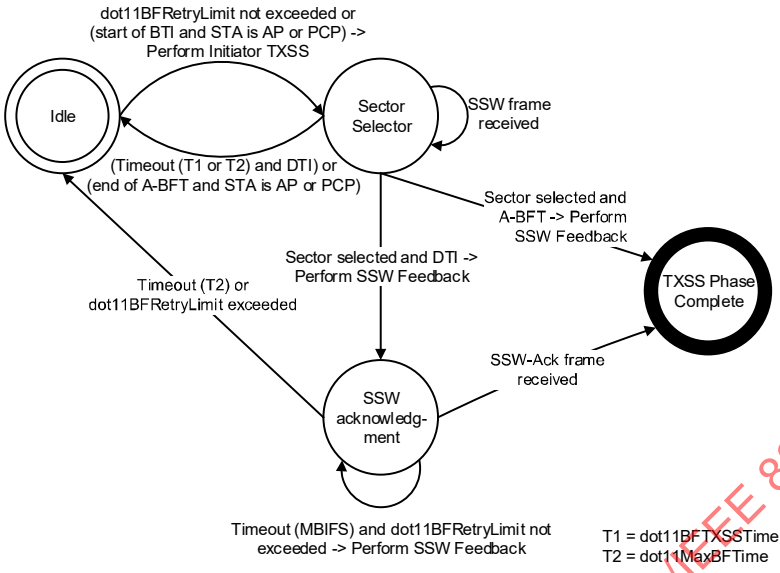

Figure 10-91—SLS phase state machine (initiator)

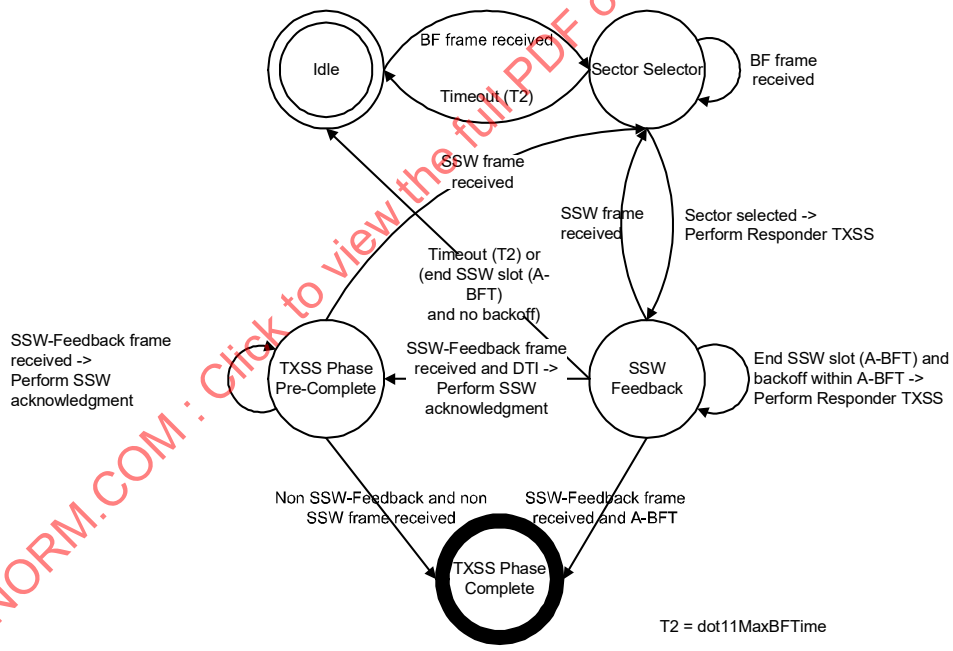

Figure 10-92—SLS phase state machine (responder)

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10.42.9 CDMG enhanced beam tracking

In addition to the beam tracking mechanism in 10.42.7, the CDMG enhanced beam tracking mechanism enables CDMG communicating STA pairs to measure and switch to an alternative link to reduce the link outage probability induced by an unexpected blockage or a rapid antenna rotation. The alternative link is a

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suboptimal link configured by a pair of CDMG STAs during the SLS phase or the BRP phase. The enhanced beam tracking mechanism extends the capabilities on the basis of the beam tracking mechanism in 10.42.7. A pair of CDMG STAs may perform beam tracking (see 10.42.7) and enhanced beam tracking described in this subclause simultaneously.

The Enhanced Beam Tracking Supported subfield in the CDMG STA Capability Information field of a CDMG STA's CDMG Capabilities element is set to 1 to indicate that the CDMG STA supports enhanced beam tracking.

The initial alternative link of the peer STA under enhanced beam tracking is configured in the BRP phase. Specifically, in the first BRP phase after the SLS, the initiator STA returns the sector and DMG antenna IDs of the alternative link to the responder STA, via transmitting the SSW Report element or the Enhanced Beam Tracking element in the BRP frame(s). The responder STA shall specify the alternative TX AWV according to the received Report Info field in the SSW Report element or the Peer TX Antenna Parameter field in the Enhanced Beam Tracking element. For the BRP phase, the index of the TRN-T subfield that was received with the second best quality in the last received BRP-TX PPDU is included in the Enhanced Beam Tracking element to specify the alternative TX AWV. The alternative link is not used for the current data transmission.

During the enhanced beam tracking phase, if a pair of STAs is operating on the link that is selected with best quality after SLS or BRP phase, switching to alternative link may be required if the signal quality of the current link deteriorates significantly based on the measurement results of e-TRN-R/T. If switching to alternative link is required, the initiator shall set the Switching to Backup AWV Request subfield of the Enhanced Beam Tracking element of the transmitted BRP frame to 1. If the initiator receives an Enhanced Beam Tracking element with the Switching to Backup AWV Enabled subfield set to 1 in the following BRP frame from the responder, the initiator and responder shall switch to the alternative link before transmitting the next frame. After switching to the alternative link, the initiator and responder shall set the last link as the new alternative link.

A CDMG STA (beam tracking initiator) may request a peer CDMG STA (beam tracking responder) to perform enhanced receive beam tracking by setting, in a transmitted PPDU, the TXVECTOR parameter ENHANCED_BEAM_TRACKING_REQUEST to ENHANCED-BEAM-TRACKING-REQUESTED, the TRN_LEN parameter to the number of requested TRN Units as described in 24.9.2.2.3, and PPDU_TYPE to TRN-R. Otherwise, the ENHANCED_BEAM_TRACKING_REQUEST parameter shall be set to ENHANCED-BEAM-TRACKING-NOT-REQUESTED.

An enhanced beam tracking responder that receives a PPDU with ENHANCED_BEAM_TRACKING_REQUEST parameter in the RXVECTOR equal to ENHANCED-BEAM-TRACKING-REQUESTED and the PPDU_TYPE parameter in the RXVECTOR equal to TRN-R) shall follow the rules described in 24.9.2.2 and shall include a beam refinement AGC field, TRN-R subfields, STF, and CE field appended to the next PPDU transmitted to the initiator. The value of the TRN_LEN parameter in the TXVECTOR of that PPDU shall be set to the value of the TRN_LEN parameter in the RXVECTOR of the PPDU from the initiator.

An enhanced beam tracking initiator requesting enhanced transmit beam tracking shall set the ENHANCED_BEAM_TRACKING_REQUEST parameter in the TXVECTOR to ENHANCED-BEAM-TRACKING-REQUESTED, the PPDU_TYPE to TRN-T, and the TRN_LEN parameter to the number of TRN Units as described in 24.9.2.2.3 and append an AGC field, TRN-R subfields, an STF, and a CE field to the PPDU. The enhanced beam tracking responder may aggregate the feedback inside an A-MPDU in a frame sent from the responder to the initiator according to the rules specified in 10.42.6.4.1. The initiator may allocate time for the feedback through a reverse direction grant, provided the reverse direction protocol is supported by both the initiator and responder. The Feedback Type field shall be set to the value of the Feedback Type field in the last BRP frame that was transmitted from the initiator to the responder with the TX-TRN-REQ subfield set to 1. If the responder has never received a BRP frame from the initiator with the TX-TRN-REQ subfield is equal to 1, the responder shall respond with all subfields of the FBCK-TYPE field set to 0 and set the

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BS-FBCK field to the best sector. If switching to the alternative link is required, the initiator shall set the Switching to Backup AWV Request subfield to 1 within the Enhanced Beam Tracking element within the transmitted BRP frame. The responder should respond with an Enhanced Beam Tracking element with the Switching to Backup AWV Enabled subfield set to 1 in the following BRP frame. If the Enhanced Beam Tracking element with the Switching to Backup AWV Enabled subfield set to 1 is transmitted or received, the initiator and responder shall switch to the alternative link before the next frame. After switching to the alternative link, the initiator and responder shall both set the last link as the new alternative link.

An enhanced beam tracking initiator may also request a beam tracking responder to perform receive beam tracking by setting, in a transmitted PPDU, the ENHANCED_BEAM_TRACKING_REQUEST parameter in the TXVECTOR to ENHANCED-BEAM-TRACKING-REQUESTED, the TRN_LEN parameter to a nonzero value, and the PPDU_TYPE parameter to 0 and appending an AGC field, TRN-R subfields, an STF, and a CE field to the transmitted PPDU.

A beam tracking responder that receives a PPDU with the ENHANCED_BEAM_TRACKING_REQUEST parameter in the RXVECTOR equal to ENHANCED-BEAM-TRACKING-REQUESTED, the TRN_LEN parameter not equal to 0, and the PPDU_TYPE parameter equal to 0 shall follow the rules described in 24.9.2.2 and may use the beam refinement AGC field, TRN-R subfields, STF, and CE field appended to the received PPDU to perform receive beam tracking. If the switching to the alternative link is required, the responder shall set the Switching to Backup AWV Request subfield within the Enhanced Beam Tracking element within the transmitted BRP frame to 1. The initiator should respond with an Enhanced Beam Tracking element with the Switching to Backup AWV Enabled subfield set to 1 in the following BRP frame. If the Enhanced Beam Tracking element with the Switching to Backup AWV Enabled subfield set to 1 is transmitted or received, the initiator and responder shall switch to the alternative link before the next frame. After switching to the alternative link, the initiator and responder shall both set the last link as the new alternative link.

The CDMG STAs that switched to the alternative link that is a suboptimal link after SLS or BRP phase should measure the quality of the original optimal beam link (the new alternative link) during the subsequent frames exchange. The initiator should transmit a beam tracking request to the responder to switch to the new alternative link if the new alternative link has a better link quality. The decision process of switching to the alternative link is implementation dependent and beyond the scope of this standard.

BRP frames transmitted during enhanced beam tracking may be aggregated within A-MPDUs. Figure 10-93 illustrates a beam tracking frame exchange sequence when the beam tracking initiator requests TRN-R subfields, while Figure 10-94 illustrates a beam tracking frame exchange sequence when the beam tracking initiator requests TRN-T subfields.

An example of beam tracking and switching for enhanced beam tracking is shown in Annex W.3.

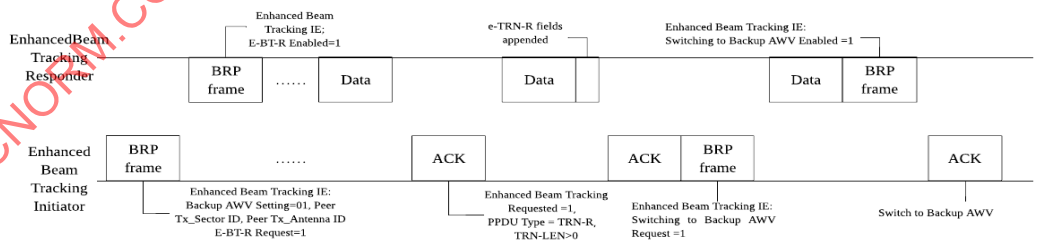

Figure 10-93—Example of an enhanced beam tracking procedure with the initiator requesting TRN-R

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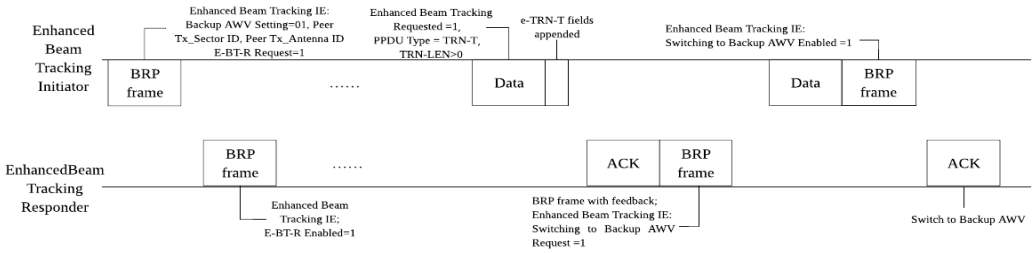

Figure 10-94—Example of an enhanced beam tracking procedure with the initiator requesting TRN-T

10.43 DMG link adaptation

10.43.1 General

A STA may transmit a Link Measurement Request frame to request a STA indicated in the RA field of the frame to respond with a Link Measurement Report frame (9.6.6.5). If the Link Measurement Request frame is sent within a PPDU defined in Clause 20, the Link Measurement Report frame shall contain the DMG Link Margin element. The requesting STA may use values of the MCS, of the SNR and of the Link Margin to transmit frames to the STA indicated in the RA field of the Link Measurement Request frame.

The requesting STA may aggregate a Link Measurement Request frame in an A-MPDU as defined in Table 9-530 and Table 9-533.

If the Dialog Token field in the Link Measurement Request frame is nonzero, the responding STA shall perform the measurement on the next frame received from the requesting STA and shall send back a Link Measurement Report frame corresponding to the received frame.

The responding STA may aggregate a Link Measurement Report frame in an A-MPDU as defined in Table 9-530 and Table 9-533.

The DMG STA whose MAC address equals the value of the Link Measurement Request frame RA field shall transmit a Link Measurement Report frame addressed to the requesting STA. The RA field of the Link Measurement Report frame shall be equal to the TA field of the Link Measurement Request frame.

If the Dialog Token field in the Link Measurement Report frame is equal to the nonzero Dialog Token field of the Link Measurement Request frame, then the MCS, SNR, and Link Margin fields of the Link Measurement Report frame shall be computed using the measurements of the PPDU that is the next frame received from the requesting STA.

If the Dialog Token field in the Link Measurement Request frame is equal to 0, the responding STA may set the MCS field in the Link Measurement Report frame to the MCS value computed based on any of the received frames from the requesting STA.

The SNR field and Link Margin field in the Link Measurement Report frame shall indicate the corresponding measurements based on the reception of the PPDU that was used to generate the MCS feedback contained in the same Link Measurement Report frame.

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The Link Measurement Request and Report frames can be used to obtain link margin information, which can be used to determine appropriate action by the requesting STA (e.g., change MCS or control transmit power or initiate FST).

A STA may send an unsolicited Link Measurement Report frame with the Dialog Token field set to 0.

10.43.2 DMG TPC

A DMG STA that receives a Link Measurement Report frame containing a DMG Link Margin element that indicates increase or decrease transmit power behaves according to the following rules:

— If the STA implements the recommendation indicated in the Activity field of the Link Measurement Report, it shall send a Link Measurement Report frame containing a DMG Link Adaptation Acknowledgment element. The Activity field of the DMG Link Adaptation Acknowledgment element shall be set to the value of the Activity field in the received DMG Link Margin Subelement.

— If the STA does not implement the recommendation indicated in the Activity field of the Link Measurement Report, it may send a Link Measurement report containing a DMG Link Adaptation Acknowledgment element. The Activity field of the DMG Link Adaptation Acknowledgment element shall be set to 0, indicating that the STA did not change its transmit power.

— A STA shall not send a Link Measurement Report later than 2×aPPDUMaxTime after it acknowledged the reception of the Link Measurement report.

A DMG STA shall not include the DMG Link Adaptation Acknowledgment element in a Link Measurement Report frame, unless the frame is being transmitted in response to a Link Measurement Report frame whose Activity field is equal to increase or decrease transmit power.

10.43.3 Fast link adaptation

A STA indicates support for fast link adaptation by setting the Fast Link Adaptation field in the STA's DMG Capabilities element to 1. A STA that does not support fast link adaptation sets the Fast Link Adaptation field in the STA's DMG Capabilities element to 0. A STA that supports fast link adaptation shall not initiate fast link adaptation with a peer STA that does not support fast link adaptation.

A STA that supports fast link adaptation shall support the reverse direction protocol (see 10.29). The STA that transmits a Link Measurement Request frame as part of fast link adaptation shall be the RD initiator and the STA that responds with a Link Measurement Report frame shall be the RD responder. Transmission of Link Measurement Request, Link Measurement Report and the frames defined below shall follow the rules of the reverse direction protocol.

A STA initiates fast link adaptation by transmitting a Link Measurement Request frame that is of subtype Action No Ack and has its Dialog Token field set to 0. The PPDU containing the frame shall have the AGGREGATION parameter in the TXVECTOR set to AGGREGATED, shall not contain any other frame that requires immediate response, and shall have a duration (as determined by the PHY-TXTIME.confirm primitive defined in 6.5.6) that is greater than aMinPPDUDurationForDMGMeasurement.

NOTE—The PPDUs have the AGGREGATION parameter in the TXVECTOR set to AGGREGATED to allow padding of the PSDUs with MPDU delimiters of size 0, therefore meeting the transmission duration requirement.

A STA that supports fast link adaptation and receives a Link Measurement Request frame of subtype Action No Ack, with the Dialog Token field equal to 0 and contained in a PPDU with the AGGREGATION parameter in the RXVECTOR equal to AGGREGATED shall respond with a Link Measurement Report frame in no longer than BRPIFS from the reception of the Link Measurement Request frame. The TPC Report element, DMG Link Margin element and other fields transmitted in the Link Measurement Report

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frame shall reflect measurements on the PPDU that contained the last received Link Measurement Request frame from the initiating STA.

The STA responding with the Link Measurement Report frame shall keep the IFS not longer than SIFS by transmitting PPDUs that do not contain frames requiring immediate response and that have a duration that is greater than aMinPPDUDurationForDMGMeasurement. All transmitted PPDUs should use the same MCS and the same transmit power.

The transmitted Link Measurement Report frame shall be of subtype Action No Ack, shall be sent using MCS 1, and shall be sent within a PPDU with the AGGREGATION parameter in the TXVECTOR set to AGGREGATED. In addition, the PPDU shall not contain any frame that requires immediate response and shall have a duration that is greater than aMinPPDUDurationForDMGMeasurement.

If at least one of the conditions above for the transmission of the Link Measurement Report frame is not met, the STA may follow the rules in 10.43.1 to respond to the received Link Measurement Request frame.

A STA that supports fast link adaptation and that receives a Link Measurement Report frame should respond with an unsolicited Link Measurement Report frame in no longer than BRPIFS from the reception of the Link Measurement Report frame. The TPC Report element, DMG Link Margin element and other fields transmitted in the unsolicited Link Measurement Report frame shall reflect measurements taken on one or more of the PPDUs received by the STA transmitting the unsolicited Link Measurement Report frame, starting with the received Link Measurement Report frame itself. If the unsolicited Link Measurement Report frame is transmitted longer than SIFS from the reception of the Link Measurement Report frame, the STA transmitting the unsolicited Link Measurement Report frame shall keep the IFS not longer than SIFS by transmitting one or more PPDUs before issuing the unsolicited Link Measurement Report frame.

An example of the fast link adaptation procedure is shown in Figure 10-95.

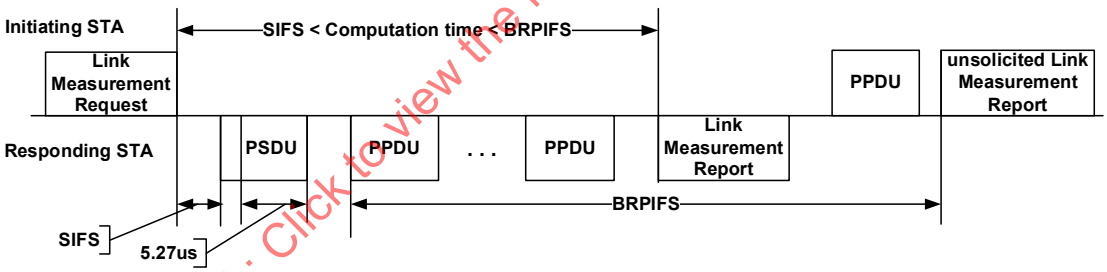

Figure 10-95—Example of fast link adaptation procedure

10.44 Link adaptation using the CMMG link measurement

10.44.1 General

A STA may transmit a Link Measurement Request frame to request a STA indicated in the RA field of the frame to respond with a Link Measurement Report frame (9.6.6.5) in SC transmission. If the Link Measurement Request frame is sent within a PPDU defined in Clause 25, the Link Measurement Report frame shall contain the CMMG Link Margin element. The requesting STA may use values of the MCS, of the SNR, and of the link margin to transmit frames to the STA indicated in the RA field of the Link Measurement Request frame.

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The requesting STA may aggregate a Link Measurement Request frame in an A-MPDU as defined in Table 9-530 and Table 9-533.

If the Dialog Token field in the Link Measurement Request frame is nonzero, the responding STA shall perform the measurement on the next frame received from the requesting STA and shall send back a Link Measurement Report frame corresponding to the received frame.

The responding STA may aggregate a Link Measurement Report frame in an A-MPDU as defined in Table 9-530 and Table 9-533.

A CMMG STA with MAC address that is equal to the value of the Link Measurement Request frame RA field shall transmit a Link Measurement Report frame addressed to the requesting STA. The RA field of the Link Measurement Report frame shall be equal to the TA field of the Link Measurement Request frame.

If the Dialog Token field in the Link Measurement Report frame is equal to the nonzero Dialog Token field of the Link Measurement Request frame, the MCS, SNR, and Link Margin fields of the Link Measurement Report frame shall be computed using the measurements of the PPDU that is the subsequent frame following the Link Measurement Request frame.

If the Dialog Token field in the Link Measurement Request frame is equal to 0, the responding STA may set the MCS field in the Link Measurement Report frame to the MCS value computed based on any of the received frames from the requesting STA.

The SNR field and Link Margin field in the Link Measurement Report frame shall indicate the corresponding measurements based on the reception of the PPDU that was used to generate the MCS feedback contained in the same Link Measurement Report frame.

The Link Measurement Request and Link Measurement Report frames can be used to obtain link margin information, which can be used to determine appropriate action by the requesting STA (e.g., change MCS or control transmit power or initiate FST).

A STA may send an unsolicited Link Measurement Report frame with the Dialog Token field set to 0.

10.44.2 CMMG TPC

A CMMG STA that receives a Link Measurement Report frame containing a CMMG Link Margin element that indicates Increase or Decrease Transmit power behaves according to the following rules:

— If the CMMG STA intends to implement the recommendation indicated in the Activity field of the Link Measurement Report frame, it shall implement the change and send a Link Measurement Report containing a CMMG Link Adaptation Acknowledgment element not later than 2×aPPDUMaxTime after it acknowledged the reception of the Link Measurement Report frame. The Activity field of the CMMG Link Adaptation Acknowledgment element shall be set to the value of the Activity field in the received CMMG Link Margin subelement.

— If the CMMG STA does not implement the recommendation indicated in the Activity field of the Link Measurement Report frame, it may send the Link Measurement report containing a CMMG Link Adaptation Acknowledgment element no later than 2×aPPDUMaxTime after it acknowledges the reception of the Link Measurement Report frame. The Activity field of the CMMG Link Adaptation Acknowledgment element shall be set to 0, indication the STA prefers to not change transmit power.

A CMMG STA shall not include the CMMG Link Adaptation Acknowledgment element in a Link Measurement Report frame unless it is in response to a Link Measurement Report with the Activity field set to increase or decrease transmit power.

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10.44.3 CMMG fast link adaptation

A CMMG STA supports fast link adaptation if the Fast Link Adaptation field in the STA's CMMG Capabilities Info field is 1. Otherwise, the STA does not support fast link adaptation. A STA that supports fast link adaptation shall not use fast link adaptation with a peer STA that does not support fast link adaptation.

A STA that supports fast link adaptation shall support the reverse direction protocol (see 10.29).

The STA that transmits a Link Measurement Request frame as part of fast link adaptation shall be the RD initiator, and the STA that responds with a Link Measurement Report frame shall be the RD responder. Transmission of Link Measurement Request frame, Link Measurement Report frame, and the frames defined below shall follow the rules of the reverse direction protocol.

A STA initiates fast link adaptation by transmitting a Link Measurement Request frame that is of subtype Action No Ack and that has the Dialog Token field set to 0. The PPDU containing the frame shall have the AGGREGATION parameter in the TXVECTOR set to AGGREGATED, shall not contain any other frame that requires immediate response, and shall have a duration (as determined by the PHY-TXTIME.confirm primitive defined in 6.5.6) that is greater than 5.27 μs.

NOTE—The PPDUs have the AGGREGATION parameter in the TXVECTOR set to AGGREGATED to allow padding of the PSDUs with MPDU delimiters of size 0, therefore meeting the transmission duration requirement.

A STA that supports fast link adaptation and that receives a Link Measurement Request frame of subtype Action No Ack with the Dialog Token field equal to 0 and contained in a PPDU with the AGGREGATION parameter in the RXVECTOR equal to AGGREGATED shall respond with a Link Measurement Report frame in no longer than BRPIFS from the reception of the Link Measurement Request frame. The TPC Report element, CMMG Link Margin element and other fields transmitted in the Link Measurement Report frame shall reflect measurements on the PPDU that contained the last received Link Measurement Request frame from the initiating STA.

The STA responding with the Link Measurement Report frame shall keep the IFS not longer than a SIFS by transmitting PPDUs that do not contain frames requiring immediate response and that have a duration that is greater than 5.27 μs. All transmitted PPDUs should use the same MCS and the same transmit power.

The transmitted Link Measurement Report frame shall be of subtype Action No Ack, shall be sent using MCS 1, and shall be sent within a PPDU with the AGGREGATION parameter in the TXVECTOR set to AGGREGATED. In addition, the PPDU shall not contain any frame that requires immediate response and shall have a duration that is greater than 5.27 μs.

If at least one of the conditions above for the transmission of the Link Measurement Report frame is not met, the STA may follow the rules in 10.32.1 to respond to the received Link Measurement Request frame.

A STA that supports fast link adaptation and that receives a Link Measurement Report frame should respond with an unsolicited Link Measurement Report frame in no longer than BRPIFS from the reception of the Link Measurement Report frame. The TPC Report element, CMMG Link Margin element, and other fields transmitted in the unsolicited Link Measurement Report frame shall reflect measurements taken on one or more of the PPDUs received by the STA transmitting the unsolicited Link Measurement Report frame, starting with the received Link Measurement Report frame itself. If the unsolicited Link Measurement Report frame is transmitted longer than a SIFS from the reception of the Link Measurement Report frame, the STA transmitting the unsolicited Link Measurement Report frame shall keep the IFS not longer than a SIFS by transmitting one or more PPDUs before issuing the unsolicited Link Measurement Report frame.

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10.45 DMG relay operation

10.45.1 General

The DMG relay procedures are specified in 11.34. This subclause specifies the supported types of DMG relay.

DMG relay operation is not supported by an IBSS STA. dot11RelayActivated is false in an IBSS STA.

A source REDS, a destination REDS and an RDS can establish two types of relay operation:

— Link switching (10.45.2): If the direct link between the source REDS and destination REDS is disrupted, the source REDS redirects the transmission of frames addressed to the destination REDS via the RDS. The RDS forwards frames received from the source REDS to the destination REDS and from the destination REDS to the source REDS. Direct communication between the source REDS and destination REDS might resume after the direct link between them is recovered.

— Link cooperation (10.45.3): In this case, the RDS is actively involved in the direct communication between the source REDS and the destination REDS. A frame transmission from the source REDS to the destination REDS is simultaneously repeated by the RDS, which might possibly increase the signal quality received at the destination REDS.

10.45.2 Link switching

10.45.2.1 General

A source REDS that has successfully completed an RLS procedure with a destination REDS for which the value of the Cooperation-Mode subfield within the negotiated Relay Transfer Parameter Set element is 0 may use the selected RDS between the source REDS and destination REDS for the purpose of link switching. This is described in this subclause.

10.45.2.2 SP request and allocation

The source REDS uses the procedures described in 11.4 to request an SP allocation between itself and the destination REDS.

Upon receiving an ADDTS Request frame for which the source AID and the destination AID fields within the DMG TSPEC element are equal to a pair of a source REDS and a destination REDS, respectively, that have successfully completed the RLS procedure defined in 11.34.2.4, the AP or PCP schedules an SP with the source DMG STA as the source REDS and the destination DMG STA as the destination REDS.

An RDS shall check the value of the source AID and the destination AID fields of each SP allocation within an Extended Schedule element it receives in a DMG Beacon or Announce frame from the AP or PCP. If the value of the source AID and the destination AID fields of an SP allocation correspond to a source REDS and a destination REDS, respectively, that have successfully completed the RLS setup procedure (11.34.2), the RDS shall operate as an RDS during that SP allocation.

10.45.2.3 Usage of RDS

In link switching, an RDS operates either in FD-AF mode or in HD-DF mode. An RDS capable of FD-AF relaying shall be in one of two frame transmission modes:

— *Normal mode*: A pair of source REDS and destination REDS exchange frames via either the direct link or the relay link until this link is determined to become unavailable due to, for example, blockage or channel degradation.

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— *Alternation mode*: A source REDS and a destination REDS exchange frames via two separate links, where the use of each link alternates at each link change interval. The link change interval specifies the time instants at which a source REDS is allowed to change the link used for a frame transmission to the destination REDS as specified in 9.4.2.148.

An RDS that supports only HD-DF shall operate in the Normal mode.

The frame transmission mode is indicated in the Relay Transfer Parameter Set element exchanged by the source REDS, destination REDS, and RDS during the RLS procedure. A source REDS or destination REDS may change the transmission mode used in a relay link following successful transmission of RLS Request and RLS Response frames as described in 11.34.2.4.

An RDS shall start to operate as RDS at the start of an SP for which the value of the source AID and destination AID fields for that SP are equal to the source REDS and destination REDS, respectively, for which the RDS has successfully completed the RLS procedure. The RDS can determine the SPs for which it operates as an RDS upon reception of an Extended Schedule element.

10.45.2.4 Relay frame exchange rules

10.45.2.4.1 General

Following the completion of the RLS procedure and SP allocation, each of the source REDS, destination REDS, and RDS have a direct link with one another.

The values of link change interval and data sensing time are indicated within the Relay Transfer Parameter Set transmitted by the source REDS to the destination REDS during the RLS procedure. Either the link change interval period or the first period begins at the start of an SP between the source REDS and the destination REDS, and any transmission by the source REDS, destination REDS, and RDS within a link change interval period shall use the same link that is used at the start of the link change interval period. A new link change interval period starts immediately after another link change interval period, but shall not exceed the end of the SP.

In the normal mode, a source REDS shall use the direct link to initiate frame transmission to the destination REDS at the start of the first SP allocated between the source REDS and destination REDS for a particular TID. At the start of the following SP allocations for that same TID, the source REDS uses the last link in which a frame transmission to the destination REDS via this link was successful. In the alternation mode, the source DMG STA shall alternate the frame transmission to the destination REDS between direct frame transmission to the destination REDS and frame transmission through the RDS. The source REDS shall alternate the link used for a frame transmission at the start of each link change interval.

If a source REDS transmits a frame to the destination REDS via the direct link but does not receive an expected Ack frame or BlockAck frame from the destination REDS during a link change interval period, the source REDS should change the link used for frame transmission at the start of the following link change interval period and use the RDS to forward frames to the destination REDS.

If a source REDS transmits a frame to the destination REDS via the RDS but does not receive an expected Ack frame or BlockAck frame from the RDS during a link change interval period or a first period, the source REDS should change the link used for frame transmission at the start of the following link change interval period or the following first period and transmit frames directly to the destination REDS.

10.45.2.4.2 Additional frame exchange rules for FD-AF RDS

If the source REDS decides to change the link at the start of the following link change interval period and the Normal mode is used, the source REDS shall start its frame transmission after data sensing time from the

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start of the following link change interval period. If the Alternation mode is used, the source REDS alternates the link used for frame transmission at the start of each link change interval period, and the value of data sensing time is ignored.

In the Normal mode, if the destination REDS does not receive a valid frame from the source REDS within data sensing time after the start of a link change interval, the destination REDS shall immediately change the link to attempt to receive frames from the source REDS through the RDS. If the More Data subfield in the last frame received from the source REDS is equal to 0, then the destination REDS shall not switch to the link in the next link change interval period even if it does not receive a frame during the data sensing time. An example of frame transfer under Normal mode with FD-AF RDS is illustrated in Figure 10-96.

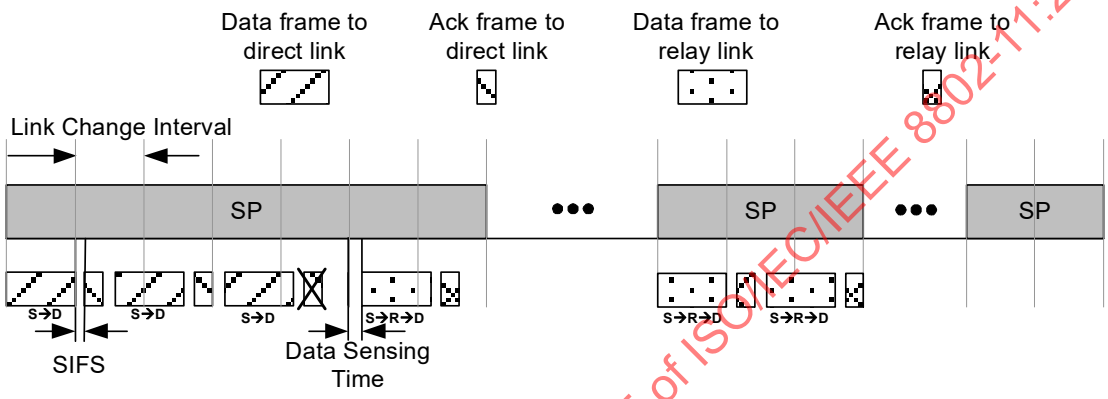

Figure 10-96—Example of Normal mode operation with FD-AF relay

In the Alternation mode, if the destination REDS receives an out of order frame, the destination REDS shall remain at the current link. If the More Data subfield in the last frame received from the source REDS is equal to 0, then the destination REDS shall not switch links in the next link change interval period. If the source REDS uses either the direct or the relay link and decides to resume alternate frame transmission, the source REDS should transmit a frame to the other link data sensing time after the next link change interval to inform the destination REDS that operation on the other link has been resumed. Note that this is the only situation when data sensing time is used in the Alternation mode.

10.45.2.4.3 Additional frame exchange rules for HD-DF RDS

When the RDS is operating as a HD-DF RDS and the RDS is used in the frame exchange between the source REDS and the destination REDS, the frame exchange is performed in two periods, which are repeated for as long as the RDS is used. In the first period, the source REDS shall transmit a frame to the RDS and then the RDS responds after SIFS if needed. In the second period, the RDS shall forward the frame received from the source REDS to the destination REDS, and then the destination REDS responds after SIFS if needed. The duration of the first period and the second period are specified in the last Relay Transfer Parameter Set element transmitted from the source REDS.

The first period and second period are valid only when the source REDS and destination REDS exchange frames via the RDS. The link change interval is valid only when the source REDS and destination REDS exchange frames via the direct link. The first period begins at the end of the link change interval when a change to the relay link occurs. The link change interval begins at the end of the second period when a change to the direct link occurs.

The source REDS may transmit a Relay Ack Request frame to the RDS to determine whether all frames forwarded through the RDS were received by the destination REDS. Upon reception of a Relay Ack Request

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frame, the RDS shall respond with a Relay Ack Response frame and set the BlockAck Bitmap field to indicate which frames have been received by the destination REDS.

If the source REDS decides to change to the relay link at the start of the following link change interval period, the source REDS shall start its frame transmission at the start of the following link change interval period. If the current link is the direct link and the destination REDS does not receive a valid frame from the source REDS within data sensing time after the start of each link change interval, the destination REDS shall change the link and consider the first period to begin at the start of the link change interval.

If a link change to the direct link occurs, the source REDS shall start to transmit a frame using the direct link at the end of the second period when the link change interval begins. The destination REDS shall switch to the direct link at each first period and listen to the medium toward the source REDS. If the destination REDS receives a valid frame from the source REDS, the destination REDS shall remain on the direct link and consider the link change interval to begin at the start of the first period. Otherwise, the destination REDS shall change the link at the start of the next second period and attempt to receive frames from the source REDS through the RDS. If the active link is the relay link and the More Data subfield in the last frame received from the RDS is equal to 0, then the destination REDS shall not switch to the direct link even if it does not receive any frame during the second period.

The source REDS that intends to use the block ack mechanism through the RDS shall perform the block ack setup procedure with the RDS using the same TID as it is used for the direct communication between the source REDS and the destination REDS. Similarly, the RDS shall perform the block ack setup procedure with the destination REDS before transmitting data using the block ack mechanism. Upon reception of an ADDBA Request frame from the source REDS, the RDS shall send an ADDBA Request frame to the destination REDS with the same content for all corresponding fields as the ADDBA Request frame received from the source REDS, except for Buffer Size field, which contains the buffer size of the RDS. Following the reception of the ADDBA Response frame from the destination REDS, the RDS shall send an ADDBA Response frame to the source REDS. The ADDBA Response frame shall have the same content for all corresponding fields as the ADDBA Response frame received from the destination REDS, except for the Buffer Size field, which shall be set to the minimum between the buffer size of the RDS and the destination REDS.

An example of frame transfer with HD-DF RDS is illustrated in Figure 10-97.

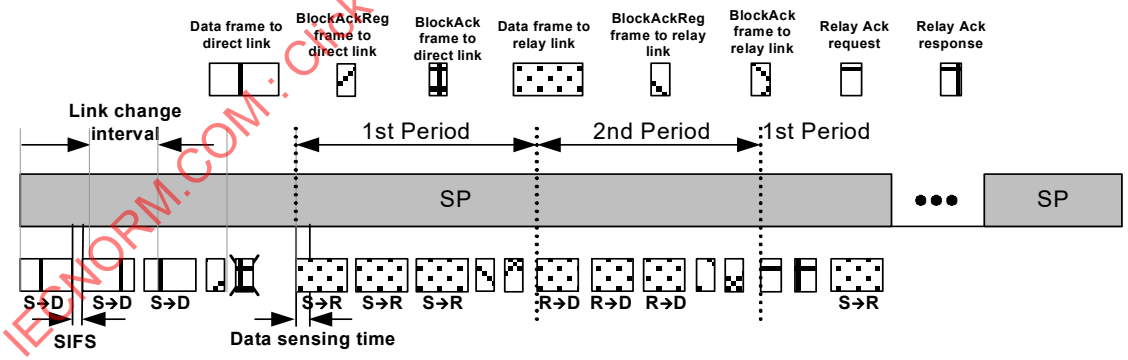

Figure 10-97—Example of operation with HD-DF relay

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10.45.2.4.4 Operation of FD-AF RDS

In an SP allocated for relay operation, a FD-AF RDS operates in an amplify-and-forward manner. This means that for each frame detected at the RF in the receive state within an SP in which it operates as a FD-AF RDS, the RDS amplifies the received signal and simultaneously retransmits it via the RF in transmit state.

At the start of the SP where it operates as a FD-AF RDS, the RDS shall initiate an RF antenna module in the receive state directed toward the source REDS and another RF antenna module in transmit state directed toward the destination REDS.

For each frame received at the RDS during the SP, the RDS shall follow the same rules for frame exchange sequences as described in Annex G and 10.39. This includes switching the state of each RF available to the RDS from receive to transmit, and vice versa, depending upon the frame type and its ack policy.

10.45.2.5 Link monitoring

After a link change, the source REDS might periodically monitor the quality of the previous link. To do that, the source REDS can use the link change mechanism described in 10.45.2.4. If the previous link is the relay link, the source REDS can acquire the channel status by using relay link measurement mechanism as described in 10.45.4. If the previous link is the direct link, the source REDS can acquire the channel status via the link adaptation mechanism defined in 10.42.9. If the channel quality of the previous link is better than the one on the current link, which is an implementation dependent decision, the source REDS may switch to the previous link.

10.45.3 Link cooperation

10.45.3.1 TPA procedure

A source REDS, a destination REDS, and an RDS use the common relay setup procedure defined in 11.34.2 to set up a link cooperation relay. In addition, to establish a link cooperation relay, the source REDS, destination REDS, and RDS shall perform the TPA procedure described in this subclause and shown in Figure 10-98.

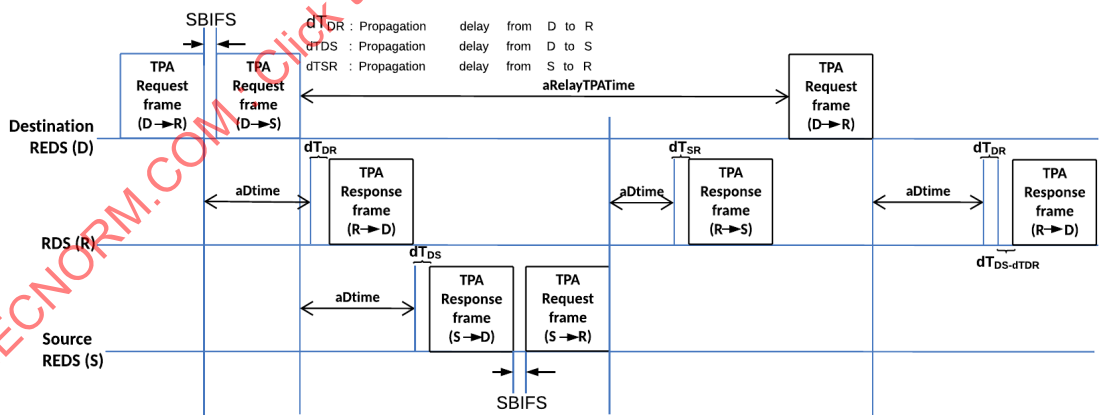

Figure 10-98—TPA mechanism

The TPA procedure is triggered by the destination REDS following the common relay setup procedure with the source REDS and RDS. First, the destination REDS uses the procedures described in 11.4 to request the

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allocation of an SP to perform TPA, wherein the source of the SP is the destination REDS and the destination of the SP is the source REDS. If the value of a source AID and the destination AID fields of an SP allocation correspond to a destination REDS and a source REDS, respectively, that have successfully completed the RLS setup procedure, a STA that performs as an RDS in that SP allocation shall operate during the allocation as a non-RDS-capable DMG STA.

Within the allocated SP, the destination REDS sends a TPA Request frame to the RDS and sets the Timing Offset field to 0 (see Figure 10-98). SBIFS following the end of the first TPA Request frame transmission, the destination REDS shall send the second TPA Request frame to the source REDS and set the Timing Offset field to 0. aDtime interval (11.37) following the reception of the first TPA Request frame, the RDS shall transmit a TPA Response frame back to the destination REDS. Upon receiving the TPA Response frame from the RDS, the destination REDS shall estimate the TPA value of the RDS and the time deviation (i.e., $2 \times dT_{DR}$) between the expected Dtime and the actual arrival time of the TPA Response frame. aDtime interval following the reception of the second TPA Request frame, the source REDS shall transmit a TPA Response frame back to the destination REDS. The destination REDS shall repeat the same procedure upon reception of the TPA Response frame received from the source REDS.

SBIFS following the end of the transmission of the TPA Response frame to the destination REDS, the source REDS shall send a TPA Request frame to the RDS and set the Timing Offset field to 0. aDtime interval following the reception of the TPA Request frame, the RDS shall transmit a TPA Response frame back to the source REDS. Upon reception of the TPA Response frame from the RDS, the source REDS shall estimate the TPA value of the RDS and the time deviation (i.e., $2 \times dT_{SR}$) between aDtime and the actual arrival time of the TPA Response frame.

At aRelayTPATime (11.37) from the end of the last TPA Request frame transmitted by the destination REDS to the source REDS, the destination REDS shall send a TPA Request frame to the RDS and set the Timing Offset field to $dT_{DS} - dT_{DR}$. Upon reception of the TPA Request frame, the RDS shall transmit a TPA Response frame to the destination REDS at $aDtime + dT_{DR} + (dT_{DS} - dT_{DR})$ from the end of the TPA Request frame. Upon reception of the TPA Response frame, the destination REDS shall estimate the time deviation [i.e., $2 \times dT_{DR} + (dT_{DS} - dT_{DR})$] between aDtime and the actual arrival time of the TPA Response frame. If the destination REDS determines that the estimated deviation is equal to $2 \times dT_{DR} + (dT_{DS} - dT_{DR})$, then the destination REDS considers that the TPA procedure was successful. As the last step of the TPA procedure, the destination REDS shall send a TPA Report frame to the source REDS that includes the information regardless of whether the last TPA procedure succeeded.

If it is not successful, the TPA procedure is repeated until it is successful or upon the decision of the destination REDS to stop performing the TPA procedure. The TPA procedure includes the estimation of the sampling frequency offset (SFO), in order for the source REDS and RDS to adjust their SFOs.

10.45.3.2 Link cooperation data transmission procedure

10.45.3.2.1 General

A source REDS that has successfully completed an RLS procedure with a destination REDS for which the value of the Cooperation-Mode subfield within the negotiated Relay Transfer Parameter Set element is equal to 1 and has successfully completed the TPA procedure shall use the selected RDS between the source REDS and destination REDS for the purpose of link cooperation. This is described in this subclause.

10.45.3.2.2 Cooperative transmission SP request and allocation

If the source REDS receives a TPA Report frame that indicates the successful completion of the TPA procedure with the RDS and the destination REDS, the source REDS uses the procedure in 11.4 to request an SP allocation with the destination REDS. The source REDS might use the SP allocation for communication with the destination REDS with the assistance of the RDS.

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10.45.3.2.3 Data transmission rules

As shown in the example of Figure 10-99, in the allocated SP the first time interval (T1) and the second time interval (T2) for a cooperative Data frame transfer are determined by the PPDU transmission time at each transmission from the source REDS to the destination REDS within the SP.

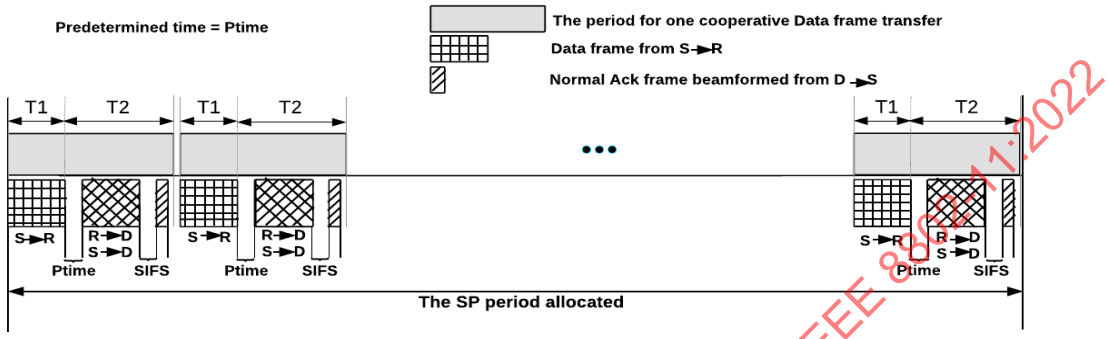

Figure 10-99—Example of data transmission in SP with link cooperation relay

The data transmission rules are as follows. At the start of each time T1, the source REDS transmits a frame with its transmit antenna pattern directed toward the RDS and with the TA and the RA fields in the MAC header set to the MAC address of the source REDS and destination REDS, respectively. After $Ptime + dT_{SR}$ from the start of T2, the source REDS retransmits the same frame sent to the RDS during the previous time T1 but now with its transmit antenna pattern directed toward the destination REDS. Similarly, after $Ptime + (dT_{DS} - dT_{DR})$ from the start of T2, the RDS retransmits the same frame it received from the source REDS during the previous time T1. So that the destination REDS might take advantage of the improved received signal level from both of these transmissions, the destination REDS should set its receive antenna pattern during T2 such that it simultaneously covers the links toward both the source REDS and the RDS.

10.45.4 Relay link adaptation

When a relay link is used for communication between a source REDS and a destination REDS, the link qualities of the S-R link, the R-D link, and the S-D link might be required.

The source REDS, destination REDS, and RDS use the procedure described in 10.42.9 to request and report the link quality among themselves with the following exception. In the Link Measurement Report frame the RDS transmits to the source REDS, the RDS shall include two Link Margin elements in this order:

— The first Link Margin element shall report the link quality between the source REDS and the RDS.
— The second Link Margin element shall report the link quality between the RDS and the destination REDS.

Upon reception of a Link Measurement Report frame, the source REDS might take several actions including changing the MCS it uses for frame transmission to the RDS and destination REDS.

10.46 S1G BSS operation

10.46.1 Basic S1G BSS functionality

An S1G STA has dot11S1GOptionImplemented equal to true.

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An S1G STA that is starting a BSS shall be able to receive and transmit at each of the <S1G-MCS, NSS> tuple values indicated by the Basic S1G-MCS and NSS Set field of the S1G Operation parameter of the MLME-START.request primitive and shall be able to receive at each of the <S1G-MCS, NSS> tuple values indicated by the Supported S1G-MCS and NSS Set field of the S1G Capabilities parameter of the MLME-START.request primitive.

An S1G STA declares its channel width capability in the Supported Channel Width subfield of the S1G Capabilities element S1G Capabilities Information field as described in Table 9-300.

An S1G STA that is an S1G AP shall set the Channel Width subfield in the S1G Operation Information field of the S1G Operation element to indicate the BSS operating channel width as defined in Table 10-32, the location of 1 MHz primary channel as defined in Table 9-311 and whether MCS 10 is permitted but not recommended as defined in Table 9-311. Table 10-32 is the only combination allowed in an S1G BSS operation. The Channel Width field in the S1G Operation element not listed in Table 10-32 shall not be declared by an S1G STA that is an S1G AP.

Table 10-32—S1G BSS operating channel width

S1G Operation element Primary Channel Width subfield	S1G Operation element BSS Channel Width subfield	BSS primary channel width (MHz)	BSS operating channel width (MHz)
0	1	2	2
0	3	2	4
0	7	2	8
0	15	2	16
1	0	1	1
1	1	1	2
1	3	1	4
1	7	1	8
1	15	1	16

An S1G STA shall determine the channelization based on the Channel Width, Primary Channel Number, and Channel Center Frequency subfields of the S1G Operation Information field (see 23.3.14).

An S1G STA that is a member of an S1G BSS with a 1 MHz, 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width and 1 MHz primary channel width shall not transmit a 1 MHz S1G PPDU that does not use the primary 1 MHz channel of the BSS, except for a 1 MHz S1G PPDU transmission on an off-channel TDLS direct link as constrained by 11.23.6.4.2 or a 1 MHz S1G PPDU transmission by an SST STA as constrained by 10.52.

An S1G STA that is a member of an S1G BSS with a 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width and 2 MHz primary channel width shall not transmit a 1 MHz S1G PPDU in a 1 MHz channel that is not the 1 MHz channel indicated by B5 of the Channel Bandwidth subfield in the S1G Operation element as defined in Table 9-311, except for a 1 MHz S1G PPDU transmission on an off-channel TDLS direct link or a 1 MHz S1G PPDU transmission by an SST STA as constrained by 10.52.

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An S1G STA that is a member of an S1G BSS with a 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width shall not transmit a 2 MHz S1G PPDU that does not use the primary 2 MHz channel of the BSS, except for a 2 MHz S1G PPDU transmission either on an off-channel TDLS direct link or a 2 MHz S1G PPDU transmission by an SST STA as constrained by 10.52.

An S1G STA that is a member of an S1G BSS with a 4 MHz, 8 MHz, or 16 MHz operating channel width shall not transmit a 4 MHz S1G PPDU that does not use the primary 4 MHz channel of the BSS, except for a 4 MHz S1G PPDU transmission either on an off-channel TDLS direct link or by an SST STA as constrained by 10.52.

An S1G STA that is a member of an S1G BSS with an 8 MHz or 16 MHz operating channel width shall not transmit an 8 MHz S1G PPDU that does not use the primary 8 MHz channel of the BSS, except for an 8 MHz S1G PPDU transmission either on an off-channel TDLS direct link or by an SST STA as constrained by 10.52.

An S1G STA that is a member of an S1G BSS with a 16 MHz operating channel width shall not transmit a 16 MHz S1G PPDU that does not use the primary 8 MHz channel and the secondary 8 MHz channel of the BSS, except for a 16 MHz S1G PPDU transmission on an off-channel TDLS direct link.

An S1G STA shall not transmit to a second S1G STA using a bandwidth that is not indicated as supported in the Supported Channel Width subfield in the S1G Capabilities element received from that S1G STA.

An S1G STA shall set the BSS BW field in the Frame Control field of the S1G Beacon frame in line with the values defined in Table 10-32 that are included in the S1G Operation element transmitted by the STA.

10.46.2 System information update procedure

The S1G AP shall increase the value (modulo 256) of the Change Sequence field in the next transmitted S1G Beacon frame(s) when a critical update occurs to any of the elements inside the S1G Beacon frame. The following events shall classify as a critical update:

a) Inclusion of an Extended Channel Switch Announcement
b) Modification of the EDCA parameters
c) Modification of the S1G Operation element

An S1G AP can classify other changes in the S1G Beacon frame as critical updates and among these updates can be included those that are described in 11.2.3.15.

The S1G STA shall either be awake to receive the next S1G Beacon frame that is transmitted at a TBTT or shall queue for transmission a Probe Request frame when it receives a Change Sequence field that contains a value that is different from the previously received Change Sequence field. When an S1G STA transmits a Probe Request frame to obtain the updated system information, it may include the Change Sequence element in the Probe Request frame to request a compressed Probe Response frame.

When an S1G AP receives a Probe Request frame that contains a Change Sequence element from an S1G STA associated with the S1G AP, it compares the value of the received Change Sequence field with the value of its current Change Sequence field. If the value of the received Change Sequence field is not equal to the value of the current Change Sequence field, the S1G AP should send a compressed Probe Response frame, which is a Probe Response frame that includes the Change Sequence element and only the elements that need be updated by the STA. Otherwise, the AP shall send a Probe Response frame as defined in 11.1.4.3.4.

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10.46.3 S1G BSS channel selection methods

Before an S1G STA starts an S1G BSS, the STA shall perform a minimum of dot11S1GOBSSScanCount OBSS scan operations to search for existing BSSs (see 10.46.5).

If an S1G AP starts an S1G BSS with a 2 MHz primary channel width that occupies some or all channels of any existing BSSs, the S1G AP may select a 2 MHz primary channel of the new S1G BSS that is identical to the 2 MHz primary channel of any one of the existing BSSs.

If an S1G AP selects a 2 MHz primary channel for a new S1G BSS with a 4 MHz, 8 MHz, or 16 MHz operating channel width from among the channels on which no beacons are detected during the OBSS scans, then the selected 2 MHz primary channel meets the following conditions:

— It shall not be identical to the secondary 2 MHz channel of any existing BSSs with a 4 MHz, 8 MHz, or 16 MHz operating channel width.
— It should not overlap with the secondary 4 MHz channel of any existing BSSs with a 16 MHz operating channel width.

An S1G STA that is an S1G AP should not start an S1G BSS with a 2 MHz operating channel width on a channel that is the secondary 2 MHz channel of any existing BSSs with a 4 MHz, 8 MHz, or 16 MHz operating channel width, or is overlapped with the secondary 4 MHz channel of any existing BSSs with a 16 MHz operating channel width.

NOTE—An S1G AP operating an S1G BSS with a 4 MHz, 8 MHz, or 16 MHz operating channel width, on detecting an OBSS whose primary channel is the S1G AP's secondary 2 MHz channel, might switch to 2 MHz BSS operation and/or move to a different channel.

If an S1G AP starts an S1G BSS with a 1 MHz primary channel width that occupies some or all channels of any existing BSSs, the S1G AP may select a 1 MHz primary channel of the new S1G BSS that is identical to the 1 MHz primary channel of any one of the existing BSSs.

If an S1G AP selects a 1 MHz primary channel for a new S1G BSS with a 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width from among the channels on which no beacons are detected during the OBSS scans, then the selected 1 MHz primary channel meets the following conditions:

— It shall not be identical to the secondary 1 MHz channel of any existing BSSs with a 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width.

An S1G STA that is an S1G AP should not start an S1G BSS with a 1 MHz operating channel width on a channel that is the secondary 1 MHz channel of any existing BSSs with a 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width.

When establishing a BSS with a 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width, the S1G AP determines and announces the location of 1 MHz primary channel located at either upper or lower side of the 2 MHz primary channel.

10.46.4 S1G BSS channel switching methods

An S1G AP announces a switch of operating channel by using the Extended Channel Switch Announcement element, Extended Channel Switch Announcement frame or both, following the procedure described in 11.9.

An S1G AP may also announce a switch of operating channel width, a new Country String field (possibly including a new Operating Class table number), new operating classes or new TPC parameters for the BSS that come into effect at the same time as the switch of operating channel.

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The New Channel Number field in the Extended Channel Switch Announcement element or Extended Channel Switch Announcement frame identifies the primary channel after the switch. The value of the New Channel Number field is set to the value that dot11CurrentPrimaryChannel (see 23.3.14) will have after the switch.

10.46.5 Scanning requirements for S1G STA

An OBSS scan operation is a passive or active scan of a set of channels that are potentially affected by S1G BSS operation (see 11.1.4.1). Each channel in the set may be scanned more than once during a single OBSS scan operation. OBSS scans are performed by S1G STAs that start an S1G BSS.

During an individual scan within an OBSS scan operation, the minimum per-channel scan duration is dot11OBSSScanPassiveDwell TUs (for a passive scan) or dot11OBSSScanActiveDwell TUs (for an active scan). During an OBSS scan operation, each channel in the set is scanned at least once per dot11BSSWidthTriggerScanInterval seconds, and the minimum total scan time (i.e., the sum of the scan durations) per channel within a single OBSS scan operation is dot11OBSSScanPassiveTotalPerChannel TUs (for a passive scan) or dot11OBSSScanActiveTotalPerChannel TUs (for an active scan).

NOTE—The values provided in the previous paragraph are minimum requirements. For some combinations of parameter values the minimum might be exceeded for some parameters in order to meet the minimum value constraints of other parameters.

10.46.6 NAV and RID assertion in an S1G BSS

An S1G STA shall update its NAV as described in 10.3.2.4 using the Duration/ID field value in any frame that does not have an RA matching the STA's MAC address or the Duration field value in NDP CMAC PPDUs of which it is not the recipient STA and that was received in a 1 MHz PPDU in the primary 1 MHz channel or received in a 2 MHz PPDU in the primary 2 MHz channel or received in a 4 MHz PPDU in the primary 4 MHz channel or received in an 8 MHz PPDU in the primary 8 MHz channel or received in a 16 MHz PPDU.

An S1G STA shall update its RID as described in 10.3.2.5 using the RXVECTOR parameters in any frame that was received in a 1 MHz PPDU in the primary 1 MHz channel or received in a 2 MHz PPDU in the primary 2 MHz channel or received in a 4 MHz PPDU in the primary 4 MHz channel or received in an 8 MHz PPDU in the primary 8 MHz channel or received in a 16 MHz PPDU.

NOTE—The PHY layer might filter out a PPDU as described in 23.3.20. If so, frames in the PPDU are not received by the MAC and have no effect on the NAV.

10.46.7 BSS Basic S1G-MCS and NSS set operation

The BSS basic S1G-MCS and NSS set is the set of <S1G-MCS, NSS> tuples that are supported by all S1G STAs that are members of an S1G BSS, where the S1G-MCS values refer to those obtained from the Max S1G-MCS For n SS subfields of the S1G Operation element as defined in 9.4.2.212. It is established by the STA that starts the S1G BSS, indicated by the Basic S1G-MCS and NSS Set field of the S1G Operation element in the MLME-START.request primitive. Other S1G STAs determine the BSS basic S1G-MCS and NSS set from the Basic S1G-MCS and NSS Set field of the S1G Operation element in the BSSDescription derived through the scan mechanism (see 11.1.4.1).

An S1G STA shall not attempt to join (MLME-JOIN.request primitive) a BSS unless it supports (i.e., is able to both transmit and receive using) all the <S1G-MCS, NSS> tuples in the BSS basic S1G-MCS and NSS set.

An S1G STA shall not attempt to (re)associate (MLME-ASSOCIATE.request primitive and MLME-REASSOCIATE.request primitive) with an S1G AP unless the S1G STA supports (i.e., is able to both

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transmit and receive using) all the <S1G-MCS, NSS> tuples in the Basic S1G-MCS and NSS Set field in the S1G Operation element transmitted by the S1G AP.

The BSS basic S1G-MCS and NSS set is defined by Max S1G-MCS, which indicate the mandatory values and Min S1G-MCS, which indicate the recommended values as defined in 9.4.2.212 and 10.6.14.

An S1G AP that indicates support for sensor STAs does not indicate minimum MCS restrictions.

10.46.8 S1G coexistence with non-IEEE-802.11 systems

This subclause describes the features available in this standard to improve coexistence with other systems operating in bands below 1 GHz, including IEEE Std 802.15.4 and IEEE Std 802.15.4g.

An S1G STA uses energy detection (ED) based CCA with a threshold of –75 dBm per MHz to improve coexistence with other S1G systems. If an S1G STA detects energy above that threshold on its channel, as described in 23.3.18.5, then the following mechanisms might be used to mitigate interference:

— Change of operating channel (11.9)
— Sectorized beamforming (10.53)
— Change the schedule of RAW(s) (10.23.5), TWT SP(s) (10.47), or SST operating channels (10.52)
— Defer transmission for a particular interval (10.61)

10.47 Target wake time (TWT)

10.47.1 TWT overview

Target wake times (TWTs) allow STAs to manage activity in the BSS by scheduling STAs to operate at different times in order to minimize contention and to reduce the required amount of time that a STA utilizing a power management mode needs to be awake.

When performing the TWT operations described in 10.47.1 to 10.47.8, if management frame protection is negotiated and both STAs set the Protected TWT Operations Support field in the RSNXE that they transmit to 1, the STAs shall

— Use individually addressed Protected TWT Setup, Protected TWT Teardown, and Protected TWT Information frames instead of TWT Setup, TWT Teardown, and TWT Information frames, respectively,
— Not transmit BAT, STACK, or TACK frames, and
— Discard any individually addressed TWT Setup, TWT Teardown, TWT Information, BAT, STACK, or TACK frame received from the peer STA, with which management frame protection is negotiated.

STAs that exchange individually addressed Protected TWT Setup, Protected TWT Teardown, or Protected TWT Information frame shall follow the rules defined in 12.6.19.

When management frame protection is not negotiated or the Protected TWT Operations Support field in the RSNXE transmitted by either STA is set to 0, the STAs shall not use any of the Protected TWT Setup frame, the Protected TWT Teardown frame, and the Protected TWT Information frame.

STAs that request a TWT agreement are called TWT requesting STAs and the STAs that respond to their requests are TWT responding STAs. A TWT requesting STA is assigned specific times to wake and exchange frames with the TWT responding STA. A TWT requesting STA communicates wake scheduling information to its TWT responding STA and the TWT responding STA devises a schedule and delivers

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TWT values to the TWT requesting STA when a TWT agreement has been established between them. When explicit TWT is employed, a TWT requesting STA wakes and performs a frame exchange and receives the next TWT information in a response from the TWT responding STA. When implicit TWT is used, the TWT requesting STA calculates the Next TWT by adding a fixed value to the current TWT value. STAs need not be made aware of the TWT values of other STAs.

The maximum number of active TWT agreements between any pair of STAs cannot exceed 8, since the TWT Flow Identifier field of the TWT element comprises 3 bits. TWT responding STAs may protect TWT times with protection mechanisms including, but not limited to NAV-setting frame exchanges. TWT responding STAs that are APs may additionally protect TWT times using RAW scheduling. TWT requesting STAs may wake at times other than TWT. An AP that is a TWT requesting STA shall not be in doze state for a duration that exceeds the value of the dot11MaxAwayDuration during a beacon interval or short beacon interval, as defined in 11.2.3.18.

A STA with dot11TWTOptionActivated equal to true and that operates in the role of TWT requesting STA shall set the TWT Requester Support subfield to 1 in all S1G Capabilities elements that it transmits. A STA with dot11TWTOptionActivated equal to true and that operates in the role of TWT responding STA shall set the TWT Responder Support subfield to 1 in all S1G Capabilities elements that it transmits.

If the TWT Responder Support subfield of the S1G Capabilities element received from its associated AP is equal to 1, a non-AP STA with dot11TWTOptionActivated equal to true may transmit a TWT element to the AP with a value of Request TWT, Suggest TWT or Demand TWT in the TWT Command field and with the TWT Request field equal to 1.

An AP with dot11TWTOptionActivated equal to true shall transmit a TWT element to a STA that is associated to the AP and from which it received a frame containing a TWT element that contained a value of Request TWT, Suggest TWT or Demand TWT in the TWT Command field and with the TWT Request field equal to 1. The transmitted TWT element shall be included in the frame that is the appropriate response frame to the received frame. The AP shall include a value of Accept TWT, Alternate TWT, Dictate TWT or Reject TWT in the TWT Command field of the response and shall set the TWT Request field to 0. If the AP response's TWT Command field includes anything other than Accept TWT or Reject TWT, the STA should send a new request for a TWT value by sending another frame that contains a TWT element, modifying the parameters of the request to indicate, for example, an acceptance of a proposed alternate TWT or dictated TWT value. If the STA receives a TWT response to a TWT request with the TWT Command value of Accept TWT, then the STA has successfully completed a TWT setup with that STA for the TWT Flow Identifier indicated in the TWT response and the STA becomes a TWT requesting STA and the STA may enter the doze state until the TSF matches the next TWT value of the STA, provided that the STA has indicated that it is in a power save mode and no other condition requires the STA to remain awake. The AP becomes a TWT responding STA of the TWT requesting STA.

The receipt of a TWT command value of Suggest TWT implies that the STA sending the command will consider accepting a proposed TWT that differs from the value found in the TWT field of the element. The receipt of a TWT command value of Demand TWT implies that the STA sending the command will not consider accepting a proposed TWT that differs from the value found in the TWT field of the element. The receipt of a TWT command value of Alternate TWT implies that the STA sending the command will consider accepting a proposed TWT that differs from the value found in the TWT field of the element. The receipt of a TWT command value of Dictate TWT implies that the STA sending the command will not consider accepting a proposed TWT that differs from the value found in the TWT field of the element.

The MAC addresses of the TWT requesting STA and the TWT responding STA and the TWT Flow Identifier indicated in the TWT Response of a successful TWT setup between those two STAs uniquely identifies a TWT agreement. A MAC variable AdjustedMinimumTWTWakeDuration is defined for each TWT of each TWT agreement and has a value equal to Nominal Minimum TWT Wake Duration minus the elapsed time from the scheduled start of the TWT SP to the actual start of the SP, where the scheduled and

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actual start times of the TWT SP are determined after any necessary TSF adjustment. Because the value of the AdjustedMinimumTWTWakeDuration depends on the actual TWT SP start time, it is computed for each TWT SP once the TWT SP begins.

The TWT Wake Interval of a TWT agreement is the value calculated as shown in 9.4.2.199 from the TWT Wake Interval Mantissa and TWT Wake Interval Exponent of the TWT response that successfully completed the TWT agreement.

An AP may transmit a TWT element in an individually addressed TWT Setup frame with a value of Request TWT, Suggest TWT or Demand TWT in the TWT Command field and with the TWT Request field equal to 1 to an associated non-AP STA if the TWT Responder Support subfield in the S1G Capabilities element received from the STA is equal to 1. An AP may transmit TWT Setup frames to more than one of its associated non-AP STAs.

A non-AP STA with dot11TWTOptionActivated equal to true shall transmit a frame containing a TWT element to the AP with which it is associated and from which it received an individually addressed frame containing a TWT element that contained a value of Request TWT, Suggest TWT or Demand TWT in the TWT Command field and with the TWT Request field equal to 1. The transmitted TWT element shall be included in the frame that is the appropriate response frame to the received frame. The non-AP STA shall include a value of Accept TWT, Alternate TWT, Dictate TWT or Reject TWT in the TWT Command field of the response and shall set the TWT Request field to 0. If the non-AP STA response's TWT Command field includes anything other than Accept TWT or Reject TWT, the AP should send a new request for a TWT value by sending another frame that contains a TWT element modifying the parameters of the request to indicate, for example an acceptance of a proposed alternate TWT or dictated TWT value. If the AP receives a TWT response to a TWT request with the TWT Command value of Accept TWT from an associated non-AP STA, then the AP has successfully completed a TWT setup with that STA for the TWT Flow Identifier indicated in the TWT response and the AP becomes a TWT requesting STA with respect to that STA.

A non-AP STA shall not transmit a frame containing a TWT element as a response to a group addressed frame with the TWT Request field equal to 1 that is transmitted by its associated AP.

If the NDP Paging field was not present in the TWT response corresponding to a TWT agreement, the TWT requesting STA shall be in the awake state following each TWT start time associated with each TWT agreement for the AdjustedMinimumTWTWakeDuration associated with that TWT agreement even if no PS-Poll frame, NDP PS-Poll frame, or U-APSD trigger frame has been transmitted by the STA or until it has received an EOSP field equal to 1 from the TWT responding STA, whichever occurs first. If the NDP Paging field was present in the TWT response, the TWT requesting STA shall follow the operational rules defined in 10.47.6.

If the Implicit bit is equal to 1 in the TWT response for a TWT agreement, the TWT associated with that TWT agreement is an implicit TWT and the TWT SP associated with that TWT is an implicit TWT SP. A TWT SP that is not an implicit TWT is an explicit TWT SP.

A TWT requesting STA that is a non-AP STA should transmit frames only within TWT SPs.

A TWT requesting STA that transmits a frame during a TWT SP is not granted any special medium access privileges, nor is there any guarantee that the TWT responding STA assigned the TWT SP to only one TWT requesting STA.

A single pair of STAs can create multiple TWT agreements. Each unique TWT agreement is identified by a TWT Flow Identifier and the MAC addresses of the TWT requesting STA and TWT responding STA. Because the TWT Flow Identifier field is 3 bits in length, the maximum number of TWTs per STA pair is 8. There are no explicit restrictions on the class of traffic (i.e., EDCA Access Category) that can be transmitted

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within any specific TWT SP when multiple TWT agreements have been set up by a single TWT requesting STA.

A TWT requesting STA that is a non-AP STA may wake to receive Beacons that are transmitted outside of a TWT SP. A TWT requesting STA that is an AP generates S1G Beacon frames as described in 11.1.3 and operates in power save mode as described in 11.2.3.18.

A TWT responding STA should include a Pentapartial Timestamp field or a Tetrapartial Timestamp field or a Timestamp field in at least one frame transmitted to a TWT requesting STA during a TWT SP for that STA.

NOTE 1—When dot11TWTOptionActivated is true, a TWT responding STA might use the TWT Wake Interval in determining the lifetime of frames that it buffers for an TWT requesting STA.

The Flow Type field in the TWT response that successfully set up a TWT agreement indicates the type of interaction between the TWT requesting STA and the TWT responding STA within each TWT SP for that TWT agreement. Flow Type field equal to 0 indicates an announced TWT. The TWT responding STA of an announced TWT agreement shall not transmit a frame to the TWT requesting STA within a TWT SP until it has received a PS-Poll frame or APSD trigger frame (see 11.2.3.5) from the TWT requesting STA. Flow Type field equal to 1 indicates an unannounced TWT. The TWT responding STA of an unannounced TWT agreement may transmit a frame to the TWT requesting STA within a TWT SP before it has received a frame from the TWT requesting STA.

NOTE 2—A TWT requesting STA that is an AP does not send PS-Poll frames, but it can send APSD trigger frames.

A TWT requesting STA that is negotiating SST operation indicates which single channel it desires to use as a temporary primary channel during a TWT SP by setting a single bit to 1 within the TWT Channel field of the TWT element, according to the mapping described for that field. A TWT responding STA that is negotiating SST operation indicates which single channel the TWT requesting STA is permitted to use as a temporary primary channel during a TWT SP by setting a single bit to 1 within the TWT Channel field of the TWT element, according to the mapping described for that field. During a TWT SP that was negotiated as part of SST operation, access to a channel that is not the primary channel of the BSS shall be performed according to the procedure described in 10.52.

10.47.2 TWT acknowledgment procedure

STAs need to be able to predict the duration of response transmissions for Duration field calculations and in addition, TWT requesting STAs might need TWT start times delivered in response frames. This subclause contains rules for TWT acknowledgments that allow both objectives to be satisfied at once by requiring specific responses to be transmitted in specific circumstances and by specifying the use of frames that provide both acknowledgment and next TWT information.

A TWT responding STA shall transmit a STACK frame in response to a frame received from a TWT requesting STA, which has the value NORMAL_RESPONSE in the RXVECTOR parameter RESPONSE_INDICATION and that is not an A-MPDU and not an S-MPDU. A TWT responding STA shall transmit a TACK frame in response to a frame received from a TWT requesting STA, which has the value NORMAL_RESPONSE in the RXVECTOR parameter RESPONSE_INDICATION and that is an S-MPDU unless the S-MPDU contains a BlockAckReq frame, in which case, the response frame is a BAT frame. A TWT responding STA shall transmit a BAT frame in response to a frame received from a TWT requesting STA, which has the value NORMAL_RESPONSE in the RXVECTOR parameter RESPONSE_INDICATION and that is an A-MPDU.

A TWT requesting STA with the transmitted TWT Responder Support subfield in the S1G Capabilities element equal to 1 shall transmit a STACK frame in response to a frame received from a TWT responding

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STA, which has the value NORMAL_RESPONSE in the RXVECTOR parameter RESPONSE_INDICATION and that is not an A-MPDU and not an S-MPDU. A TWT requesting STA with the transmitted TWT Responder Support subfield in the S1G Capabilities element equal to 1 shall transmit a TACK frame in response to a frame received from a TWT responding STA, which has the value NORMAL_RESPONSE in the RXVECTOR parameter RESPONSE_INDICATION and that is an S-MPDU unless the S-MPDU contains a BlockAckReq frame, in which case, the response frame is a BAT frame. A TWT requesting STA with the transmitted TWT Responder Support subfield in the S1G Capabilities element equal to 1 shall transmit a BAT frame in response to a frame received from a TWT responding STA, which has the value NORMAL_RESPONSE in the RXVECTOR parameter RESPONSE_INDICATION and that is an A-MPDU.

A TWT requesting STA that transmits a frame containing a Pentapartial Timestamp field shall set the field to all 0s. A TWT requesting STA that transmits a frame containing a Tetrapartial Timestamp field shall set the field to all 0s. A TWT requesting STA that transmits a frame containing a Next TWT Info field shall set the field to all 0s. A TWT requesting STA that transmits a frame containing a Change Sequence field shall set the field to all 0s.

A TWT requesting STA with the transmitted TWT Responder Support subfield in the S1G Capabilities element equal to 0 that receives a frame that requires an immediate response shall transmit an appropriate response is determined in 10.3.2.17.

If the intended recipient of a STACK or BAT frame is an AP, then the A1 field of the frame shall be set to 0.

If a TWT responding STA or a TWT requesting STA receives a frame within a TWT SP that has a value other than NORMAL_RESPONSE in the RXVECTOR parameter RESPONSE_INDICATION, the appropriate response is as determined in 10.3.2.17.

10.47.3 Explicit TWT operation

Each TWT SP start value for an explicit TWT is transmitted by the TWT responding STA to the TWT requesting STA in the Next TWT Info/Suspend Duration field of a frame that can contain the field as described in this subclause. The TWT responding STA for an explicit TWT may provide TWT SP start times that are related to one another in a periodic or aperiodic manner.

During an explicit TWT SP, if a TWT responding STA receives a frame from a TWT requesting STA that permits a BAT frame, TACK frame or STACK frame to be sent in response, then the TWT responding STA shall respond with a frame that includes a Next TWT Info/Suspend Duration field either if it is required to do so according to 10.47.2, or if it has not already transmitted a nonzero Next TWT Info/Suspend Duration field to the STA within this TWT SP. If the TWT responding STA has already transmitted a nonzero Next TWT Info/Suspend Duration field to the STA within this TWT SP, and is not otherwise required to respond with a BAT frame, TACK frame or STACK frame, the TWT responding STA may respond to the STA with a frame that contains a Next TWT Info/Suspend Duration field. When present in the response frame, the Next TWT Info/Suspend Duration field may contain the value of the TSF timer corresponding to the next scheduled TWT SP for the STA that is the intended recipient of the frame or may contain the value 0 to indicate that the Next TWT is not currently available for this TWT.

A TWT requesting STA awake for an explicit TWT SP shall not transmit a PS-Poll frame with the Poll Type subfield equal to any value other than 2.

A TWT requesting STA that is awake for an explicit TWT SP shall not enter doze state until it has received a nonzero Next TWT Info/Suspend Duration field from the TWT responding STA and has either been in the awake state for a duration of at least Nominal Minimum TWT Wake Duration from the TWT SP start time as identified by the TWT responding STA or has received an EOSP field equal to 1 from the TWT responding STA. If more than one nonzero Next TWT Info/Suspend Duration field is received from the

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TWT responding STA during a TWT SP, the receiving STA shall discard all but the most recently received value. If no nonzero Next TWT Info/Suspend Duration field is received from the TWT responding STA during the TWT SP, then following the end of the TWT SP when not otherwise prohibited from transmitting, the TWT requesting STA may transmit a frame that is addressed to the TWT responding STA as a means to solicit a response frame that contains a Next TWT value. Examples of frames that will solicit a Next TWT Info/Suspend Duration field include

— A TWT Information frame with the TWT Flow Identifier subfield equal to the TWT Flow Identifier corresponding to the TWT agreement for which a Next TWT value is requested and with the Next TWT Size subfield equal to 0, soliciting a STACK frame response.
— An A-MPDU containing a TWT Information frame with the TWT Flow Identifier subfield equal to the TWT Flow Identifier corresponding to the TWT agreement for which a Next TWT value is requested and with the Next TWT Size subfield set to 0, soliciting a BAT frame response.
— An S-MPDU containing a TWT Information frame with the TWT Flow Identifier subfield equal to the TWT Flow Identifier corresponding to the TWT agreement for which a Next TWT value is requested and with the Next TWT Size subfield equal to 0, soliciting a TACK frame response.

A TWT requesting STA that transmits a PPDU containing a TWT Information frame receives a response frame that can include a Next TWT field, as indicated above, and therefore, is not required to set the value of the Next TWT Request subfield to 1 to solicit the response of a TWT Information frame that includes a Next TWT field.

During an explicit TWT SP, a TWT responding STA that has transmitted a frame containing a Next TWT subfield equal to 0 shall queue for transmission at least one frame to the same recipient containing the nonzero Next TWT corresponding to the TWT Flow Identifier indicated in the frame with the Next TWT subfield equal to 0.

If a TWT requesting STA has transmitted a frame soliciting a response that contains a Next TWT value and the STA is in a Power Save mode, the STA shall remain in the awake state following the transmission until it receives a response from the TWT responding STA that contains a nonzero Next TWT value. The TWT responding STA shall assume that the TWT requesting STA is in the doze state if the TWT requesting STA is in a Power Save mode, the TWT SP has ended and the TWT responding STA has not received a frame from the TWT requesting STA that solicits a response that contains a nonzero Next TWT value. If a TWT responding STA receives a TWT Information frame from a TWT requesting STA with the Next TWT Request subfield equal to 1, then the TWT responding STA shall queue for transmission a TWT Information frame that contains a nonzero Next TWT value corresponding to the TWT Flow Identifier of the received TWT Information frame and shall assume that the TWT requesting STA is in the awake state until the TWT responding STA has transmitted the frame containing the nonzero Next TWT value.

A TWT responding STA may include a nonzero Next TWT value in any TACK frame or STACK frame or BAT frame that is transmitted as a response to a TWT requesting STA.

The TWT responding STA shall include the initial TWT SP start time for an explicit TWT agreement in the Target Wake Time field of the TWT element, which contains a value of Accept TWT in the TWT Setup Command field, a value of 0 in the Implicit bit and the TWT Flow Identifier value corresponding to that TWT agreement in the TWT Flow Identifier subfield.

10.47.4 Implicit TWT operation

The TWT values for an implicit TWT are periodic. A TWT requesting STA operating with an implicit TWT agreement shall determine the next TWT SP start time by adding the value of TWT Wake Interval associated with this TWT agreement to the value of the start time of the current TWT SP. A TWT requesting STA operating with an implicit TWT agreement with a TWT flow identifier that matches the TWT flow identifier of

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a received TWT Information frame from its TWT responding STA shall replace its next TWT SP start time value with the value from the Next TWT subfield of the TWT Information frame.

The TWT responding STA shall include the start time for a series of TWT SPs corresponding to a single TWT Flow Identifier of an Implicit TWT agreement in the Target Wake Time field of the TWT element which contains a value of Accept TWT in the TWT Setup Command field and the TWT Flow Identifier value corresponding to that TWT agreement in the TWT Flow Identifier subfield. The start time of the TWT SP series indicates the beginning time of the first TWT SP in the series. Subsequent TWT SPs start times are determined by adding the value of TWT Wake Interval to the current TWT SP start time.

A TWT requesting STA awake for an implicit TWT SP may transition to the doze state after a duration AdjustedMinimumTWTWakeDuration has elapsed from the TWT SP start time as identified by the TWT requesting STA or after receiving an EOSP field equal to 1 from the TWT responding STA, whichever occurs first.

A TWT responding STA that receives a frame from a TWT requesting STA with which it has established an implicit TWT agreement may respond to the STA with a frame that contains a Next TWT Info/Suspend Duration field (e.g., BAT frame, TACK frame, STACK frame). A TWT requesting STA that is awake for an implicit TWT SP and receives a frame with a Next TWT Info/Suspend Duration field from its TWT responding STA shall use the received Next TWT Info/Suspend Duration field value as the start of the next TWT, instead of the TWT value calculated by adding the value of TWT Wake Interval associated with the TWT SP to the current TWT. Subsequent TWT start times associated with the same TWT agreement are calculated based on the next TWT that was sent by the TWT responding STA.

10.47.5 TWT grouping

An AP may include an S1G STA as a member of a TWT group if the STA indicated TWT requester support and indicated support for TWT grouping in the S1G Capabilities Information field in the S1G Capabilities element in its (Re)Association Request frame and may signal TWT times to that STA using the TWT Group Assignment field of the TWT element.

An AP shall not include a non-S1G STA within a TWT group.

When dot11TWTGroupingSupport is true, the AP may assign a TWT group ID to a TWT requesting STA when the TWT Grouping Support subfield is equal to 1 within the S1G Capabilities element received from that STA. The AP indicates the TWT value to the TWT requesting STA that supports TWT grouping by transmitting to the STA an individually addressed frame containing a TWT element, which includes

— The value of the assigned group ID in the TWT Group ID subfield.
— The lower 48 bits of a TSF value in the Zero Offset of Group subfield to indicate the TWT value corresponding to the first member of the TWT group that is identified by the TWT group ID.
— A TWT unit value in the TWT Unit subfield (9.4.2.199).
— A positive offset value indicated in the TWT Offset subfield (9.4.2.199). The allowed values in the TWT Unit subfield are given in Table 9-298.

The intended recipient of the frame containing the TWT element calculates its TWT from the TWT Group Assignment field by multiplying the TWT Unit interpretation value with the value indicated in the TWT Offset subfield and adding the result to the value in the Zero Offset of Group field corresponding to the TWT Group ID subfield in the TWT Group Assignment field of the TWT element.

10.47.6 NDP Paging setup

This subclause defines a protocol for power saving at a STA by using the TWT protocol to set up scheduled wakeup intervals and by defining efficient signaling for the presence of BUs and synchronization.

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A frame including a TWT element with the NDP Paging field present is referred to as NDP Paging Request or NDP Paging Response as clarified later. A STA sending an NDP Paging Request is referred to as NDP Paging requester. A STA sending an NDP Paging Response in a response to an NDP Paging Request is referred to as NDP Paging responder.

A STA requests an NDP Paging TWT by sending an NDP Paging Request. A non-S1G STA shall not transmit NDP Paging frames.

The setup procedure follows the protocol described in 10.47.1, unless otherwise described in this subclause.

A non-AP STA sending an NDP Paging Request shall set the P-ID field of the NDP Paging Request to one of the partial AIDs assigned to it by the intended receiver of the NDP Paging Request (see 10.21).

An AP sending an NDP Paging Request to a non-AP STA should set the P-ID field of the NDP Paging Request to the partial BSSID.

Upon receiving an NDP Paging Request, the recipient STA shall respond with an NDP Paging Response with the NDP Paging fields set as follows:

— The P-ID subfield should be set to the same value as the P-ID subfield of the NDP Paging Request.
— The Max NDP Paging Period subfield shall be set to any value that is less than or equal to the Max NDP Paging Period subfield of the NDP Paging Request.
— The Action subfield shall be set to one of the values in Table 9-299.
— The Partial TSF Offset subfield and Min Sleep Duration subfield are reserved.

The NDP Paging setup is successful if the TWT Setup Command subfield of the Request Type field in the NDP Paging Response is equal to 4 (Accept TWT), otherwise the setup is considered as failed.

A STA that has sent an NDP Paging Response with the TWT Setup Command field equal to 4 (Accept TWT) shall schedule an NDP Paging frame as the first frame for transmission at the TWTs indicated by the NDP Paging Response, if any of the following conditions is satisfied:

— There are BUs for the requesting STA.
— No NDP Paging frame was sent in the *N* consecutive preceding TWT(s), where *N* is equal to the value of the Max NDP Paging Period subfield in the NDP Paging Response.

The AP shall schedule an NDP Paging frame if there are critical updates to the S1G Beacon frame as defined in 10.46.2 and 11.2.3.15. An AP may additionally send an NDP Paging frame at any of the TWTs indicated by the NDP Paging Response.

If the NDP Paging frame is sent by the AP to the NDP Paging requester then this frame shall precede any frame that is sent by the AP to it during its indicated TWT SP and shall have the Direction field equal to 1.

If any frame is sent by a non-AP STA to an NDP Paging requester during its indicated TWT SP then the first frame sent shall be an NDP Paging frame with the Direction field equal to 0.

The P-ID field of the NDP Paging frame shall be set to the same value as P-ID field in the NDP Paging Response if and only if there are BUs for the STA identified by the partial AID indicated in the P-ID field of the NDP Paging Request. The P-ID field shall be set to 0 to indicate the presence of group addressed BUs.

NOTE—When a group AID is assigned to the corresponding group MAC address as described in 10.55, then the P-ID field can be set to the partial AID that corresponds to the group AID as defined in 10.21.

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If the Direction field of the NDP Paging frame is equal to 1, the subfields of the APDI field of the NDP Paging frame shall be set as follows:

- The PTSF subfield is set to TSF[Partial TSF Offset + 4 : Partial TSF Offset + 11], where TSF is the 8-octet value of the TSF timer and Partial TSF Offset is the value of the Partial TSF Offset field in the NDP Paging Request.
- The Check Beacon Flag subfield shall be set to the LSB of the Change Sequence field in the most recently transmitted S1G Beacon frame or of the Check Beacon field in the most recently transmitted TIM frame, if any was sent before the NDP Paging frame.

If the Direction field of the NDP Paging frame is equal to 0, the Partial AID field of NDP Paging frame indicates the partial AID of the STA transmitting the NDP Paging frame.

If no NDP Paging frame is received during the TWT, the TWT requester STA may transition to doze state at the end of the Nominal Minimum TWT Wake Duration for the TWT. If an NDP Paging frame is received, the TWT requester STA may transition to doze state immediately after receiving the NDP Paging frame, unless Min Sleep Duration field was equal to 0 and Action subfield equal to 1 in the NDP Paging Response frame that successfully completed the NDP Paging setup, in which case the STA shall be in active mode.

Upon reception of an NDP Paging frame with the P-ID field matching the value of the P-ID field in the NDP Paging Response, the NDP Paging requester STA shall behave as follows:

- If the Action subfield of the NDP Paging Response is 0:
  - If the NDP Paging requester STA is a non-AP STA, it shall send a (NDP) PS-Poll frame or uplink trigger frame addressed to the NDP Paging responder, after either SIFS or using EDCA within Nominal Minimum TWT Wake Duration.
  - If the NDP Paging requester STA is an AP, it shall send an NDP CTS frame to self with the duration field equal to 0 after either SIFS or using EDCA within Nominal Minimum TWT Wake Duration.
- If the Action subfield of the NDP Paging Response is 1, the STA shall be in the awake state starting at a time indicated by the Min Sleep Duration field after the end of reception of the NDP Paging frame, and it shall remain in the awake state until a frame is received from the NDP Paging responder with the EOSP subfield equal to 1.
- If the Action subfield of the NDP Paging Response is 2, the STA shall be in the awake state at the first TBTT that occurs after a time indicated by the Min Sleep Duration field in the NDP Paging Response after the end of reception of the NDP Paging frame to receive the S1G Beacon frame.
- If the Action subfield of the NDP Paging Response is 3, the STA shall be in the awake state at the first DTIM that happens after a time indicated by the Min Sleep Duration field in the NDP Paging Response after the end of reception of the NDP Paging frame to receive the DTIM Beacon frame.
- If the Action subfield of the NDP Paging Response is 4, the STA shall be in the awake state starting at a time T after the end of reception of the NDP Paging frame and it shall remain in the awake state until a frame is received from the NDP Paging responder with the EOSP subfield equal to 1. The value of T is in units of SIFS and is equal to the value of the Min Sleep Duration field of the NDP Paging Request plus the value of the ASD subfield in the APDI field of the NDP Paging frame.

If the NDP Paging requester is an AP, values 2–7 of the Action subfield are reserved.

A non-AP STA that has set up NDP Paging and receives an NDP Paging frame with Direction field equal to 1 and the Check Beacon Flag subfield value different from the LSB of the most recently received Change Sequence value shall either be awake to receive the next S1G Beacon frame that is transmitted at a TBTT or TSBTT or shall queue for transmission a Probe Request frame to obtain the updated system information as described in 10.46.2.

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10.47.7 TWT Sleep setup

A Responder PM Mode bit in the Control field of the TWT response equal to 1 indicates that the Responder STA may be in doze state outside the indicated TWT SP.

10.47.8 TWT teardown

Either STA that is a party to an established TWT agreement may delete the TWT agreement by successfully transmitting a TWT Teardown frame. The TWT Flow Identifier field of the TWT Teardown frame shall be set to the value of the TWT Flow Identifier field of the TWT element of the frame that successfully concluded the setup of the TWT agreement that is the subject of the teardown request.

When a TWT Teardown frame is successfully transmitted or received, the TWT agreement corresponding to the TWT Flow Identifier field, TWT requesting STA MAC address and TWT responding STA MAC address of the TWT Teardown frame shall be deleted.

10.48 Non-TIM operation

10.48.1 Resource protection for S1G STAs in non-TIM mode

10.48.1.1 General

Resource protection for S1G STAs in non-TIM mode allows an AP to protect specific times for participating S1G STAs in non-TIM mode from medium access by S1G STAs in TIM mode. The objective of this procedure is to minimize contention between S1G STAs in non-TIM mode and S1G STAs in TIM mode and thus reduce power consumption of S1G STAs in non-TIM mode caused by medium contention with S1G STAs in TIM mode. For this purpose, an AP may set up RAW(s) for S1G STAs in non-TIM mode and then indicate to S1G STAs in TIM mode RAW information during which no S1G STA in TIM mode is allowed to contend. The RAW(s) are used for protecting either TWT(s) scheduled by the AP or specific interval(s) for S1G STAs in non-TIM mode.

When an AP schedules TWT(s) for S1G STAs in non-TIM mode, the AP may set up RAW(s) to protect the TWT(s) for S1G STAs in non-TIM mode. The AP may schedule more than one TWT for S1G STAs in non-TIM mode so that it can set up a RAW which covers the interval summing up the duration indicated by the corresponding Nominal Minimum TWT Wake Duration field assigned to each S1G STA in non-TIM mode in a sequence.

An AP is a TWT-protection capable AP if it sets both dot11RAWOperationActivated and dot11TWTOptionActivated to true.

An S1G STA in non-TIM mode with dot11TWTOptionActivated equal to true may request for the TWT protection for a TWT-protection capable AP when it sets up a TWT agreement with the AP. In the TWT setup procedure specified in 10.47.1, an S1G STA in non-TIM mode transmits a TWT element in a (Re)Association Request frame or a TWT Setup frame to the AP, and the S1G STA in non-TIM mode may request for a TWT protection by setting the TWT Protection subfield in the Request Type field of the TWT element (9.4.2.199) to 1. If the protection is not required by the S1G STA in non-TIM mode, the TWT Protection subfield shall be set to 0.

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When a TWT-protection capable AP receives a TWT element from an S1G STA in non-TIM mode with the TWT Protection subfield equal to 1 during the TWT setup procedure, it is recommended that the AP allocates RAW(s) to protect the TWT SPs corresponding to the particular TWT Flow Identifier.

When a TWT-protection capable AP receives a TWT element from an S1G STA in non-TIM mode during the TWT setup procedure and if the AP can guarantee to protect the scheduled TWT(s) for the S1G STA in non-TIM mode by allocating RAW(s), it shall set the TWT Protection subfield in the TWT element included in the (Re)Association Response frame or a TWT Setup frame that is transmitted to the STA during the TWT setup procedure to 1. If the AP cannot guarantee to protect the scheduled TWT(s) by allocating RAW(s), it shall set the TWT Protection subfield in the TWT response to 0.

After a TWT-protection capable AP has successfully completed the TWT setup as described in 10.47.1 and if the AP has set the TWT Protection subfield in the TWT element to 1 during the TWT setup procedure with the STA, the AP shall set up RAW(s) that covers at least the duration indicated by the Nominal Minimum TWT Wake Duration field (9.4.2.199) assigned to the S1G STA in non-TIM mode. If the AP has set the TWT Protection subfield to 0, the AP may set up RAW(s) that covers at least the duration indicated by the Nominal Minimum TWT Wake Duration field.

To protect contention for medium access for an S1G STA in non-TIM mode, an AP with dot11RAWOperationActivated equal to true may schedule TWTs within a RAW that is not assigned to any S1G STA in TIM mode. When the AP is polled by TWT STAs that were not scheduled during the RAW duration, the AP may reschedule their awake/doze cycle as described in 10.48.2.

The AP uses either generic RAW(s) or non-TIM RAW(s) for protecting S1G STAs in non-TIM mode:

— In a generic RAW, medium access is only allowed to a group of STAs indicated by the RAW Group field as specified in 10.23.5.4.

In a non-TIM RAW, the RAW Group field is not present and medium access is only allowed to S1G STAs in non-TIM mode that are scheduled within the duration calculated from the RAW Slot Definition field as specified in 10.23.5.1.

10.48.1.2 Resource protection for S1G STAs in non-TIM mode using periodic RAW (PRAW) operation

In resource protection for S1G STAs in non-TIM mode specified in 10.48.1, PRAW, which is specified in 10.23.5.8 can be used to indicate to S1G STAs in TIM mode information related to periodically scheduled RAWs during which no S1G STAs in TIM mode are allowed to contend.

An example of a basic operation of a PRAW allocation is shown in Figure 10-100. In this figure, PRAW is allocated at every short beacon interval, but the allocation of the PRAW is indicated at every DTIM Beacon frame. STA1 is an S1G STA in TIM mode that is not included in the PRAW allocation and STA2 is an S1G STA in non-TIM mode for which the AP has scheduled TWT and is included in the PRAW allocation. When STA1 listens to the Beacon frame, it can identify the allowed user group, start time, duration, and the periodicity of the allocated PRAW. As STA1 is not included in the allowed user group of the PRAW, STA1 will not access the channel during the allocated PRAW, which is indicated in the S1G Beacon frame that is transmitted every short beacon interval. And, STA2 wakes up at its scheduled TWT, which is within the PRAW, and send its uplink data if it has a Data frame to send.

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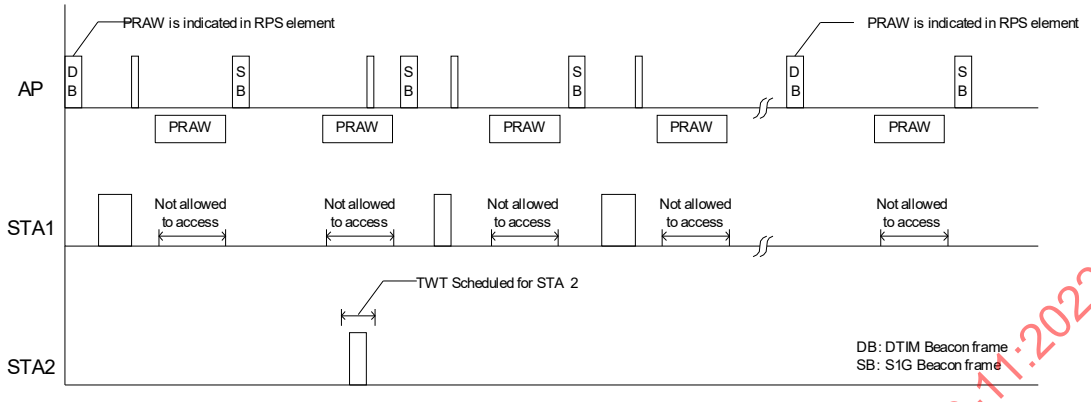

Figure 10-100—Example of PRAW operation

10.48.2 Rescheduling of awake/doze cycle

This subclause defines a procedure for the S1G AP to reschedule the awake/doze cycle of an S1G STA in Non-TIM Mode.

An S1G STA in non-TIM mode that transmits a PS-Poll frame may set the Poll Type subfield of the Frame Control field to

- 0 if it requests to the AP delivery of DL BUs but without a request for rescheduling of the doze/awake cycle.
- 1 if it solicits information regarding the change sequence of the Beacon and the partial timestamp.
- 2 if it is not a TWT STA and requests to the AP delivery of the DL BUs and resynchronizing to the next TBTT.
- 2 if it is a TWT requester STA that transmits the frame to the TWT responder AP within the negotiated TWT SP to request delivery of DL BUs and information for the next TWT.
- 3 if it requests to the AP to reschedule its doze/wake cycle to another service period.

Upon receiving an NDP PS-Poll frame, trigger frame or PS-Poll frame with the Poll Type subfield equal to 0 sent by an S1G STA, the S1G AP responds as described in 11.2.3.6.

NOTE—The S1G STA can be an S1G STA in TIM mode or an S1G STA in non-TIM mode.

Upon receiving a PS-Poll frame with the Poll Type subfield not equal to 0 sent by an S1G STA in non-TIM mode, the AP responds with different frames depending on the value of the Poll Type subfield in the Frame Control field of the PS-Poll frame that elicited the response as follows:

- If the Poll Type subfield is equal to 1 then the AP with dot11PollTACKResponseImplemented equal to true shall respond with a TACK frame that does not contain the Next TWT Info/Suspend Duration field. An S1G STA shall not send a PS-Poll frame with the Poll Type subfield equal to 1 to an AP unless the TACK Support as PS-Poll Response field of the S1G Capabilities element received from that AP is equal to 1.
- If the Poll Type subfield is equal to 2 and is sent by a TWT requester STA within the negotiated TWT SP then the AP responds with a TACK frame as described in 10.47. A TWT requester STA shall not send a PS-Poll frame with the Poll Type subfield equal to 2 to an AP unless the TWT Responder Support field of the S1G Capabilities element received from that AP is equal to 1.
- If the Poll Type subfield is equal to 2 and is either sent by a STA that is not a TWT requester STA or is sent by a TWT requester STA not within the negotiated TWT SP then the AP shall either respond

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with the DL BU or with an NDP Ack frame. The NDP Ack frame may include a wakeup timer value (i.e., its Idle Indication field is equal to 1), which expires at the next TBTT.

  - The AP may also respond with a control response frame that includes a Duration field that indicates a wakeup timer (i.e., an NDP Ack or NDP PS-Poll-Ack frame with Idle Indication field equal to 1) if it receives a trigger or NDP PS-Poll frame from an S1G STA in non-TIM mode, which satisfies the criteria above.
  - The S1G STA in non-TIM mode may resynchronize to the S1G Beacon frame with the help of the wakeup timer.

- If the Poll Type subfield is equal to 3, then the AP may respond with an NDP Ack frame that includes a wakeup timer as described in 11.2.3.6:
  - If the STA has requested time slot protection and the AP is UL-Sync capable, then the AP shall protect the TXOP duration following the expiration of the wakeup timer as described in 10.49.
  - A UL-Sync capable AP may also respond with a control response frame that includes a Duration field that indicates a wakeup timer (i.e., an NDP Ack or NDP PS-Poll-Ack frame with Idle Indication field equal to 1) if it receives a trigger or NDP PS-Poll frame from an S1G STA in non-TIM mode that satisfies the criteria above.

The S1G AP shall set More Data field to 1 in the responding control frame if there is a BU buffered for the non-TIM S1G STA. If the non-TIM S1G STA receives a responding control frame in which the Idle Indication field is equal to 1 and the Duration field is a nonzero value, there is no frame transmission for the STA in the indicated duration in which the S1G STA may enter the doze state. After an amount of time that is equal to the value in the Duration field, it shall be in the awake state.

An S1G AP may set the wakeup timer (Duration field) as the duration to a TBTT in the responding control frame (either NDP Ack frame or NDP PS-Poll-Ack frame) and treat the S1G STA in non-TIM mode as an S1G STA in TIM mode starting from the TBTT if the bit corresponding to the S1G STA in non-TIM mode in the traffic indication virtual bitmap is equal to 1 and the STA has indicated support for temporary PS mode switch by setting the Temporary PS Mode Switch subfield to 1 in the S1G Capabilities element it transmitted to the AP. After the amount of time that is equal to the Duration field value in the responding control frame from the S1G AP, the non-TIM S1G STA shall wake up to receive a Beacon frame. Upon receiving the Beacon frame, the S1G STA in non-TIM mode infers from the TIM element indicating that there is BU for it that it is treated as an S1G STA in TIM mode and operates as an S1G STA in TIM mode from then on, setting dot11NonTIMModeActivated to false and switching to TIM mode (see 11.2.3.2). The S1G STA returns to the S1G STA in non-TIM mode operation mode by setting dot11NonTIMModeActivated to true if the S1G AP indicates that there is no more data buffered for the S1G STA and the S1G STA indicates to the S1G AP that there is no more data to transmit. The S1G AP treats the S1G STA as an S1G STA in non-TIM mode if the STA indicates that there is no more data to transmit and the S1G AP indicates that there is no more data buffered for the STA.

10.49 Sync frame operation

This subclause describes a sync frame transmission procedure for uplink traffic, which minimizes the time for medium synchronization for a STA that is changing from doze state to awake state in order to transmit. The sync frame is a frame that solicits a Data frame as an immediate response, if any is available, from the receiving STA.

If dot11S1GUplinkSyncOptionImplemented is true, an AP shall set the Uplink Sync Capable field in the S1G Capabilities element to 1. If dot11S1GUplinkSyncOptionImplemented is false, the AP shall set the Uplink Sync Capable field in the S1G Capabilities element to 0.

An AP is an UL-Sync (Uplink Sync) capable AP if it sets the Uplink Sync Capable field to 1.

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A STA may request an UL-Sync capable AP to transmit a sync frame at the slot boundary of the STA in a RAW or at the target wake time of the STA.

A STA may request for a sync frame transmission to the UL-Sync capable AP either during association by sending a (Re)Association Request frame in which the Uplink Sync Capable field in the S1G Capabilities element is equal to 1 or at any time by sending a Sync Control frame (an Action frame of category S1G) in which the Uplink Sync Request field in the Sync Control field is equal to 1.

A STA may request the UL-Sync capable AP to stop the sync frame transmission at any time by sending a Sync Control frame in which the Uplink Sync Request field in the Sync Control field is equal to 0.

When a STA is requesting for a sync frame transmission, a STA may also request an AP to protect a RAW slot in a RAW defined in the Slot Duration field (9.4.2.191) or a duration at a TWT defined in the Nominal Minimum TWT Wake Duration field (9.4.2.199), or by setting the Time Slot Protection Request field in the Sync Control field to 1. A STA may also request an AP protection for a TXOP duration after the expiration of a wakeup timer as described in 10.48.2. The time slot protection is not requested if the Time Slot Protection Request field is equal to 0. When an AP receives a Sync Control frame from a STA with the Time Slot Protection Request field equal to 1, the AP shall protect a time slot that is assigned for the STA in a RAW, or a duration that is assigned for the STA at a TWT, or a TXOP duration after the expiration of a wakeup timer of the STA with NAV-setting frame exchanges. Note that NAV-setting frame exchanges refer to any frame that can set NAV to other third-party stations, and an AP has the flexibility to choose any NAV-setting frame exchanges for protection.

For a STA that requested for a sync frame transmission, the UL-Sync capable AP shall schedule a sync frame at the slot boundary of the STA in the RAW if the Time Slot Protection Request field is equal to 1 or the Cross Slot Boundary field is equal to 1, or at the TWT of the STA, or at the expiration of the wakeup timer, as the next frame for transmission according to the medium access rules specified in Clause 10.

If the medium is busy at the slot boundary of a STA in the RAW or at the TWT of the STA, or at the expiration of the wakeup timer, or if the UL-Sync capable AP determines that the remaining time in the RAW slot or the TWT SP, or the TXOP duration to be too short to transmit a sync frame, the UL-Sync capable AP shall cancel the scheduled sync frame transmission. When the STA is changing from doze state to awake state in order to transmit, the STA shall follow the rules defined in 11.2.3.2.

The UL-Sync capable AP should use an NDP CTS frame as a sync frame. The AP may cause any NAV-setting frame as sync frame provided that the frame solicits a Data frame as an immediate response from the receiving STA (e.g., a reverse direction grant).

When a STA receives an NDP CTS frame with the RA/Partial BSSID field equal to the S1G partial AID of the STA from the UL-Sync capable AP with which the STA is associated, the STA shall transmit a Data frame to the AP a SIFS after the reception of the NDP CTS frame if the STA has a Data frame to transmit to the AP and has requested the AP for a sync frame transmission. When a STA receives an NDP CTS frame with the RA/Partial BSSID field not equal to the S1G partial AID of the STA, the STA shall follow the NAV setting rules defined in 10.3.2.4. After transmitting the NDP CTS frame, the AP shall wait for an AckTimeout interval (as defined in 10.3.2.11), starting at the PHY-TXEND.confirm primitive. If a PHY-RXSTART.indication primitive does not occur during the AckTimeout interval, the AP may transmit a CF-End frame or an NDP CF-End frame to reset the NAV provided that the remaining duration is long enough to transmit this frame.

For a STA requesting for a sync frame transmission with the Time Slot Protection Request field set to 0, the AP should not send a sync frame at each slot boundary within a RAW period if the Cross-Slot Boundary field is equal to 0.

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Figure 10-101 illustrates an example of the uplink sync frame transmission procedure in a RAW. STA1 is allocated Slot1 in the RAW and STA2 is allocated Slot3 in the RAW. Both STA1 and STA2 have requested the UL-Sync capable AP to transmit a sync frame at the slot boundary. At the slot boundary of Slot1, the medium is idle and thus the AP transmits a sync frame at the slot boundary. However, at the slot boundary of Slot3, the medium is busy and thus the AP cancels the scheduled sync frame transmission for STA2.

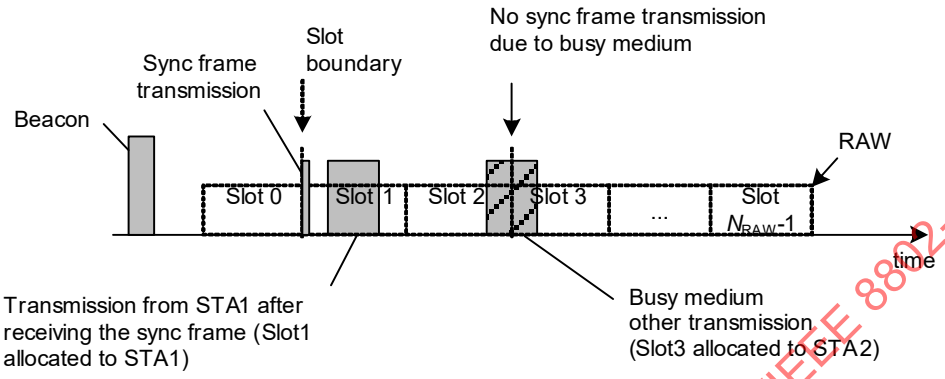

Figure 10-101—Example of uplink sync frame transmission procedure in RAW

10.50 Bidirectional TXOP

10.50.1 Overview

Bidirectional TXOP (BDT) allows an S1G AP and an S1G non-AP STA to exchange a sequence of uplink and downlink PPDUs separated by SIFS. This operation combines both uplink and downlink channel access into a continuous frame exchange sequence between a pair of S1G STAs. S1G STAs that participate in BDT use information that is present in the Frame Control field, SIGNAL field and NDP CMAC PPDUs to signal an undergoing BDT as described in 10.50.2. The objective of this operation is to minimize the number of contention-based channel accesses, improve channel efficiency by reducing the number of frame exchanges, and reduce S1G STA power consumption by shortening Awake state times.

An S1G STA with dot11BDTImplemented equal to true shall set the BDT Capable field in the S1G Capabilities element to 1. An S1G STA with dot11BDTImplemented equal to false shall set the BDT Capable field in the S1G Capabilities element to 0. An S1G STA shall not use the BDT procedure to transmit frames to another S1G STA whose BDT Capable field is equal to 0.

10.50.2 Rules for BDT

Throughout this subclause, an S1G STA signals a Response Indication of Long Response by setting the TXVECTOR parameter RESPONSE_INDICATION to Long Response for non-NDPs and by setting the Idle Indication field to 1 and the Duration field to 0 for NDP (PS-Poll-)Ack frames. The S1G STA signals a Response Indication of No Response by setting the TXVECTOR parameter RESPONSE_INDICATION to No Response for non-NDPs or by setting the Idle Indication field to 0 and the Duration field to 0 for NDP (PS-Poll-)Ack frames. The S1G STA signals a Response Indication of Normal Response by setting the TXVECTOR parameter RESPONSE_INDICATION to Normal Response for non-NDPs.

An S1G AP may initiate a BDT exchange with an NDP PS-Poll-Ack frame that is sent as a response to an NDP PS-Poll frame. An S1G non-AP STA shall not initiate a BDT exchange with a PS-Poll frame unless it is a PS-Poll+BDT frame with the More Data field equal to 1. A BDT exchange consists of one or more BDT sequences.

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A BDT sequence comprises the following:

a) The transmission of one PPDU that is either an NDP PS-Poll-Ack frame or satisfies the following conditions:
   1) Contains a Response Indication of Long Response
   2) Follows the same rule as the initial frame for TXOP as defined in 10.23.2 if the PPDU is the first frame sent by the BDT Initiator during this TXOP
   3) Contains a Duration/ID field that sets the NAV
   4) Contains no HT Control field with the RDG/More PPDU subfield equal to 1.

   An S1G STA that transmits this PPDU is known as a BDT Initiator.

b) The transmission of one or more PPDUs (BDT response burst) by the S1G STA addressed in the PPDUs transmitted by the BDT Initiator, separated by SIFS. Only the last (or only) PPDU of the BDT response burst may contain any MPDU requiring an immediate response. All the other PPDUs in the BDT response burst (if there are any) except the last one shall indicate "No Response" in the response indication field. The S1G STA that transmits the BDT response burst is known as the BDT Responder.

c) The transmission of one PPDU by the BDT Initiator containing an immediate response (the BDT Initiator final PPDU), if so required by the last PPDU of the BDT response burst.

NOTE 1—A BDT Initiator can include multiple BDT sequences, separated by SIFS, within a single TXOP.

NOTE 2—A BDT sequence cannot be started with a PPDU that can not signal a Response Indication, e.g., an NDP PS-Poll frame.

NOTE 3—A BDT sequence can be started with a PS-Poll+BDT frame.

The total duration of the BDT Initiator PPDUs shall not exceed the TXOP limit as described in 10.23.2.3. The BDT responder PPDU transmission(s) and any expected responses shall fit entirely within the remaining TXOP or SP duration, as indicated in the Duration/ID field of the latest MPDU transmitted by the BDT initiator. The PPDUs may carry Data frames of any TID. A BDT exchange is subject to TXOP duration limits for the current AC.

A BDT Responder sending a BDT response burst containing an immediate response to an eliciting PPDU that had the More Data field equal to 1 shall set the Response Indication to Long Response for the last PPDU in the BDT response burst.

A BDT Responder sending a BDT response burst containing an immediate response to an eliciting PPDU that had the More Data field equal to 0 shall not set the Response Indication of the last PPDU of the BDT response burst to Long Response.

A non-AP STA shall remain in the awake state until the end of the current TXOP when one of the following conditions is met:

— It is the intended receiver of a frame with More Data field equal to 1 that is sent by the AP.
— It is a BDT Initiator of a BDT sequence within a single TXOP.

A non-AP STA may transition to the doze state if it is the intended receiver of a frame with More Data field equal to 0, which is sent by the AP.

Upon receiving a PS-Poll+BDT frame with the More Data field equal to 0, an S1G AP that intends to respond with immediate Data frames may use the RTS/CTS scheme to send buffered data until it transmits a frame with the More Data field equal to 0 or until the duration of the exchange, including the initial PS-Poll+BDT frame reaches the TXOP limit whichever comes first.

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Figure 10-102 illustrates an example of BDT signaling. STA A initiates the BDT exchange by setting the Response Indication to Long Response in the PS-Poll+BDT frame and in the preamble of two PV0 PPDUs to allow STA B to transmit its BUs. At the end, STA B sends a PPDU with the Response Indication 2 (Normal Response) and STA A will terminate the BDT exchange by sending a PPDU with the Response Indication equal to 0 (No response).

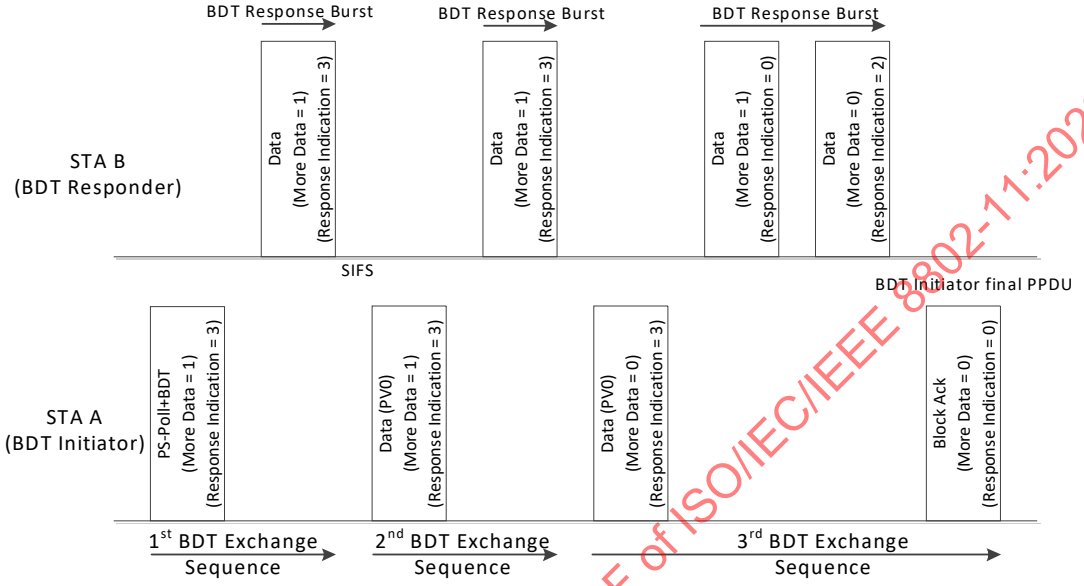

Figure 10-102—Example of BDT exchange

NOTE 4—For error recovery, a BDT initiator can transmit the next frame when the CS mechanism (see 10.3.2.1) indicates that medium is idle at TxPIFS slot boundary (defined in 10.3.7).

10.51 Page slicing

An S1G STA with dot11PageSlicingImplemented equal to true shall set the Page Slicing Support field in the S1G Capabilities element to 1. An S1G STA with dot11PageSlicingImplemented equal to false shall set the Page Slicing Support field in the S1G Capabilities element to 0.

If an S1G STA supports the page slicing mechanism as defined in this subclause, then it shall set dot11PageSlicingImplemented to true. Otherwise, an S1G STA that does not support the page slicing mechanism or a non-S1G STA shall set dot11PageSlicingImplemented to false.

The TIM element indicates downlink buffered data for all STAs in the BSS. However, in an S1G BSS with a large number of associated STAs corresponding to a single TIM and page, a single TIM element indicating the downlink buffered data for all STAs in the page can be quite large. To reduce the size of the element needed to communicate buffered data status to power save S1G STAs, an S1G AP may send one portion of a page in the TIM element virtual bitmap of each Beacon frame if dot11PageSlicingActivated is true as described in this subclause.

The traffic-indication virtual bitmap in a TIM includes a subset of the blocks from a single page. This subset of blocks is called a page slice and the size of the subset is indicated in the Page Slice Length subfield of the Page Slice element (9.4.2.192). The case of 4 TIMs and their 4 assigned page slices is depicted in

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Figure 10-103. All page slices corresponding to a single Page Slice element shall have equal size except for the last page slice.

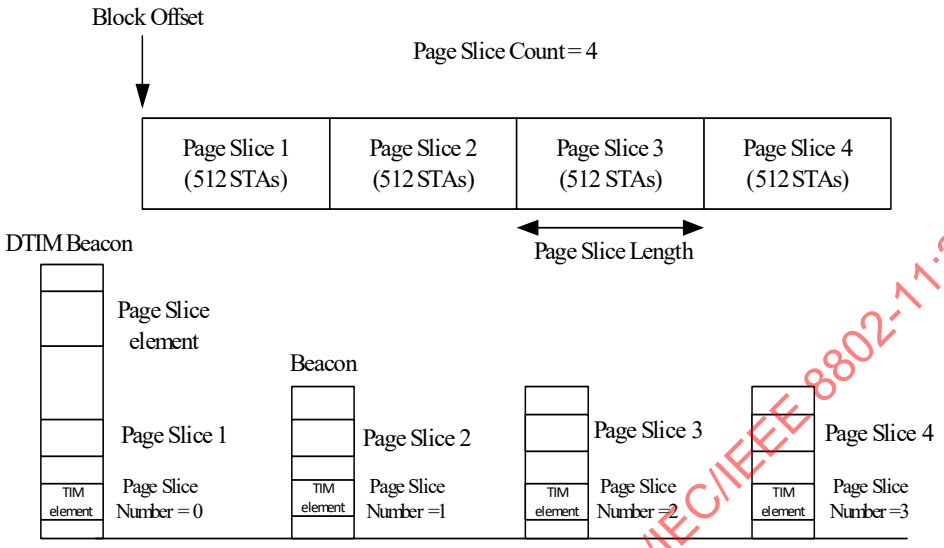

Figure 10-103—Page slicing with Page Slice element with 4 TIMs

An S1G STA for which dot11PageSlicingImplemented is true shall process all received TIM elements that include a Page Slice Number that matches its Page Slice Number and a page index that matches its Page index, and it shall follow the rules of 11.2.3.7 if the partial virtual bitmap of any of the processed TIM elements included the value of 1 in the position corresponding to any of its AIDs.

An AP that has dot11PageSlicingActivated equal to true shall not include the bit in the partial virtual bitmap that corresponds to the AID of the S1G STA with dot11PageSlicingImplemented equal to false within a TIM element that has a value for the Page Slice Number field that is in the range of 0 to 30. An AP that has dot11PageSlicingActivated equal to false shall not transmit a TIM element that has a value for the Page Slice Number field that is in the range of 0 to 30.

If an AP meets the following conditions:

— Its dot11PageSlicingActivated is true.
— Has at least one associated non-AP STA from which it has received an S1G Capabilities element with the Page Slicing Support field equal to 0 within a page.

then the AP shall

— Include in all the S1G Beacons a TIM element with Page Index subfield equal to the corresponding page index and Page Slice Number field equal to 31, if there is buffered traffic for at least one of the STA(s).
— Set the bits in the virtual bitmap of that TIM for those STAs, according to the rules described in 11.2.3.6.

An AP with dot11PageSlicingActivated equal to true and that has at least one associated STA with dot11PageSlicingActivated equal to true and whose AID is contained in

— The final block (32nd block) of a page, and has indicated a Page Slice Count equal to 0 and a Page Length greater than 1 in the Page Slice element shall include in the last S1G Beacon frame that precedes the next scheduled DTIM Beacon frame, a TIM element with Page Index subfield equal to

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the page index specified in the previously transmitted Page Slice element. The TIM element shall have the Page Slice Number equal to 31 for the indicated page, if there is buffered traffic for at least one of the STA(s) that support page slicing and belong in the final block of the page.

— Any block of a page, and has indicated a Page Slice Count equal to 0 and a Page Length equal to 1 in the Page Slice element shall include in the only S1G Beacon frame that precedes the next scheduled DTIM Beacon frame, a TIM element with Page Index subfield equal to the page index specified in the previously transmitted Page Slice element. The TIM element shall have the Page Slice Number equal to 31 for the indicated page, if there is buffered traffic for at least one of the STA(s) that support page slicing and belong in any block of the page.

The setting of the bits in the virtual bitmap of that TIM for STAs that do not support page slicing follows the rules described in 11.2.3.6.

For each page from which an AP with a value of false for dot11PageSlicingActivated has assigned at least one AID corresponding to STA(s) for which there is buffered traffic, the AP shall include in all the S1G Beacons a TIM element for that page with Page Slice Number equal to 31 and shall set the bits in the virtual bitmap of that TIM for all the STAs indicated by the Page Index subfield, according to the rules described in 11.2.3.6.

An AP with dot11PageSlicingActiviated equal to true may include more than one TIM representing different page slices within a Beacon frame. An AP with dot11PageSlicingActiviated equal to true shall not transmit a Page Slice element in any frame other than a Beacon frame that has DTIM count equal to 0. Each page slice corresponding to a TIM, except the last TIM, shall have a size that is equal to the Page Slice Length subfield indicated in the Page Slice element. However, the length of page slice may vary over multiple page periods. The AP shall transmit the first page slice in the N-th Beacon frame after the DTIM in which the Page Slice element appears, where N is equal to the TIM offset subfield. Subsequent page slices indicated in the Page Slice element appear sequentially in the following Beacons, e.g., the second slice appears in (N+1)th Beacon frame after the DTIM that contained the Page Slice element. A value of zero for TIM offset corresponds to the DTIM Beacon frame. The TIMs can be flexibly scheduled for page slices of different pages over beacon intervals. Figure 10-103 is an illustration with 4 page slices, which appear in the DTIM Beacon frame and the three following Beacons when the TIM Offset subfield of the Page Slice element is equal to 0.

The Page slice element indicates assignment of STAs in page slices corresponding to their assigned TIMs. STAs within the assigned page slice wake up at corresponding TIM sequentially to receive buffered data from AP. In order to wake up at the appropriate TBTT to receive the Page Slice element, a STA may compute the page slice assignment to the TIMs using the length of the Page Bitmap field and the value in the Page Slice Length and Page Slice Count subfields of the Page Slice element. The length of the page slice that appears in each TIM, except for the last TIM identified by a Page Slice element, is indicated in the Page Slice Length subfield. The last TIM includes the blocks indicated by the bits of the Page Bitmap field that have not appeared in previous TIMs.

An S1G STA with dot11PageSlicingActivated equal to true wakes up to receive a DTIM Beacon frame that contains the Page Slice element for its associated page slice from the AP. The STAs check the DTIM frame comprising of the Page Bitmap field and the Block Bitmap fields in Page Slice element and TIM, respectively. The Page Bitmap field in the Page Slice element provides an early indication of buffered data for all blocks in the assigned page slices. If a bit in the Page Bitmap field of the Page Slice element is equal to 0, it indicates that there is no buffered data for STAs with AIDs located in the block corresponding to that bit. These STAs may return to doze state immediately when there is no buffered group addressed data or after receiving buffered broadcast/group data as indicated in the DTIM. If the block bit in the Page Bitmap field is equal to 1, then it indicates that there is buffered data at the AP for at least one of the STAs with AIDs in that block.

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For STAs that have their AIDs that correspond to a block for which the bit in the Page Bitmap field of the Page Slice element is equal to 1, they compute the length of the page slice and the corresponding TIM to wake up. If they are not assigned in page slice 1 that is allocated to DTIM slice, then these STAs may return to doze state immediately or after receiving buffered broadcast/group data as indicated in the DTIM till their scheduled TIM.

At the assigned page slice, the STAs decode the page slice in order to determine whether there is buffered data available at the AP.

When dot11PageSlicingActivated is true, an S1G AP may use the Listen Interval field and Page Slice element information in determining the lifetime of frames that it buffers for an S1G STA in TIM mode that supports page slicing.

10.52 Subchannel selective transmission (SST)

10.52.1 SST overview

S1G STAs that are associated with an S1G AP transmit and receive on the channel or channels that are indicated by the AP as the enabled operating channels for the BSS.

An SST BSS is an S1G BSS for which the following conditions are satisfied:

a) The BSS operating channel width indicated in the Channel Width field of the S1G Operation Information element transmitted by the AP is less than or equal to 2 MHz.
b) The SST AP indicates that it enables SST operation by including the SST Operation element in the (Re)Association Response frame sent to the non-AP STA.

In an S1G BSS that is not an SST BSS, the enabled operating channels are indicated in the most recently received S1G Operation element transmitted by the AP. In an S1G SST BSS, the enabled operating channels are indicated in the most recently received SST Operation element transmitted by the AP.

An SST AP is an S1G AP with dot11SelectiveSubchannelTransmissionPermitted equal to true. During aperiodic SST operation, an SST AP indicates the set of enabled SST operating channels in an SST Operation element. During aperiodic SST operation, an SST AP indicates the subset of SST channels that SST STAs are allowed to access during a beacon interval or short beacon interval (see 11.1.3.10.2) in the SST element that is transmitted in the S1G Beacon frame that initiates that interval and/or in the Channel Indication subfield of RPS elements that include SST STAs in the RAW group. During periodic SST operation, an SST AP indicates the set of enabled SST operating channels in an SST Operation element and indicates the subset of SST channels that SST STAs are allowed to access during a beacon interval or short beacon interval in an RPS element with the Periodic RAW Indication subfield equal to 1.

An SST STA is an S1G STA that is associated with an SST AP and chooses a subset of the operating channels enabled for SST operation on which to operate in the BSS, when SST operating channels are activated by the AP as indicated in the SST element, the SST operation element, or the RPS element.

SST STAs operating in an SST BSS are allowed to transmit on an SST channel during a beacon interval or short beacon interval only if the channel is permitted for SST use as indicated by the SST AP in an SST element included in the S1G Beacon frame that initiates that interval or as indicated by an RPS element in the case of periodic SST operation.

10.52.2 Aperiodic SST operation

An SST AP that sets up an SST BSS shall include the SST Operation element in (Re)Association Response frames sent during association. An S1G AP may include the SST Operation element in S1G Beacon frames.

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The SST AP indicates the set of enabled SST operating channels, the offset of the primary channel, and the channel width unit in the SST Operation element as described in 9.4.2.214. The set of enabled SST operating channels may include channels that are not in use by the BSS as specified by the SST Enabled Channel bitmap of the element. The SST AP that sets up an SST BSS shall choose the subset of allowed SST operating channels from the subset of enabled SST operating channels indicated in the SST Operation element. The set of enabled SST operating channels indicated by the AP is not static. The S1G AP may include the RPS element in S1G Beacon frames to signal additional channels allowed for SST operation within specific RAWs. The channels that are allowed for SST operation in the RPS element can be different from the channels allowed for SST operation in the SST element.

At each TBTT or TSBTT, an SST AP may send S1G Beacon frames on more than one channel from the set of enabled operating channels for the BSS either in parallel or in series or a combination of the two. A STA transmitting parallel S1G Beacons shall use either the value S1G_DUP_1M or the value S1G_DUP_2M for the TXVECTOR parameter FORMAT of the PHY-TXSTART.request primitive for the transmission. An example of Beacons sent in parallel is when one Beacon frame is transmitted with a value of S1G_DUP_2M for the TXVECTOR parameter FORMAT and a value of CBW8 for the TXVECTOR parameter CH_BANDWIDTH in a BSS with an operating width of 8 MHz. An example of Beacons sent in series is when several different Beacons are transmitted in sequence, each with a value of S1G for the TXVECTOR parameter FORMAT and a value of CBW2 for the TXVECTOR parameter CH_BANDWIDTH and each transmitted on a different 2 MHz subchannel in a BSS with an 8 MHz operating width. When beacons are transmitted in series, all of the beacons may be queued for transmission at TBTT or TSBTT, but only one Beacon frame is transmitted at a time. SIFS or later after any Beacon frame in the series is transmitted, another Beacon frame may be transmitted in the series, provided that normal medium access rules for the channel of transmission of the Beacon frame have been satisfied.

NOTE—When a series of S1G Beacon frames is transmitted, the AP can use the channel activity schedule of the SST element in those beacons to describe when UL transmissions are permitted by SST STAs in order to protect the beacon sequence and to avoid attempts to communicate with the AP during the beacon transmission sequence. RAW, CTS-to-self and other NAV-setting mechanisms can also be employed for this purpose.

An SST AP shall include an SST element in the S1G Beacon frame that immediately precedes a beacon interval or short beacon interval when it allows SST operation within that interval (see Figure 10-104).

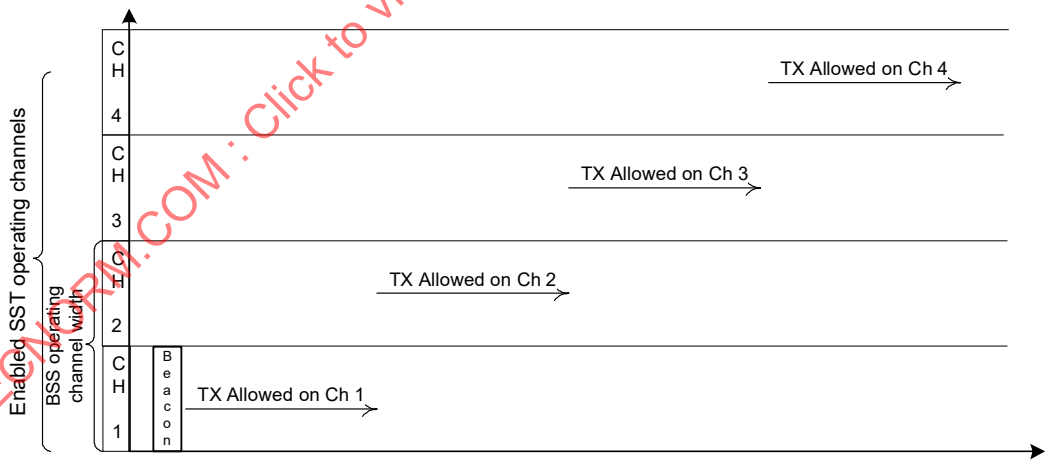

Figure 10-104—Selective Subchannel Transmission channel transmission permission allocation for SST element

An SST AP may include an SST element in transmitted S1G Beacon frames. An SST AP includes an SST element with the DL Activity bit in the SST element set to 1 and estimated start times and SST channels for

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DL transmissions in the Channel Activity Schedule field to indicate the expected times for the transmission of DL frames. These frames can be used by SST STAs to estimate the channel parameters which can be used as input to an algorithm for the selection of an SST channel.

The AP may transmit sounding frames to SST STAs for the purpose of estimating channel parameters. The AP may transmit sounding frames for SST STA channel estimation either in parallel or in series or a combination of the two, where a parallel transmission by an S1G AP shall use either the value S1G_DUP_1M or the value S1G_DUP_2M for the TXVECTOR parameter FORMAT of the PHY-TXSTART.request primitive for the transmission.

An S1G AP may include an SST element (see 9.4.2.201) in an S1G Beacon frame to indicate on which channels an SST STA is allowed to transmit within the BSS or SST BSS.

An S1G AP may indicate on which SST channels it intends to transmit sounding and nonsounding frames following the transmission of an S1G Beacon frame by including an SST element in the S1G Beacon frame with a nonzero value in at least one bit of the Channel Activity Bitmap subfield and a value of 1 in the corresponding DL Activity subfield. An SST STA may choose an SST channel for transmissions based on its analysis of the sounding signals and received transmissions.

In an SST BSS, an SST STA shall not transmit in a channel that is not the primary channel of the BSS if the corresponding bit of the Channel Activity Bitmap is 0 in the most recently received SST element or RPS element from its associated AP. An SST STA shall not transmit using a channel width that is greater than the value of the SST Channel Unit indicated in the most recently received SST Operation element from its associated AP.

When no SST Operation element has been received by an SST STA from its associated AP, the STA shall not transmit a frame with a BSSID that is equal to the BSSID of the BSS of which the STA is a member, in a channel of operation that is not included in the channels of operation of the BSS.

If the frames that are transmitted by an S1G AP in response to an announcement of transmission activity within an SST element are sounding frames, the S1G AP shall use the same value for the TXPWR_LEVEL parameter of the TXVECTOR for each of the sounding frame transmissions associated with the SST element announcement. An S1G AP should transmit SST sounding frames at times and on SST channels indicated for downlink activity in the Activity Start Time and Channel Activity Bitmap fields of the SST elements that it transmits.

The AP may signal the presence of a RAW for the purpose of SST sounding for a group of STAs using an SST sounding RAW as indicated within a transmitted RPS element. Such an SST sounding RAW may be scheduled for periodic or nonperiodic operation. Additional RAW(s) may be scheduled as SST report RAW(s) (see 9.4.2.191) after the SST sounding RAW for the transmission of NDP CMAC PPDUs (e.g., NDP PS-Poll frame) by SST STAs on their selected channel(s) for the purpose of communicating a selected subchannel to the AP. The AP is not required to use a RAW for SST sounding.

In an SST report RAW, the STA transmits a report frame to the AP not earlier than the start of its assigned RAW slot, followed by the AP's response for confirmation after SIFS.

When the AP uses a RAW for SST sounding, the RAW Type subfield is equal to sounding RAW, and the RAW Type Options subfield is equal to SST sounding RAW in the RPS element (see 9.4.2.191) transmitted by the AP. The SST sounding sequence within the SST sounding RAW comprises a series of NDP CMAC PPDUs (e.g., NDP CTS frames), each transmitted on one of the channels among those indicated by the Channel Indication field of the RAW, starting with the lowest frequency channel and continuing in sequence with the next higher frequency channel if more than one channel is indicated. The RPS element for the SST sounding RAW specifies a start time, channel(s) and RAW duration for each RAW assignment. The AP shall not transmit any NDP CMAC PPDU on a channel within an SST sounding RAW before the TxPIFS

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slot boundary as defined in 10.3.7. If the AP does not observe an idle medium condition within one PIFS after switching to a channel, then the AP shall not transmit an NDP, but shall wait for the duration of an NDP before switching to the next channel. This deterministic channel switching allows listening SST STAs to predict the timing of the sounding transmission for each channel. An AP may schedule multiple SST sounding RAWs to increase the probability that a sounding frame is transmitted on each SST channel. The amount of time allocated in the sounding RAW for the channel switch operations performed by the AP is implementation dependent, and is calculated at the non-AP STA by subtracting the value $N \times$ (PIFS + NDPTxTime) from the total RAW duration and dividing the result by N-1, where N is the number of channels to be sounded.

When the AP uses a RAW for SST operation and the RAW is not a sounding RAW, then the RAW Type is generic RAW and the Channel Indication Presence bit is set to 1 and the number of channels indicated in the Channel Indication in the RPS element (see 9.4.2.191) transmitted by the AP shall be one, unless there is only one STA assigned to each slot in the RAW defined by the RPS element. An AP shall not schedule any non-SST STA within a RAW that has a Channel Indication Presence bit equal to 1.

A local S1G Beacon frame is one that was transmitted by the AP with which a STA is associated.

An SST STA may select one or more SST channels from the enabled SST operating channels as indicated in the SST Operation element transmitted by the SST AP with which it is associated. The SST STA may operate on those SST channels for the beacon interval or short beacon interval following a TBTT or TSBTT if a local S1G Beacon frame with an SST element indicating that a subset of the enabled SST channel(s) are allowed for SST operation has been received by the SST STA during that interval. The STA shall not transmit frames on the indicated allowed SST channels with a bandwidth that is wider than the Maximum Transmission Width specified in the SST element. If no local S1G Beacon frame is received following a TBTT or TSBTT, then no SST STA transmission is allowed during the beacon interval or short beacon interval that begins at that TBTT or TSBTT except on the primary channel of the BSS. If an SST STA receives a local S1G Beacon frame which contains no SST element, the SST STA may transmit on the primary channel of the BSS a PPDU of width up to the BSS bandwidth indicated in the S1G Beacon frame during the beacon interval or short beacon interval that immediately follows the reception of the S1G Beacon frame.

An SST STA that has selected an SST operating channel that is not the primary channel for the BSS shall operate on the selected channel as though the channel is the primary channel of the BSS, but only at the times allowed for operation on the selected channel as indicated in this subclause.

An SST STA that selected its best SST operating channel(s) may report its selection to the SST AP by sending an NDP PS-Poll frame on the primary channel of the BSS, including the selected SST channel offset in the UDI field. The transmission of any frame on an allowed subchannel by an SST STA is an implicit indication to the AP as to the subchannel selection made by the SST STA. An SST STA may queue for transmission a QoS NULL frame addressed to the AP for this purpose. To avoid ambiguity in which subchannel has been selected by the STA as its primary channel, the STA can send the frame using the minimum width channel for the band of operation on the selected primary channel.

An SST STA that has selected a subchannel for operation should operate on that subchannel during times indicated for permitted downlink and uplink operation according to the DL Activity and UL Activity fields and the Activity Start Time field in the SST element. An AP should transmit frames to the SST STA on their selected subchannels.

An SST STA shall not transmit to the AP on an SST operating channel that is not indicated as allowed by the AP in the SST element. The set of allowed SST channels indicated by the AP in the SST element is dynamic and can change every beacon interval or short beacon interval.

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An SST AP shall not be away from the primary channel of the BSS for a duration of time that exceeds the value of the dot11MaxAwayDuration during a beacon interval or short beacon interval, as defined in 11.2.3.18.

10.52.3 Periodic SST operation

During aperiodic SST operation, an SST AP signals explicit permission of SST STA transmissions during each single beacon interval or short beacon interval in which SST operation is activated by transmitting the SST element. During periodic SST operation, an SST AP signals permission of SST STA transmissions over multiple beacon intervals or short beacon intervals through the transmission of the RPS element with the Channel Indication Presence bit equal to 1 and the Periodic RAW Indication bit equal to 1.

Periodic SST operation shall follow the procedure in 10.52.2 with the additional requirement that the SST AP shall transmit at least one RPS element with the Channel Indication Presence bit set to 1 and the Periodic RAW Indication bit set to 1 preceding the first beacon interval or short beacon interval during which SST operation is permitted and no SST element shall be transmitted. The periodicity, validity, and start offset of the periodic SST operation are indicated in the Periodic Operation Parameters subfield of the RAW Assignment subfield of RPS element. When the RPS element is used to indicate a periodic SST sounding schedule, the RAW Type subfield of the RPS element is set to sounding RAW and the RAW Type Options subfield of the RPS element is set to SST sounding RAW.

10.53 Sectorized beam operation

10.53.1 Introduction

The partition of the coverage area of a BSS into sectors, each containing a subset of STAs, is called sectorization. This partitioning is generally achieved by the AP transmitting or receiving through a set of antennas or a set of synthesized antenna beams to cover different sectors of the BSS. The goal of the sectorization is to reduce medium contention or interference by the reduced number of STAs within a sector. AP shall cover all STAs associated to it with at least one sector or an omnidirectional beam. STAs are allowed to move from one sector to another sector. The entire BSS is assumed to be covered by the omnidirectional beam or the omnidirectional antenna of the AP.

10.53.2 Sector Capabilities Exchange

After the sectorized beam-capable non-AP STA is associated with a sectorized beam-capable AP, the AP can transmit through its sectorized beam to the non-AP STA.

If dot11S1GSectorImplemented is true, a non-AP STA shall set the Sectorized Beam-Capable field in the S1G Capabilities element it transmits to 1. The sectorized beam-capable non-AP STA shall support both group sectorization and TXOP-based sectorization operations.

If dot11S1GSectorImplemented is true, an AP shall set the Sectorized Beam-Capable field in the S1G Capabilities element it transmits as follows:

— 1 if the AP supports only TXOP-based sectorization
— 2 if the AP supports only group sectorization
— 3 if the AP supports both TXOP-based sectorization and group sectorization

A STA with dot11S1GSectorImplemented equal to false shall set the Sectorized Beam-Capable field in the S1G Capabilities element to 0.

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If dot11S1GSectorTrainingOperationImplemented is true, a STA shall set the Sector Training Operation Support field in the S1G Capabilities element to 1 in the Association Request frame. If dot11S1GSectorTrainingOperationImplemented is false, the STA shall set the Sector Training Operation Support field in the S1G Capabilities element to 0. If dot11S1GSectorTrainingOperationImplemented is true, dot11HTControlFieldSupported is true.

When the AP sets the Sectorized Beam-Capable field to 3 in the S1G Capabilities element it transmits then group sectorization and TXOP-based sectorization may optionally be used at the same time if

— The AP intends to apply TXOP-based sectorization during the omnidirectional beacon interval or the sectorized beacon interval to STAs with the corresponding Sector ID.
— The AP or non-AP STA, intending to apply TXOP-based sectorization during the omnidirectional beacon interval or the sectorized beacon interval, follows the rule according to which a non-AP STA is not allowed to transmit in certain beacon intervals as described in 10.53.3.

After the exchange of the S1G Capabilities element during the Association, a sectorized beam-capable AP supporting group sectorization operation shall transmit an S1G Sector Operation element with the Sectorization Type field equal to 0 to advertise the period of the current sector, omnidirectional or sectorized beam, the current sector ID, the allowable group IDs, and the duration of the current sector in the Beacon frame to start a beacon interval. A sectorized beam-capable AP supporting TXOP-based sectorization operation may transmit an S1G Sector Operation element with the Sectorization Type field set to 1 to advertise if periodic sector training is on or off, its training period, and the remaining beacon intervals to the next periodic training in the S1G Sector Operation element in a Beacon frame.

A sectorized beam-capable AP may (re)assign a specific Sector ID to a sectorized beam-capable STA after the Association. A sectorized beam-capable STA may optionally send Sector ID feedback to its associated sectorized beam-capable AP. A sectorized beam-capable STA may optionally request sector training from its associated sectorized beam-capable AP. A sectorized beam-capable AP has at least two sectors.

A STA, which is not sectorized beam-capable may skip the S1G Sector Operation element in the Beacon frame. In a BSS where the AP does not support group sectorization, a STA, whether it is sectorized beam-capable or not, is allowed to transmit at any beacon interval.

10.53.3 Group sectorization operation

Group sectorization operation is based on the AP transmitting a sectorized Beacon frame. A sectorized Beacon frame is a Beacon frame transmitted through a sectorized beam, which covers a specific sector of the BSS.

A BSS that is employing a sectorization operation is called a Sectorized BSS. The sectorization scheme of operation in a BSS is signaled by the presence of an S1G Sector Operation element in Beacon frames, Probe Response frames, and Association Response frames.

In a Sectorized BSS, the AP may alternate the sectorized beacons and the nonsectorized (omnidirectional) beacons, as illustrated by the example in Figure 10-105. More than one sector could be active at the same time, i.e., they can overlap in time. In such case, STAs from different sectors are allowed to transmit while their sectors are active. During the omnidirectional beacon interval all the STAs in the BSS may transmit regardless of their geographical locations. Sectorized beacons are transmitted to selected geographical areas to inform groups of STAs that they are allowed to transmit during the sector intervals specified in the S1G Sector Operation element. The AP with group sectorization operation receives transmissions from all sectors continuously.

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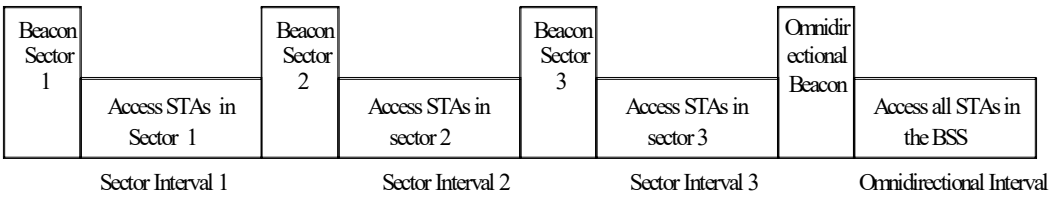

Figure 10-105—Sectorized BSS operation

All beacons in a sectorized BSS carry the S1G Sector Operation element. The 1-bit Omni field indicator within the S1G Sector Operation element distinguishes between the sectorized Beacon frame and the omnidirectional Beacon frame transmission. The S1G Sector Operation element further specifies the type of sectorization operation, the type of Beacon frame (sectorized or omnidirectional), the complete rotation period of all (sectorized and omnidirectional) beacons, the subperiod for the current Beacon frame, and the list of groups of STAs that are allowed to transmit during the current beacon interval.

In a Sectorized BSS with group sectorization operation, each STA is allocated a group ID related to the sectorization operation. STAs that have group ID zero are allowed to transmit in all beacon intervals. A STA that is sectorized beam capable and whose group ID is contained in the list of group IDs carried in the S1G Sector Operation element in a Beacon frame is allowed to transmit until the next TBTT. By default all STAs have group ID 0 unless otherwise specified at the association. Because by default all STAs that support group sectorization belong to group ID 0 before association, all the STAs can transmit at any time before their association. It is expected that during the association, STAs receive a nonzero group ID, which will restrict their activity to a particular sector interval and omnidirectional time interval. The AP may allow some STAs to have the group zero even after association, for instance public safety STAs or some high priority sensors.

A STA that receives a Beacon frame in a Sectorized BSS shall verify if its group ID is contained in the group ID list of the S1G Sector Operation element in the Beacon frame if it intends to transmit before the next TBTT. A STA that has a nonzero group ID, which is not listed in the S1G Sector Operation element of the Beacon frame, is not allowed to transmit during that sector duration.

The STAs that do not support the group sectorization operation are not subject to the rules defined in this subclause.

In a Group Sectorized BSS:

— The S1G AP shall transmit omnidirectional Beacon frames every dot11BeaconPeriod as described in 11.1.2.1.

— The S1G AP may transmit sectorized Beacon frames every sectorized beacon interval. A non-AP STA that is associated to the AP and is group sectorized capable shall wake up to read the sectorized Beacon frame if it intends to access the medium during the sectorized beacon interval. A non-AP STA that is not group sectorized capable may ignore the sectorized Beacon frame and is not subject to the rules described in this subclause.

The purpose of group sectorization operation is to allow the channel access of one or multiple groups of STAs at the time, where the STA group allocation is based on STA sector location and other grouping criteria (e.g., the device type, or traffic type, or the received SNR) in order to reduce the number of hidden nodes that simultaneously access the AP.

Two or more sectors may be active at the same time, i.e., their active time can overlap. In this case the STAs are allowed to transmit in more than one sector. Figure 10-105 presents an example of three nonoverlapping sectors followed by an omnidirectional period. Each sector starts with sectorized Beacon frame that provides the sector ID and the duration of sector activity.

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10.53.4 TXOP-based sectorization operation

TXOP-based sectorization operation is based on an AP transmitting or receiving through the sectorized beam within a TXOP. At the beginning of a frame exchange, the AP may start with the omnidirectional beam transmission to establish a link with a STA and to set up protection duration within a TXOP before switching to the sectorized beam transmission and reception. In different TXOPs, the AP may use different sectorized beams to communicate with different STAs. A Sectorized beam capable AP supporting TXOP-based sectorization operation shall be able to transmit or receive through both the omnidirectional beam or the sectorized beams.

In a BSS with TXOP-based sectorization operation, the AP shall signal the operation in Beacon frames, Probe Response frames, Association Response frames, or other frames using the S1G Sector Operation element. The operation of TXOP-based sectorization is defined by the following rules:

— The switching from an omnidirectional beam transmission to a sectorized beam transmission occurs when the bit position corresponding to the sector is set to 1 in the TXVECTOR parameter SECTOR_ID.
— When an AP is aware of the sector in which a STA is in, AP may select the sectorized beam by setting the bit position corresponding to the sector to 1 in the TXVECTOR parameter SECTOR_ID when it transmits to or receives from the STA. Otherwise, the AP transmits or receives through the omnidirectional beam to the STA.
— Once AP transmits to a STA through a sectorized beam by setting the bit in the TXVECTOR parameter SECTOR_ID that corresponds to that sector to 1, it shall use the same sectorized beam to receive from the STA within the same TXOP.
— Once the AP switches to the sectorized beam transmission during an exchange, it shall continue with sectorized beam transmission using the same sectorized beam and the TXOP truncation is not allowed for the remaining duration of the NAV/RID protection.
— An AP shall use the same sectorized beam for transmission after PIFS recovery or backoff recovery in a TXOP.
— TXOP sharing for relaying shall not be used in a TXOP.

Note that a possible realization of an omnidirectional beam is by setting bit positions of all available sectors to 0. Another possible realization of omnidirectional beam is by setting all bit positions to 1 in the TXVECTOR parameter SECTOR_ID and the CSD are inserted to different sectorized beams to avoid unintentional beamforming.

In TXOP-based sectorization operation, during a frame exchange between the AP employing sectorized beamforming and a non-AP STA, spatial reuse by OBSS APs or OBSS non-AP STAs sharing the same wireless medium is allowed under the following rules:

When a protection NAV and RID for a TXOP is set up by an AP's omnidirectional beam transmission and a spatially orthogonal (SO) condition is confirmed by an OBSS non-AP STA or OBSS AP, the OBSS non-AP STA or OBSS AP may initiate an SO exchange after an SO-Backoff. For a non-AP STA the SO-Backoff is initialized with the AC_VO parameters from the most recently received EDCA parameter set element sent by the AP with which the STA is associated. For an AP the SO-Backoff is initialized with the AC_VO parameters of the AP. The SO-Backoff function begins or resumes when the SO condition is confirmed. The SO-Backoff function is independent of all other backoff functions but follows the EDCAF backoff procedure as defined in 10.2.3. An OBSS non-AP STA or OBSS AP that invokes or resumes an SO-Backoff at the confirmation of an SO condition shall set an SO timer to MAX(NAV, RID) and reset its NAV and RID and suspend EDCAF backoff procedures. At the expiry of the SO timer, the SO-Backoff is suspended and the suspended EDCAF backoff procedures resume. An OBSS non-AP STA or OBSS AP that initiates a new spatially orthogonal frame exchange after an SO-Backoff procedure shall start the exchange with a nonbeamformed RTS/CTS and shall limit the duration of the exchange such that it ends before the expiry of

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the SO timer. The new frame exchange as described is called a spatially orthogonal frame exchange. The new spatially orthogonal frame exchange initiator may transmit frames from any AC. The STA shall obey the TXOP limit of the AC of the frames transmitted within the SO frame exchange. A STA that transmits an SO frame exchange may transmit additional SO frame exchanges by continuing to use the SO-Backoff function until the expiry of the SO timer. If the ongoing frame exchange transmission is between a pair of STAs within its BSS, the STA does not reset its NAV and its RID even though the spatially orthogonal conditions are met. Within the new spatially orthogonal exchange, an OBSS AP shall use an antenna setting which is same as the antenna setting used to detect the SO condition for transmission.

The SO condition is satisfied if an OBSS non-AP STA or OBSS AP which receives the omnidirectional transmission but not the subsequent sectorized beam transmission from the AP and not the transmission from the STA involving in the frame exchange.

Four types of frame exchange sequences, which can lead to the SO conditions by OBSS non-AP STAs or OBSS APs are described.

a) SO frame exchange sequence 1: As illustrated in Figure 10-106, the AP starts a frame exchange with the omnidirectional beam to establish a link with a STA and set up the protection for the duration of the sectorized beam transmission. The second PPDU has a long format, AP switches to the sectorized beam transmission after the omnidirectional preamble of the long preamble. The AP continues with the sectorized beam transmission for the remaining duration of the NAV/RID protection. An OBSS non-AP STA or OBSS AP receives the omnidirectional beam transmission from the AP may attempt to start an SO frame exchange by detecting an SO condition. An SO condition is confirmed by an OBSS non-AP STA or OBSS AP, which observes the omnidirectional transmission of the AP but not the beamformed preamble of the AP and not the STA's transmission.

   Note that an OBSS non-AP STA or OBSS AP infers its spatial orthogonality by

   1) Observing the first omnidirectional beam PPDU and the omnidirectional preamble of the long preamble from the AP.
   2) Not observing the subsequent sectorized beam transmission from the AP for the duration of one symbol (D-STF as shown in Figure 23-2) following the omnidirectional portion of the S1G_LONG format.
   3) Observing a gap of no transmission between the first omnidirectional beam PPDU and the omnidirectional preamble of the long preamble by the AP.

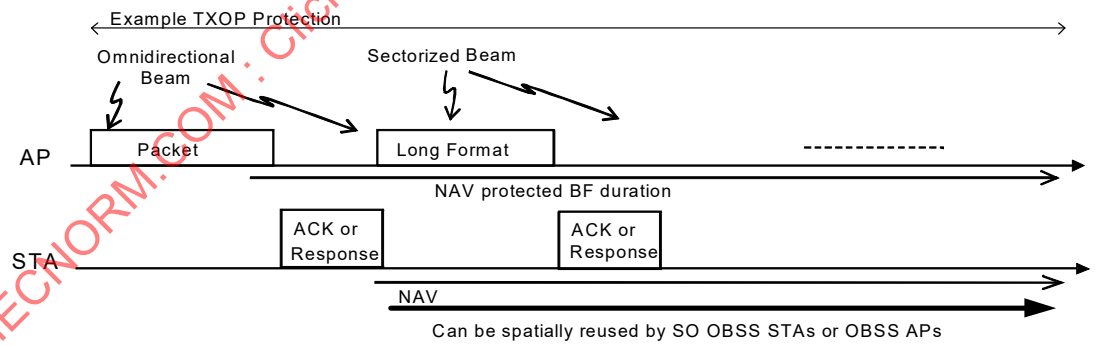

Figure 10-106—SO frame exchange sequence 1

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b) SO frame exchange sequence 2: As illustrated in Figure 10-107, the AP starts a frame exchange with the omnidirectional transmission of a PPDU to establish a link with a STA and to set up the protection for the duration of the sectorized beam transmission. Subsequently, the AP switches to a sectorized beam transmission for the remaining duration of the NAV/RID protection. An OBSS non-AP STA or OBSS AP receives the omnidirectional beam transmission from the AP may attempt to start an SO frame exchange by detecting the SO condition. SO condition is confirmed by an OBSS non-AP STA or OBSS AP, which observes the omnidirectional transmission of the AP but not the beamformed transmission of the AP and not the STA's transmission.

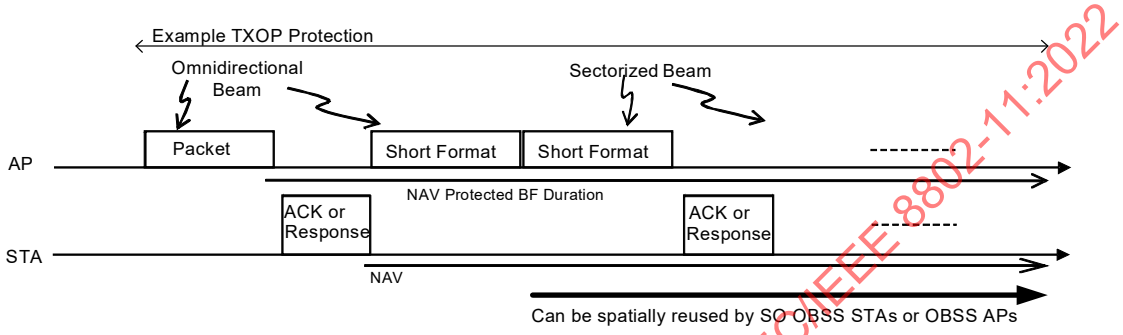

Figure 10-107—SO frame exchange sequence 2

Note that an OBSS non-AP STA or OBSS AP infers its spatial orthogonality by

1) Observing the omnidirectional beam transmission by the AP.
2) Not observing the subsequent sectorized beam transmission by the AP for aSIFSTime + aSlotTime + aRxPHYStartDelay duration.
3) Observing a gap of no transmission between the first two omnidirectional beam PPDUs by the AP.

c) SO frame exchange sequence 3: The AP starts a frame exchange with an omnidirectional RTS frame to solicit a CTS response from a STA and uses the omnidirectional transmission to set up the protection for the duration of the sectorized beam transmission and then switches to the sectorized beam transmission for the remaining duration of the NAV/RID protection. SO condition is confirmed by an OBSS non-AP STA or OBSS AP, which observes the omnidirectional transmission of the AP but not the beamformed transmission of the AP and not the STA's transmission. Note that in the first diagram in Figure 10-108, an OBSS non-AP STA or OBSS AP infers its spatial orthogonality with the AP by observing the omnidirectional beam RTS frame and the omnidirectional portion of the long format for the duration of one symbol (D-STF as shown in Figure 23-2) following the omnidirectional portion of the S1G_LONG format but not the subsequent sectorized beam transmission and with the STA by observing a gap of no transmission between the omnidirectional RTS frame and the omnidirectional preamble of the long preamble. Note that in the second diagram in Figure 10-108, an OBSS non-AP STA or OBSS AP infers its spatial orthogonality with the AP by observing the transmission of the omnidirectional beam RTS frame and the omnidirectional beam PPDU of the short format but not observing the subsequent sectorized beam transmission for aSIFSTime + aSlotTime + aRxPHYStartDelay duration and with the STA by observing a gap of no transmission between the omnidirectional RTS frame and the omnidirectional beam PPDU of the short format by the AP.

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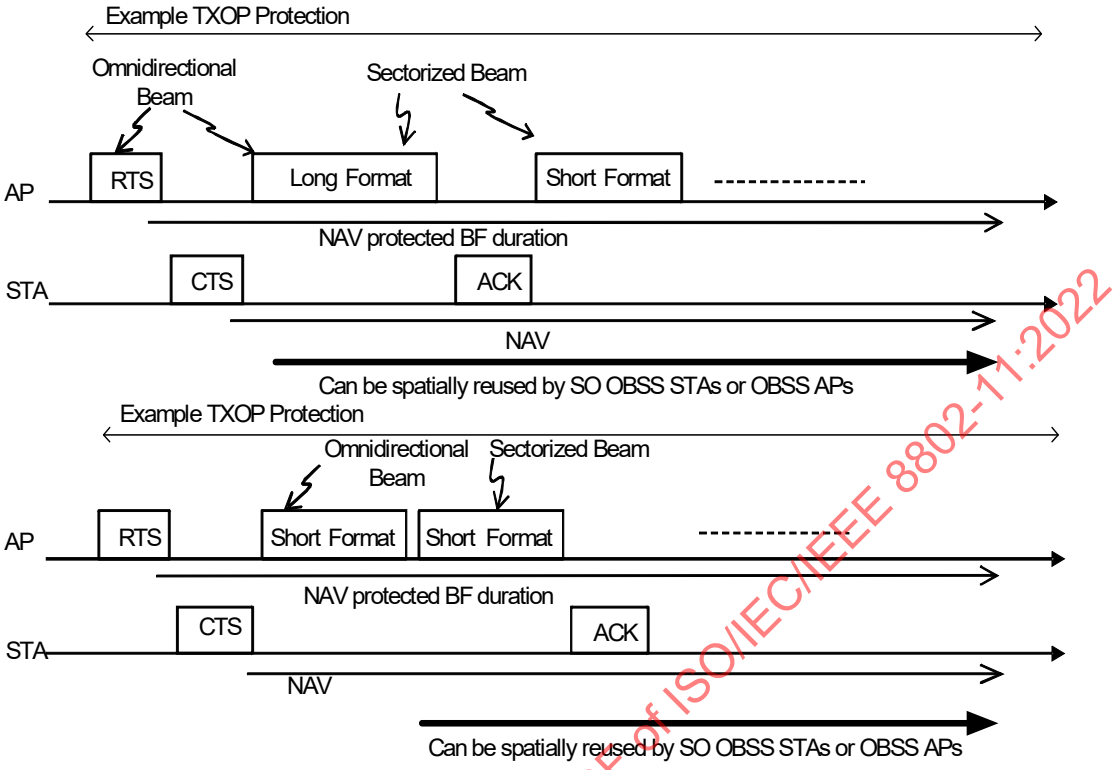

Figure 10-108—SO frame exchange sequence 3

d) SO frame exchange sequence 4: A STA starts with the omnidirectional beam to establish a link with the AP. AP uses omnidirectional transmission as the responding and to set up the protection for the duration of the remaining TXOP. Then the AP transmits the sectorized beam transmission (either an omnidirectional preamble of a long preamble or an omnidirectional transmission of a subsequent PPDU) and switches to the sectorized beam transmission. The AP continues with the sectorized beam transmission for the remaining duration of the NAV/RID protection. SO condition is confirmed by an OBSS non-AP STA or OBSS AP, which observes the omnidirectional transmission of the AP but not the beamformed transmission of the AP and not the STA's transmission.

Note that in the first diagram in Figure 10-109, an OBSS non-AP STA or OBSS AP infers its spatial orthogonality with the AP by observing the omnidirectional beam frame and the omnidirectional portion of the long format for the duration of one symbol (D-STF) following the omnidirectional portion of the S1G_LONG format but not the subsequent sectorized beam transmission and with the STA by observing a gap of no transmission before the AP response to PS-Poll frame or trigger frame from the STA. Note that in the second diagram in Figure 10-109, an OBSS non-AP STA or OBSS AP infers its spatial orthogonality by

1) Observing the omnidirectional beam PPDU of the short format from the AP.
2) Not observing the subsequent sectorized beam transmission by the AP for aSIFSTime + aSlotTime + aRxPHYStartDelay duration.
3) Observing a gap of no transmission before the first omnidirectional beam PPDU of the short format by the AP.

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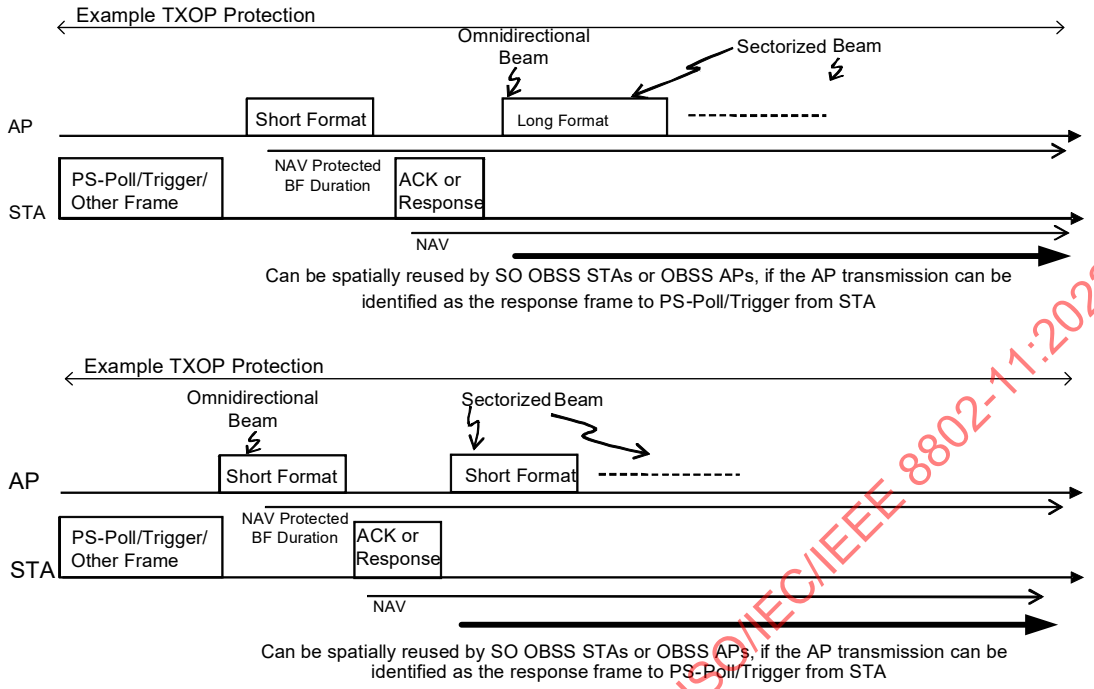

Figure 10-109—SO frame exchange sequence 4

To facilitate the detection of the spatially orthogonal conditions by OBSS non-AP STAs or OBSS APs, the NDP CTS frame may be transmitted preceding the SO frame exchange. If the Early Sector Indicator in the NDP CTS frame is equal to 1, it indicates that the NDP CTS frame is followed by the sectorized beam frame exchange. Setting the Early Sector Indicator to 1 and Address Indicator to 0 also indicates to the OBSS STAs that it might cancel its NAV and its RID setting if the spatially orthogonal conditions are subsequently met. If the ongoing frame exchange transmission preceding the NDP CTS frame is between a pair of STAs within its BSS, the STA does not reset its NAV and its RID even though the spatially orthogonal conditions are met. The RXVECTOR parameter COLOR is utilized to detect the SO condition by classifying the received PPDU between a same BSS transmission and an OBSS transmission. Hence, if the Early Sector Indicator is equal to 0, OBSS STA need not check for spatially orthogonal conditions. Figure 10-110 illustrates the frame exchange preceded by CTS-to-self using NDP CTS frame.

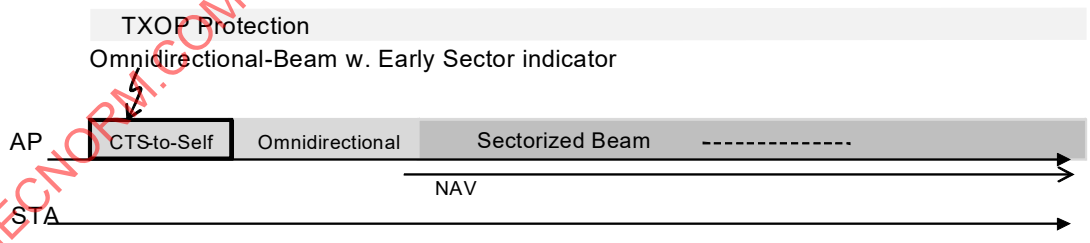

Figure 10-110—CTS-to-self preceding SO frame exchange sequence

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10.53.5 Sector training operation

10.53.5.1 Introduction

Sector training is one way to help the STAs to determine the best sectors to communicate with the AP. In sector training, an AP with dot11S1GSectorTrainingOperationImplemented equal to true shall transmit training NDP CTSs over all sectors. The best sector might be chosen by a STA based on instantaneous or averaged CSI. The specific method of choosing the sector is beyond the scope of this standard. The results of sector training may be fed-back by the STAs to the AP using Sector ID feedback frame. These training NDP CTSs (with the Address Indication bit set to 1 and the RA/Partial BSSID field set to the partial BSSID of the AP's BSS) shall be transmitted consecutively and should be sent within a single TXOP. Sector training is set up or requested using the HT variant Control field. Sector training supports up to eight sectors. The AP may use other methods to determine the STA's best sector.

10.53.5.2 Procedure

In sector training, the AP sends a sector training announcement followed by a series of NDP CTS sector training frames separated by SIFS.

In TXOP-based sectorization operation, sector training may occur periodically with the training period and the beacon interval in which the training occurs as indicated in S1G Sector Operation element (TXOP-based), in response to a request from a STA, or initiated by the AP. The STAs may perform sector training by receiving the training NDP CTSs from AP. When the AP receives the sector training request from a STA, the AP shall schedule sector training. AP supporting TXOP-based sectorization shall support sector training and sector training request. In the S1G Sector Operation element (TXOP-based) (see 9.4.2.195), which is transmitted in Beacon frame, Probe Response frame, or Association Response frame, the AP indicates in which beacon interval sector training occurs.

In group sectorization operation, a STA can find its best sector ID by listening to all the sectorized beacons transmitted during dot11BeaconPeriod. The S1G Sector Operation element (group) carried in the sectorized Beacon frame provides the sectorized beacons' rotation period, current sector ID, the subperiod of the current sector and the group IDs of the groups of STAs, which are allowed to transmit within the current beacon interval. Sector training may also be used for STAs to reduce time for sector discovery and allow STAs, which do not listen to all the sectorized beacons for its power saving.

The STA may use the Sector ID feedback frame (see 9.6.24.11) to indicate to the AP which sector is selected.

The STA may request sector training from AP by using the HT variant Control field if it is capable of sector training request. By setting the MAI=14 in the Link Adaptation Control subfield of the HT variant Control field, the STA indicates HT variant control field is used for sector training (or antenna selection) information. Sector training (or sector training resumption) is requested by a STA when the ASELC subfield is equal to 1 and the ASEL Data subfield with values in the range of 1 to 15, being the number of the first NDP CTS training frames to be transmitted when the command is sector training resumption, where 0 corresponds to the first training frame in the sector training request. When the HT NDP Announcement subfield is also equal to 1, it indicates training NDP CTS frames to follow with consecutive training NDP CTS frames separated by SIFS.

The frame exchange sequence for sector training is shown in Figure 10-111, where the AP transmits training NDP CTS frames, and the STA provides Sector ID feedback. The frame exchange comprises the following steps:

a) (Optional) A STA may initiate sector training by sending a +HTC frame with the ASELC set to 1 for sector training request.

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b) The AP sends out consecutive training NDP CTSs (with the Address Indication bit set to 1 and the RA/Partial BSSID field set to the partial BSSID of the AP's BSS) separated by SIFS in a TXOP of which it is the TXOP holder with no Ack over different sectorized beams. NDP CTS frames (23.3.12.2.1), with NDP CMAC PPDU Type=0, are used in sector training. Each training NDP CTS frame is transmitted over one sector beam. The first training NDP CTS frame shall be preceded by a +HTC frame with HT NDP Announcement subfield set to 1. The positions of the training NDP CTS frames correspond to the sector IDs of the sectorized beams, in ascending order starting with Sector ID =0.

c) The STA(s) may perform training by selecting the antenna sector based on NDP CTS training frames.

d) The STA(s) engages in the training by receiving the sector training frames may respond with a selected sector ID using the sector ID feedback frame in a subsequent TXOP or during sector report RAW, which may be indicated by Beacon frame for fast sector discovery of multiple STAs (see 10.53.5.4),

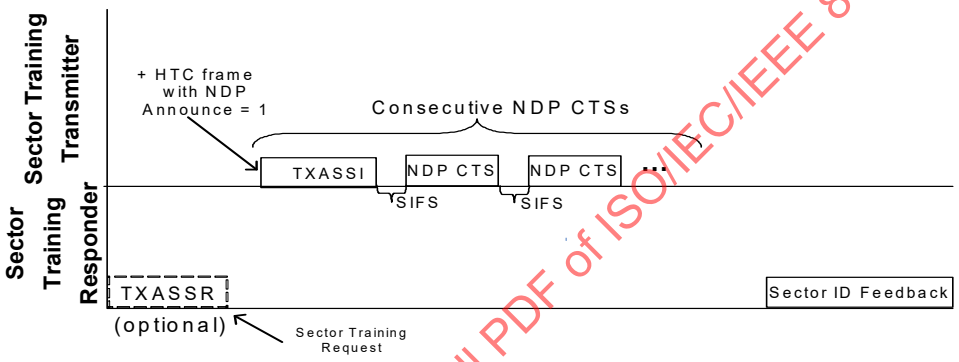

Figure 10-111—Sector training

If the AP receives a +HTC MPDU with the MAI subfield equal to 14, the ASEL Command subfield equal to sector training request (i.e., the value of the field is 1), and the ASEL Data subfield equal to zero to correspond to the command sector training, the STA shall assume a total number of training NDP CTSs that corresponds to the total number of sectors. If the AP receives a +HTC MPDU with the MAI subfield equal to 14, the ASEL Command subfield equal to sector training request (i.e., the value of the field is 1), and the ASEL Data subfield equal nonzero value to correspond to the command sector training resumption (a resumption MPDU), the STA shall assume the number of training frames that follow the resumption MPDU is equal to the number of training NDP CTSs from the total number of sectors minus the order number transmitted in the ASEL Data subfield of the Resumption MPDU.

An AP may schedule sector sounding for multiple STAs by RAW in a beacon interval using the RAW Parameter Set element with the RAW Type field equal to sounding RAW and the RAW Type Options subfield equal to sector sounding RAW (see 9.4.2.191). During the sounding RAW, non-AP STAs that are associated with the AP are expected not to access the WM during the RAW duration as described in 10.23.5 and can elect to listen to the training NDP CTS frames transmitted by the AP. This sector sounding RAW may be scheduled as periodic or nonperiodic.

Sector training within the sector sounding RAW starts with a frame with HT NDP Announcement subfield equal to 1 in the HT control field and is followed in SIFS by a number of NDP CTS frames, each transmitted through different antenna sector starting with Sector ID equal to 0, and separated by SIFS. If the RAW Type and the RAW Type Options subfield do not indicate that the RAW is a sector sounding RAW, no sector sounding is performed within the RAW.

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Channel bandwidth for sector training shall be a width up to the BSS bandwidth indicated in the S1G Beacon frame during the beacon interval. The AP may transmit NDP CTS frames for sector sounding in parallel (e.g., with a value of S1G_DUP_2M for the TXVECTOR parameter FORMAT and a value of CBW8 for the TXVECTOR parameter CH_BANDWIDTH in a BSS with an operating width of 8 MHz). The Bandwidth Indication field in the sounding frames (in NDP_2M CTS frame) and the Channel Indication field in the sounding RAW shall comply with the TXVECTOR parameter CH_BANDWIDTH.

10.53.5.3 Sector ID feedback

A STA may optionally use an Unprotected S1G Action frame (see 9.6.24.11) for (solicited and unsolicited) Sector ID feedback.

10.53.5.4 Fast Sector Discovery

When multiple STAs report their sector IDs using the Sector ID feedback frames to AP, Sector ID feedback frames may be protected by sector report RAW(s) (see 9.4.2.191) indicated in the Beacon frame to avoid contentions with others. The sector report RAW(s) may be assigned after the sector sounding RAW for fast sector discovery of multiple STAs.

In the sector report RAW, the STA transmits a report frame to the AP not earlier than the start of its assigned RAW slot, followed by the AP's response for confirmation after SIFS.

10.54 S1G relay operation

10.54.1 General

An S1G relay consists of an S1G relay AP, an S1G relay STA and a relay function.

An S1G relay consists of an AP with dot11RelayAPImplemented equal to true and a STA with dot11RelaySTAImplemented equal to true.

An example of a relay function is illustrated in Figure 10-112, where Relay 1, Relay 2, and Relay 3 are S1G relays, each of which consisting of an S1G relay STA, an S1G relay AP and a relay function. The S1G relay STAs of Relay 1 and Relay 2 are associated with an AP that is an S1G root AP. The S1G relay STA of Relay 3 is associated with the S1G relay AP of Relay 1. STA 1 is a non-AP STA associated with the S1G relay AP of Relay 1. STA 2, and STA 3 are non-AP STAs associated with the S1G relay AP of Relay 3. STA 4 and STA 5 are non-AP STAs associated with the S1G relay AP of Relay 2. Frames from STA 1 are forwarded via the relay function of Relay 1 from the S1G relay AP to the S1G relay STA and then to the S1G root AP. Similarly, frames from the S1G root AP are forwarded to STA 1 via the S1G relay STA, the relay function and the S1G relay AP of Relay 1. Similar forwarding is done by Relay 3 and Relay 1 in sequence to handle frames from STA 2 and STA 3 relaying multiple times to or from the root AP.

Relay STA in this context refers to a non-AP STA.

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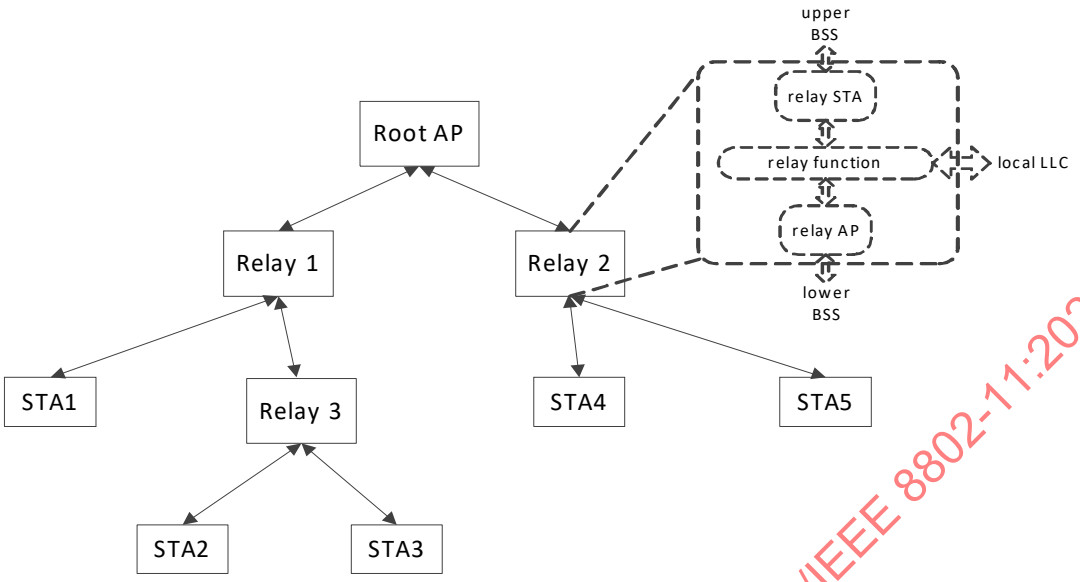

Figure 10-112—S1G relay architecture

10.54.2 S1G relay operation

A non-AP STA with dot11RelaySTAImplemented equal to true shall include the S1G Relay Activation element in (Re)Association Request frames.

A non-AP STA with dot11RelaySTAImplemented equal to true may include an S1G Relay Activation element with Relay Activation Mode subfield equal to 1 in (Re)Association Request frames, Relay Activation Request frames or Relay Activation Response frames. A non-AP STA with dot11RelaySTAImplemented equal to true may transmit a Relay Activation Request frame to the AP with which it is associated.

A non-AP STA shall not transmit an S1G Relay Activation element that has the Enable Relay Function and the Relay Activation Mode subfields equal to 1 if the most recently received S1G Relay element from the AP to which it is associated had the No More Relay Flag subfield equal to 1.

A non-AP STA with dot11RelaySTAImplemented equal to false shall not include the S1G Relay Activation element in any frames that it transmits.

A non-AP STA transmitting an S1G Relay Activation element shall set the Direction subfield of the element to 0. An AP transmitting S1G Relay Activation element shall set the Direction subfield of the element to 1.

An AP that is the intended receiver of a frame that contains an S1G Relay Activation element with Relay Activation Mode subfield equal to 1 shall respond with the appropriate frame (Probe, (Re)Association, Relay Activation Response) that contains an S1G Relay Activation element with Relay Activation Mode subfield equal to 0.

A non-AP STA with dot11RelaySTAImplemented equal to true shall transmit a Relay Activation Response frame if it receives the corresponding S1G Relay Activation element in a Relay Activation Request frame.

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A non-AP STA with dot11RelaySTAImplemented equal to true that is the intended receiver of a frame that contains an S1G Relay Activation element with Relay Activation Mode subfield equal to 1 and Enable Relay Function subfield equal to 0 shall respond with a frame that contains an S1G Relay Activation element with Relay Activation Mode and Enable Relay Function subfields equal to 0.

An AP may indicate the maximum number of STAs, N_{max}, that an S1G relay is allowed to associate by including a Number of STAs field in an S1G Relay Activation element with the Enable Relay Function subfield equal to 1 transmitted to the S1G relay.

A non-AP STA with dot11RelaySTAImplemented equal to true shall set dot11RelaySTAOperationActivated to false unless

a) It receives an S1G Relay Activation element from the AP to which it is associated with Enable Relay Function subfield equal to 1 and Relay Activation Mode subfield equal to 0 as a response of a transmitted S1G Relay Activation element with Enable Relay Function and Relay Activation Mode subfield equal to 1.

b) It transmits an S1G Relay Activation element to the AP to which it is associated with Enable Relay Function subfield equal to 1 and Relay Activation Mode subfield equal to 0 as a response of a received S1G Relay Activation element with Enable Relay Function and Relay Activation Mode subfield equal to 1.

If event a) or b) occurs, then it shall set dot11RelaySTAOperationActivated to true.

A non-AP STA with dot11RelaySTAOperationActivated equal to true is referred to as an S1G relay STA.

An AP with dot11RelayAPImplemented equal to true may include an S1G Relay Activation element with Relay Activation Mode subfield equal to 0 in (Re)Association Response frames, Probe Response frames, Relay Activation Request frames or Relay Activation Response frames.

An AP with dot11RelayAPImplemented equal to true (e.g., the AP in an S1G relay) shall set dot11RelayAPOperationActivated to true only if dot11RelaySTAOperationActivated of the non-AP STA in the relay is true, otherwise it shall set dot11RelayAPOperationActivated to false.

An AP with dot11RelayAPOperationActivated equal to true is referred to as an S1G relay AP.

An S1G relay AP shall include an S1G Relay element in transmitted Beacon frames, PV1 Probe Response frames and Probe Response frames.

An S1G relay AP shall set the No More Relay Flag subfield of an S1G Relay element to 1 if the No More Relay Flag subfield of the latest S1G Relay element received from its parent AP was set to 1. An S1G relay AP may set the No More Relay Flag subfield of the S1G Relay element to 1 in order to limit the number of Relays in its associated STAs.

An S1G Relay AP shall reject association requests when N_{max} has been reached, citing status code 17 (DENIED_NO_MORE_STAS).

An AP with dot11RelayAPImplemented equal to true shall include the S1G Relay element in its Beacon frames and may include the S1G Relay element in its Probe Response frames, PV1 Probe Response frames, and (Re)Association Response frames.

An S1G root AP is defined as an AP with dot11RelayAPImplemented equal to true that sets the Hierarchy Identifier field of transmitted S1G Relay elements to 0.

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An S1G relay AP shall not set the Hierarchy Identifier field of transmitted S1G Relay elements to 0.

An S1G relay AP shall use the same SSID as the AP to which its S1G relay STA is associated.

An S1G relay STA shall send a Reachable Address element that contains the current list of reachable addresses, in the (Re)Association Request frame to the AP to which it is associating. In this frame the relay STA shall set the Initiator MAC address field of the element to its own MAC address, and the Add/Remove subfield to 1.

An S1G relay STA shall send a Reachable Address Update frame to the AP to which it is associated when one of the following conditions occurs:

1) A new non-AP STA associates with the S1G relay AP of the relay.
2) A non-AP STA is disassociated or deauthenticated from the S1G relay AP of the S1G relay.
3) A Reachable Address Update frame is received at the S1G relay AP of the S1G relay.

For conditions 1 and 2 above, the transmitted Reachable Address Update frame shall include Reachable Address subfields for STAs with a changed association or authentication status.

For condition 3 above, the transmitted Reachable Address Update frame shall include all Reachable Address subfields from the received Reachable Address Update frame,

a) Where the received Reachable Address subfield had the Add/Remove subfield equal to 1 (STA joining the relay).
b) Where the received Reachable Address subfield had the Add/Remove subfield equal to 0 (STA leaving the relay), except when the received Reachable Address Update frame came from a Relay STA that is not the next hop for the indicated STA.

The Reachable Address Update frame shall not contain Reachable Address subfields other than those defined for conditions 1) to 3) above. Because the generation of a Reachable Address Update frame might not be immediate, Reachable Address subfields which have different initiator MAC addresses may be combined in a single Reachable Address Update frame under the above conditions.

Reachable Address subfields with the Add/Remove subfield equal to 0 (STA leaving the relay) shall be ignored when received from an S1G relay STA which is not the S1G relay STA that transmitted the most recently received Reachable Address Update frame containing a Reachable Address subfield for the indicated STA with the Add/Remove subfield equal to 1 (STA joining the relay).

An S1G relay STA generating a Reachable Address frame [under conditions 1) and 2) above] shall set the Initiator MAC address field of the element to its own MAC address.

An S1G relay STA shall set the Add/Remove subfield of a Reachable Address Update frame to 1 if the STA identified by the MAC Address subfield of Reachable Address subfield is associated to the relay AP of the S1G relay and shall set the Add/Remove subfield to 0 if the STA identified by the MAC Address subfield of Reachable Address subfield disassociated from the S1G relay AP of the S1G relay.

An S1G relay STA shall set the Relay Capable subfield of the Reachable Address subfield of the Reachable Address element to 1 only if the STA identified by the MAC address subfield of the Reachable Address subfield has indicated that it is capable of relay function, otherwise, it shall set it to 0.

An S1G root AP shall update the DS upon receipt of a Reachable Address Update frame.

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10.54.3 Addressing and forwarding of individually addressed relay frames

A MAC service tuple (including an MSDU) received via the WM at an S1G relay AP is examined by the relay function, and if the DA matches the address of the STA of the S1G relay the MAC service tuple is delivered via the MAC service to the local higher layer entity. Otherwise, the MAC service tuple is passed to the S1G relay STA and then is forwarded via the WM to the AP to which it is associated, using either a four-address frame format or an A-MSDU format except when the frame carrying the (A-)MSDUs is a PV1 QoS Data frame for which header compression is used as described in 10.58.

The addressing of the four-address frame shall be as follows in this case:

- Address 1 is the MAC address of the AP (the receiver of the MPDU)
- Address 2 is either the MAC address or the AID of the S1G relay STA (the transmitter of the MPDU)
- Address 3 is the DA of the MSDU (the destination address of the MSDU)
- Address 4 is the SA of the MSDU (the source address of the MSDU)

If the four-address frame is a PV1 QoS Data frame that contains an A-MSDU then the DA and/or SA field(s) shall not be present in any of the A-MSDU subframe headers unless the DA and/or SA for the MSDU contained in the A-MSDU subframe are not equal to the values contained in Address 3 and/or Address 4 of the frame.

Otherwise, the addressing of the frame containing an A-MSDU shall be as follows in this case:

- Address 1 is the MAC address of the AP (the receiver of the MPDU)
- Address 2 is either the MAC address or the AID of the S1G relay STA (the transmitter of the MPDU)
- Address 3 is the MAC address of the AP (the BSSID)
  - If the frame is a PV1 QoS Data frame then Address 3 is not present
- DA in A-MSDU subframe header is the DA of the MSDU (the destination address of the MSDU)
- SA in A-MSDU subframe header is the SA of the MSDU (the source address of the MSDU)

A MAC service tuple passed to a root AP from the DS, or received at an S1G relay STA via the WM, is examined by the relay function, and if the DA matches the address of the AP or an associated non-AP STA, it is delivered using legacy (non-relay) methods. Otherwise, the included MSDU is forwarded via the WM to the associated S1G relay STA, which most recently included the MSDU's DA in a Reachable Address element, using either a four-address frame format or an A-MSDU format.

The addressing of a four-address frame shall be as follows in this case:

- Address 1 is either the MAC address or the AID of the S1G relay STA (the receiver of the MPDU)
- Address 2 is the MAC address of the AP (the transmitter of the MPDU)
- Address 3 is the DA of the MSDU (the destination address of the MSDU)
- Address 4 is the SA of the MSDU (the source address of the MSDU)

If the four-address frame is a PV1 QoS Data frame that contains an A-MSDU then the DA and/or SA field(s) shall not be present in any of the A-MSDU subframe headers except when DA and/or SA for the MSDU contained in the A-MSDU subframe are different from the values contained in Address 3 and/or Address 4 of the frame.

Otherwise, the addressing of a frame containing an A-MSDU shall be as follows in this case:

- Address 1 is either the MAC address or the AID of the S1G relay STA (the receiver of the MPDU)
- Address 2 is the MAC address of the AP (the transmitter of the MPDU)

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- Address 3 is the MAC address of the AP (the BSSID)
  - If the frame is a PV1 QoS Data frame then Address 3 is not present
- DA in A-MSDU subframe header is the DA of the MSDU (the destination address of the MSDU)
- SA in A-MSDU subframe header is the SA of the MSDU (the source address of the MSDU)

When the frame is a PV1 QoS Data frame and the intended receiver has confirmed storing A3 and/or A4 as described in 10.58 then the DA and/or SA should not be present in either the A3 and/or A4 fields of the frame or in the DA and/of SA of the A-MSDU subframe header contained in the frame except when the DA and/or SA for the MSDU are different from the stored values.

10.54.4 Addressing and forwarding of group addressed relay frames

An group addressed MAC service tuple (including an MSDU) received via the WM at an S1G relay AP is passed by the relay function to the S1G relay STA and then is forwarded via the WM to the AP to which the S1G relay STA is associated, using either a four-address frame format or an A-MSDU format except when the frame carrying the (A-)MSDUs is a PV1 QoS Data frame for which header compression is used as described in 10.58.

The addressing of the four-address frame shall be as follows in this case:

- Address 1 is the MAC address of its associated AP (the receiver of the MPDU)
- Address 2 is either the MAC address or the AID of the S1G relay STA (the transmitter of the MPDU)
- Address 3 is the DA of the MSDU (the group address).
- Address 4 is the SA of the MSDU (the source address of the group addressed MSDU)

If the four-address frame is a PV1 QoS Data frame that contains an A-MSDU then the DA and/or SA field(s) shall not be present in any of the A-MSDU subframe headers unless the DA and/or SA for the MSDU contained in the A-MSDU subframe are not equal to the values contained in Address 3 and/or Address 4 of the frame.

Otherwise, the addressing of the frame containing an A-MSDU shall be as follows in this case:

- Address 1 is the MAC address of its associated AP (the receiver of the MPDU)
- Address 2 is either the MAC address or the AID of the S1G relay STA (the transmitter of the MPDU)
- Address 3 is the MAC address of its associated AP (the BSSID)
  - If the frame is a PV1 QoS Data frame then Address 3 is not present
- DA in A-MSDU subframe header is the DA of the MSDU (the group address)
- SA in A-MSDU subframe header is the SA of the MSDU (the source address of the group addressed MSDU)

When the frame is a PV1 QoS Data frame and the intended receiver has confirmed storing A3 and/or A4 as described in 10.58 then DA and/or SA should not be present in either the A3 and/or A4 fields of the frame or in the DA and/of SA field(s) of the A-MSDU subframe header contained in the frame except when the DA and/or SA for the MSDU contained in the frame or in the A-MSDU subframe are different from the stored values.

A group addressed MAC service tuple passed to a root AP from the DS, or received at an S1G relay STA via the WM, is forwarded via the WM using a 3-address frame format.

The addressing of a 3-address frame shall be as follows in this case:

- Address 1 is the DA of the MSDU (the group address)
- Address 2 is the MAC address of the AP (the BSSID)
- Address 3 is the SA of the MSDU (the source address of the group addressed MSDU)

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Group addressed MSDUs received via the WM at an S1G relay AP are not forwarded to the WM as a broadcast transmission, but are instead forwarded to the S1G relay STA as specified in 10.3.6. Therefore, group addressed MSDUs in a relay network first travel to the root AP as an individually addressed transmission, after which they travel down the tree as group transmissions by the S1G root AP and the S1G relay AP(s).

10.54.5 Procedures of TXOP sharing for S1G relay operation

10.54.5.1 General

An S1G STA that supports TXOP sharing procedure may set the Relayed Frame field in the Frame Control field of PV1 QoS Data frames (defined in 9.8), the Relayed Frame field in NDP Ack frames, and the Order field in the Frame Control field of an S1G RTS frame to 1. Otherwise, it shall set the Relayed Frame field or Order field in any frame to 0 unless the frame is an NDP Ack frame used for flow control as described in 10.61. The S1G STA may use TXOP sharing to transmit to the S1G relay (S1G relay AP or S1G relay STA) either one PV1 QoS Data frame in the TXOP or the last PV1 QoS Data frame of the TXOP where the TXOP is obtained as described in 10.23.2.4 and the PV1 QoS Data frame has the Ack Policy Indicator subfield equal to 0 and is carried in an MPDU or in an S-MPDU.

Reception of a valid PV1 QoS Data frame with the Relayed Frame field equal to 1 or of an S1G RTS frame with the Order field equal to 1 indicates a relay-shared TXOP.

An S1G STA indicates support of TXOP sharing with implicit Ack using the TXOP Sharing Implicit Ack Support subfield of the S1G Capabilities Information field in the S1G Capabilities element. If dot11TXOPSharingImplicitACKImplemented is true, the S1G STA shall set the TXOP Sharing Implicit Ack Support subfield to 1 in transmitted frames containing the S1G Capabilities element. Otherwise, the S1G STA shall set the TXOP Sharing Implicit Ack Support subfield to 0.

A non-S1G STA shall not perform TXOP sharing.

An S1G relay entity shall not perform TXOP sharing if the S1G relay STA and S1G relay AP are operating in different primary channels for the duration of the TXOP. An S1G relay that performs TXOP sharing shall use a channel width that is the same or narrower than the channel width indicated by the STA that initiated the TXOP.

The sequence of frames exchanged over the first hop and second hop during a relay-shared TXOP depends on the acknowledgment procedure used by the S1G relay.

When an S1G relay (S1G relay STA or S1G relay AP) receives a valid PV1 QoS Data frame with the Relayed Frame field in the Frame Control field equal to 1, the S1G relay may acknowledge the received PV1 QoS Data frame using the implicit or explicit Ack procedure. The S1G relay shall not acknowledge the received valid PV1 QoS Data frame using either implicit or explicit Ack procedure if the Relayed Frame field in the Frame Control field is equal to 0 in the received PV1 QoS Data frame.

NOTE—The frames transmitted over the first hop and second hop can be sent at two different MCSs.

For error recovery purposes, during a relay-shared TXOP, the TXOP owner may transmit its next PPDU when the CS mechanism (see 10.3.2.1) indicates that the medium is idle at the TxPIFS slot boundary (defined in 10.3.7) (this transmission is a continuation of the current TXOP or SP).

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10.54.5.2 Explicit Ack procedure

Throughout this subclause, a Response Indication of Long Response is signaled in an NDP Ack frame by setting the Idle Indication field to 1 and the Duration field to 0 and a Response Indication of No Response is signaled by setting the Idle Indication field to 0 and the Duration field to 0 (see 10.3.2.17).

A non-AP STA (AP) that intends to start a relay-shared TXOP starts it by sending a PV1 QoS Data frame addressed to the S1G relay AP (S1G relay STA) with the Relayed Frame field equal to 1. The S1G relay AP (S1G relay STA), addressed by an RTS frame, that intends to use the explicit Ack procedure, shall respond with an NDP CTS frame with the Duration field set as described in 10.54.5.4.

When using the explicit Ack procedure, the S1G relay AP (S1G relay STA) shall signal a Response Indication of Long Response in the NDP Ack frame that is transmitted as an acknowledgment to the non-AP STA (AP). In addition it shall set the Relayed Frame field of the NDP Ack frame to 1. Otherwise, it shall signal a Response Indication of No Response in the NDP Ack frame and shall set the Relayed Frame field to 0.

When using the explicit Ack procedure, the S1G relay STA (S1G relay AP) shall forward the previously received PV1 QoS Data frame to the AP (non-AP STA), SIFS after the S1G relay AP (S1G relay STA) sent the NDP Ack frame to the non-AP STA (AP). In addition, the S1G relay STA (S1G relay AP) may protect the forwarded frame with a protection mechanism such as RTS/CTS exchange. Upon receipt of the relayed PV1 QoS Data frame, the AP (non-AP STA) shall transmit an NDP Ack frame to the S1G relay STA (S1G relay AP), which shall signal a Response Indication of No Response terminating this relay-shared TXOP.

NOTE—The description above applies to both uplink and downlink procedures with the non-AP STA (AP), i.e., either the non-AP STA or the AP is the TXOP owner for the TXOP sharing session.

10.54.5.3 Implicit Ack procedure

A STA that supports implicit Ack procedure and intends to transmit a frame to a next hop STA via an S1G relay (S1G relay STA or S1G relay AP) using the implicit Ack procedure needs to enable the implicit Ack procedure (and acquire the required information to operate using implicit Ack) with the S1G relay. The implicit Ack procedure is enabled between the STA and the S1G relay (S1G relay STA or S1G relay AP) if

- The STA is an AP to which the S1G relay STA of the S1G relay is associated and the S1G relay STA has successfully transmitted to the AP a STA Information Announcement frame containing the AID that the S1G relay AP of the S1G relay has assigned to the next hop non-AP STA.
  - The S1G relay STA may transmit a STA Information Announcement frame to its associated AP that supports the implicit Ack procedure when the S1G relay AP either assigns an AID to the next hop non-AP STA during association or changes the AID of the non-AP STA as described in 10.20.
  - The AP shall determine the PARTIAL_AID of the next hop non-AP STA as described in 10.21 using the BSSID of the S1G relay AP's BSS and the AID of the next hop non-AP STA to be able to use the implicit Ack procedure.
- The STA is a non-AP STA that is associated to the S1G relay AP and the S1G relay AP has transmitted to the STA an S1G Relay element with the Parent AP BSSID field containing the BSSID of the BSS of the parent AP with which the S1G relay STA of the S1G relay is associated.
  - The non-AP STA shall determine the PARTIAL_AID and the COLOR of the next hop AP as described in 10.21 using the BSSID and COLOR values used by the next hop AP to be able to use the implicit Ack procedure.

After the implicit Ack procedure is enabled and all the required information is acquired as described above, the implicit Ack may be used to acknowledge eliciting PV1 QoS Data frames carried in

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S1G_SHORT/S1G_LONG PPDUs (i.e., that contain a PARTIAL AID, UPLINK_INDICATION, and COLOR in their PHY header).

A STA that intends to share the TXOP with the S1G relay may start the TXOP by sending to the S1G relay an S1G RTS frame with the Order field set to 1 or a PV1 QoS Data frame that has the Relayed Frame field set to 1. An S1G relay (S1G relay STA or S1G relay AP) that is the intended receiver of the S1G RTS frame which intends to use the implicit Ack procedure shall respond with an NDP CTS frame with the Duration field set as described in 10.54.5.4.

When an S1G relay receives a PV1 QoS Data frame during a relay-shared TXOP, the S1G relay may directly forward the received frame without sending back an acknowledgment frame to the transmitter of the frame. If the PV1 QoS Data frame was preceded by an RTS frame then the S1G relay should protect the forwarded frame by sending an RTS frame to the intended receiver as described in 10.54.5.4.

If the MPDU is transmitted by a non-AP STA, which is associated to an S1G relay AP, to the AP, then the S1G relay AP forwards the received MPDU to the AP to which it is associated, using SIFS. After transmitting the MPDU, the non-AP STA shall wait for an AckTimeout interval to detect a PPDU that would acknowledge the reception of the MPDU as described in 10.3.2.11. An indication of reception allows the frame sequence to continue, or to end without retries, as appropriate for the particular frame sequence in progress.

If the MPDU is transmitted by an AP to an S1G relay STA, then the S1G relay STA forwards the received MPDU to the non-AP STA that is associated to the S1G relay AP, using SIFS. After transmitting the MPDU, the AP shall wait for an AckTimeout interval to detect a PPDU that would acknowledge the reception of the MPDU as described in 10.3.2.11. An indication of reception allows the frame sequence to continue, or to end without retries, as appropriate for the particular frame sequence in progress. If the RA of the forwarded MPDU is different from the DA of the MPDU transmitted by the AP, then the S1G relay STA shall use the explicit Ack procedure.

10.54.5.4 Relay-shared TXOP protection mechanisms

An S1G STA that supports TXOP sharing should initiate a relay-shared TXOP by sending an S1G RTS frame as the first frame in the exchange under EDCA. The S1G STA may set the Order field of the RTS frame to 0 to indicate that the duration of the initiated TXOP is limited as described in 10.23.2.9 and that it expects an NDP CTS frame whose Duration field is set as described in 10.3.2.9. Otherwise, it may set the Order field to 1 to indicate that the duration of the initiated TXOP can be extended (i.e., it is not necessarily limited as described in 10.23.2.9) and that it expects an NDP CTS frame whose Duration field is set as described in this subclause.

An S1G relay that is the intended receiver of the S1G RTS frame with the Order field equal to 1 and intends to use the relay-shared TXOP responds with an NDP CTS frame with a value of the Duration field that depends on the acknowledgment procedure it shall use during this relay-shared TXOP:

— If explicit Ack procedure (see 10.54.5.2) then the Duration field of the NDP CTS frame shall be set to a value D:

$$T_{\text{RTS}} + T_{\text{PENDING}} - T_{\text{CTS}} \leq D \leq T_{\text{TXOP_REMAINING}} - T_{\text{PPDU}}$$

where

T_{RTS} is the value obtained from the Duration/ID field of the S1G RTS frame that elicited the response

T_{CTS} is the time, in microseconds, between the end of the PPDU carrying the RTS frame and the end of the NDP CTS frame

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$T_{PENDING}$	is the estimated time required for the transmission of the frame to be forwarded, its response if required, protection frame exchanges if required, plus applicable IFS durations
$T_{TXOP_REMAINING}$	is equal to any T_{TXOP} as defined in 9.2.5.2 minus T_{RTS}
T_{PPDU}	is the time required for transmission of the current PPDU

— If implicit Ack procedure (see 10.54.5.3), then the Duration/ID field of the NDP CTS frame shall be set according to 9.2.5.7. When using the implicit Ack procedure, upon reception of a PV1 QoS Data frame that is preceded by the transmission of an NDP CTS frame as described above, the S1G relay (S1G relay STA or S1G relay AP) should protect the PV1 QoS Data frame transmission with an RTS/CTS protection mechanism. The Duration/ID field of the RTS frame shall be less than or equal to T_{TXOP} for that AC, as defined in 9.2.5.2, minus the estimated time since the start of the reception of the RTS frame with the Order field equal to 1 that was sent by the relay-shared TXOP owner.

An S1G relay (S1G relay STA or S1G relay AP) that uses the relay-shared TXOP may transmit an (NDP) CF-End frame after successfully forwarding the PV1 QoS Data frame if the remaining duration is long enough to transmit this frame.

An S1G relay that is the intended receiver of the S1G RTS frame with the Order field equal to 0 responds with an NDP CTS frame as described in 10.3.2.9.

10.54.6 S1G relay discovery procedure

A single hop link is an one-hop link between a non-AP STA and the root AP.

A relay link is a multi-hop link between a non-AP STA performing an active scan for S1G relays, and the S1G root AP through the S1G relay.

A non-AP STA that performs active scanning may use the Probe Request frame with an S1G Relay Discovery element when relay discovery procedure is implemented. A non-AP STA with dot11RelayDiscoveryOptionImplemented equal to true may transmit a Probe Request frame including an S1G Relay Discovery element with link budget information for the single hop link and additional QoS requirements for the relay link. This information shall be conveyed using the S1G Relay Discovery element as defined in 9.4.2.207 if present. The formulas for calculating link budget and QoS requirements are implementation specific.

An S1G relay with dot11RelayDiscoveryOptionImplemented equal to true that receives a Probe Request frame becomes eligible to be an S1G relay for this non-AP STA if the link budget and QoS requirements are met and the SSID and other capability parameters match. If these requirements are met, an S1G relay may respond to the non-AP STA with a Probe Response frame, or a PV1 Probe Response frame as an S1G relay candidate for this non-AP STA. When a non-AP STA uses the S1G Relay Discovery element to indicate the DL/UL maximum/minimum/mean data rates of the direct link or the Delay Bound Requirement of the connection through the S1G relay in the Probe Request frame, the S1G relay may also use those parameters as the criteria of responding to the Probe Request frame. The principle for this operation is to reduce the number of Probe Response, or PV1 Probe Response frames sent from S1G relays.

An S1G relay may optionally include link budget information along with other information in S1G Relay Discovery elements such as DL/UL maximum/minimum/mean data rates, relay STA count or channel utilization information in a Probe Response frame, a PV1 Probe Response frame, or a Beacon frame. This information is used for the non-AP STA, when multiple Probe Response, or PV1 Probe Response, frames are received, to select an S1G relay among multiple S1G relay candidates.

An S1G relay with dot11RelayDiscoveryOptionImplemented equal to true that receives a Probe Request frame with the S1G Relay Discovery element from a non-AP STA may respond to the non-AP STA with a

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probe response frame with the S1G Relay Discovery element carrying the Information Not Available field set to 1 to indicate that for the remaining duration of the current association it will not provide any requested relay discovery information.

10.55 Group AID

An S1G STA with dot11GroupAIDActivated equal to true supports the implementation of group addressed traffic delivery using group AID. An S1G STA with dot11GroupAIDActivated equal to true shall set the Group AID Support subfield in the S1G Capabilities element it transmits to 1. Otherwise, it shall set it to 0.

A group AID is an AID that is assigned by an S1G AP to identify a group of S1G STAs. A group AID corresponds to a bit in the traffic-indication virtual bitmap. An S1G AP signals the presence of group addressed BUs that correspond to a group AID using the same signaling as the signaling of individually addressed BUs, i.e., the AP sets the bit corresponding to the group AID in the traffic-indication virtual bitmap to 1 when BUs are present, and sets it to 0 otherwise.

An S1G STA with dot11GroupAIDActivated equal to true that has a group MAC address may request a group AID from the S1G AP to which it is associated to by sending an AID Switch Request frame. Upon receiving the AID Switch Request frame, the S1G AP that supports group AID responds with an AID Switch Response frame that contains the assigned group AID that corresponds to that group MAC address and the group listen interval as described in 10.20. The S1G AP may assign different group AIDs to S1G STAs that have the same group MAC address but different group listen intervals. The S1G STA should maintain the link between the assigned group AID to its group MAC address and group listen interval.

An S1G AP that has negotiated a group AID shall indicate the presence of group addressed BUs corresponding to the group AID in the TIM included in the S1G Beacon frame that is sent every group listen interval, following the expiration of a counter that corresponds to the AID Switch Count field included in the AID Response element containing the group AID and that started upon transmission of that element.

An S1G STA that has negotiated a group AID and has not negotiated TWTs (see 10.47) shall wake up every group listen interval that corresponds to the group AID to receive the S1G Beacon frame, starting from the TBTT or TSBTT that follows the expiration of a counter that corresponds to the AID Switch Count field included in the AID Response element containing the group AID and that started upon receipt of that element. An S1G STA that has negotiated both group AID and TWTs wakes at specific target wake times as defined in 10.47.

For example, when S1G AP with dot11PageSlicingActivated equal to true has data buffered for a group of S1G STAs with dot11PageSlicingActivated equal to true that belong to a group AID, it indicates this condition in the Page Slice element (9.4.2.192) transmitted in a DTIM Beacon frame. The S1G STAs that detect this indication will wake up at the assigned beacon interval to determine the TIM and extract the assigned time slots that carry the buffered group data. The S1G AP transmits the buffered group data within the assigned time slots for the S1G STAs' reception.

The S1G AP that has indicated the presence of group addressed BUs for a given group AID in an S1G Beacon frame shall deliver these BUs using a PV1 frame with the group AID in the A1 field (see 9.8.3.2) and setting the partial AID as described in 10.21. These group addressed frames should be delivered during the beacon interval or short beacon interval that follows the S1G Beacon frame or within negotiated TWT SPs if that group AID is assigned to a non-AP STA that follows 10.47.

An S1G STA that has a group AID assigned for a particular group MAC address shall discard any received frame that contains that group MAC address in the RA field.

NOTE—This avoids that the STA receives duplicate groupcast BUs with different group delivery procedures.

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For the S1G STAs with the group MAC address, which do not have the group AID, the S1G AP does not follow this subclause to transmit group data.

10.56 Traveling pilot operation

An S1G STA with dot11S1GTravelingPilotOptionActivated equal to true shall set the Traveling Pilot Support field in the S1G Capabilities Info field of the S1G Capabilities element, as described in 9.4.2.200 to

— 1 if reception of traveling pilots is supported only for one space-time stream
— 3 if reception of traveling pilots is supported for both one and two space-time streams

An S1G STA with dot11S1GTravelingPilotOptionActivated equal to false shall set the Traveling Pilot Support field in the S1G Capabilities element to 0.

An S1G STA shall not transmit a PSDU with the TXVECTOR parameter TRAVELING_PILOTS equal to 1 to an S1G STA unless the Traveling Pilot Support field of the S1G Capabilities element received from that STA contained a value of 1 or 3 and dot11S1GTravelingPilotOptionActivated is true (if there is more than one intended receiver, then this requirement applies for each intended receiver).

10.57 Bitmap protection for NDP BlockAck frames

NDP BlockAck frames are protected by the 4 bit CRC of the S1G SIG-A field, which might not be enough to protect the BlockAck Bitmap field contained in the frame. This subclause describes a mechanism that offers increased protection for the BlockAck Bitmap field of NDP BlockAck frames.

The originator of an NDP BlockAck (NDP_1M BlockAck or NDP_2M BlockAck) frame (see 23.3.12.2.6) shall protect the BlockAck Bitmap field of the NDP BlockAck frame (shown in Figure 23-22 and Figure 23-23) by using the encoding procedure defined in this subclause.

Initially the bit sequences [B3: B10] for NDP_1M BlockAck and [B3:B18] for NDP_2M BlockAck frames are set as described in 10.25.6.5 or 10.3.2.12. Then, prior to transmission, the originator encodes the bit sequences following the procedure below.

Encoding procedure:

For an NDP_1M BlockAck frame:
— [B3: B10] = XOR([B3: B10], [B17: B24]);

For an NDP_2M BlockAck frame
— [B3: B18] = XOR([B3: B18], [B21: B36]);

The intended recipient shall perform the same procedure to decode the bit sequences [B3: B10] for NDP_1M BlockAck and [B3:B18] for NDP_2M BlockAck frames.

10.58 Generation of PV1 MPDUs and header compression procedure

An S1G STA that sets the STA Type Support subfield in a transmitted S1G Capabilities element to 0 or 1, as described in 10.63, shall set the PV1 Frame Support subfield in the S1G Capabilities element to 1. An S1G STA that sets the STA Type Support subfield in a transmitted S1G Capabilities element to 2 may set the PV1 Frame Support subfield in the S1G Capabilities element to 0.

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An S1G STA shall not transmit PV1 MPDUs with the Type subfield equal to 0, 1 or 3 to a peer STA unless the PV1 Frame Support subfield of the S1G Capabilities element received from the peer STA contained a value of 1. An S1G STA with dot11PV1MACHeaderOptionImplemented equal to true shall use the PV1 format instead of the PV0 format to transmit QoS Data, Action, and Action No Ack frames that are individually addressed to a peer STA from which it has received an S1G Capabilities element with PV1 Frame Supported subfield equal to 1.

NOTE 1—An S1G STA can use the PV1 format to transmit group addressed frames as described in 10.55.

The header compression procedure enables S1G STAs to store addresses and/or update security parameters at the receiver. An S1G STA with dot11PV1MACHeaderOptionImplemented equal to true shall set dot11RSNAProtectedManagementFramesActivated to true and dot11RSNAUnprotectedManagementFramesAllowed to false.

An S1G STA with dot11PV1MACHeaderOptionImplemented equal to true may include a Header Compression element in Header Compression frames. The STA may include the Header Compression element in (Re)Association Request frames and (Re)Association Response frames when management frame protection is not negotiated for the association. The STA may set the PV1 Data Type 3 Supported subfield in the Header Compression element to 1 to indicate that it supports reception of PV1 frames that have the Type subfield in the Frame Control field equal to 3.

After association, an S1G STA with dot11PV1MACHeaderOptionImplemented equal to true may transmit Header Compression frames and PV1 frames. An S1G STA shall not transmit PV1 frames with Type subfield equal to 3 to a peer STA unless the PV1 Data Type 3 Supported subfield is 1 in the most recently received Header Compression element sent by the peer STA. An S1G STA in an IBSS shall not transmit PV1 frames with a value of the Type subfield equal to 0 or 1.

NOTE 2—A PV1 frame is an MPDU with Protocol Version field in the Frame Control field equal to 1 (see 9.8).

The header compression procedure uses a Header Compression element, which is referred to as a header compression request or a header compression response, depending on the Request/Response subfield setting of the Header Compression element.

A STA that transmits PV1 frames with Type subfield equal to 0 shall include the A3 field if the value of this field

— Is not equal to the address identified by the A1 field and an A3 is not stored at the receiver.
— Is not equal to the A3 stored at the receiver.

Otherwise, the A3 field shall not be included in the frame.

A STA that transmits PV1 frames with Type subfield equal to 0 shall include the A4 field if the value of this field

— Is not equal to the address identified by the A2 field and an A4 is not stored at the receiver.
— Is not equal to the A4 stored at the receiver.

Otherwise, the A4 field shall not be included in the frame.

An S1G STA indicates a request to store address fields by sending a header compression request with the Store A3 and/or Store A4 subfields equal to 1. Upon receipt of such a request, the receiving STA shall respond with a header compression response indicating which of the optional fields it stores, by setting the Store A3 and/or Store A4 subfields in the transmitted header compression response to 1. Stored address

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fields can subsequently be omitted from the MAC header of PV1 frames transmitted by the STA that sent the header compression request. Address A3 and/or A4 fields for which the header compression response indicated 0 are not stored at the receiver and cannot be omitted by the transmitter when the A3 and/or A4 fields contain values that are different from the A1 and/or A2 fields of the same.

An S1G STA indicates a request to update security parameters by sending a header compression request with the CCMP Update subfield equal to 1. The receiver STA shall respond with a header compression response acknowledging receipt of the updated security parameters. The receiver STA shall compare the received BPN value to the current locally stored BPN value. If the received BPN value is greater than the locally stored BPN value, the receiver STA shall update the locally stored BPN value. Otherwise, the receiver STA shall not update the locally stored BPN value.

After sending a header compression request, an S1G STA shall postpone the transmission of PV1 frames that do not include the fields that were requested to be stored to the recipient of the header compression request until it receives the corresponding header compression response.

After receiving a header compression request, an S1G STA shall store and activate the included addresses it intends to store and/or the security information included in the header compression request before transmitting the corresponding header compression response.

When no header compression response has been received in response to a header compression request within dot11HeaderCompressionResponseTimeout, an S1G STA shall transmit another header compression request.

A STA that receives a PV1 frame with one or more compressed addresses that it has not stored or which causes a decryption error should transmit an unsolicited header compression response to the transmitter of the PV1 frames, in which the Store A3, and Store A4 fields are all equal to 0. The unsolicited header compression response shall include the TID/ACI of the received PV1 frame in the TID/ACI subfield of the CCMP Update field if the received frame caused a decryption error, where the CCMP Update field shall indicate the stored values for the BPN and Key ID that correspond to the received PV1 frame.

A STA that has previously transmitted PV1 frames of a given TID/ACI to a peer STA and that receives an unsolicited header compression response from the peer STA relative to that TID/ACI shall transmit a header compression request to the transmitter of the header compression response. The header compression request shall include all the addresses that the transmitting STA requests to be stored at the receiver and/or the security information that corresponds to the indicated TID/ACI.

10.59 Transmission of an NDP CMAC PPDU

An S1G STA transmitting an NDP CMAC PPDU shall use the following TXVECTOR parameters:

— NDP_INDICATION set to 1
— NUM_STS indicates one space-time stream
— APEP_LENGTH set to 0
— NUM_USERS set to 1

An S1G STA in an IBSS shall not transmit an NDP CMAC PPDU, except for an NDP Ack, NDP BlockAck or NDP Probe Request frame.

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10.60 S1G_Long operation

An S1G STA with dot11S1GLONGOptionActivated equal to true shall set the S1G_LONG Support field in the S1G Capabilities element to 1. An S1G STA with dot11S1GLONGOptionActivated equal to false shall set the S1G_LONG Support field in the S1G Capabilities element to 0.

An S1G STA shall not transmit a PSDU with the TXVECTOR parameter PREAMBLE_TYPE set to S1G_LONG_PREAMBLE to an S1G STA unless the S1G_LONG Support field of the S1G Capabilities element received from that STA contained a value of 1 and dot11S1GLONGOptionActivated is true.

10.61 S1G flow control

This subclause describes flow control operation for an S1G STA.

NOTE 1—The S1G relay operation can use the flow control mechanism described in this subclause to prevent from the overflow condition.

A STA that supports flow control shall set the Flow Control Supported subfield to 1 in the S1G Capabilities element it transmits. An S1G AP that implements flow control may refuse (re)association or can disassociate a non-AP STA that sets the Flow Control Supported subfield to 0 in the S1G Capabilities element. The S1G AP that refuses (re)association or disassociates the STA shall set the Status Code field in the (Re)Association Response frame or in the Disassociation frame to FLOW_CONTROL_OPERATION_SUPPORTED.

A STA that sets the Flow Control Supported subfield to 1 in the S1G Capabilities element that it transmits may instruct a second STA that sets the Flow Control Supported subfield to 1 in the S1G Capabilities element that it transmits to stop sending Data frames using a flow-control instruction. The STA sending the flow-control instruction is called the flow-controlling STA. A STA that sets the Flow Control Supported subfield to 0 in the S1G Capabilities element that it transmits shall not instruct a second STA to stop sending Data frames using a flow-control instruction as described in this subclause. A STA that is the intended recipient of a flow-control instruction and that correctly receives that instruction is called a flow-controlled STA. A flow-controlled STA does not transmit any Data frames to the flow-controlling STA that transmitted the flow-control instruction, for the amount of time indicated in the flow-control instruction. A flow-control instruction is any of the following:

- A Flow Suspension frame
- A BAT frame with the Flow Control bit in the Frame Control field equal to 1
- A TACK frame with the Flow Control bit in the Frame Control field equal to 1
- A STACK frame with the Flow Control bit in the Frame Control field equal to 1
- An NDP Ack frame with the Relayed Frame field equal to 1 and the Idle Indication field equal to 1 and the Duration field not equal to 0

NOTE 2—The transmission of BAT frames, STACK frames, TACK frames is only permitted within TWT SP as described in 10.47, 10.25, and 10.3.2.11.

The Suspend Duration field of the Flow Suspension frame listed above indicates the length of time during which a flow-controlled STA shall not transmit Data frames to the flow-controlling STA identified by the TA field of the Flow Suspension frame.

The Suspend Duration field of the TACK/BAT/STACK frame listed above indicates the length of time during which a flow-controlled TWT STA shall not transmit Data frames to the flow-controlling STA identified by the TA field of the TACK/BAT frame and the RA field of the frame that elicited the STACK frame.

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The Duration field of the NDP Ack frame listed above indicates the length of time during which a flow-controlled STA shall not transmit Data frames to the flow-controlling STA identified by the RA field of the frame that elicited the NDP Ack frame.

A flow-controlled STA may resume transmission of Data frames addressed to the flow-controlling STA that had previously suspended transmission after the expiration of the time indicated in the Suspend Duration field of a Flow Suspension frame, TACK frame, BAT frame, or TACK frame or in the Duration field of an NDP Ack frame.

A flow-controlling STA may send a Flow Resumption frame to cancel any outstanding flow suspension time for the flow-controlling STA identified by the TA field of the Flow Resumption frame.

A flow-controlled STA that receives a Flow Resumption frame with a BSSID that matches the BSSID of the BSS of which the flow-controlled STA is a member or with an RA field that matches the address of the flow-controlled STA shall cancel any outstanding flow suspension time, and may resume transmission of Data frames to the flow-controlling STA identified by the TA field of the Flow Resumption frame.

A STA should send a next TWT value in the Next TWT Info/Suspend Duration field of the response frame it transmits to a TWT STA if the More Data bit is equal to 0 in the eliciting frame. A STA may send a suspend time value in the Next TWT Info/Suspend Duration field of a response frame it transmits to a TWT STA if the More Data bit is equal to 1 in the eliciting frame.

10.62 Energy limited STAs operation

An S1G STA keeps two timers, ELMaxAwakeTimer and ELRecoveryTimer, for each EL STA; and these timers are initialized upon reception of an EL Operation element from the EL STA:

— The ELMaxAwakeTimer is set to 0.
— The ELRecoveryTimer is set to the value of the Recovery Time field of the EL Operation element.

These timers uniformly count down to 0 when their values are nonzero. Figure 10-113 shows an example of the EL STA frame exchanges with the S1G STA.

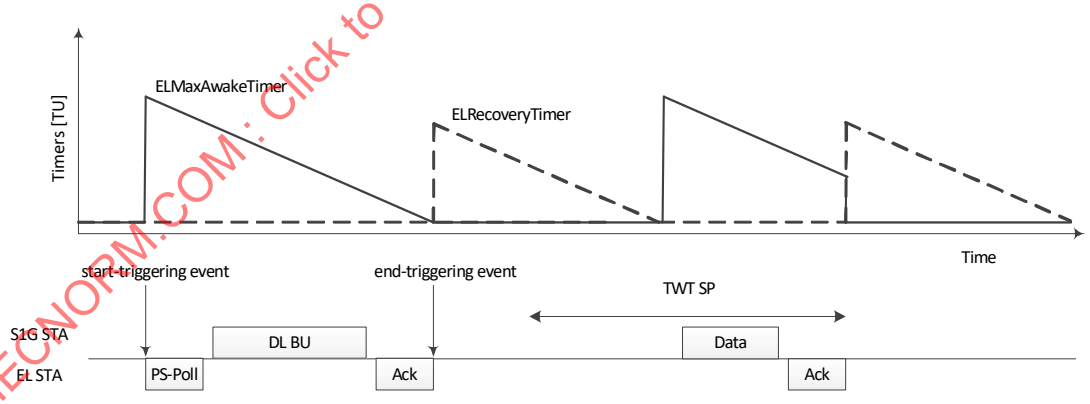

Figure 10-113—EL STA operation

The S1G STA shall not transmit to the EL STA, or cause the EL STA to transmit, a PPDU containing individually addressed frames and whose duration would exceed the value of the ELMaxAwakeTimer.

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The S1G STA shall set the ELMaxAwakeTimer to the value of the Max Awake Duration field of the most recently received EL Operation element from the EL STA and the ELRecoveryTimer to 0 when a start-triggering event occurs (see Figure 10-113 for an example). A start-triggering event occurs when both ELMaxAwakeTimer and ELRecoveryTimer are 0, and one of the following events that identify a transition of the EL STA from doze to awake state occurs:

— An (NDP) PS-Poll or trigger frame sent by the EL STA is received by the S1G STA.
— A TWT starts for the EL STA, where the TWT corresponds to any TWT agreement that the EL STA has set up with the S1G STA.
— A RAW slot allocated for the EL STA starts, where the RAW slot is scheduled in a RAW scheduled for the EL STA by the S1G STA.
— A TBTT or TSBTT at which the EL STA has to be awake is due, where the TBTT or TSBTT is the time the S1G STA sends an S1G Beacon frame that is intended to be received by the EL STA.

NOTE—An EL STA can send a frame that is not a trigger frame to the S1G STA anytime and the reception of this frame from the S1G STA does not qualify as a start-triggering event.

The S1G STA shall not schedule a transmission of a PPDU carrying an individually addressed MPDU intended for the EL STA, or cause the EL STA to transmit an individually addressed frame until the ELRecoveryTimer has reached 0.

The S1G STA shall set the ELRecoveryTimer to the value of the Recovery Time field of the most recently received EL Operation element from the EL STA and the ELMaxAwakeTimer to 0 when an end-triggering event occurs (see Figure 10-113 for an example). An EL STA may indicate the recovery duration in the Duration field of an NDP (PS-Poll-)Ack frame with the Idle Indication field set to 1. An end-triggering event occurs when the ELRecoveryTimer is 0 and one of the following events that identify a transition of the EL STA to doze state occurs:

— An acknowledgment is received from the EL STA as a response to the transmission of a BU, where the BU is sent by the S1G STA in response to an (NDP) PS-Poll or trigger frame generated by the EL STA.
— An acknowledgment is received from the EL STA as a response to of a frame with EOSP field equal to 1, where the frame is sent by the S1G STA.
— An NDP (PS-Poll-)Ack frame is received from the EL STA as a response to a frame generated by the S1G STA, where the NDP (PS-Poll-)Ack frame has an Idle Indication field equal to 1 and a nonzero value of the Duration field.
  — In this case, the ELRecoveryTimer is set to the value of the Duration field of the NDP (PS-Poll-)Ack frame when the Idle Indication field is 1.
— The AdjustedMinimumTWTWakeDuration for a TWT has ended, where the TWT corresponds to any TWT agreement that the EL STA has set up with the S1G STA.
— The RAW slot allocated for the EL STA has ended, where the RAW slot was scheduled in a RAW for the EL STA by the S1G STA.
— The transmission of an S1G Beacon frame has ended, where the S1G Beacon frame is sent at a TBTT or TSBTT at which the EL STA was expected to be awake.
— The transmission of group addressed BU(s) has ended, where the group addressed BU(s) are expected to be received by the EL STA following a DTIM Beacon.

When the S1G STA cannot complete frames exchanges within ELMaxAwakeTimer, a new backoff procedure is invoked after stopping the current transmission and once the ELRecoveryTimer has expired.

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10.63 S1G BSS type and STA type

S1G non-AP STAs are categorized into two types, sensor STAs and non-sensor STAs.

A non-AP STA that is a sensor STA shall set the STA Type Support subfield in the S1G Capabilities element it transmits to 1. A non-AP STA that is a non-sensor STA shall set the STA Type Support subfield in the S1G Capabilities element it transmits to 2.

There are three types of S1G BSS that an S1G AP can set up: sensor BSS, non-sensor BSS, or mixed BSS. A sensor BSS only supports sensor STAs. A non-sensor BSS supports only non-sensor STAs. A mixed BSS supports both sensor STAs and non-sensor STAs.

An AP may declare a non-sensor BSS by transmitting the S1G Capabilities element in Beacon frames, Probe Response, or PV1 Probe Response frames in which the STA Type Support subfield is 2 (i.e., it indicates that only non-sensor STAs are allowed to associate and operate with that AP).

An AP may declare a sensor BSS by transmitting the S1G Capabilities element in Beacon frames, Probe Response frames, or PV1 Probe Response frames in which the STA Type Support subfield is 1 (i.e., it indicates that only sensor STAs are allowed to associate and operate with that AP).

An AP may declare a mixed BSS by transmitting the S1G Capabilities element in a Beacon, Probe Response or PV1 Probe Response frame, in which the STA Type Support subfield is 0 (i.e., it indicates that any type of STA is allowed to associate and operate with that AP).

An S1G AP that indicates support for sensor STAs shall not indicate minimum MCS restrictions as specified in 10.6.14.3.

10.64 DBC mechanism for CDMG STAs

10.64.1 General

A CDMG STA supports the operation of variable bandwidth channels according to the channelization specified in Annex E.1. A CDMG infrastructure BSS or PBSS can operate on a 1.08 GHz or 2.16 GHz bandwidth channel. As specified in Annex E.1, each 2.16 GHz channel encompasses two 1.08 GHz channels. A CDMG infrastructure BSS or PBSS shall use the following DBC mechanism when operating in the country that requires the support of variable bandwidth channels operation to mitigate interference between other CDMG and DMG BSSs.

A CDMG AP or PCP shall follow the procedures in 11.1.4.4.2 to initialize a CDMG BSS on a 1.08 GHz or a 2.16 GHz bandwidth channel. An AP or PCP operating the BSS on a 1.08 GHz channel shall periodically transmit DMG Beacon frames (10.3.4.2) on the 2.16 GHz channel that encompasses the 1.08 GHz channel on which the BSS is operating. A CDMG AP or PCP may change the operating bandwidth of its BSS dynamically from 1.08 GHz to 2.16 GHz or vice versa.

A CDMG AP or PCP may request the AP or PCP of an existing CDMG BSS operating on a 2.16 GHz channel (e.g., channel 2) to shift its operating channel to one of the 1.08 GHz channels (e.g., channel 35) within its original 2.16 GHz channel by sending a Channel Splitting Request frame (9.6.28.4) or an Extended Channel Splitting Request frame (9.6.7.43). If the existing CDMG BSS changed its operating channel to one of the 1.08 GHz channels (e.g., channel 35), the CDMG AP or PCP that sends the request frame may then operate a new BSS on the other adjacent 1.08 GHz channel (i.e., channel 36) within the 2.16 GHz channel (i.e., channel 2).

A pair of CDMG APs or PCPs operating on the adjacent 1.08 GHz channels (e.g., channel 35 and channel 6) within a 2.16 GHz channel (i.e., channel 2) should maintain synchronization with each other to mitigate the

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interference caused by the transmission of the DMG Beacon frame and other frames on the 2.16 GHz channel (i.e., channel 2) according to 10.64.2.3.

10.64.2 CDMG channel access

10.64.2.1 CDMG BSS operating on a 2.16 GHz channel

A CDMG AP or PCP operating an infrastructure BSS or PBSS on a 2.16 GHz channel (e.g., channel 2) shall follow the channel access rules as described in 10.39.

10.64.2.2 CDMG BSS operating on a 1.08 GHz channel

A CDMG AP or PCP operating an infrastructure BSS or PBSS on a 1.08 GHz channel (e.g., channel 35) shall periodically transmit DMG Beacon frames (9.3.4.2) on the 2.16 GHz channel (i.e., channel 2) that encompasses its operating channel (i.e., channel 35). The time interval between two consecutive DMG Beacon frames transmitted on the 2.16 GHz channel shall be no more than aMaxBIDuration. The generation of the DMG Beacon frames shall follow the rules in (11.1.3.3.3).

The AP or PCP that starts an infrastructure BSS or PBSS on a 1.08 GHz channel (e.g., channel 35) shall set a TSF timer to track the beacon interval on the encompassing 2.16 GHz channel (i.e., channel 2). At the beginning of a beacon interval on the 2.16 GHz channel, the AP or PCP shall schedule a notification period (NP) or a BHI (10.39.2) indicated by the DBC Option subfield of the Dynamic Bandwidth Control element (9.4.2.220) contained in each DMG Beacon frame as shown in Figure 10-114 and Figure 10-115, respectively. If a NP is scheduled on the 2.16 GHz channel, at least one BHI shall be scheduled on the 1.08 GHz channel. The NP may include the BTI, A-BFT, and ATI.

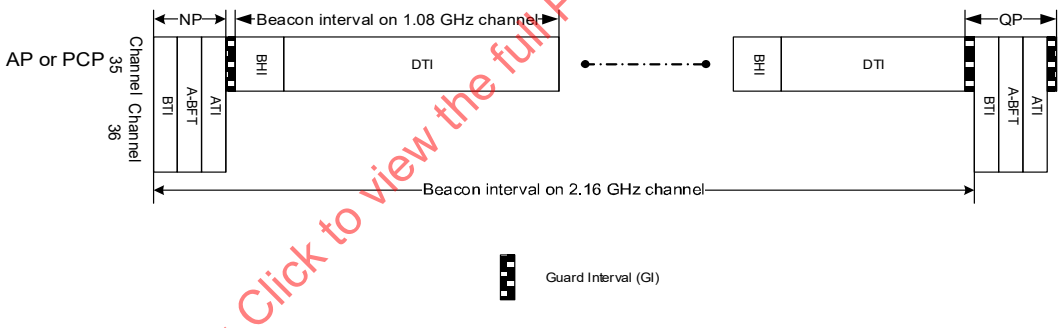

Figure 10-114—Example of an AP or PCP that starts its infrastructure BSS or PBSS on channel 35 by transmitting DMG Beacon frames on both channel 2 and channel 35

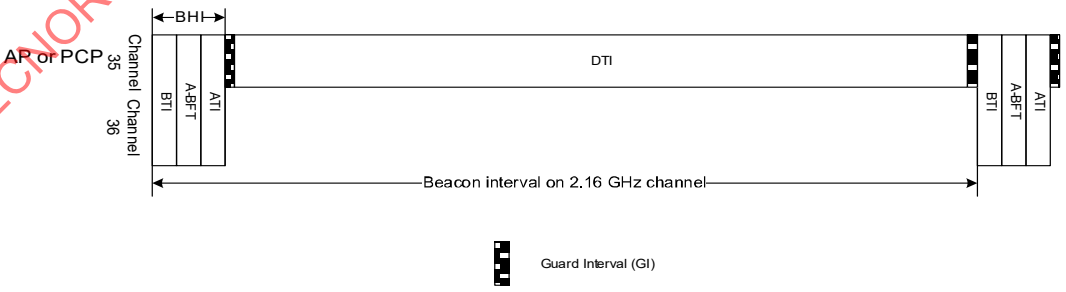

Figure 10-115—Example of a CDMG AP or PCP that starts its infrastructure BSS or PBSS on channel 35 by transmitting DMG Beacon frames on channel 2 only

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During the BTI on the 2.16 GHz channel, the AP or PCP shall transmit a DMG Beacon frame containing the Dynamic Bandwidth Control element (9.4.2.220) that includes information on the operating status of the BSS through the DBC Control field and Channel Number field. The beacon interval length on the 2.16 GHz channel is indicated by the Beacon Interval field (9.4.1.3) contained in each DMG Beacon frame.

The AP or PCP may also establish an independent beacon interval on its operating 1.08 GHz channel and set another TSF timer to track it. As illustrated in Figure 10-114, the beacon interval length on 1.08 GHz channel shall be set as an integer factor of the beacon interval length on 2.16 GHz channel in units of TUs. The maximum length shall be the beacon interval length on the 2.16 GHz channel. The channel access on the 1.08 GHz shall follow the rules described in 10.39 with a BHI period within each beacon interval. If BHIs are present on the 1.08 GHz channel, the DBC Option subfield of the Dynamic Bandwidth Control element within the DMG Beacon frame is set to 0; otherwise, it is set to 1.

A guard interval (GI) that is an interframe space follows a NP/BHI on the 2.16 GHz channel as shown in Figure 10-114 and Figure 10-115 for CDMG STAs to switch from transmitting and receiving frames on the 2.16 GHz channel to transmitting and receiving frames on the 1.08 GHz channel. The determination of the length of the GI is implementation dependent. At the end of the GI (or the NP/BHI if the GI is not present), the AP or PCP shall be ready to transmit or receive frames on the 1.08 GHz channel indicated by the Channel Number field of the Dynamic Bandwidth Control element.

If a CDMG AP or PCP transmits a DMG Beacon frame with the DBC Option subfield of the Dynamic Bandwidth Control element set to 0, it shall schedule quiet periods (QPs) on a 1.08 GHz channel by scheduling SPs with the AllocationType subfield set to 2 in the Allocation field and the Source AID subfield and Destination AID subfield set to its own AID. The starting times and durations of these QPs shall coincide with the starting times and durations of the NPs on the 2.16 GHz channel. The AP or PCP may also schedule the starting times of the QPs to be earlier than the NPs and the durations of the QPs to be greater than the durations of the NPs to establish a GI before and after each NP as shown in Figure 10-114.

If a CDMG AP or PCP transmits a DMG Beacon frame with the DBC Option subfield of the Dynamic Bandwidth Control element set to 1, it may schedule QPs before and after the BHIs to serve as GIs as shown in Figure 10-115. The GIs in this case should be longer than the time taken for all the CDMG STAs to switch from transmitting and receiving frames on the 2.16 GHz channel to transmitting and receiving frames on the 1.08 GHz channel. The determination of the length of the GIs is, however, implementation dependent.

If a non-AP and non-PCP CDMG STA receives a DMG Beacon frame from the CDMG AP or PCP with the BSSID equal to the BSSID of the BSS of which the STA is a member and with the DBC Option subfield of the Dynamic Bandwidth Control element set to 0, the STA shall switch to the 1.08 GHz channel indicated by the Channel Number field of the received Dynamic Bandwidth Control element to receive the DMG Beacon frame transmitted on the corresponding 1.08 GHz channel and follow the beamforming rules in 10.42 and the channel access rules in 10.41 on the 1.08 GHz channel. The non-AP and non-PCP STA may use the BI Offset subfield of the Dynamic Bandwidth Control element in the received DMG Beacon frame to predict the starting time of the BTI on the 1.08 GHz channel. In the following medium time, the non-AP and non-PCP STA should be prepared to receive and transmit frames on the 1.08 GHz channel unless it is assigned by the AP or PCP to monitor the 2.16 GHz common channel, or it communicates with other DMG STAs, or it leaves the current infrastructure BSS or PBSS, or the infrastructure BSS or PBSS ceases its services.

Alternatively, if a non-AP and non-PCP CDMG STA receives a DMG Beacon frame from the CDMG AP or PCP with the BSSID equal to the BSSID of the BSS of which the STA is a member and with the DBC Option subfield of the Dynamic Bandwidth Control element set to 1, the STA shall follow the beamforming rules in 10.42 and the channel access rules in 10.39 within the 2.16 GHz channel during the BHI duration. During the DTI, the STA shall switch to the 1.08 GHz operating channel indicated by the Channel Number field of the received Dynamic Bandwidth Control element to receive and transmit frame following the channel access rules in 10.39 on the 1.08 GHz channel.

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10.64.2.3 Synchronization of CDMG infrastructure BSS or PBSSs on the adjacent 1.08 GHz channels within a 2.16 GHz channel

A CDMG AP or PCP setting up an infrastructure BSS or PBSS on a 1.08 GHz channel (e.g., channel 35) that has a CDMG BSS established on the adjacent 1.08 GHz channel (i.e., channel 36) within the same 2.16 GHz channel (i.e., channel 2) should follow the procedures below to maintain synchronization.

A CDMG AP or PCP shall scan the 2.16 GHz channel (e.g., channel 2) that encompasses the 1.08 GHz channel (e.g., channel 36) on which the CDMG AP or PCP is going to set up its BSS for DMG Beacon frames. If the CDMG AP or PCP received a DMG Beacon frame containing a Dynamic Bandwidth Control element with the Channel Splitting subfield set to 1, the Channel Number field indicating the existing AP or PCP works on a 1.08 GHz channel, and the Adjacent Channel Occupancy subfield set to 1, the AP or PCP may send an Extended Notification Period Request frame (9.6.7.41) during the following ATI of the BSS indicated by the BSSID field of the received DMG Beacon frame to request the existing AP or PCP to allocate time for NPs/BHI to transmit DMG Beacon frames on the encompassing 2.16 GHz channel with the NP/BHI Duration field in the Extended Notification Period Request frame indicating the requested duration of NPs/BHIs.

Alternatively, the scanning AP or PCP may attempt to associate with the infrastructure BSS or PBSS indicated by the BSSID field of the received DMG Beacon frame following the rules in 11.3 and subsequently send a Notification Period Request frame (9.6.29.2). A non-AP and non-PCP CDMG STA within an infrastructure BSS or PBSS operating on a 1.08 GHz channel may send a Notification Period Request frame (9.6.29.2) during the ATI, SP, or CBAP to request the AP or PCP to allocate time for NPs/BHIs to transmit DMG Beacon frames on the encompassing 2.16 GHz channel with the -NP/BHI Duration field in the Notification Period Request frame indicating the requested duration of NPs/BHIs.

If a CDMG AP or PCP receives a Notification Period Request frame or an Extended Notification Period Request frame, it may allocate QPs on its operating 1.08 GHz channel at the same recurring position in each beacon interval of the 2.16 GHz channel and reply with a Notification Period Response frame (9.6.29.3) or an Extended Notification Period Response frame (9.6.7.42) containing a Dynamic Bandwidth Control element with the TBTT Offset field indicating the target starting time of the allocated NPs/BHIs and the NP/BHI Duration field and the Adjacent NP/BHI Duration field indicating the lengths of the NPs/BHIs on the 2.16 GHz channel of itself and the scanning AP or PCP. The CDMG AP or PCP may schedule the starting times of the QPs to be earlier than the NPs and the durations of the QPs to be greater than the durations of the NPs to establish a GI before and after each NP/BHI as shown in Figure 10-116 and Figure 10-117. The AP or PCP shall scan for DMG Beacon frames in the allocated NPs to determine if a new BSS has been established on the adjacent 1.08 GHz channel.

If a CDMG STA receives a Notification Period Response frame or Extended Notification Period Response frame addressed to it, it may establish an infrastructure BSS or PBSS on the 1.08 GHz channel adjacent to the channel indicated in the Channel Number field of the Dynamic Bandwidth Control element and become the AP or PCP using the following steps. The scanning AP or PCP shall start to transmit DMG Beacon frames at the start of the allocated NP/BHI indicated by the TBTT Offset field of the Dynamic Bandwidth Control element and set a TSF timer to track its beacon interval on the 2.16 GHz channel. The duration of the beacon interval on the 2.16 GHz channel shall be equal to the Beacon Interval field in the received Notification Period Response frame or an Extended Notification Period Response frame. The duration of NP/BHI on the 2.16 GHz channel shall be set to the value of the Adjacent NP/BHI Duration field of the Dynamic Bandwidth Control element in the received Notification Period Response frame or an Extended Notification Period Response frame. The scanning AP or PCP shall continue to receive the DMG Beacon frames from the existing AP or PCP during the NPs/BHIs starting at the time obtained from the Beacon Interval field minus the TBTT Offset field from the beginning of each beacon interval on the 2.16 GHz channel with the length indicated by the NP/BHI Duration field of the Dynamic Bandwidth Control element in the previously received Notification Period Response frame or Extended Notification Period Response frame and maintain synchronization by adjusting its TSF to match the Timestamp field (9.4.1.10) in the received DMG Beacon frames transmitted in these NPs/BHIs. The scanning AP or PCP shall also use the DBC Option subfield of the Dynamic Bandwidth Control element in

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each DMG Beacon frame to announce whether the beacon interval on its 1.08 GHz operating channel is present or not as described in 10.64.2.2.

A CDMG AP or PCP operating on a 1.08 GHz channel may also actively allocate reserved NPs/BHIs on the 2.16 GHz channel to allow a new CDMG BSS to be established on the adjacent 1.08 GHz channel. The CDMG AP or PCP may allocate QPs on its operating 1.08 GHz channel at the same recurring position in each beacon interval of the 2.16 GHz channel and announce the presence of the reserved NPs/BHIs by transmitting DMG Beacon frames on the 2.16 GHz channel containing a Dynamic Bandwidth Control element with the Channel Splitting subfield equal to 1, the Adjacent Channel Occupancy subfield equal to 1, and the Adjacent NP/BHI Duration field nonzero. The TBTT Offset field and the Adjacent NP/BHI Duration field in the Dynamic Bandwidth Control element indicate the target starting time and the duration of the reserved NPs/BHIs, respectively. The AP or PCP shall scan for DMG Beacon frames in the reserved NPs to determine if a new BSS has been established on the adjacent 1.08 GHz channel.

If a CDMG AP or PCP receives a DMG Beacon frame on the 2.16 GHz channel containing a Dynamic Bandwidth Control element with the Channel Splitting subfield set to 1, the Adjacent Channel Occupancy field set to 1, and the Adjacent NP/BHI Duration field nonzero, it may establish an infrastructure BSS or PBSS on the 1.08 GHz channel adjacent to the channel indicated in the Channel Number field of the Dynamic Bandwidth Control element using the following steps. The AP or PCP shall continue to scan for DMG Beacon frames on the 2.16 GHz channel during the reserved NPs/BHIs indicated by the TBTT Offset field of the Dynamic Bandwidth Control element for an interval of at least aMinChannelTime. If it does not receive any valid DMG Beacon frame, it may start a new BSS by transmitting a DMG Beacon frame at the start of the reversed NP/BHI and set a TSF timer to track its beacon interval on the 2.16 GHz channel. The duration of the beacon interval on the 2.16 GHz channel shall be equal to the Beacon Interval field in the received DMG Beacon frame of the existing AP or PCP. The scanning AP or PCP shall continue to receive the DMG Beacon frames in NPs/BHIs of the existing AP or PCP operating on the adjacent 1.08 GHz channel to maintain synchronization by adjusting its TSF to match the Timestamp field (9.4.1.10) in the received DMG Beacon frames. The scanning AP or PCP shall also use the DBC Option subfield of the Dynamic Bandwidth Control element contained in each DMG Beacon frame to announce whether the beacon interval on its 1.08 GHz operating channel is present or not described in 10.64.2.2.

The NPs/BHIs of the two APs or PCPs operating on the adjacent 1.08 GHz channels within a 2.16 GHz channel may be arranged consecutively without interspaces to reduce the number of times they need to switch between transmitting and receiving frames on the 2.16 GHz channel and the 1.08 GHz channels.

Figure 10-116 shows an example of two APs establishing BSSs on channels 35 and 36, respectively, with two NPs, NP 1 of AP 1 and NP 2 of AP 2, arranged consecutively without interspaces. The same arrangement might apply to PCPs establishing PBSSs. Figure 10-117 shows another example of two APs establishing BSSs on channels 35 and 36, respectively, with two BHIs, BHI 1 of AP 1 and BHI 2 of AP 2, arranged arbitrarily apart from each other. The same arrangement might apply to PCPs establishing PBSSs.

If a CDMG AP or PCP operating on a 1.08 GHz channel with the adjacent 1.08 GHz channel occupied by another CDMG BSS does not receive any DMG Beacon frame transmitted by the CDMG AP or PCP operating on the adjacent 1.08 GHz channel in the assigned NPs/BHIs for a period of 4×aMinBTIPeriod beacon intervals on the 2.16 GHz channel, starting from when the last frame is received from the neighboring AP or PCP, it may proceed to make changes to the assigned NPs/BHIs on the 2.16 GHz channel. The AP or PCP may continue to allocate a NP/BHI on 2.16 GHz channel at the same position to allow another AP or PCP to establish a new BSS on the adjacent 1.08 GHz channel as described above or it may stop allocating QPs on its operating channel that correspond to the NPs/BHIs on 2.16 GHz channel of the BSS operating on the adjacent 1.08 GHz channel. Figure 10-118 shows an example that an AP or PCP can cease its service on channel 35, a 1.08 GHz channel.

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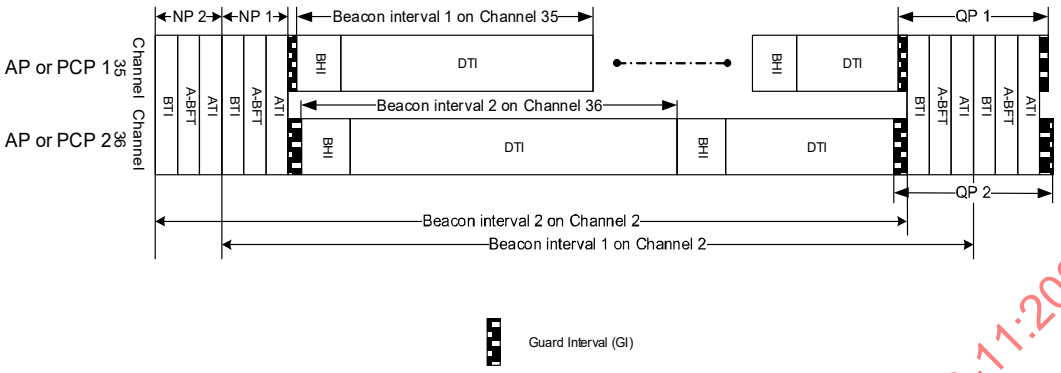

Figure 10-116—Two APs or PCPs with NPs arranged consecutively

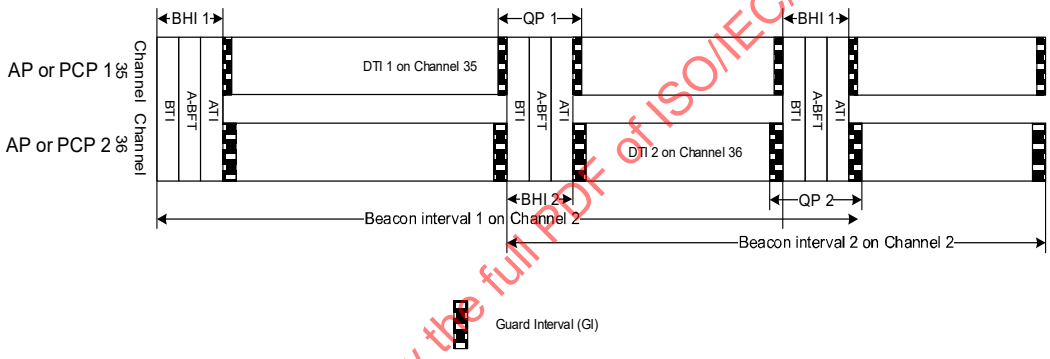

Figure 10-117—Two APs or PCPs with BHIs arranged apart from each other

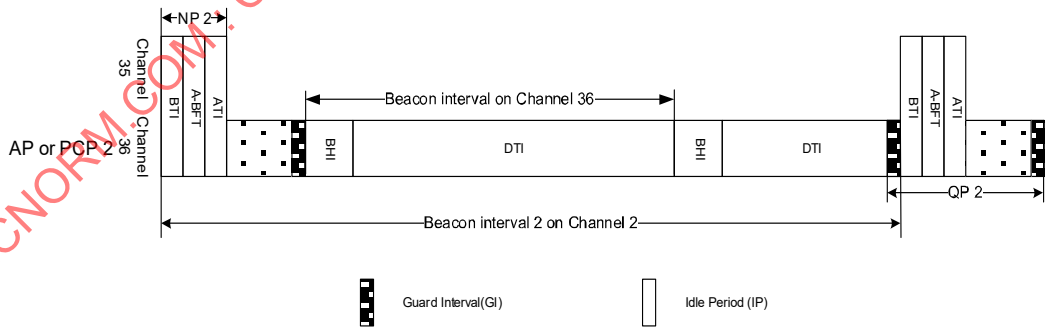

Figure 10-118—Service cessation for an AP or PCP on channel 35

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The CDMG AP or PCP may also move its TBTT (11.29.2) on the 2.16 GHz channel (e.g., channel 2) backward so that its NPs/BHIs are followed closely by the BHI on its 1.08 GHz operating channel (e.g., channel 36) as illustrated in Figure 10-119.

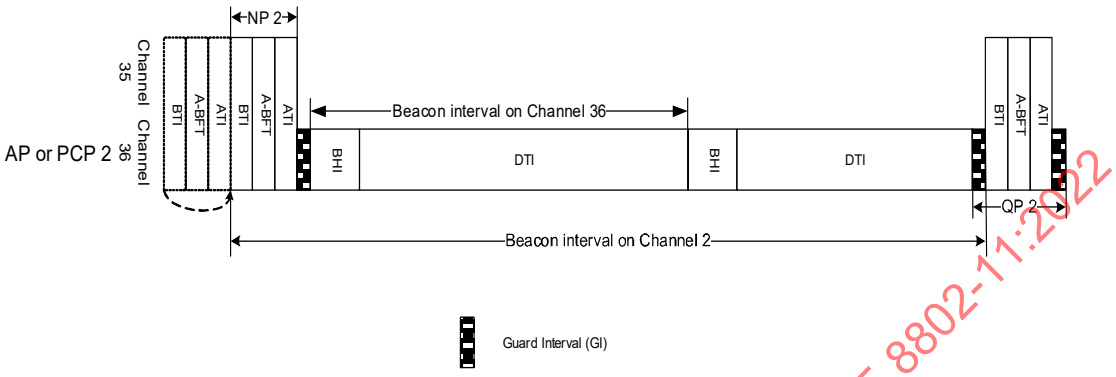

Figure 10-119—Moving TBTT by a neighboring AP or PCP on channel 2

10.64.3 Channel splitting of a 2.16 GHz channel

If a CDMG STA receives a DMG Beacon frame from a CDMG AP or PCP operating on a 2.16 GHz channel (e.g., channel 2), it may request the AP or PCP to shift its operating channel to one of the 1.08 GHz channels (e.g., channel 35) within its original 2.16 GHz channel by sending an Extended Channel Splitting Request frame (9.6.7.43) during the following ATI or it may associate with the infrastructure BSS or PBSS indicated by the BSSID field of the received DMG Beacon frame following the rules in 11.3 and subsequently send a Channel Splitting Request frame (9.6.28.4).

A non-AP and non-PCP CDMG STA within an infrastructure BSS or PBSS operating on a 2.16 GHz channel (e.g., channel 2) may send a Channel Splitting Request frame (9.6.28.4) during the ATI, SP, or CBAP, to request the AP or PCP to shift its operating channel to one of the 1.08 GHz channels (e.g., channel 35) within its original 2.16 GHz channel. If the existing CDMG BSS changed its operating channel to one of the 1.08 GHz channels (e.g., channel 35), the CDMG STA that sends the Channel Splitting Request frame may then operate a new BSS on the other adjacent 1.08 GHz channel (i.e., channel 36) within the 2.16 GHz channel (i.e., channel 2) as the role of AP or PCP.

The Channel Splitting Request frame or Extended Channel Splitting Request frame shall use the NP/BHI Duration field to indicate the required length of NP/BHI on a 2.16 GHz channel.

If a CDMG AP or PCP receives a Channel Splitting Request frame (9.6.28.4) or Extended Channel Splitting Request frame (9.6.7.43), the AP or PCP may follow the rules in 11.8.8.6 to switch its operating channel to a 1.08 GHz channel (e.g., channel 35) within its original 2.16 GHz channel (i.e., channel 2). If the AP or PCP switches the operating channel after receiving a Channel Splitting Request frame, it shall inform all its non-AP and non-PCP STAs of the DBC option it selects to operate on the 1.08 GHz channel after channel splitting, the target 1.08 GHz channel number to which it switches, and the starting time of the first beacon interval on 2.16 GHz channel when the channel splitting begins through the DBC Option subfield of the Dynamic Bandwidth Control element and the New Channel Number field and the Channel Switching Count field of the Channel Switch Announce element contained in the DMG Beacon and/or Announce frames. The AP or PCP shall also send a Channel Splitting Response frame (9.6.28.5) or Extended Channel Splitting Response frame (9.6.7.44) to announce the target 1.08 GHz channel number to which it switches and the starting time of the first beacon interval on 2.16 GHz channel when the channel splitting begins through the New Channel Number field and the Channel Switching Count field of the Channel Switch Announce element, the length of its beacon interval on 2.16 GHz channel after channel splitting through the Beacon Interval field, and the time offset of

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the scanning AP's or PCP's beacon interval relative to the existing AP's or PCP's beacon interval on 2.16 GHz channel and the lengths of NP/BHI durations for both APs or PCPs on 2.16 GHz channel through the TBTT Offset field, the NP/BHI Duration field, and the Adjacent NP/BHI Duration field of the Dynamic Bandwidth Control element to the CDMG STA indicated in the Source AID field in the received Channel Splitting Request frame or Extended Channel Splitting Request frame.

If a CDMG AP or PCP receives a Channel Splitting Request frame or Extended Channel Splitting Request frame but is not switching its operating channel, it may reply a Channel Splitting Response frame or an Extended Channel Splitting Response frame to reject the request.

If a CDMG STA sends a Channel Splitting Request frame or Extended Channel Splitting Request frame and then receives Channel Splitting Response frame or an Extended Channel Splitting Response frame with the Channel Splitting subfield set to 1, it shall follow the procedures described in 10.64.2.3 to maintain synchronization with the CDMG AP or PCP that sends the Channel Splitting Response frame or an Extended Channel Splitting Response frame when it starts a new BSS on the adjacent 1.08 GHz channel as the role of AP or PCP.

10.64.4 Channel expansion of a 1.08 GHz channel

A CDMG AP or PCP operating an infrastructure BSS or PBSS services on a 1.08 GHz channel (e.g., channel 35) may expand its operating bandwidth by switching to the 2.16 GHz channel (i.e., channel 2) encompassing its original operating channel without interruption to its BSS services.

If a CDMG AP or PCP operating an infrastructure BSS or PBSS on a 1.08 GHz channel (e.g., channel 35) transmits DMG Beacon frames on the 2.16 GHz channel containing a Dynamic Bandwidth Control element with the Channel Splitting subfield set to 1 and the Adjacent Channel Occupancy subfield set to 1, the AP or PCP may follow 11.8.8.6 to switch its operating channel to the 2.16 GHz channel (e.g., channel 2).

If a CDMG AP or PCP operating an infrastructure BSS or PBSS on a 1.08 GHz channel (e.g., channel 35) transmits DMG Beacon frames on the 2.16 GHz channel containing a Dynamic Bandwidth Control element with the Channel Splitting subfield set to 1 and the Adjacent Channel Occupancy subfield set to 0 but does not receive any DMG Beacon frame during the allocated NPs/BHI from another CDMG AP or PCP for a time period of 4×aMinBTIPeriod beacon intervals on the 2.16 GHz channel, the AP or PCP may follow 11.8.8.6 to switch its operating channel to the 2.16 GHz channel (e.g., channel 2).

If a CDMG AP or PCP operating an infrastructure BSS or PBSS on a 1.08 GHz channel (e.g., channel 35) transmits DMG Beacon frames on the 2.16 GHz channel containing a Dynamic Bandwidth Control element with the Channel Splitting subfield set to 1 and the Adjacent Channel Occupancy subfield set to 0 and receives a DMG Beacon frame during a NP/BHI from another CDMG AP or PCP operating on the adjacent 1.08 GHz channel (e.g., channel 36) within a 2.16 GHz channel (i.e., channel 2), it shall not expand its operating bandwidth by switching to the 2.16 GHz channel.

If the CDMG AP of PCP is switching the operating channel, it shall transmit DMG Beacon frames during the scheduled NPs on the 2.16 GHz channel containing a Dynamic Bandwidth Control element with the Channel Splitting subfield equal to 1 and the Adjacent Channel Occupancy subfield equal to 0 until the intended channel switch time. The AP or PCP shall inform all the non-AP and non-PCP STAs in the BSS with the target 2.16 GHz channel number to which it switches and the starting time of the first beacon interval on the 2.16 GHz channel after the channel expansion through the New Channel Number field and the Channel Switching Count field of the Channel Switch Announce element contained in the DMG Beacon and/or Announce frames. Here, the starting time is set until to the end of a subsequent beacon interval on the 2.16 GHz channel. Note that the beacon interval length after channel expansion might be different with that before channel expansion.

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Figure 10-120 and Figure 10-121 illustrate the examples that an AP or PCP (e.g., AP or PCP 1) operating on channel 35 switches to channel 2. In Figure 10-120, the AP or PCP 1 established an independent beacon interval on channel 35 while in Figure 10-121, the AP or PCP 1 does not.

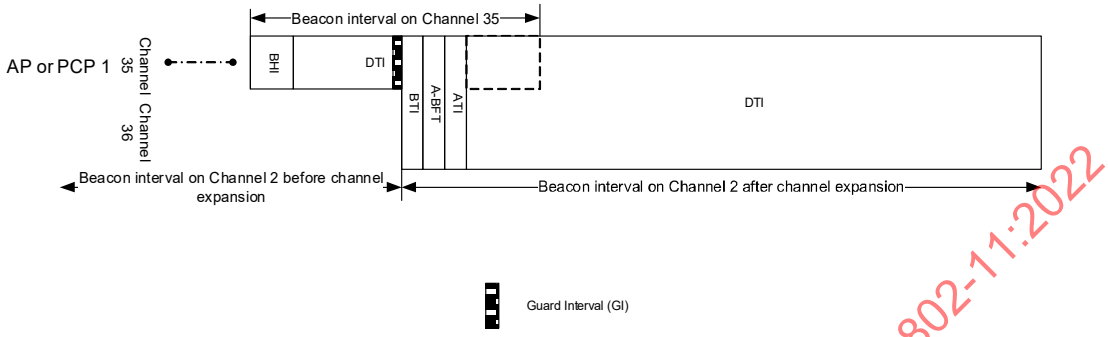

Figure 10-120—AP or PCP operating on channel 35 with independent beacon interval expanding the operating bandwidth to channel 2

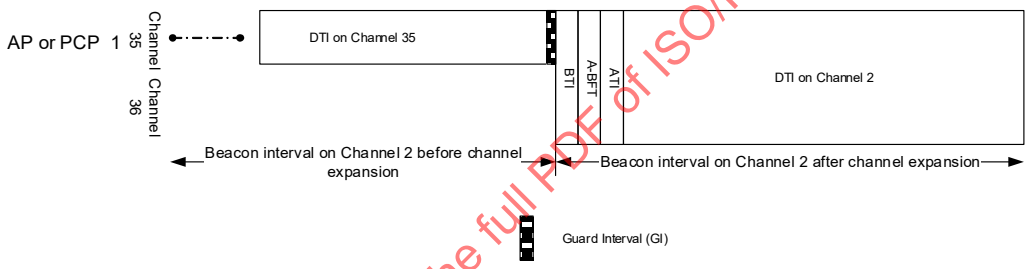

Figure 10-121—AP or PCP operating on channel 35 without independent beacon interval expanding the operating bandwidth to channel 2

10.64.5 Backward compatibility and interoperation

A CDMG AP or PCP operating an infrastructure BSS or PBSS shall provide interoperability to DMG STAs regardless of the BSS's operating channel. If a CDMG BSS is operating on a 2.16 GHz channel, the CDMG AP or PCP shall follow the channel access rules as described in 10.39 to provide services to non-AP and non-PCP DMG STAs.

A CDMG STA should not establish a 1.08 GHz BSS within a 2.16 GHz channel on which it received a DMG Beacon frame from a DMG AP or PCP. A CDMG AP or PCP operating on a 1.08 GHz channel shall transmit DMG Beacon frames on both the 1.08 GHz channel and the corresponding 2.16 GHz channel. A DMG STA can request to join a CDMG BSS. If the DMG STA successfully joins the CDMG BSS, the CDMG AP or PCP of the BSS shall schedule SPs and/or CBAPs for the DMG STA on the 2.16 GHz channel. The length of the scheduled SPs or CBAPs for DMG STAs on the 2.16 GHz channel is variable and may be up to the entire DTI. In other words, all STAs in the CDMG BSS operate on the 2.16 GHz channel if SPs and/or CBAPs are scheduled only on the 2.16 GHz channel during the DTI. The algorithm to schedule SPs or CBAPs for DMG STAs in a CDMG BSS is implementation dependent and beyond the scope of this standard but should aim to improve the network efficiency.

During an SP or a CBAP, the source and destination CDMG STAs operating on a 1.08 GHz channel in a CDMG BSS shall transmit an RTS frame and a DMG CTS or DMG DTS frame, respectively, on the

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corresponding 2.16 GHz channel after successfully transmitting and receiving an RTS frame and a DMG CTS or DMG DTS frame, respectively, on the 1.08 GHz channel if the 2.16 GHz channel is idle. Then the DMG STAs can set their NAVs by receiving the RTS or DMG CTS or DMG DTS frames transmitted on the 2.16 GHz channel by the CDMG STAs. After transmitting a CF-End frame to truncate an SP or TXOP on a 1.08 GHz channel within a 2.16 GHz channel, a CDMG STA shall also transmit a corresponding CF-End frame on the 2.16 GHz channel if it is idle.

If a CDMG infrastructure BSS or PBSS is operating on a 1.08 GHz channel, the CDMG AP or PCP shall follow the channel access rules in the BHI as described in 10.39 during the NPs/BHIs on the 2.16 GHz channel to admit non-AP and non-PCP DMG STAs into the BSS and provide scheduling information to DMG STAs. In the following medium time, the CDMG AP or PCP shall follow the rules in 10.39.6 to schedule the SPs or CBAPs for non-AP and non-PCP DMG STAs on the 2.16 GHz channel. If the CDMG AP or PCP establishes an independent beacon interval on its operating 1.08 GHz channel, it shall schedule SPs or CBAPs with non-AP and non-PCP DMG STAs as the source or destination STAs such that the scheduled SPs or CBAPs shall not be overlapped in time with the BHI periods on the 1.08 GHz channel. The CDMG AP or PCP may also schedule SPs or CBAPs on the 2.16 GHz channel for DMG STAs within the BSS to communicate with CDMG STAs within the BSS.

If a CDMG AP or PCP that is operating on a 1.08 GHz channel, with another CDMG BSS operating on the adjacent 1.08 GHz channel within a 2.16 GHz channel, the CDMG AP or PCP shall schedule only SPs or CBAPs with non-AP and non-PCP DMG STAs as the source or destination STAs in time periods that has been reported as unoccupied by the other CDMG AP or PCP through the Extended Schedule element in its DMG Beacon frames. The CDMG AP or PCP shall announce all its allocated SPs and CBAPs for the other CDMG AP or PCP, and the other CDMG AP or PCP can allocate SPs or CBAPs on the common 2.16 GHz channel in the unallocated time. The CDMG AP or PCP that intends to allocate time on the 2.16 GHz channel may also transmit a CDMG Allocation Request frame (9.6.28.6) during the ATI of the other AP's or PCP's NP/BHI on the 2.16 GHz channel to request for the available time for allocations on the 2.16 GHz channel. A CDMG AP or PCP that receives a CDMG Allocation Request frame from a CDMG AP or PCP operating on its adjacent 1.08 GHz channel shall reply with a CDMG Allocation Response frame (9.6.28.7) with an Extended Schedule element to indicate the schedule of all its allocations.

A CDMG AP or PCP that is operating on a 1.08 GHz channel, with another CDMG BSS operating on the adjacent 1.08 GHz channel within a 2.16 GHz channel, should appropriately reserve and schedule the available time for the AP or PCP operating on the adjacent 1.08 GHz channel and itself to allocate SPs or CBAPs on the 2.16 GHz channel, but the method to determine the reservation is implementation dependent. Four cases of backward compatibility and interoperation between DMG STAs and CDMG STAs are illustrated as follows.

A CDMG AP or PCP establishing an infrastructure BSS or PBSS on channel 35, with one or more beacon intervals starting on this channel, allows DMG STAs to join as non-AP and non-PCP STAs and allocates their SPs or CBAPs on channel 2 only, as shown in Figure 10-122.

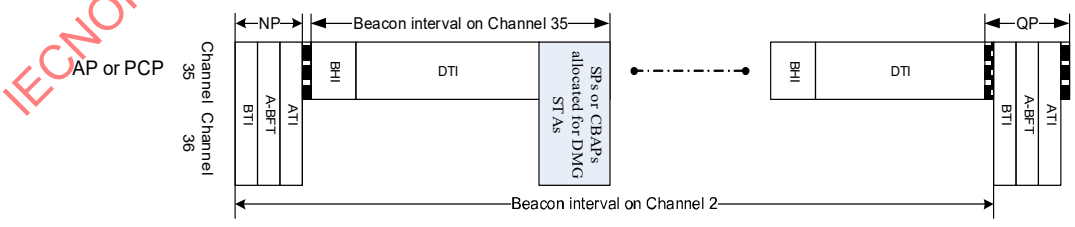

Figure 10-122—SPs or CBAPs allocated for DMG STAs on channel 2 with beacon intervals starting on channel 35

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A CDMG AP or PCP establishing an infrastructure BSS or PBSS on channel 35, without starting a beacon interval on this channel, allows the DMG STAs to join as non-AP and non-PCP STAs and allocates their SPs or CBAPs on channel 2 only, as shown in Figure 10-123.

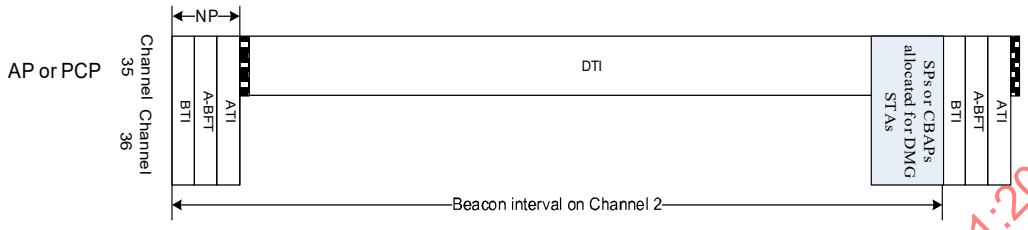

Figure 10-123—SPs or CBAPs allocated for DMG STAs on channel 2 without starting a beacon interval on channel 35

CDMG APs or PCPs establishing infrastructure BSSs or PBSSs on channels 35 and 36, respectively, with beacon intervals starting on this channel, allow the DMG STAs to join any of the BSSs or PBSSs as non-AP and non-PCP STAs and allocate their SPs or CBAPs on channel 2 only, as shown in Figure 10-124.

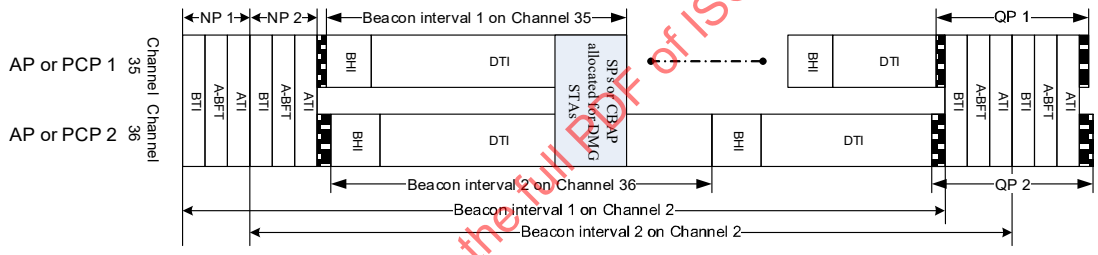

Figure 10-124—SPs or CBAPs allocated for DMG STAs on channel 2 with beacon intervals starting on channels 35 and 36

CDMG APs or PCPs establishing infrastructure BSSs or PBSSs on channels 35 and 36, respectively, without starting a beacon interval on this channel, allow the DMG STAs to join any of the BSSs or PBSSs as non-AP and non-PCP STAs and allocate their SPs or CBAPs on channel 2 only, as shown in Figure 10-125.

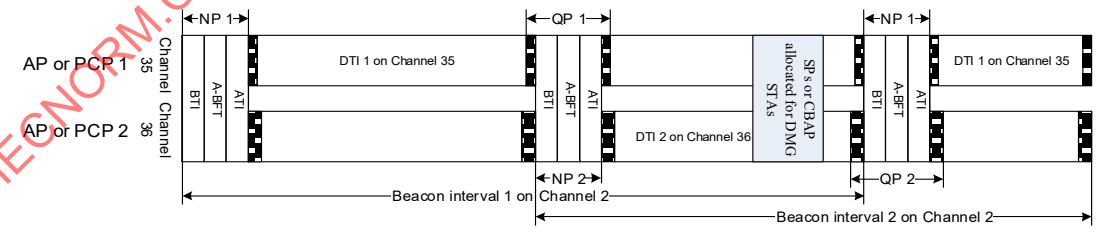

Figure 10-125—SPs or CBAPs allocated for DMG STAs on channel 2 without starting a beacon interval on channels 35 and 36

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10.65 Addressing of GLK Data frame transmission

If a corresponding IEEE 802.1Q Bridge provides a station vector parameter that indicates a single general link, then the GLK STA shall transmit the MSDU using individually addressed MPDU(s) to the peer STA with one of the following methods:

- A frame with a three-address MAC header if the RA and the DA are equal and the transmitter is an AP.
- A frame with a four-address MAC header.
- A frame containing a Basic A-MSDU.

If a corresponding IEEE 802.1Q Bridge provides a station vector parameter that indicates multiple general links, then GLK transmission of the MSDU shall use one of the following methods:

- Transmit multiple individually addressed MPDUs to peer STAs.
- Transmit group addressed MPDU(s) using a SYNRA in a frame with a four-address MAC header with the following restrictions:
  - Shall not be sent by a non-GLK STA or non-AP STA.
  - Shall not address a STA that is in PS mode.
  - Shall not address a STA whose general link might pass through a relay.

A GLK AP may use any combination of these methods, such that each peer STA is addressed once. This also applies for each retry triggered by GLK-GCR, which shall use the same method for all transmission attempts.

The addressing of the frame with a four-address MAC header shall be as follows:

- Address 1 is the MAC address of the immediate destination STA (the receiver of the MPDU) or a SYNRA.
- Address 2 is the MAC address of the transmitter STA (the transmitter of the MPDU).
- Address 3 is the DA of the MSDU (the destination address of the MSDU), or BSSID for a Basic A-MSDU.
- Address 4 is the SA of the MSDU (the source address of the MSDU), or BSSID for a Basic A-MSDU.

The addressing of the frame with the three-address MAC header format containing a basic A-MSDU shall be as follows:

- Address 1 is the MAC address of the immediate destination STA (the receiver of the MPDU).
- Address 2 is the MAC address of the transmitter STA (the transmitter of the MPDU).
- Address 3 is the BSSID.
- DA in A-MSDU subframe header is the DA of the MSDU (the destination address of the MSDU).
- SA in A-MSDU subframe header is the SA of the MSDU (the source address of the MSDU).

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10.66 SYNRA filtering operation

A GLK infrastructure non-AP STA shall support reception of frames with a SYNRA as RA.

When a GLK non-AP STA receives an RA that is a group address in an MPDU from its associated GLK AP, if the SYNRA Type subfield does not represent a supported SYNRA type, or the From DS and To DS subfields in the Frame Control field are not both 1, then the non-AP STA shall discard the frame, and not use the frame for updating any scoreboard used for GLK-GCR block ack. All other group addressed Data frames received from the associated GLK AP shall be counted as received for the purposes of the scoreboard used for GLK-GCR block ack, even if discarded based on the subsequent SYNRA filtering, as described below.

For Basic SYNRA Control subfield, the frame shall be discarded if any of the following filter rules are satisfied:

— The AID of the STA falls within the range of AID values covered by the AID Bitmap subfield, and the bit representing its AID value is 0.

— The AID of the STA falls outside the range of AID values covered by the AID Bitmap subfield, and the Other AID subfield is 0.

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11. MLME

11.1 Synchronization

11.1.1 General

STAs in a single infrastructure BSS, PBSS, or IBSS are synchronized to a common clock using the mechanisms defined in 11.1.

STAs in mesh BSSs use a synchronization method that is part of the extensible synchronization framework. The synchronization in an MBSS is described in 14.13.

A STA for which dot11OCBActivated is true is not a member of a BSS and, therefore, is not required to synchronize to a common clock or to use these mechanisms.

A timing synchronization function (TSF) keeps the timers for all STAs in the same BSS synchronized. All STAs in which dot11OCBActivated is false maintain a local TSF timer. STAs in which dot11OCBActivated is true may maintain a TSF timer for purposes other than synchronization.

A multi-band capable device (11.31) shall maintain a local TSF timer for each channel in which the STA operates.

11.1.2 Basic approach

11.1.2.1 TSF for an infrastructure BSS or a PBSS

In an infrastructure BSS or in a PBSS, the AP in the infrastructure BSS or the PCP in the PBSS shall be the timing master for the TSF. In a non-DMG and non-S1G BSS, the AP shall periodically transmit frames called *Beacon frames*. Instead of Beacon frames, an S1G AP shall periodically transmit S1G Beacon frames (as described in 11.1.3.10.1), which provide a similar function to the Beacon frame in a non-S1G BSS. Within an S1G BSS, the generation and/or reception of a Beacon frame and all references to it refer to that of the S1G Beacon frame. In a DMG BSS, the AP or PCP shall regularly transmit frames called *DMG Beacon frames* and *Announce frames*, which provide a similar function to the Beacon frame in a non-DMG BSS. Beacon, S1G Beacon, DMG Beacon, and Announce frames contain the value of the AP's or PCP's TSF timer in order to synchronize the TSF timers of other STAs in a BSS. A receiving STA shall accept the timing information in Beacon, S1G Beacon, DMG Beacon, and Announce frames sent from the AP or PCP servicing its BSS. An S1G STA that receives an S1G Beacon frame shall update its TSF timer according to the algorithm described in 11.1.3.10.3. If a STA's TSF timer is different from the timestamp in the received Beacon, S1G Beacon, DMG Beacon, or Announce frame, the receiving STA shall set its local TSF timer to the received timestamp value. A STA that receives a frame from its currently associated AP containing a Tetrapartial Timestamp or a Pentapartial Timestamp field may update its local TSF using the received portions of the AP's TSF timer contained in the received field, following the procedure described in 11.1.3.10.3.

In a non-DMG and non-S1G BSS, Beacon frames shall be generated for transmission by the AP once every dot11BeaconPeriod TUs. In an S1G BSS, the S1G AP shall generate S1G Beacon frames every dot11BeaconPeriod TUs; and if dot11ShortBeaconInterval is true, it shall additionally generate S1G Beacon frames every dot11ShortBeaconPeriod TUs as described in 11.1.3.10.1.

NOTE 1—The beacon interval, and hence the valid values of dot11BeaconPeriod, is constrained for APs in which dot11PublicHCCATXOPNegotiationActivated is true or dot11ProtectedHCCATXOPNegotiationActivated is true as specified in 11.26.4.1.

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In a DMG infrastructure BSS, zero or more DMG Beacon frames shall be generated for transmission by the AP every dot11BeaconPeriod TUs (see 11.1.3.3). The AP shall transmit at least one DMG Beacon frame through each sector the AP chooses to use, within a time interval that is not longer than dot11BeaconPeriod × dot11MaxLostBeacons TUs. The determination of the sectors the AP chooses to use is implementation dependent, but should be determined in a way that allows unassociated STAs to discover the AP. The TXSS Span field in the DMG Beacon frame shall be set to a value that is less than or equal to dot11MaxLostBeacons.

NOTE 2—The AP can change the sectors it transmits DMG Beacon frames through, and the value of the TXSS Span field, depending on the number and location of associated STAs, and the AP's intention to be discoverable in various sectors.

In a PBSS, the value of the TSF timer is delivered to the STA by the DMG Beacon frames generated at each BTI and by the Announce frames generated during the ATI. In a PBSS, at TBTTs that do not start with a BTI, the PCP begins a beacon interval with an ATI sequence (see 11.1.3.3.2). The time interval in between two consecutive BTIs shall be an integer multiple of dot11BeaconPeriod TUs. A PCP or DMG AP shall set the Next Beacon subfield of the Beacon Interval Control field in the DMG Beacon frame to a value that indicates the number of beacon intervals following the current beacon interval during which the DMG Beacon frame will not be transmitted. The PCP shall transmit at least one DMG Beacon frame to each associated STA within a time interval that is not longer than dot11BeaconPeriod × dot11MaxLostBeacons TUs. The PCP shall transmit at least one DMG Beacon frame through each possible antenna configuration in a full-coverage set of antenna configurations within the number of beacon intervals specified within the most recently updated TXSS Span field.

11.1.2.2 TSF for an IBSS

The TSF in an IBSS is implemented via a distributed algorithm that is performed by all of the members of the BSS. Each STA in the IBSS shall transmit Beacon or S1G Beacon frames according to the algorithm described in this clause. Each IBSS STA shall adopt the TSF value received from any Beacon or S1G Beacon frame or probe response from the IBSS of which it is a member and which has a TSF value later than its own TSF timer. All Beacon frames transmitted in an S1G IBSS shall be S1G Beacon frames, and all references to the Beacon frame (generation and/or reception) in an S1G BSS refer to that of the S1G Beacon frame.

11.1.2.3 TSF for an MBSS

The TSF in an MBSS is provided by the MBSS's active synchronization method. A mesh STA shall initialize its TSF timer according to the MBSS's active synchronization method. The mesh STA shall periodically transmit Beacon frames that contain the value of its TSF timer to announce its local time reference. Mesh STAs receiving a Beacon frame use the timing information in the Beacon frame as specified by the MBSS's active synchronization method. See 14.13.2 for details.

11.1.3 Maintaining synchronization

11.1.3.1 General

Each STA shall maintain a TSF timer with modulus 2^{64} counting in increments of microseconds. STAs expect to receive Beacon frames at a nominal rate. In a non-DMG infrastructure BSS, the interval between Beacon frames is defined by dot11BeaconPeriod. In a DMG infrastructure BSS, the STAs expect to receive at least one DMG Beacon frame every dot11BeaconPeriod × dot11MaxLostBeacons TUs. In a PBSS, STAs expect to receive at least one DMG Beacon frame or one Announce frame every dot11BeaconPeriod × dot11MaxLostBeacons TUs.

A non-DMG STA sending a Beacon, Timing Advertisement, or Probe Response frame, or a TIM frame with a TSF timestamp, shall set the frame's Timestamp field so that it equals the value of the STA's TSF timer at the time that the start of the data symbol containing the first bit of the Timestamp field appears at the transmit

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antenna connector. The Address 1 field of the Beacon or Timing Advertisement frame shall be set to the broadcast address.

A DMG STA sending a DMG Beacon, Announce, Timing Advertisement, or Probe Response frame, or a TIM frame with a TSF timestamp, shall set the frame's Timestamp field so that it equals the value of the STA's TSF timer at the time that the start of the data symbol containing the first bit of the frame appears at the transmit antenna connector. The Address 1 field of the Timing Advertisement frame shall be set to the broadcast address.

NOTE—In order that the value of the Timestamp field match the TSF value at the correct time, implementations need to compensate for delays along the transmit path, such as delays through the local PHY from the MAC-PHY interface to the transmit antenna connector.

11.1.3.2 Beacon generation in non-DMG infrastructure networks

If the AP is a non-S1G AP, it shall define the timing for the entire BSS by transmitting Beacon frames according to dot11BeaconPeriod. If the AP is an S1G AP, it shall define the timing for the entire BSS by transmitting S1G Beacon frames according to dot11BeaconPeriod. This defines a series of TBTTs exactly dot11BeaconPeriod TUs apart. Time 0 is defined to be a TBTT with the Beacon frame being a DTIM. At each TBTT, the AP shall schedule a Beacon frame as the next frame for transmission according to the medium access rules specified in Clause 10.

NOTE 1—To achieve this requirement, the AP suspends any pending transmissions until the beacon has been transmitted. In the case of a DTIM, the AP also suspends any pending individually addressed transmissions until any pending group addressed transmissions have been performed (see 11.2.3.4).

The beacon period is included in Beacon and Probe Response frames, and a STA shall adopt that beacon period when joining the BSS, i.e., the STA sets dot11BeaconPeriod to that beacon period. An non-S1G AP shall not transmit S1G Beacon frames. The operation of an S1G AP is further defined in 11.1.3.10.1.

NOTE 2—Though the transmission of a Beacon frame might be delayed because of CSMA deferrals, subsequent Beacon frames are scheduled at the undelayed nominal beacon interval. This is shown in Figure 11-1.

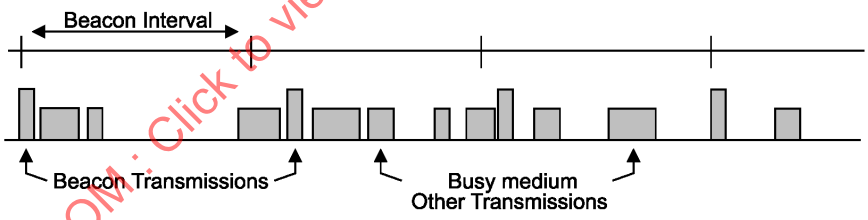

Figure 11-1—Beacon transmission on a busy network

If a STA that does not support short slot time associates with an AP that supports Clause 18 operation, and the AP is using short slot time, the AP shall use long slot time beginning at the first Beacon frame subsequent to the association of the long slot time STA.

An AP whose last transmitted values for the Tx STBC subfield and Rx STBC subfield of the HT Capability Information field of the HT Capabilities element are both nonzero may transmit an STBC Beacon frame and group addressed traffic using the basic STBC MCS, as defined in 10.6.3. An AP that transmits an STBC Beacon frame shall set the Dual Beacon field to 1 in transmitted HT Operation elements. A VHT AP shall set the Dual Beacon field to 0 in transmitted HT Operation elements. The STBC Beacon field shall be set to 1 to identify an STBC Beacon frame. The TBTT for the STBC Beacon frame shall be offset by half of a beacon interval from the TBTT of the non-STBC Beacon frame. Except for the setting of the STBC Beacon field, TIM

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element, and TSF field, all other fields inside the STBC Beacon frame shall be identical to the non-STBC Beacon frame.

The dual beacon mechanism is obsolete. Support for this mechanism might be removed in a later revision of the standard.

11.1.3.3 Beacon generation in a DMG infrastructure BSS and in a PBSS

11.1.3.3.1 General

A DMG STA acting as an AP or PCP follows the DMG channel access procedures (see 10.39) and the rules described in this subclause to transmit DMG Beacon frames.

Each DMG Beacon frame transmitted by a PCP and by a DMG AP shall have the Discovery Mode field within the DMG Beacon frame set to 0.

The Duration field of each transmitted DMG Beacon frame shall be set to the time remaining until the end of the current BTI.

A PCP and a DMG AP establish a series of target beacon transmission times (TBTTs) spaced dot11BeaconPeriod TUs apart. The period between two TBTTs is referred to as the *beacon interval*. The beacon interval length shall be no more than aMaxBIDuration. Time value zero of the TSF is defined to be a TBTT.

The length of the beacon interval is included in the DMG Beacon, Announce, and Probe Response frames, and a DMG STA shall adopt that beacon interval when joining the BSS.

A PCP and a DMG AP that move the TBTT (11.29.2) or change the beacon interval duration (11.29.3) shall reestablish the TBTT by resetting the TSF to 0 at the time the BSS parameter change takes effect in the BSS.

At each BTI, a PCP and a DMG AP schedule DMG Beacon frames for transmission according to the procedure specified in 10.42.4. Subject to this constraint, the AP or PCP may delay the DMG Beacon frame transmission if the medium is determined by the CCA mechanism to be busy. When delaying a DMG Beacon frame transmission, the AP or PCP shall check that the BTI, A-BFT, and ATI do not overlap in time with pseudo-static SPs for which the AP or PCP is not the source DMG STA and, if AP or PCP clustering is in use, that the DMG Beacon frame transmission follows the additional rules described in 10.40.

An AP or PCP may transmit DMG Beacon frames through different antenna configurations during the BTI, but shall not transmit more than one DMG Beacon frame through the same antenna configuration during the BTI of any beacon interval. For any beacon interval that does not include a DMG Beacon frame transmission in the BTI, the AP shall begin the beacon interval with an ATI, and the PCP may begin the beacon interval with an ATI (11.2.7.3).

When the DMG Beacon frame transmission is performed as multiple directional transmissions, an AP or PCP should change the sequence of directions through which a DMG Beacon frame is transmitted after it has transmitted a DMG Beacon frame through each direction in the current sequence of directions. When the ECAPC Policy Enforced field is equal to 1 in the DMG Beacon frame most recently transmitted by an AP or PCP, then

— When the AP or PCP transmits a DMG Beacon frame as multiple directional transmissions, the AP or PCP shall change the sequence of directions through which a DMG Beacon frame is transmitted after it has transmitted a DMG Beacon frame through each direction in the current sequence of directions.

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— When the AP or PCP transmits a DMG Beacon frame as a single transmission, the AP or PCP shall randomly delay the transmission of the DMG Beacon frame by up to min(4×TXTIME(DMG Beacon), 1024×dot11MinBHIDuration) μs after the TBTT.

This is done to randomize and potentially minimize interference to/from the DMG Beacon. One such example is indicated in Figure 11-2. If the sequence of directions is changed, the sequence of directions shall be pseudorandomly chosen from a sequence of directions covering the full set of directions available to an AP or PCP.

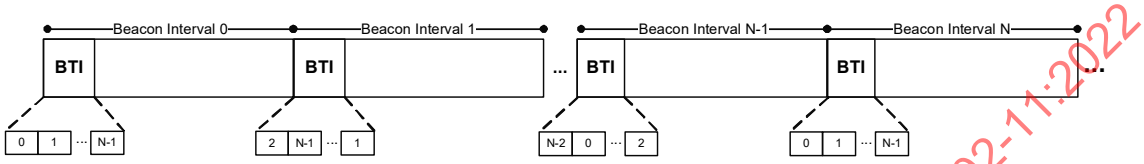

Figure 11-2—Example of DMG beacon transmission by an AP or PCP during the BTI

NOTE—An AP or PCP operating in a DMG BSS can transmit Announce frames during the ATI (10.39.3). An Announce frame can perform the function of a DMG Beacon frame, can be transmitted as an individually addressed frame directed to a STA, and can provide a much more spectrally efficient access than using a DMG Beacon frame.

A DMG STA that is an AP or a PCP shall include a DMG Operation element within a transmitted DMG Beacon frame if the CBAP Only field within the DMG Beacon frame is equal to 1. A DMG STA that is an AP or a PCP shall include a DMG Operation element within a transmitted DMG Beacon frame if the CBAP Only field within the DMG Beacon frame is equal to 0 and the Extended Schedule element is included in the DMG Beacon frame. A DMG STA that is an AP or a PCP shall include a DMG Operation element within a transmitted Announce frame if the Extended Schedule element is included in the Announce frame.

11.1.3.3.2 Beacon generation in a PBSS

In a PBSS, every beacon interval shall start with a BTI or ATI, except in PCP power save (PPS) mode, where a PCP D-BI need not start with a BTI or ATI (see 11.2.7.3.3).

A PCP that transmits a DMG Beacon frame with the CBAP Only field equal to 1 within a BTI shall include a BTI in any following beacon intervals until the completion of the TXSS of which the DMG Beacon frame is a part.

11.1.3.3.3 Beacon generation in a DMG infrastructure BSS

A DMG AP shall set dot11MaxLostBeacons to the value of the aMinBTIPeriod parameter.

11.1.3.4 DMG beacon generation before establishment of a BSS

A DMG STA can transmit DMG Beacon frames before establishment of a BSS to discover and perform beamforming during the A-BFT with another DMG STA so that the following frame exchanges between these STAs do not have to be done as a sector sweep (see 11.1.4.3.3).

A DMG STA that transmits DMG Beacon frames before establishment of a BSS shall set the Discovery Mode field in each transmitted DMG Beacon frame to 1 to indicates that the establishment of a BSS procedure defined in 11.1.4.4 has not been performed. In addition, the STA shall set the Next A-BFT field to 0.

Before establishment of a BSS, the spacing between TBTTs can change, and the time to the next TBTT is contained in each DMG Beacon frame transmitted at the last BTI. At each TBTT, the STA should generate a

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random value for the Beacon Interval field within the DMG Beacon frame from a uniform distribution between (10 TUs, 200 TUs), i.e., 10 TUs to 199 TUs. Every DMG Beacon frame transmission in the same BTI shall have the same value in its Beacon Interval field.

The TSF shall be set to 0 at the first TBTT for which the Discovery Mode field within the DMG Beacon frame is equal to 1. After that, the TSF shall be set to 0 at the TBTT of the beacon interval in which the STA changes the Beacon Interval field.

A STA shall transmit the first DMG Beacon frame of the next BTI at the time indicated by the start of the transmission of the first DMG Beacon frame within the last BTI and the Beacon Interval field contained in the DMG Beacon frame transmitted within the last BTI, unless the medium is determined by the CCA mechanism to be busy in which case the STA may delay the transmission of the first DMG Beacon frame transmission.

A STA that transmits a DMG Beacon frame with the Discovery Mode field equal to 1 may indicate the STA(s) that is allowed to respond in the A-BFT following the BTI where the DMG Beacon frame is transmitted. To do that, in the DMG Beacon frame the STA shall set the CC Present field to 1 and shall set the A-BFT Responder Address subfield to an individual address or to a group address of a group that includes the STA(s) that is allowed to respond in the A-BFT.

A DMG STA that is transmitting DMG Beacon frames with the Discovery Mode field equal to 1 should configure its receive antenna to a quasi-omni antenna pattern and stay in receiving state during portions of the DTI defined by the DMG Beacon frame transmissions. This enables the STA to receive frames transmitted by any STA that is covered by this antenna pattern.

A STA that is transmitting DMG Beacon frames with the Discovery Mode field equal to 1 should cease transmitting these beacons when it has received a DMG Beacon frame from another STA, or when it has received acknowledgment of a transmitted Probe Response frame. If a BSS is not initialized as a result of the channel scanning, the STA can resume transmitting DMG Beacon frames with the Discovery Mode field equal to 1.

The procedure of TBTT change described in the preceding paragraph is applicable for DMG Beacon frame generation before establishment of a BSS, whereas the procedures defined in 11.29.2 and 11.29.3 are used to change the DMG BSS parameters after an infrastructure BSS or PBSS has been established.

A STA shall set the Duration field of each transmitted DMG Beacon frame to the time remaining until the end of the current BTI.

11.1.3.5 Beacon generation in an IBSS

Beacon generation in an IBSS is distributed. The beacon period is included in Beacon, Announce, and Probe Response frames, and a STA shall adopt that beacon period when joining the IBSS. All members of the IBSS participate in beacon generation. Each STA shall maintain its own TSF timer that is used for dot11BeaconPeriod timing. The beacon interval within an IBSS is established by the STA at which the MLME-START.request primitive is performed to create the IBSS. An S1G STA in an IBSS has dot11ShortBeaconInterval set to false. This defines a series of TBTTs exactly dot11BeaconPeriod TUs apart. Time zero is defined to be a TBTT. At each TBTT the STA shall

a) Suspend the decrementing of the backoff counter for any pending transmission that is not a Beacon or DMG Beacon frame,

b) Calculate a random delay uniformly distributed in the range between zero and twice aCWmin × aSlotTime when the STA is a non-DMG STA, and between zero and the result of two multiplied by aCWminDMGIBSS multiplied by the duration of the STA's following BTI when the STA is a DMG STA,

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c) Wait for the period of the random delay, decrementing the random delay timer using the same algorithm as for backoff, except that SIFS + aSlotTime should be used as the initial medium idle period within the backoff procedure. If the ATIM window in use within the IBSS is greater than 0 and the end of the ATIM window occurs before the random delay timer expires, cancel the remaining random delay and pending Beacon frame transmission and proceed to step f),

d) Cancel the remaining random delay and the pending Beacon frame transmission or BTI (DMG only), if a Beacon frame arrives from the IBSS of which the STA is a member before the random delay timer has expired,

e) Send a Beacon frame in a non-DMG BSS or DMG Beacon frame(s) in a DMG BSS if the random delay has expired and no Beacon frame in a non-DMG BSS or no DMG Beacon frame in a DMG BSS has arrived from the IBSS of which the STA is a member during the delay period,

f) If the ATIM window in use within the IBSS is greater than 0, then

   1) Resume decrementing the backoff counter for any pending transmission allowed inside the ATIM window and

   2) At the end of the ATIM window duration resume the backoff for any pending frames intended for transmission outside the ATIM window,

g) If the ATIM window in use within the IBSS is 0, then resume decrementing the backoff counter for any pending transmissions.

Figure 11-3 illustrates beacon transmission in an IBSS.

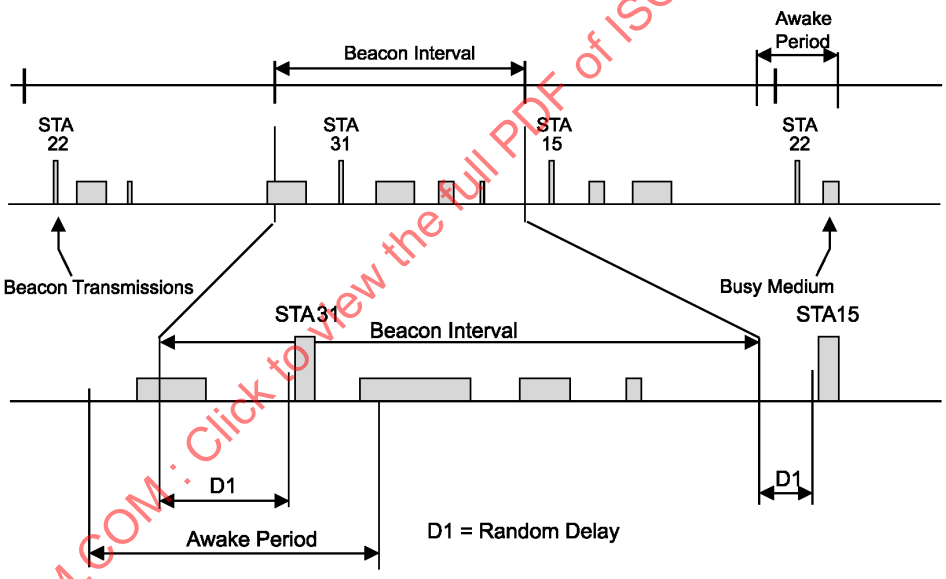

Figure 11-3—Beacon transmission in an IBSS

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11.1.3.6 Beacon generation in an MBSS

Beacon generation in an MBSS is described in 14.13.3.1.

11.1.3.7 Beacon reception

STAs in an infrastructure network or PBSS shall use information in received Beacon frames, DMG Beacon frames, or Announce frames only if the BSSID field is equal to the MAC address currently in use by the STA contained in the AP of the BSS or to the MAC address currently in use by the PCP of the PBSS. A non-AP STA in an infrastructure BSS and a non-PCP STA in a PBSS that supports the Multiple BSSID capability shall

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use other information in received Beacon or DMG Beacon frames only if the BSSID field of the non-AP or non-PCP STA is equal to the MAC address currently in use by the STA contained in the AP or PCP, respectively, of the BSS corresponding to the transmitted BSSID or if the BSSID field of the non-AP or non-PCP STA is equal to one of the nontransmitted BSSIDs.

STAs in a non-DMG IBSS shall use information in any received Beacon frame for which the IBSS subfield of the Capability field is 1, the content of the SSID element is equal to the SSID of the IBSS, and the TSF value is later than the receiving STA's TSF timer. Use of this information is specified in 11.1.5.

STAs in an MBSS shall use information in received Beacon frames as described in 14.13.3.2.

A non-AP STA in which dot11MultiBSSIDImplemented is true shall support frame filtering for up to two BSSIDs; one for the transmitted BSSID and one for the nontransmitted BSSID. The STA, when associated with a BSS corresponding to a nontransmitted BSSID, shall discard all Data and Management frames that use the transmitted BSSID as the transmitter address, except for Beacon, FILS Discovery, Probe Response, and TIM frames.

DMG IBSS STAs shall use other information in any received DMG Beacon (excluding those with the Discovery Mode field equal to 1) and Announce frames for which the BSS Type subfield is 1, the content of the SSID element is equal to the SSID of the IBSS, and the TSF value is later than the receiving STA's TSF timer. Use of this information is specified in 11.1.5.

A STA shall ignore the BSS Type field contained in a received DMG Beacon frame if the Discovery Mode field within the DMG Beacon frame is 1.

An active DMG STA operating in a BSS shall be ready to receive from its AP or PCP for a period of time of at least dot11MinBHIDuration following the TBTT or expected ATI start time as specified in the last Next DMG ATI element (9.4.2.135) transmitted by the AP or PCP.

An active DMG STA that is receive beamforming trained with the AP or PCP shall direct its receive antenna pattern toward the AP or PCP or use a quasi-omni antenna pattern during this time.

A non-PCP STA that receives a DMG Beacon frame from a PCP in which the PCP Association Ready field is 0 shall not transmit an Association Request frame addressed to the PCP that transmitted the received DMG Beacon. A non-PCP STA that receives a DMG Beacon frame from a PCP with the PCP Association Ready field set to 1 may transmit an Association Request frame addressed to the PCP that transmitted the received DMG Beacon.

11.1.3.8 Multiple BSSID procedure

A STA that supports the Multiple BSSID capability has dot11MultiBSSIDImplemented equal to true and shall set to 1 the Multiple BSSID field of the Extended Capabilities elements that it transmits. Support for the Multiple BSSID capability is mandatory for a FILS STA.

The nontransmitted BSSID profile shall include the SSID element (see 9.4.2.2) and Multiple BSSID-Index element (see 9.4.2.73) for each of the supported BSSIDs. The AP or PCP may include all other elements allowed per 9.4.2.45 in the nontransmitted BSSID profile. The AP or PCP may include two or more Multiple BSSID elements containing elements for a given BSSID index in one Beacon frame or DMG Beacon frame. If two or more are given, the profile is considered to be the complete set of all elements given in all such Multiple BSSID elements sharing the same BSSID index. Since the Multiple BSSID element is also present in Probe Response frames, an AP or PCP may choose to advertise the complete or a partial profile of a BSS corresponding to a nontransmitted BSSID only in the Probe Response frames. In addition, the AP or PCP may choose to include only a partial list of nontransmitted BSSID profiles in the Beacon frame or DMG Beacon frame or to include different sets of nontransmitted BSSID profiles in different Beacon frames or DMG Beacon

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frames. An AP advertising a complete list of nontransmitted BSSID profiles shall set the Complete List Of NonTxBSSID Profiles field of Extended Capabilities element to 1.

NOTE—A non-AP STA can send a Probe Request frame to an AP to gather information about all BSSIDs in the multiple BSSID set when the AP advertises partial list of nontransmitted BSSID profiles.

See 11.1.4.3.4 for the rules governing transmission of Probe Response frames in a multiple BSSID set.

When a station receives a Beacon frame or DMG Beacon frame with a Multiple BSSID element that consists of a nontransmitted BSSID profile with only the mandatory elements, it may inherit the complete profile from a previously received Beacon frame, DMG Beacon frame, or Probe Response frame, or it may send a Probe Request frame to obtain the complete BSSID profiles. Each Beacon element not transmitted in a nontransmitted BSSID subelement is inherited from previous Beacon, DMG Beacon, or Probe Response frame in which the element is present, except for the Quiet element, which shall take effect only in the Beacon frame or DMG Beacon frame that contains it and not carry forward as a part of the inheritance. An AP or PCP is not required to include all supported nontransmitted BSSID profiles in a Probe Response frame, and may choose to only include a subset based on any criteria. When a nontransmitted BSSID profile is present in the Multiple BSSID element of the Probe Response frame, the AP or PCP shall include all elements that are specific to this BSS. If any of the optional elements are not present in a nontransmitted BSSID profile, the corresponding values are the element values of the transmitted BSSID unless the element is listed in the Non-Inheritance element (if included) in the nontransmitted BSSID profile for that BSS.

A non-AP and non-PCP STA derives its nontransmitted BSSID value according to 9.4.2.45 and 9.4.2.73.

The Partial Virtual Bitmap field of the TIM element carried in the Beacon(11ah), S1G Beacon, or TIM frame shall indicate the presence or absence of traffic to be delivered to all stations associated to a transmitted or nontransmitted BSSID. The first 2^n bits of the bitmap are reserved for the indication of group addressed frame for the transmitted and all nontransmitted BSSIDs (see 9.4.2.5.1). The AID space is shared by all BSSs and the lowest AID value that shall be assigned to a non-S1G STA is 2^n (see 9.4.2.5). The value of the 11 LSBs of the AID assigned to an S1G STA shall be greater than 2^n. The Encoded Blocks that contain these first 2^n AIDs (if any) shall precede the Encoded Blocks that contain AIDs for the S1G STAs in the S1G Partial Virtual Bitmap field of each page.

Multiple BSSID rate selection is defined in 10.6.9.

11.1.3.9 TSF timer accuracy

A non-DMG STA's TSF timer shall be accurate to within ± 100 ppm. A DMG STA's TSF timer shall be accurate to within ± 20 ppm.

NOTE—The worst-case drift between two non-DMG STAs is, therefore, ± 200 ppm, and between two DMG STAs, ± 40 ppm.

Upon receiving a Beacon, a DMG Beacon, or an Announce frame for the BSS, as described in 11.1.3.7, a STA shall update its TSF timer according to the following algorithm

— Non-DMG STA: The received timestamp value shall be adjusted by adding an amount equal to the receiving STA's delay through its local PHY components plus the time since the first bit of the timestamp was received at the MAC/PHY interface.

— DMG STA: The received timestamp value shall be adjusted by adding an amount equal to the receiving STA's delay through its local PHY components plus the time since the last data symbol of the PHY header, excluding any guard interval, was received as indicated by the PHY-RXSTART.indication primitive.

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In the case of an infrastructure BSS or a PBSS, the STA's TSF timer shall then be set to the adjusted value of the timestamp. In the case of an IBSS, the STA's TSF timer shall be set to the adjusted value of the received timestamp, if the adjusted value of the timestamp is later than the value of the STA's TSF timer.

When a STA is a member of a BSS with a nontransmitted BSSID, it shall use the TSF from the Beacon, S1G Beacon or DMG Beacon frame.

11.1.3.10 Maintaining synchronization using S1G Beacon frames

11.1.3.10.1 General S1G synchronization

An S1G AP schedules an S1G Beacon frame at intervals given by the dot11BeaconPeriod or dot11ShortBeaconPeriod as described in 11.1.2.1.

An S1G Beacon frame scheduled at TSBTT that is not a TBTT may include the elements from the minimum set of elements shown in Table 9-46. An S1G Beacon frame scheduled at TBTT shall include the S1G Beacon Compatibility element as the first optional element and may include all the other elements from the full set of elements shown in Table 9-46. Note that the S1G Beacon Compatibility element replaces the following fields of the Beacon frame body: Timestamp, Beacon Interval and Capability Information which are not included in an S1G Beacon frame. The S1G Beacon Compatibility element shall be generated no later than the Timestamp field of the S1G Beacon frame that carries the element and not earlier than 2^{31}–1 microseconds. A STA can reconstruct the 8-octet TSF timer at the AP by concatenating the 4-octet TSF Completion field in the S1G Beacon Compatibility element with the Timestamp field in the S1G Beacon frame as described in 11.1.3.10.3.

11.1.3.10.2 Generation of S1G Beacon frames

In an infrastructure BSS, S1G Beacon frames shall be transmitted by an S1G AP. Each S1G STA in an IBSS shall transmit S1G Beacon frames. An AP with dot11ShortBeaconInterval equal to true shall further define the timing for the BSS by sending S1G Beacon frames according to the dot11ShortBeaconPeriod. The value for the dot11ShortBeaconPeriod shall be such that dot11BeaconPeriod = n×dot11ShortBeaconPeriod, where n is a positive integer. This defines a series of TSBTTs exactly dot11ShortBeaconPeriod TUs apart. If n is greater than 1, the Next TBTT field shall be present in S1G Beacon frames transmitted at TSBTT that is not a TBTT; otherwise, it shall not be present in S1G Beacon frames.

Time 0 is defined to be a TBTT or TSBTT with the S1G Beacon frame being a DTIM. At each TBTT or TSBTT, the AP shall schedule an S1G Beacon frame as the next frame for transmission. At each TBTT or TSBTT the AP should suspend the decrementing of the backoff counter for any pending non-beacon transmission and transmit the S1G Beacon frame according to the medium access rules specified in Clause 10.

The beacon period is included in S1G Beacon, Probe Response, and PV1 Probe Response frames, and a STA shall adopt that beacon period when joining the S1G BSS and S1G IBSS, i.e., the STA shall set its dot11BeaconPeriod to that beacon period. If dot11ShortBeaconInterval is equal to true, short beacon period included in the Short Beacon Interval element shall be carried in an S1G Beacon, Probe Response, and PV1 Probe Response frames. An S1G STA shall adopt that short beacon period when joining the S1G BSS or S1G IBSS, i.e., the STA shall set its dot11ShortBeaconInterval to true and its dot11ShortBeaconPeriod to that short beacon period.

11.1.3.10.3 TSF timer accuracy with S1G Beacon frame

Upon receiving an S1G Beacon frame with a valid FCS and BSSID, an S1G STA shall update its TSF timer according to the algorithm described below.

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The received Timestamp value shall be adjusted by adding an amount equal to the receiving STA's delay through its local PHY components plus the time since the first bit of the Timestamp field was received at the MAC/PHY interface.

If the received S1G Beacon frame does not include an S1G Beacon Compatibility element:

— If the most significant bit (MSB) of the adjusted value of the received Timestamp is not equal to the MSB of the 4 least significant octets of the local TSF timer then the value of the 4 most significant octets of the TSF timer shall be adjusted to account for roll over as follows:
  — The value shall be increased by one unit (modulo 2^{32}) if LT > AT and LT > AT + 2^{31}
  — The value shall be decreased by one unit (modulo 2^{32}) if LT < AT and LT < AT – 2^{31}

  where AT is the adjusted value of the received Timestamp and LT is the value of the 4 least significant octets of the local TSF timer
— The 4 least significant octets of the STA's local TSF timer shall be set to the adjusted value of the Timestamp.

If the received S1G Beacon frame includes an S1G Beacon Compatibility element:

— The 4 least significant octets of the STA's TSF timer shall then be set to the adjusted value of the Timestamp.
— If the most significant bit of the adjusted value of the Timestamp is 0 and the TSF Rollover Flag field in the S1G Beacon Compatibility element is 1, then the 4 most significant octets of the TSF timer shall be adjusted to account for roll over (i.e., the value obtained from the TSF Completion field shall be increased by one unit (modulo 2^{32}). Otherwise, the 4 most significant octets of the TSF timer shall be set to the TSF Completion field in the S1G Beacon Compatibility element.

11.1.4 Acquiring synchronization, scanning

11.1.4.1 General

A STA shall operate in either a Passive Scanning mode or an Active Scanning mode depending on the current value of the ScanMode parameter of the MLME-SCAN.request primitive.

NOTE 1—Active scanning is restricted in some frequency bands and regulatory domains.

Upon receipt of the MLME-SCAN.request primitive, a STA shall perform scanning procedures according to the parameters given in the primitive. The SSID parameter indicates the SSID for which to scan. The SSID List parameter indicates one or more SSIDs for which to scan.

To become a member of a particular ESS using passive scanning, a STA shall scan for Beacon and DMG Beacon frames containing that ESS's SSID, returning all Beacon and DMG Beacon frames matching the desired SSID in the BSSDescriptionSet parameter of the corresponding MLME-SCAN.confirm primitive with the appropriate bits in the Capability Information field or DMG Capabilities field indicating whether the Beacon frame or DMG Beacon frame came from an infrastructure BSS, PBSS, or IBSS. If dot11RMMeasurementPilotActivated is greater than 1, the STA shall additionally scan for Measurement Pilot frames, returning in the BSSDescriptionFromMeasurementPilotSet parameter all Measurement Pilot frames that equal the requested BSSID of the corresponding MLME-SCAN.request primitive and are not already members of the BSSDescriptionSet. A FILS STA shall additionally scan for FILS Discovery frames, returning in the BSSDescriptionFromFDSet parameter all FILS Discovery frames of the scanned ESSs. The STA is not required to return a BSSDescriptionFromFDSet parameter for any BSS that is already a member of the BSSDescriptionSet.

To actively scan, the STA shall transmit Probe Request frames containing a wildcard SSID (see 9.4.2.2), the desired SSID or one or more SSID List elements, but a DMG STA might also have to transmit DMG Beacon

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frames or perform beamforming training prior to the transmission of Probe Request frames. When the SSID List element is present in the Probe Request frame, one or more of the SSID elements may include a wildcard SSID (see 9.4.2.2). The exact procedure for determining the SSID or SSID List values in the MLME-SCAN.request primitive is not specified in this standard. When a STA scans for a BSS whose AP does not support the SSID List element, or for a BSS for which AP support of the SSID List element is unknown, the SSID element with an SSID or wildcard SSID shall be included in the MLME-SCAN.request primitive. During FILS scanning, the scanning STA may optimize the scanning process by using intermediate results, including the Reduced Neighbor Report element. Details of how to optimize scanning is out of scope of this standard. An MLME-SCAN.confirm primitive is issued each time that a BSS matching the selection criteria in the MLME-SCAN.request primitive is discovered when the ReportingOption parameter in the MLME-SCAN.request primitive is present and is equal to IMMEDIATE. An MLME-SCAN.confirm primitive is issued each time that the scanning STA has completed the scanning of a channel when the value of the ReportingOption parameter in the MLME-SCAN.request primitive is present and is equal to CHANNEL_SPECIFIC.

NOTE 2—MLME-SCAN.request primitives and resulting Probe Request frames might include a Request element or Extended Request element(s) that can be used to request radio measurement information for the scanned BSSs. Requested radio measurement information from the scanned BSSs is included in the Probe Response frames and in the MLME-SCAN.confirm primitive.

Upon completion of scanning, an MLME-SCAN.confirm primitive is issued by the MLME indicating all of the BSS information received.

In DMG BSSs, the Active Scan procedure (11.1.4.3) can be used for device discovery prior to initializing or joining a BSS.

Upon receipt of an MLME-JOIN.request primitive, the nonmesh STA shall use the synchronization procedure described in 11.1.4.5. The MLME-JOIN.request primitive is not used to start synchronization in an MBSS. The synchronization in an MBSS is described in 14.13.

Upon receipt of an MLME-SCAN.request primitive with the SSID parameter equal to the wildcard SSID, the STA shall passively scan for any Beacon, DMG Beacon, FILS Discovery, Measurement Pilot frames, or Probe Response frames containing Address 1 field equal to the broadcast address, or actively transmit Probe Request or DMG Beacon frames containing the wildcard SSID, as appropriate depending upon the value of ScanMode.

If a STA's scanning does not result in finding a BSS with the target SSID and of the target type, or does not result in finding any BSS, the STA may start an IBSS upon receipt of the MLME-START.request primitive.

NOTE 3—Starting an IBSS is restricted in some frequency bands and regulatory domains.

When scanning MBSSs, the STA shall process the procedures described in 14.2.

When a STA starts a BSS, that STA shall determine the BSSID of the BSS. If the BSSType indicates an infrastructure BSS, then the STA shall start an infrastructure BSS and the BSSID shall be equal to the STA's dot11StationID. If the BSSType indicates a PBSS, then the STA shall start a PBSS. For both the infrastructure BSS and the PBSS, the value of the BSSID shall remain unchanged, even if dot11StationID is changed after the completion of the MLME-START.request primitive. If the BSSType indicates an IBSS, the STA shall start an IBSS, and the BSSID shall be an individual locally administered IEEE MAC address as defined in Clause 8 of IEEE Std 802-2014. The remaining 46 bits of that MAC address shall be a number selected in a manner that minimizes the probability of STAs generating the same number, even when those STAs are subjected to the same initial conditions. The value of the SSID parameter shall be used as the SSID of the new BSS.

NOTE 4—It is important that designers recognize the need for statistical independence of the random number streams between STAs.

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11.1.4.2 Passive scanning

11.1.4.2.1 Passive scanning for non-DMG STAs

If the ScanType parameter indicates a passive scan, the STA shall listen to each channel scanned for no longer than a maximum duration defined by the MaxChannelTime parameter.

11.1.4.2.2 Passive scanning for DMG STAs

Upon receipt of the MLME-SCAN.request primitive with the ScanType parameter set to Passive, a DMG STA shall passively scan for transmissions on each channel specified within the ChannelList parameter of the MLME-SCAN.request primitive. The channel traversal order during passive scanning is implementation specific.

That is, the STA shall be in the receive state scanning for a period of time in a channel no less than MinChannelTime and return information on all DMG Beacon frames received matching a particular BSSID or SSID parameters specified in the MLME-SCAN.request primitive. If no DMG beacon scan parameters are specified in the request, then the STA shall return information on all received DMG Beacon frames.

If at any time during the scan the STA detects a frame that is not a DMG Beacon frame, the STA shall continue to scan the current channel until the scanning timer expires. After scanning one channel, the STA shall initiate scanning in another channel if at least one channel within the ChannelList parameter has not yet been scanned.

When the STA has completed scanning all indicated channels, it returns the scan results via the MLME-SCAN.confirm primitive.

NOTE—Unlike a DMG STA that is actively scanning and that is not a member of PBSS (see 11.1.4.3.3), a DMG STA that is passively scanning does not respond to probe requests (see 11.1.4.3.4).

11.1.4.3 Active scanning and probing procedures

11.1.4.3.1 Introduction

Active scanning involves the generation of Probe Request frames and the subsequent processing of received probe responses. The details of the active scanning procedures are as specified in the following subclauses.

11.1.4.3.2 Active scanning procedure for a non-DMG STA

Upon receipt of the MLME-SCAN.request primitive with ScanType parameter indicating an active scan, a STA shall use the following procedure.

For each channel to be scanned:

a) Wait until the ProbeDelay time has expired or a PHY-RXSTART.indication primitive has been received.

b) If the STA is a FILS STA, set the FILSProbeTimer to 0 and starts the FILSProbeTimer. While the FILSProbeTimer is less than dot11FILSProbeDelay the STA may skip a probe request transmission and proceed to step g) after setting the ActiveScanningTimer to 0 and starting the ActiveScanningTimer, if one of the following conditions matches:

   1) The STA receives a broadcast Probe Request frame that the SME considers to be suitable to discover a candidate AP for association.

   2) The STA receives one or more of Probe Response, Beacon, Measurement Pilot, or FILS Discovery frame that identify an AP that the SME considers a suitable candidate for association.

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NOTE—How an SME considers a probe request or AP suitable is outside the scope of this standard.

c) Perform the basic access procedure as defined in 10.3.4.2. Send a probe request to the broadcast destination address. The probe request is sent with the SSID and BSSID from the received MLME-SCAN.request primitive. If dot11SSIDListActivated is true and the SSID List parameter is present in the MLME-SCAN.request primitive, then one or more SSID List elements should be present in the probe request, indicating all SSIDs in the SSID List parameter if possible.

d) When dot11SSIDListActivated is true and the SSID List parameter is present in the MLME-SCAN.request primitive, send zero or more probe requests to the broadcast destination address, each with an SSID indicated in the SSID List parameter and the BSSID from the MLME-SCAN.request primitive. These additional probe requests [following step c)] should only carry SSIDs not indicated in the step c) probe request. The basic access procedure (10.3.4.2) is performed prior to each probe request transmission.

e) Initialize the ActiveScanningTimer to 0 and start the ActiveScanningTimer.

f) If a PHY-CCA.indication (BUSY) primitive is not received before the ActiveScanningTimer reaches MinChannelTime, then proceed to step j).

g) If the STA is a non-FILS STA, receive all Probe Response and Beacon frames while the ActiveScanningTimer is less than MaxChannelTime.

h) If the STA is a FILS STA and while the ActiveScanningTimer is less than MaxChannelTime:

   1) Receive Probe Response, FILS Discovery, and Beacon frames regardless of the receiver address. Process any received FILS Discovery, Probe Response, and Beacon frames.

   2) If the ReportingOption parameter of the MLME-SCAN.request primitive is IMMEDIATE, and the scanning FILS STA detects a BSS whose MLME-SCAN.confirm primitive has not been issued during the ongoing scan, then an MLME-SCAN.confirm primitive with the ResultCode equal to INTERMEDIATE_SCAN_RESULT and one or more of BSSDescriptionSet, BSSDescriptionFromFDSet, or BSSDescriptionFromMeasurementPilotSet containing information of the detected BSS is immediately issued.

i) If the ReportingOption parameter of the MLME-SCAN.request primitive is CHANNEL_SPECIFIC, do the following:

   1) If the ActiveScanningTimer has not reached MaxChannelTime, wait until the ActiveScanningTimer reaches the MaxChannelTime and then proceed to item 2); otherwise, proceed directly to item 2).

   2) Issue an MLME-SCAN.confirm primitive, with the ResultCode equal to INTERMEDIATE_SCAN_RESULT and one BSSDescriptionSet, BSSDescriptionFromFDSet, or BSSDescriptionFromMeasurementPilotSet containing information of all BSSs that have been discovered from the scanned channel.

j) Process all probe responses received until the timer reaches MaxChannelTime, constructing BSSDescriptions corresponding to the probe responses that match the criteria specified in the MLME-SCAN.request primitive.

k) Set the NAV to 0 and scan the next channel.

l) When all channels in the ChannelList have been scanned, and the ReportingOption parameter of the MLME-SCAN.request primitive is AT_END or not present, the MLME shall issue an MLME-SCAN.confirm primitive with one or more of the BSSDescriptionSet, BSSDescriptionFromFDSet, or BSSDescriptionFromMeasurementPilotSet containing all of the information gathered during the scan.

See Figure 11-4 and Figure 11-5.

If the MLME receives an MLME-SCAN-STOP.request primitive, the STA shall stop scanning. The STA should discard any Probe Request frame queued for transmission. If the STA is transmitting a Probe Request frame, the STA shall complete the transmission of the Probe Request frame. The STA shall not continue the

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active scanning process on unscanned channels listed in the ChannelList parameter of the MLME-SCAN.request primitive. If the ReportingOption parameter of the MLME-SCAN.request primitive is AT_END or not present, then the MLME shall issue an MLME-SCAN.confirm primitive with the ResultCode set to SUCCESS and with one or more of BSSDescriptionSet, BSSDescriptionFromFDSet, or BSSDescriptionFromMeasurementPilotSet containing all of the information gathered during the scan.

A FILS STA shall indicate its MaxChannelTime in the Max Channel Time field of the FILS Request Parameters element of the Probe Request frame to prevent the responding STA from transmitting the Probe Response frame after the time indicated by the MaxChannelTime has elapsed.

The Max Channel Time field shall be set to the MaxChannelTime of the MLME-SCAN.request primitive as defined in 9.4.2.177.

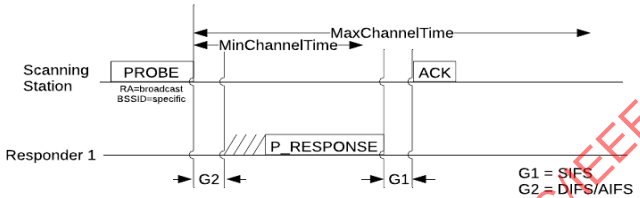

Figure 11-4—Active scanning by a non-DMG STA with a probe request addressed to a specific BSSID

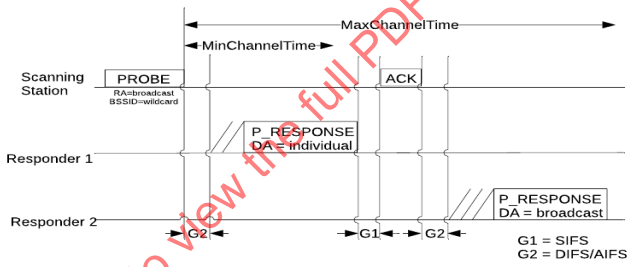

Figure 11-5—Active scanning by a non-DMG STA with a probe request addressed to wildcard BSSID

11.1.4.3.3 Active scanning procedure for a DMG STA

Upon receipt of the MLME-SCAN.request primitive with ScanType parameter indicating an active scan, a DMG STA shall use the following procedure.

For each channel to be scanned:

a) Wait until the ProbeDelay time has expired or a PHY-RXSTART.indication primitive has been received.
b) Initialize a timer to 0 and start it running.
c) If the DiscoveryMode parameter of the MLME-SCAN.request primitive is equal to 1, generate DMG Beacon frames as (described in 11.1.3.4) for a period no longer than MaxChannelTime.
d) If a DMG Beacon frame is received before the timer reaches MaxChannelTime and beamforming training is required (see 10.42), perform beamforming training defined in 10.42.5.

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e) Perform the basic access procedure defined in 10.3.4.2.

f) If an SSW-Feedback frame is transmitted or received in step d), then:

1) Send a probe request to the broadcast destination address or

— Following the transmission of an SSW-Feedback frame, send a probe request to the MAC address of the STA addressed by the SSW-Feedback frame.

— Optionally, following the reception of an SSW-Feedback frame, send a probe request to the MAC address of the STA that transmitted the SSW-Feedback frame.

In all probe requests sent under step f) 1), the probe request is sent with the SSID and BSSID from the received MLME-SCAN.request primitive and includes the DMG Capabilities element. The basic access procedure (10.3.4.2) is performed prior to the probe request transmission.

2) When the SSID List parameter is present in the MLME-SCAN.request primitive, send zero or more probe requests to the broadcast destination address. Each probe request is sent with an SSID indicated in the SSID List parameter and the BSSID from the received MLME-SCAN.request primitive and includes the DMG Capabilities element. The basic access procedure (10.3.4.2) is performed prior to each probe request transmission.

g) If an SSW-Feedback frame is neither transmitted nor received in step d), then:

1) Optionally send a probe request to the broadcast destination address. The probe request is sent with the SSID and BSSID from the received MLME-SCAN.request primitive and includes the DMG Capabilities element. The basic access procedure (10.3.4.2) is performed prior to the probe request transmission.

2) When the SSID List is present in the MLME-SCAN.request primitive, send zero or more probe requests to the broadcast destination address. Each probe request is sent with an SSID indicated in the SSID List and the BSSID from the MLME-SCAN.request primitive and includes the DMG Capabilities element. The basic access procedure (10.3.4.2) is performed prior to each probe request transmission.

h) Respond with a probe response to any probe request received, subject to the conditions in 11.1.4.3.4.

NOTE—The requirement to respond with a probe response also applies to a non-AP non-PCP DMG STA that is not a member of a PBSS.

i) Process all probe responses received until the timer reaches MaxChannelTime, constructing BSSDescriptions corresponding to the probe responses that match the criteria specified in the MLME-SCAN.request primitive.

j) Set the NAV to 0 and scan the next channel.

When all channels in the ChannelList have been scanned, the MLME shall issue an MLME-SCAN.confirm primitive with the BSSDescriptionSet containing all the BSSDescriptions constructed during the scan.

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See Figure 11-6 for DMG STAs that generate DMG Beacon frames with the Discovery Mode field set to 1, where STA A and STA B are actively scanning at the same time and STA B is not a member of a PBSS. STA A may or may not be a member of a PBSS.

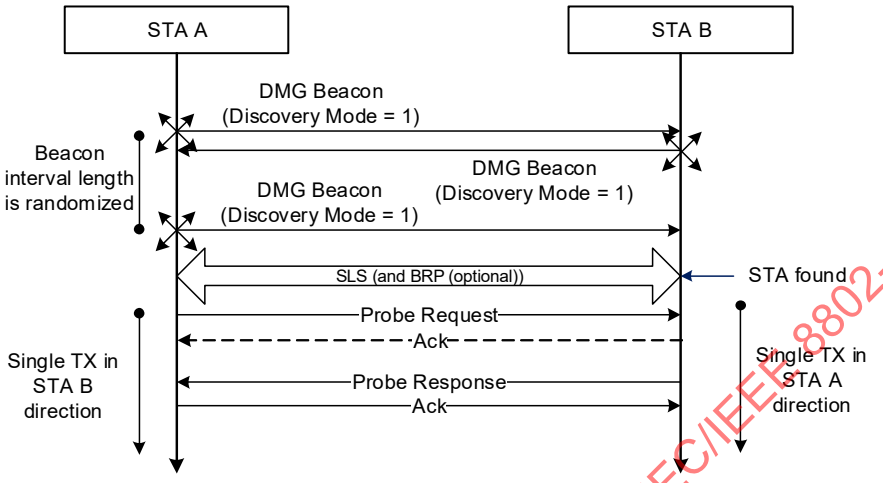

Figure 11-6—Active scanning for DMG STAs

11.1.4.3.4 Criteria for sending a response

If a STA that receives a Probe Request frame is not in a multiple BSSID set, that STA shall send the Probe Response frame(s), subject to the criteria below. If a STA that receives a Probe Request frame is in a multiple BSSID set, the STA corresponding to the transmitted BSSID shall send the Probe Response frame(s), subject to the criteria below; other STAs in the multiple BSSID set shall not send a Probe Response frame.

A STA that receives a Probe Request frame shall not respond if any of the following apply:

a) The STA does not match any of the following criteria:
   1) The STA is an AP.
   2) The STA is an IBSS STA.
   3) The STA is a mesh STA.
   4) The STA is a DMG STA that is not a member of a PBSS and that is performing active scan as defined in 11.1.4.3.3.
   5) The STA is a PCP.

b) The Address 1 field of the Probe Request frame contains an individual address and one of the following criteria is met:
   1) The STA is not a member of a multiple BSSID set, and the individual address is not the MAC address of the STA.
   2) The STA is a member of a multiple BSSID set, and the individual address does not match the BSSID of any of the BSSs in the multiple BSSID set.

c) The STA is a non-AP STA in a DMG infrastructure BSS and the Address 1 field of the Probe Request frame contains the broadcast address.

d) The STA is a non-PCP STA in a PBSS and the Address 1 field of the Probe Request frame contains the broadcast address.

e) The STA is in an IBSS and did not transmit a Beacon or DMG Beacon frame since the last TBTT, and the Address 1 field of the Probe Request frame contains the broadcast address.

f) The STA is a mesh STA and either of the following criteria are met:

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1) The Probe Request frame does not contain a Mesh ID element.
2) The Mesh ID element in the Probe Request frame is present but does not contain the wildcard Mesh ID and does not match the Mesh ID of the MBSS with which the STA is peered.

g) The STA is not a mesh STA and none of the following criteria are met:
1) The SSID in the Probe Request frame is the wildcard SSID.
2) The SSID in the Probe Request frame matches the SSID of the STA's BSS.
3) The STA is a member of a multiple BSSID set and the SSID in the Probe Request frame matches any of the SSIDs of the members of that multiple BSSID set.
4) The SSID List element is present in the Probe Request frame and includes the SSID of the STA's BSS.

h) The STA is not a mesh STA and the Address 3 field of the Probe Request frame does not contain a wildcard BSSID and one of the following criteria is met:
1) The STA is not a member of a multiple BSSID set and the Address 3 field of the Probe Request frame does not match the BSSID of the STA's BSS.
2) The STA is a member of a multiple BSSID set and the Address 3 field of the Probe Request frame does not match the BSSID of any of the BSSs in the multiple BSSID set.

i) The STA has dot11InterworkingServiceActivated equal to true and the Probe Request frame contains an Interworking element and an Extended Capabilities element whose Interworking field contains the value 1, and at least one of the following criteria is not met:
1) The HESSID field of the Interworking element is absent, or is present and contains the wildcard HESSID or matches the HESSID field of the InterworkingInfo parameter of the last MLME-START.request or MLME-JOIN.request primitive.
2) The Access Network Type field of the Interworking element contains the wildcard access network type or matches the access network type of the STA.

j) The Probe Request frame contains a DSSS Parameter Set element in which the Current Channel field contains a value that is not the same as dot11CurrentChannel.

k) The STA is a DMG STA and the transmit antenna of the DMG STA is not trained to transmit to the STA from which the Probe Request frame was received.

A FILS STA shall not respond to a Probe Request frame if any of the following criteria is met for a FILS Request Parameters element contained in the Probe Request frame:

1) If the FILS Criteria field is present in the FILS Requests Parameters element and the Max Delay Limit field of the FILS Request Parameters indicates a delay shorter than the selected average access delay of the responding STA. The BSS Delay Criterion field of the FILS Criteria field of the FILS Request Parameters element indicates the selected average access delay for the comparison as defined in Table 9-287. The Max Delay Limit field contains the maximum selected average access delay. If the compared Average Access Delay indicates Measurement not available, the STA shall respond and the response shall include a BSS AC Access Delay element as described in 9.4.2.43 and Average Access Delay as described in 9.4.2.38 or Average Access Delay as described in 9.4.2.38 that was requested in the Probe Request frame. If the compared Average Access Delay indicates Service unable to access channel, the response shall not be transmitted.
2) If the FILS Criteria field is present in the FILS Requests Parameters element and the PHY Support Criterion of the FILS Criteria field of the FILS Request Parameters element is 1 and the responding STA is not HT capable.
3) If the FILS Criteria field is present in the FILS Requests Parameters element and the PHY Support Criterion of the FILS Criteria field of the FILS Request Parameters element is 2 and the responding STA is not VHT capable.

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4) If the Minimum Data Rate is present in the FILS Request Parameters element and the Minimum Data Rate field of the FILS Request Parameters element indicates a data rate higher than the one that is provided over the MAC SAP.
5) If the RCPI Limit field is present in the FILS Request Parameters element and either of the following conditions is true:
   — The RCPI of the Probe Request frame > –90 dBm + the RCPI Limit field of the FILS Request Parameters element.
   — The RCPI Limit field of the FILS Request Parameters element contains value 255.
6) If the OUI Response Criteria field is present in the FILS Request Parameters element and if any of the OUIs specified by the OUI Response Criteria field are not in the list of known OUIs configured in the AP (see Known OUIs, 6.3.5.2.2).

If the FILS Request Parameters element is present in the Probe Request frame, the responding FILS STA should discard any Probe Response frame that has not been transmitted as a response to the Probe Request frame when the elapsed time measured from the end of the reception of the Probe Request frame by the MAC entity of the responding STA exceeds the time indicated by the Max Channel Time field of the FILS Request Parameters element of the Probe Request frame. If the FILS Request Parameter element is not present in the Probe Request frame, transmission time of the Probe Response frame to the Probe Request frame by the responding STA is only limited by the retransmission procedure in 10.23.2.12.

NOTE 1—It is possible for the STA to leave the channel on which it sent the Probe Request frame prior to MaxChannelTime. Should this occur the STA might not receive some of the Probe Response frames transmitted.

An individually addressed Probe Response frame, subject to the criteria above, shall be transmitted to all non-FILS STAs from which a Probe Request frame is received.

If a FILS STA has dot11FILSOmitReplicateProbeResponses equal to false, an individually addressed Probe Response frame, subject to the criteria above, shall be transmitted to all STAs from which a Probe Request frame is received.

If a FILS STA receives one or more Probe Request frame(s) and the STA has dot11FILSOmitReplicateProbeResponses equal to true, then the responding STA shall respond, subject to the criteria above, via the next Beacon frame, a broadcast Probe Response frame, or one or more individually addressed Probe Response frames.

The FILS STA shall respond with the next Beacon frame, as described in 11.1.3, to Probe Request frames addressed to individual or broadcast address if all of the following conditions are met:

— The STA is queuing a Beacon frame for transmission;
— The next TBTT of the responding STA is within dot11FILSBeaconResponseWindow;
— The next TBTT is no later than any deadline of Max Channel Time indicated in the FILS Request Parameter element of the Probe Request frame(s), if present; and
— The Beacon frame contains all elements requested by the Request element.

If the next Beacon frame is not used as a response, a Probe Response frame is transmitted. The Probe Response frame shall be addressed to the broadcast or the address of the transmitter of the Probe Request frame. The Probe Response frame may be transmitted to all or some of the Probe Request frames received from FILS STAs. A first FILS STA may choose not to respond to Probe Request frames from a second FILS STA addressed to the broadcast address if the first STA receives an acknowledged probe response addressed to the second STA containing the SSID of the first STA's BSS. A non-S1G AP shall remain in the awake state, and shall respond to probe requests, subject to the criteria above.

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An S1G AP that is awake shall respond to probe requests, subject to the criteria above. The response to the probe requests shall have the same CH_BANDWIDTH as the preceding probe request. The S1G AP may send a PV1 Probe Response frame instead of a Probe Response frame as specified in 11.1.4.3.7.

NOTE 2—This rule does not allow an S1G AP to respond with a probe response in 1 MHz channel width after receiving a probe request in 2 MHz channel width.

An IBSS STA that sent a Beacon or DMG Beacon frame shall remain in the awake state, and shall respond to probe requests, subject to the criteria above, until a Beacon or DMG Beacon frame with the BSSID of the STA's IBSS is received.

A mesh STA or PCP that is awake shall respond to probe requests, subject to the criteria above.

NOTE 3—Results of the procedures defined in this subclause are as follows:

a) Infrastructure BSS: The AP is always awake to respond to probe requests.
b) IBSS: At least one STA will be awake to respond to probe requests. More than one STA might respond to any given probe request, particularly when more than one STA transmitted a Beacon or DMG Beacon frame following the most recent TBTT, either due to not receiving a previous Beacon or DMG Beacon frame or due to collisions between beacon transmissions.
c) MBSS or PBSS: At any given time it might be the case that no STA is awake to respond to probe requests.

11.1.4.3.5 Active scanning for relay discovery

An S1G STA that is performing an active scan to discover operating APs, or S1G relay APs may include the S1G Relay Discovery element (see 9.4.2.207) in the Probe Request frame. This element provides information on the QoS criteria on the relay path.

The active scanning procedure for relay AP is similar to the active scanning procedure outlined in 11.1.4.3.

An S1G relay AP receiving Probe Request frames may respond with a Probe Response or a PV1 Probe Response frame, if the criteria outlined in 11.1.4.3.2 are met. An S1G relay AP shall not respond with a Probe Response, or a PV1 Probe Response frame if the QoS criteria on the relay path specified in the S1G Relay Discovery element (see 9.4.2.207) cannot be satisfied.

An S1G relay AP sending Probe Response, or PV1 Probe Response frames may include the S1G Relay Discovery element (see 9.4.2.207) to carry link budget information between the S1G relay AP and S1G root AP.

An S1G STA may use the information received from different S1G relay APs to determine a suitable S1G relay AP for association. The S1G relay AP selection is made by the S1G STA, and the specific selection procedure is up to the implementation.

11.1.4.3.6 NDP Probing

An NDP probing procedure is used to reduce the energy consumption during the scanning procedure. Upon receipt of the MLME-SCAN.request primitive with ActiveScanType parameter indicating an NDP, a STA for which dot11NDPProbingActivated is true shall transmit an NDP Probe Request frame, instead of a Probe Request frame, that has either a compressed SSID or an access network option. The NDP probing procedure is allowed when an S1G STA knows the operating frequency bands and regulatory domains. A non-S1G STA shall not transmit an NDP Probe Request frame.

APs receiving an NDP Probe Request frame shall transmit a broadcast Probe Response only if

a) The compressed SSID in the NDP Probe Request frame is the specific compressed SSID of the AP's BSS.

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b) The access network option in the NDP Probe Request frame is the access network option of the AP.

The response to the NDP Probe Request frame shall be a PV1 Probe Response frame if all the criteria below are satisfied:

— dot11PV1ProbeResponseOptionImplemented is true at the responding STA.
— The Requested Probe Response Type field in the NDP Probe Request frame is set to 0.

If any of the criteria above is not satisfied, then the response to the NDP Probe Request frame shall be a Probe Response frame. The AP shall follow the channel access procedure defined in 9.3.4.3 to transmit the probe response.

If PHY-CCA.indication (busy) primitive has not been detected before the ActiveScanningTimer reaches MinChannelTime, then set NAV to 0 and scan the next channel. Otherwise, if it receives a PV1 Probe Response frame, the STA may transmit an Association Request frame, or may transmit a Probe Request frame or listen to a full Beacon frame for obtaining the more information. If it receives a Probe Response frame, the STA may transmit an Association Request frame.

An illustration of the NDP probing procedure is shown in Figure 11-7.

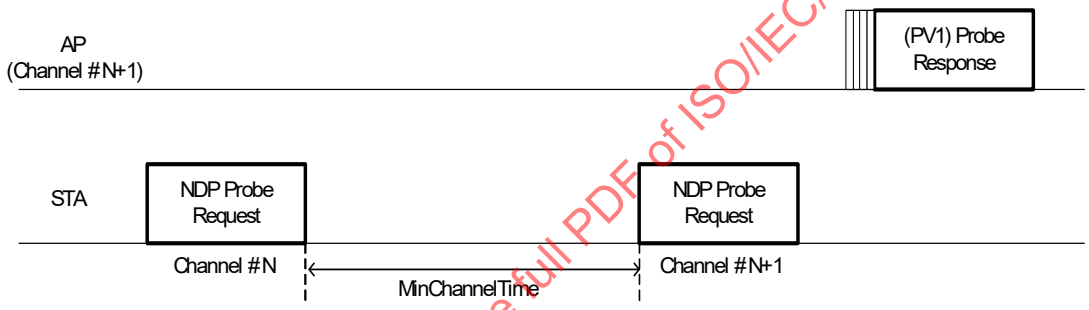

Figure 11-7—NDP probing procedure

11.1.4.3.7 Active scanning using PV1 Probe Response

An S1G STA may use PV1 Probe Response frames as defined in 9.8.5.3 instead of Probe Response frames as defined in 9.3.3.10. PV1 Probe Response frame is used for reducing overhead of using long Probe Response frame in active scanning by optimizing the frame format and by allowing STA to request minimum information that is required for association with the responding STA to be included in the PV1 Probe Response frame.

An S1G STA may solicit PV1 Probe Response frames by including the PV1 Probe Response Option element defined in 9.4.2.209 in the Probe Request frames it transmits or by setting the Requested Probe Response Type field in the NDP Probe Request frame it transmits to 0.

A STA may include the PV1ProbeResponseOption parameter in the MLME-SCAN.request primitive to include the PV1 Probe Response Option element in the Probe Request frames. The requesting STA indicates which optional information is requested to be included in the PV1 Probe Response frame to the responding STA by setting one or more bits in the Probe Response Option bitmaps in the PV1 Probe Response Option element.

An S1G STA responds to the probe request subject to the criteria defined in 11.1.4.3.4. The response to the probe request shall be a PV1 Probe Response frame if all the criteria below are satisfied:

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— dot11PV1ProbeResponseOptionImplemented is true at the responding STA.
— A PV1 Probe Response Option element is included in the received Probe Request frame.

If any of the criteria above is not satisfied, then the response to the probe request shall be a Probe Response frame.

When an NDP Probe request frame is used instead of a Probe Request frame, the response shall be either a PV1 Probe Response frame or a Probe Response frame as described in 11.1.4.3.6.

If any of the criteria above is not satisfied, then the response to the NDP Probe Request frame shall be a Probe Response frame.

An S1G STA that responds with a PV1 Probe Response frame shall include the following information in the frame:

— The elements that are requested by the requesting STA as indicated in the PV1 Probe Response Option element contained in the received Probe Request frame.
  — If a bit in a Probe Response Option bitmap in the PV1 Probe Response Option element is equal to 1, then the corresponding element is requested and it shall be included in the PV1 Probe Response frame (see 9.4.2.209).
  — If the S1G Beacon Compatibility element is included in the PV1 Probe Response frame, then it shall be included as the first optional element and shall be generated no later than the Timestamp field of the frame and not earlier than $2^{31} - 1$ microseconds.
— Either the SSID element or the compressed SSID field.
  — If the Request Full SSID bit in the PV1 Probe Response Option element is equal to 1, then the SSID element shall be present in the PV1 Probe Response frame and the Compressed SSID shall not be present. If it is equal to 0 or is not present in the PV1 Probe Response Option element, then the Compressed SSID shall be present and the SSID element shall not be present.
— The 1 MHz Channel Primary Location field in the Frame Control field shall indicate the location of the 1 MHz primary channel within the 2 MHz primary channel.

PV1 Probe Response frames shall be sent as directed frames to the address of the STA that generated the Probe Request frame.

Upon reception of a PV1 Probe Response frame that includes an S1G Beacon Compatibility element an S1G STA that included the PV1 Probe Response Option element in a previously transmitted Probe Request frame or that set the Requested Probe Response Type to 0 in a previously transmitted NDP Probe Request frame may update its TSF timer using the same TSF timer update procedure described in 11.1.3.10.3 for S1G Beacon frames.

11.1.4.3.8 Non-scanning probe request transmission

A STA may send an individually addressed or broadcast Probe Request frame to a peer STA that it has determined is within range, in order to solicit information contained within a response frame, see 11.1.4.3.9. When the Probe Request frame is sent to the broadcast address, the Address 3 (BSSID) field shall be set to the MAC address of the peer STA.

NOTE 1—A STA might determine that a peer STA is within range by, for example, receiving a frame from that peer STA or, if the peer STA is an AP, by receiving a frame from another AP that corresponds to a co-located BSS of the AP.

NOTE 2—Transmission of an individually addressed frame can provide more reliable delivery to a peer STA since it is acknowledged and retransmit procedures apply. The responder STA responds in accordance with 11.1.4.3.4. See Figure 11-8 for an example in which both the probe request and response are individually addressed. When a STA has not determined that a peer STA is in range, Probe Request frames it sends to discover the peer STA are transmitted in

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accordance with the active scanning procedures in 11.1.4.3.4. For a non-DMG STA, such Probe Request frames are always sent to the broadcast address.

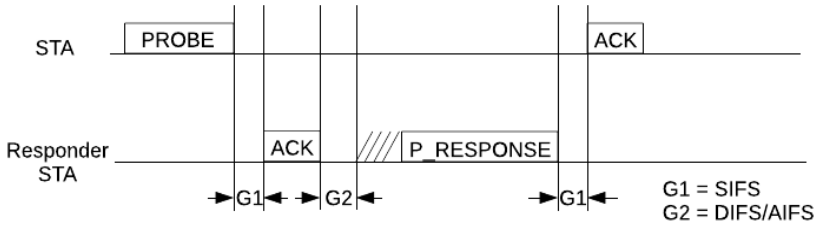

Figure 11-8—Example of a probe request addressed to an individual address

11.1.4.3.9 Contents of a probe response

A STA that responds to a Probe Request frame according to 11.1.4.3.4 shall transmit a Probe Response frame or a Beacon frame to the STA that transmitted the Probe Request frame.

A FILS STA that transmits a Probe Response frame shall either set the Address 1 field to the address of the STA that generated the probe request or to the broadcast address if the STA that generated the probe request indicated FILS Capability. A non-FILS STA that transmits a Probe Response frame shall set the Address 1 field to the address of the STA that generated the probe request.

When a FILS AP responds to a Probe Request frame containing a FILS Capability field in the Extended Capabilities element equal to 1, and when both the FILS AP and the FILS STA that transmitted the Probe Request frame support other than DSSS/CCK rates (see Clause 15 or Clause 16), the AP shall transmit a Probe Response frame in a PPDU using a rate other than a DSSS/CCK.

Number element containing one or more current version numbers of the CAG information associated with the AP, where each version number is associated with an advertisement protocol. The current CAG information associated with the AP can be acquired by the GAS query mechanism as described in 11.22.3 using the associated advertisement protocol.

If there was a Request element, Extended Request element, or Vendor Specific Request element in the Probe Request frame, then:

— Each element that is listed by a non-FILS STA in the Request element, Extended Request element(s), or Vendor Specific Request element and that is supported by the STA shall be included in the Probe Response frame. An element that is listed in a Request element, Extended Request element, or Vendor Specific Request element and that is not supported by the STA shall not be included. Each element requested by a FILS STA in a Request element shall be included in the Probe Response frame or a Beacon frame if the responding FILS STA supports that element.
— Elements that would not have been included otherwise shall be included after all of the elements that would have been included even in the absence of the Request element, Extended Request element, or Vendor Specific Request element.
— Elements that would have been included even in the absence of the Request element, Extended Request element, or Vendor Specific Request element shall be included in their normal position (see Table 9-39), and may be included again after all of the elements that would have been included even in the absence of the Request element.

NOTE—An element that would necessarily be included anyway is not expected to be requested.

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— Elements after all of the elements that would have been included even in the absence of the Request element, Extended Request element, or Vendor Specific Request element shall be included in the order that they appear in the (Extended) Request element(s) of the Probe Request frame.

— If dot11RadioMeasurementActivated is true and the RCPI element was requested, an RCPI element containing the RCPI of the Probe Request frame shall be included. If no measurement result is available, the RCPI value shall be set to indicate "Measurement not available" (see Table 9-176).

— If dot11RadioMeasurementActivated is true and the RSNI element was requested, an RSNI element containing the RSNI of the Probe Request frame shall be included. If no measurement result is available, the RSNI value shall be set to indicate that a measurement is not available. (see 9.4.2.40).

— If a Probe Request frame includes a Request element that contains the element ID of the Reduced Neighbor Report element, a Probe Response frame or a Beacon frame if transmitted may include the Reduced Neighbor Report element if the criteria as defined in 11.1.4.3.4 are met for the included BSS. The reported BSSs may have different primary channels to the responding STA.

11.1.4.3.10 PCP selection in a PBSS

The PCP selection procedure is performed by the SME when:

— An MLME-SCAN.confirm primitive is received in response to an MLME-SCAN.request primitive with the value of the ScanType parameter equal to ACTIVE and BSSType parameter equal to PERSONAL

— There is a PCP handover (see 11.27.2)

The decision of whether a STA or its peer STA is the PCP depends on a comparison of their respective PCP factors (self_PCP_factor and peer_PCP_factor). The PCP factor, for a DMG STA and a CDMG STA operating on a 2.16 GHz channel, defined in Figure 11-9, is the concatenation of the value of some of the fields from the DMG Capabilities element transmitted by the STA (see 9.4.2.127). The PCP factor for a CDMG STA operating on a 1.08 GHz channel is constructed by concatenating the value of select fields present in the STA's DMG Capabilities element and the Supported Channel Width Set field. The PCP factor for a CDMG STA operating on a 1.08 GHz channel is defined in Figure 11-10.

NOTE—According to convention, the least significant bit is the leftmost bit (B0).

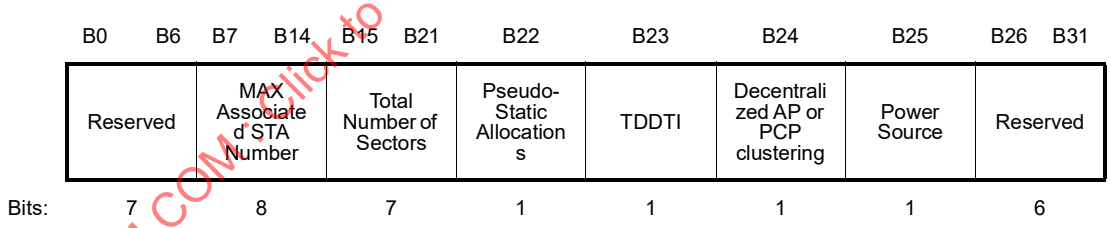

Figure 11-9—PCP factor for a DMG STA

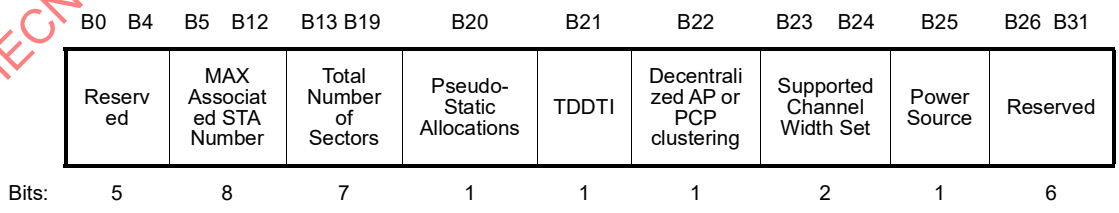

Figure 11-10—PCP factor for a CDMG STA operating on a 1.08 GHz channel

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The Supported Channel Width Set field in Figure 11-10 is obtained via encoding based on the supported channel widths that are indicated by the Operating Classes field of the received Country element or the Supported Operating Classes element of the peer STA. The encoding of the Supported Channel Width Set field is given in Table 11-1.

Table 11-1—Encoding of the Supported Channel Width Set field

Bit 23	Bit 24	Meaning
0	0	The CDMG STA supports 1.08 GHz channel width in 60 GHz band.
0	1	The CDMG STA supports both the 1.08 GHz and 2.16 GHz channel widths in 60 GHz band.
All other combinations		Reserved

For each peer STA reported as part of an MLME-SCAN.confirm primitive or considered as part of a PCP handover, the STA proceeds as follows. If the STA's value of self_PCP_factor is greater than the value of peer_PCP_factor or if the values are equal and the MAC address of the STA is greater than (see 12.7.1 for MAC address comparison) the MAC address of the peer STA contained in the peer STA's DMG Capabilities element, the STA becomes a candidate PCP. Otherwise, the STA does not become a candidate PCP.

Subclause 11.1.4.4.2 specifies the rules followed by the SME of a candidate PCP to start a PBSS.

11.1.4.3.11 Enhanced FILS active scanning to preferred AP

A FILS non-AP STA may maintain one or more BSS Configuration Parameter Sets. A BSS Configuration Parameter Set is obtained from a preferred AP by using a preferred AP determination process that is out of scope of this standard. Each BSS Configuration Parameter Set may be different according to the preferred AP's capabilities. A BSS Configuration Parameter Set is a set of elements of the Beacon frame or the Probe Response frame. The following dynamic elements are excluded from a BSS Configuration Parameter Set:

- TIM element
- Quiet element
- BSS Load element
- EDCA Parameter element
- BSS Average Access Delay element
- BSS Available Admission Capacity element
- BSS AC Access Delay element
- Time Advertisement element
- Emergency Alert Identifier element
- Beacon Timing element
- QLoad Report element
- Extended BSS Load element
- Quiet Channel element
- Reduced Neighbor Report element (see NOTE 1)
- CAG Number element
- AP-CSN element
- DILS element

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— Fragment element (see NOTE 2)
— Vendor Specific element

NOTE 1—The Reduced Neighbor Report element is excluded from the BSS Configuration Parameter Set based on the principle that an element is excluded from the BSS Configuration Parameter Set if that element has no impact on a FILS STA's ability of using AP-CSN to make a decision of initiating an association procedure with an AP without receiving Beacon or Probe Response frame from the AP.

NOTE 2—Any change in a Fragment element is considered under the context of the element being fragmented by the Fragment element.

If a vendor-specific subelement is included in an element within the BSS Configuration Parameter Set, the AP-CSN does not provide any indication regarding if that vendor-specific subelement has changed or not, and AP-CSN is not increased if the only change within the BSS Configuration Parameter Set is due to the change to a vendor-specific subelement embedded in an element within the BSS Configuration Parameter Set.

NOTE 3—A vendor-specific subelement can be included in a BSS Configuration Parameter Set within one of the permitted elements, even though the Vendor Specific element is excluded.

A FILS AP maintains an AP-CSN list consisting of the current AP-CSN value and an implementation-dependent number of zero of more previous AP-CSN values. The AP initializes the AP-CSN to a random integer value in the range of 0 to 255. For each maintained previous AP-CSN value, the AP also maintains the identifiers of the changed elements.

NOTE 4—The AP maintains the AP-CSN values in the AP-CSN list for a duration whose value is out of the scope of this standard.

An AP maintaining an AP-CSN list shall increase the current AP-CSN value (modulo 256) by one if an update occurs to any of the fields or elements within the BSS Configuration Parameter Set.

A FILS AP may provide FILS STAs its AP-CSN value by sending a Beacon frame or a Probe Response frame including an AP-CSN element (as defined in 9.4.2.181).

A FILS non-AP STA identifies an BSS Configuration Parameter Set by its associated AP-CSN value and the AP's BSS's BSSID.

A FILS non-AP STA may send a Probe Request frame that includes an AP-CSN element (as defined in 9.4.2.181) if the STA has the BSS Configuration Parameter Set associated with the AP-CSN of an AP. When sending such a Probe Request frame, the FILS non-AP STA shall send it to the broadcast destination address and set the Address 3 (BSSID) field in the Probe Request frame to the BSSID of the AP's BSS.

When a FILS AP receives a Probe Request frame with an AP-CSN element where the Address 3 (BSSID) field matches the BSSID of this AP's BSS, and the criteria for responding to a Probe Request frame (11.1.4.3.4) are met, the AP sends a Probe Response frame according to comparison result, as follows:

a) If the AP does not maintain an AP-CSN list, the AP sends a Probe Response frame.
b) If the received AP-CSN element matches with the current AP-CSN of the AP, the AP sends an optimized Probe Response frame including mandatory fields (i.e., Timestamp, Capability, and Beacon Interval), the current AP-CSN element, and one or more elements among dynamic elements defined in this subclause.
c) If the received AP-CSN element that matches one of the previous AP-CSN in the AP-CSN list, the AP sends an optimized Probe Response frame including mandatory fields, the current AP-CSN element, the elements that need to be updated at the STA, and one or more elements among dynamic elements defined in this subclause.

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If the received AP-CSN value does not match with any of AP-CSN values in the AP-CSN list, the AP shall send a Probe Response frame with its current AP-CSN, the information fields, and elements as defined in 9.3.3.10.

11.1.4.4 Initializing a BSS

11.1.4.4.1 General

Upon receipt of an MLME-START.request primitive, a STA shall determine the BSS's BSSID (as described in 11.1.4), select channel synchronization information, select a beacon period, initialize and start its TSF timer, and begin transmitting Beacon frames if the STA is a neither a DMG nor an S1G STA, or DMG Beacon frames if the STA is a DMG STA, or S1G Beacon frames if the STA is an S1G STA. See 9.3.3.2 for the description of a Beacon frame, and see 9.3.4.2 for the description of a DMG Beacon frame. Upon receipt of an MLME-START.request primitive, an S1G STA with dot11ShortBeaconInterval equal to true shall select short beacon period and begin transmitting S1G Beacon frames.

11.1.4.4.2 Initializing a DMG BSS

Prior to choosing a suitable operating channel and starting a BSS, the SME of a DMG STA should perform a channel scan to ascertain the quality of each channel that the STA supports. The rules for choosing a suitable operating channel are implementation specific and might be subject to regulatory requirements.

When a STA's MAC receives an MLME-START.request primitive, the MAC shall attempt to start a BSS. The STA may listen for a duration of aMinChannelTime, the listening duration, in the channel specified by the SME in the request. If the STA determines the channel is suitable for BSS operation at the end of this listening duration, the STA initializes the BSS by commencing transmission of DMG Beacon frames according to 11.1.3.3 in the case of a PBSS or an infrastructure BSS and according to 11.1.3.5 in the case of an IBSS. If AP or PCP clustering is in use on the selected channel, the DMG Beacon frame transmission by an AP or PCP commences following the additional rules described in 10.40.

If the STA determines that no channels are suitable or available, it responds with an MLME-START.confirm primitive with a ResultCode of NOT_SUPPORTED. Otherwise, the MLME shall respond with an MLME-START.confirm primitive with a ResultCode of SUCCESS.

The SME should issue an MLME-START.request primitive with BSSType parameter equal to PERSONAL for at least one network in which the STA becomes a candidate PCP as defined in 11.1.4.3.10. If the STA becomes a candidate PCP of more than one network, the SME may issue an MLME-START.request primitive with BSSType parameter equal to PERSONAL for any of the remaining networks. In either case, the MLME-START.request primitive should be issued no later than 4×aMaxBIDuration after the MAC receives an MLME-SCAN.confirm primitive.

The SME should not issue an MLME-START.request primitive with BSSType parameter equal to PERSONAL for networks in which the STA does not become a candidate PCP as defined in 11.1.4.3.10. If the SME issues the MLME-START.request primitive under this circumstance, it shall not be issued if less than 4 × aMaxBIDuration has elapsed since the MAC received the MLME-SCAN.confirm primitive.

11.1.4.5 Synchronizing with a BSS

Upon receipt of an MLME-JOIN.request primitive, a STA shall adopt the BSSID in the request. Upon receipt of a Beacon frame from the BSS, a STA shall adopt the TSF timer value of the parameters in the Beacon frame using the algorithm described in 11.1.3.9, and the MLME shall issue an MLME-JOIN.confirm primitive indicating the operation was successful.

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In addition to these synchronization parameters, a STA joining an infrastructure BSS adopts each of the parameters found in the SelectedBSS parameter of the MLME-JOIN.request primitive except Local time, Capability Information, BSSBasicRateSet parameters, and HT Capabilities element. Local time is not adopted but is used in adopting the TSF as described in 11.1.3.9. The Capability Information reflects the capabilities of the sender and is not adopted but may be used to determine local configuration or behavior. The BSSBasicRateSet parameter is not adopted but may determine if the STA can join the BSS.

If the JoinFailureTimeout timer expires prior to the receipt of a Beacon frame from the BSS, the MLME shall issue an MLME-JOIN.confirm primitive indicating the operation was unsuccessful.

If dot11MultiDomainCapabilityActivated is true, a STA that is joining an infrastructure BSS and receives a Beacon or Probe Response frame containing a Country element shall adopt the applicable parameters included in that Country element, and the dot11RegDomainsSupportedEntry shall be set to Other.

In addition to adopting the synchronization parameters as described in the first paragraph of this subclause, a STA joining an IBSS shall adopt each of the parameters found in the SelectedBSS parameter of the MLME-JOIN.request primitive according to the rule found for that parameter in the “IBSS adoption” column of the matching row of the BSSDescription table found in 6.3.3.3.2 when those parameters exist at the STA. Parameters adopted by a STA when joining an IBSS shall not be changed by the STA except when adopting parameters following the reception of a Beacon frame with a later timestamp as described in 11.1.5. When an IBSS contains STAs with a mix of STA capabilities, e.g., non-HT and HT, a STA in the IBSS adopts the behavioral parameters of the last beacon with the highest TSF (e.g., a HT STA does not continue use of HT and does not include an HT Operations element in its beacons).

In addition to the table entries in 6.3.3.3.2, if dot11MultiDomainCapabilityActivated is true, a STA that is joining an IBSS and receives a Beacon or Probe Response frame containing a Country element shall adopt the applicable parameters included in that Country element, and the dot11RegDomainsSupportedEntry shall be set to Other.

A DMG STA shall be capable of transmitting DMG Beacon frames. A DMG STA obtains the operational parameters in use by its AP or PCP through the DMG Operation Information field of the DMG Operation element. A DMG STA shall update the value of its local MIB attributes with the corresponding field value transmitted by its AP or PCP within the DMG BSS Parameter Configuration field of the DMG Operation element (9.4.2.128). Except for the prefix “dot11” used in the MIB attribute naming convention, the name of the field is the same as the name of the corresponding MIB attribute.

11.1.4.6 Operation of Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element

The Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element in Beacon and Probe Response frames is used by STAs in order to avoid associating with a BSS if they do not support all of the data rates in the BSSBasicRateSet parameter or all of the BSS membership requirements in the BSSMembershipSelectorSet parameter.

A STA shall include the rates from its OperationalRateSet parameter and the rates from the BSSBasicRateSet parameter and the BSS membership selectors from the BSSMembershipSelectorSet parameter in frames it transmits containing Supported Rates and BSS Membership Selectors elements and Extended Supported Rates and BSS Membership Selectors elements according to the rules described in this subclause, except that a non-AP STA may omit the HT and VHT BSS membership selectors, as the (V)HT capabilities are indicated through the presence of a (V)HT Capabilities element.

For a STA that supports a combined total of eight or fewer data rates and BSS membership selectors the Extended Supported Rates and BSS Membership Selectors element is optional, and may be included in all of the frame types that include the Supported Rates and BSS Membership Selectors element.

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A STA that supports a combined total of the number of rates in the OperationalRateSet parameter and the number of BSS membership selectors that exceeds eight shall include an Extended Supported Rates and BSS Membership Selectors element to specify the supported rates and BSS membership selectors that are not included in the Supported Rates and BSS Membership Selectors element.

If the BSSMembershipSelectorSet parameter contains at least one BSS membership selector, then the STA shall include at least one BSS membership selector value from the BSSMembershipSelectorSet parameter in the Supported Rates and BSS Membership Selectors element.

NOTE 1—Inclusion of at least one BSS membership selector in the Supported Rates and BSS Membership Selectors element causes a receiving STA that was implemented before the existence of the Extended Supported Rates and BSS Membership Selectors element to still receive at least one BSS membership selector, which it will consider to be a basic rate that it does not support, and therefore it will not associate to the BSS.

Upon receipt, the Supported Rates and BSS Membership Selectors element in Beacon and Probe Response frames is delivered to the management entity in a STA via the BSSBasicRateSet parameter in the MLME-SCAN.confirm primitive. The BSS membership selector information in Beacon and Probe Response frames is delivered to the management entity in a STA via the BSSMembershipSelectorSet parameter in the MLME-SCAN.confirm primitive. Together, these parameters are used by the management entity in a STA to avoid associating with a BSS if the STA cannot receive and transmit all of the data rates in the BSSBasicRateSet parameter or does not support all of the features represented in the BSSMembershipSelectorSet parameter.

A STA that is implemented after the existence of the BSSMembershipSelectorSet parameter includes each octet of the Supported Rates and BSS Membership Selectors element that is encoded with the MSB (bit 7) equal to 1 and that it does not recognize as a rate in its BSSMembershipSelectorSet parameter. The STA then determines if it can support all of the features represented in its BSSMembershipSelectorSet parameter before attempting to join the network. If some BSSMembershipSelectorSet parameter values are not recognized by the STA, the STA does not attempt to join the network.

NOTE 2—STA that was implemented before the existence of the BSSMembershipSelectorSet parameter interprets each BSS membership selector in the Supported Rates and BSS Membership Selectors element as though it were a rate from the BSSBasicRateSet parameter. These values of BSS membership selectors will not match a rate that is known to the STA and, therefore, the management entity in the STA will not associate with the BSS, because it will determine that the STA cannot receive or transmit at what appears to be a required rate.

11.1.5 Adjusting STA timers

A STA in an infrastructure BSS or PBSS shall adopt the TSF timer value in a Beacon, S1G Beacon, Probe Response, PV1 Probe Response, DMG Beacon, or Announce frame transmitted by the BSS's AP or PCP. The STA shall use the algorithm specified in 11.1.3.9.

To response to an MLME-JOIN.request primitive, a STA joining an IBSS shall initialize its TSF timer to 0 and shall not transmit a Beacon, S1G Beacon, Probe Response, PV1 Probe Response, or DMG Beacon frame until it receives from a member of the IBSS a Beacon, S1G Beacon, Probe Response, PV1 Probe Response, or DMG Beacon frame that has a matching SSID. Consequently, the STA joining an IBSS adopts the timer from the next Beacon, S1G Beacon, Probe Response, PV1 Probe Response, or DMG Beacon frame from its IBSS.

A STA receiving a Beacon, S1G Beacon, Probe Response, PV1 Probe Response, DMG Beacon, or Announce frame from another IBSS STA with the same SSID shall compare the Timestamp field with its own TSF time. If the Timestamp field of the received frame is later than its own TSF timer, a STA that is neither a DMG nor an S1G STA in the IBSS shall adopt all parameters contained in the Beacon frame according to the rule for that parameter found in the "IBSS adoption" column of the matching row of the BSSDescription table found in 6.3.3.3.2. An S1G STA shall adopt all parameters contained in the S1G Beacon frame according to the rule for that parameter found in "IBSS adoption" column of the matching row of the BSSDescription table found

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in 6.3.3.2.2 if the Timestamp field of the received frame is later than its own TSF timer and the TSF Completion field in the S1G Beacon Compatibility element is not less than the value of the 4 most significant octets of its own TSF timer. A DMG IBSS STA shall adopt each parameter contained in the DMG Beacon or Announce frames. Parameters adopted by a STA due to the receipt of a later timestamp shall not be changed by the STA except when adopting parameters due to a subsequently received Beacon, S1G Beacon, DMG Beacon, or Announce frame with a later timestamp.

11.1.6 Terminating a BSS

At any time an infrastructure BSS or PBSS may be terminated. At any time a STA may cease support for an IBSS that it formed. Upon receipt of an MLME-STOP.request primitive, a STA shall stop transmitting Beacon, S1G Beacon, Probe Response, PV1 Probe Response, DMG Beacon, and Announce frames and deauthenticate all associated STAs.

11.2 Power management

11.2.1 General

A STA can be in one of two power states:

— Awake: STA is fully powered.
— Doze: STA is not able to transmit or receive and consumes very low power.

The manner in which a STA transitions between power states is determined by its power management mode and reflected in dot11PowerManagementMode.

The power management mode of a STA is selected by the PowerManagementMode parameter of the MLME-POWERMGT.request primitive or MLME-MESHPOWERMGT.request primitive. Once the STA updates its power management mode, the MLME shall issue an MLME-POWERMGT.confirm primitive or MLME-MESHPOWERMGT.confirm primitive respectively indicating the success of the operation.

When MSDUs or A-MSDUs are buffered for power management purposes, the information in the MAC service tuple(s) for the MSDU(s) shall be maintained (and reordered) as a unit.

11.2.2 Bufferable MMPDUs

MMPDUs are categorized as bufferable or nonbufferable, as shown in Table 11-2. Bufferable MMPDUs are eligible to be queued for delivery using a power-saving mechanism.

Nonbufferable MMPDUs are delivered without reference to a power saving mechanism.

Table 11-2—Bufferable/nonbufferable classification of MMPDUs

Description	Classification
An MMPDU that is carried in one or more Action (except for Fine Timing Measurement frame and Fine Timing Measurement Request frame), Disassociation, or Deauthentication frame	Bufferable
An individually addressed MMPDU that is carried in one or more Probe Response frames and that is sent in an IBSS in response to an individually addressed Probe Request frame.	Bufferable
All other MMPDUs.	Nonbufferable

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11.2.3 Power management in a non-DMG infrastructure network

11.2.3.1 General

A STA that is associated with an AP and that changes power management mode shall inform the AP of this fact using the Power Management subfield within the Frame Control field of transmitted frames. The STA shall remain in its current power management mode until it informs the AP of a power management mode change via a frame exchange that includes an acknowledgment from the AP. Power management mode shall not change during any single frame exchange sequence, as described in Annex G.

NOTE 1—This means the Power Management subfield is the same for all MPDUs in an A-MPDU.

The AP shall buffer individually addressed BUs addressed to STAs operating in a PS mode. These buffered BUs shall be transmitted only at designated times.

If any non-GLK STA in its BSS is in PS mode, the AP shall buffer all non-GCR-SP group addressed BUs that arrive via the DS and deliver them to all non-GLK STAs immediately following the next Beacon frame containing a DTIM transmission. If the AP is an S1G AP, the AP may additionally deliver these BUs using group AID as defined in 10.55. If any GLK STA in its BSS is in PS mode, the AP shall not include any such STAs as a SYNRA destination and shall buffer all group addressed BUs that arrive from the attached bridge and are destined to such STAs, delivering them with individually addressed MPDUs using power save delivery methods.

NOTE 2—The group addressed buffered BUs containing one or more MSDUs for GLK type STAs and for non-GLK type STAs are not repeated by the AP to the other type of STA. Network entities external to the AP, such as the bridged network, may repeat these MSDUs to both types of STAs by other means, outside the scope of this standard.

An S1G AP with dot11NDPPSPollSupport equal to true shall set the NDP PS-Poll Supported field in the S1G Capabilities element to 1. Otherwise it shall set the NDP PS-Poll Supported field in the S1G Capabilities element to 0.

The STAs that currently have buffered BUs (excluding those BUs for a STA associated with ACs that are U-APSD delivery-enabled when not all ACs are delivery-enabled by that STA) within the AP are identified in a TIM, which shall be included as an element within all Beacon frames generated by the AP. A STA shall determine that a BU is buffered for it by receiving and interpreting a TIM.

In a non-S1G STA, the traffic-indication virtual bitmap, maintained by the AP, shall be transmitted in a TIM element. In an S1G STA, the traffic-indication virtual bitmap may be divided into more than one page and each page shall be transmitted in a TIM element, hence, more than one TIM element may appear in an S1G Beacon frame. If more than one TIM element is present, then the TIM elements shall be ordered based on the Page Index and Page Slice Number subfields in the Bitmap Control field. TIM elements with Page Slice Number equal to 31 (if any) shall be the first ones and ordered from page 0 to page 3, and may be followed by TIM elements (if any when Page Slicing is supported) with Page Slice Number from 0 to 30 each of which shall also be ordered from page 0 to page 3. In an S1G STA, the traffic virtual bitmap shall be encoded as defined in 9.4.2.5 where the ADE mode may be used by the AP only if the TIM ADE Support field in the S1G Capabilities element received from every STA with AID included in the TIM element, is 1. Otherwise ADE mode shall not be used to encode the TIM element.

A STA operating in PS mode with dot11NonTIMModeActivated equal to false that is not in WNM sleep mode shall periodically listen for Beacon frames, as determined by the ListenInterval parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive and the ReceiveDTIMs parameter of the MLME-POWERMGT.request primitive. STAs operating in PS modes with dot11NonTIMModeActivated equal to true transmit at least one PS-Poll or trigger frame that is individually addressed to the associated AP

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every ListenInterval parameter used by the MLME primitives starting from the last known transition of the S1G STA in non-TIM mode in doze state unless it follows the TWT or NDP Paging procedure.

WNM sleep mode enables an extended power save mode for non-AP STAs in which a non-AP STA need not listen for every DTIM Beacon frame, and need not perform GTK/IGTK/BIGTK updates. STAs in WNM sleep mode can wake up as infrequently as once every WNM sleep interval to check whether the corresponding TIM bit is set or group addressed traffic is pending.

NOTE 3—A STA may use both WNM sleep mode and PS mode simultaneously.

If an S1G AP with dot11NDPPSPollSupport equal to true has a buffered BU for a STA associated with the AP and receives an NDP PS-Poll frame from the STA, it should send the buffered BU with the MCS level that is calculated based on the value indicated in the Preferred MCS subfield in the received NDP PS-Poll frame unless the indicated MCS level violates rate selection rule for Data frames (as defined in 10.6.5).

The Power Management subfield of the Frame Control field may be set to 0 or 1 within a frame sent by a STA in WNM sleep mode.

When a STA is in WNM sleep mode and in PS mode, the AP buffers individually addressed frames according to the traffic filtering agreement established between the AP and STA, as specified in 11.21.12.2. When a STA is in WNM sleep mode but not in PS mode, the traffic filtering agreement between the AP and STA and the timer for the WNM sleep interval remain in place, and the AP queues for nonbuffered delivery all matched frames (i.e., matched by the traffic filtering agreement) destined to the STA.

In a BSS operating under the DCF or EDCA, upon determining that a BU is currently buffered in the AP, a STA operating in the normal (non-APSD) PS mode transmits a (NDP) PS-Poll frame to the AP, which responds with the corresponding buffered BU immediately, or acknowledges the (NDP) PS-Poll frame and responds with the corresponding BU at a later time.

An S1G STA may transmit NDP PS-Poll frames instead of PS-Poll frames to an S1G AP from which it has received a frame containing an S1G Capabilities element with the NDP PS-Poll Supported field equal to 1; otherwise, the S1G STA shall not transmit NDP PS-Poll frames. If an S1G STA detects that the partial BSSID of the BSS of which it is a member is equal to the partial BSSID of another BSS from which it receives frames, then the S1G STA shall not transmit NDP PS-Poll frames to its associated AP to avoid ambiguity. A non-S1G STA shall not transmit NDP PS-Poll frames. An S1G STA shall set the Poll Type subfield in the Frame Control field of the transmitted PS-Poll(+BDT) frame to 0 unless it is an S1G STA in non-TIM mode that follows the procedure described in 10.48.2. An S1G STA in TIM mode shall not send a PS-Poll with the Poll Type subfield equal to 1 to an S1G STA.

A non-AP QoS STA may be in PS mode before the setup of block ack. BUs for a TID without a schedule are sent using Normal Ack following a PS-Poll frame as described in rest of 11.2.3. Uplink block ack agreements, block ack agreements for any TID with a schedule, and any block ack agreements to APSD STAs continue to operate normally.

NOTE 4—When a STA is in normal (non-APSD) PS mode, the rules described in 11.2.3.6 for PS-Poll operation apply to any downlink block ack agreement without an associated schedule. An (A-)MSDU delivered for this block ack agreement in response to the PS-Poll frame might be delivered in an A-MPDU.

An S1G AP may change its Power Management mode as described in 11.2.3.18.

An S1G STA in PS mode shall set the More Data field to 1 in a frame transmitted to its AP when the STA intends to transmit another frame to the AP within this SP. An S1G STA in PS mode shall set the More Data field to 0 in a frame transmitted to its AP when the STA does not intend to transmit another frame to the AP within this SP.

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11.2.3.2 Non-AP STA power management modes

A non-AP STA can be in one of two power management modes:

— Active mode: The STA receives and transmits frames at any time. The STA remains in the awake state.

— Power save (PS) mode: The STA enters the awake state to receive or transmit frames. The STA remains in the doze state otherwise.

A non-AP STA shall be in active mode upon (re)association, except that if the (re)association is performed using the on-channel tunneling procedure defined in 11.31.5, then the non-AP STA shall be considered to be in power save mode and in doze state upon (re)association on the BSS identified by the BSSID, Band ID, and Channel Number fields contained in the Multi-band element transmitted in the On-channel Tunnel Request frame that carries the (Re)Association Request frame.

A STA that has transmitted a frame to an AP with which it is not associated and from which it expects a response shall remain in the awake state until such a response is received or until the procedure has timed out.

To change power management modes a STA shall inform the AP by completing a successful frame exchange (as described in Annex G) that is initiated by the STA. This frame exchange shall include a Management frame, Extension frame or Data frame from the STA, and an Ack or a BlockAck frame from the AP. The Power Management subfield(s) in the Frame Control field of the frame(s) sent by the STA in this exchange indicates the power management mode that the STA shall adopt upon successful completion of the entire frame exchange, except where the Power Management subfield is reserved (see 9.2.4.1.7). A non-AP STA shall not change power management mode using a frame exchange that does not receive an Ack or BlockAck frame from the AP, or using a BlockAckReq frame.

NOTE 1—A PS-Poll frame exchange does not necessarily result in an Ack frame from the AP, so a non-AP STA cannot change power management mode using a PS-Poll frame.

NOTE 2—The Power Management subfield is ignored in frame exchanges initiated by the AP.

A non-S1G STA that is changing from doze to awake state in order to transmit shall perform CCA until a frame is detected by which it can set its NAV, or until a period of time indicated by the NAVSyncDelay from the MLME-JOIN.request primitive has transpired. An S1G STA that is changing from doze to awake state in order to transmit shall perform CCA until a frame is detected by which it can set its RID or NAV, or until a period of time indicated by the NAVSyncDelay from the MLME-JOIN.request primitive has transpired.

To change power management mode, a STA that is coordinated by an MM-SME shall inform the AP through a successful frame exchange initiated by the STA. The Power Management subfield in the Frame Control field of the frame sent by the STA in this exchange indicates the power management mode that the STAs coordinated by the MM-SME and advertised in the MMS element sent by the STA shall adopt upon successful completion of the entire frame exchange. To change the power management mode of the coordinated STA, the frame may be sent using any of the MMSLs within the MMSL cluster established with the AP.

An S1G AP that sets the STA Type Support in transmitted S1G Capabilities elements to 0 or 1 shall set dot11NonTIMModeActivated to true and the Non-TIM Support field in the S1G Capabilities element to 1. An S1G AP that sets the STA Type Support in transmitted S1G Capabilities elements to 2 may set dot11NonTIMModeActivated to false and the Non-TIM Support field in the S1G Capabilities element to 0. An S1G AP that sets the STA Type Support in transmitted S1G Capabilities elements to 2 may set dot11NonTIMModeActivated to true and the Non-TIM Support field in the S1G Capabilities element to 1.

An S1G AP shall not set the Non-TIM Support field to 1 in response to a non-TIM Support field equal to 0.

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An S1G AP that includes an AID Response element in a (Re)Association Response frame shall set the AID/Group AID field to the AID assigned to the (re)associating STA, the AID Switch Count field to 0, and the AID Response Interval field to the Listen Interval field.

NOTE 3—The S1G AP can specify a listen interval that is different from the listen interval requested by the S1G non-AP STA in the (Re)Association Request frame if the AP cannot buffer the S1G STA's BUs for the requested listen interval.

An S1G non-AP STA requests the type of PS mode (TIM mode or non-TIM mode) through the (Re)Association Request frame transmitted to the S1G AP.

An S1G non-AP STA requests operation in non-TIM mode by setting the Non-TIM Support field in the S1G Capabilities element in the (Re)Association Request frame to 1.

An S1G non-AP STA requests operation in TIM mode by setting the Non-TIM Support field in the S1G Capabilities element in the (Re)Association Request frame to 0.

An S1G non-AP STA determines the type of PS mode (TIM mode or non-TIM mode) from the (Re)Association Response frame received from the S1G AP.

If an S1G AP sets the Non-TIM Support field in the S1G Capabilities element in the (Re)Association Response frame to 1, then the S1G non-AP STA shall set dot11NonTIMModeActivated to true and operate in non-TIM mode following association, and is referred to as a non-TIM STA.

If an S1G AP sets the Non-TIM Support field in the S1G Capabilities element in the (Re)Association Response frame to 0, then the S1G non-AP STA shall set dot11NonTIMModeActivated to false and operate in TIM mode following association, and is referred to as a TIM STA.

An S1G non-AP STA shall operate in the negotiated PS mode during association unless a PS mode switch is negotiated as described in 10.20 or a temporary PS mode switch has occurred as described in 10.48.2. The STA shall update the value of the ListenInterval parameter it uses in invocations of primitives with the AID Response Interval field in the AID Response element of the (Re)Association Response frame.

An S1G STA in TIM mode listens to selected Beacon frames (based upon the ListenInterval parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive) and sends PS-Poll frames to the AP if the TIM element in the most recent Beacon frame indicates an individually addressed BU is buffered for that STA.

An S1G STA in non-TIM mode shall transmit at least one PS-Poll or trigger frame that is individually addressed to the associated AP every listen interval and might not listen to selected S1G Beacon frames (based upon the ListenInterval parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive) unless it follows the TWT or NDP Paging procedure. An S1G STA in non-TIM mode may send (NDP) PS-Poll frames to an S1G AP regardless of whether individually addressed buffered BUs have been indicated by the S1G AP.

11.2.3.3 AP TIM transmissions

The TIM shall identify the STAs for which traffic is pending and buffered in the AP. This information is coded in a *partial virtual bitmap*, as described in 9.4.2.5. In addition, the TIM contains an indication whether non-SYNRA group addressed traffic is pending. Every STA is assigned an AID by the AP as part of the association process. AID 0 (zero) is reserved to indicate the presence of buffered non-GCR-SP group addressed BUs that will be delivered using MPDUs with an RA other than a SYNRA but that are not delivered using group AID.

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The AP shall identify those STAs for which it is prepared to deliver[40] buffered BUs by setting bits in the TIM's partial virtual bitmap that correspond to the appropriate AIDs.

For an S1G band, the TIM is coded in an S1G partial virtual bitmap, as described in 9.4.2.5. This information is constructed with one of the four encoding modes: the Block Bitmap mode, the Single AID model, the OLB (offset, length, bitmap) mode, and the ADE (AID with differential encoding) mode. An S1G AP shall not transmit the TIM with the encoding mode in the Block Control subfield set to ADE mode to another S1G STA unless the TIM ADE Support field of the S1G Capabilities element received from that STA contained a value of 1 and dot11TIMADEImplemented is true.

11.2.3.4 TIM types

Two different TIM types are distinguished: TIM and DTIM. After a DTIM, the AP shall transmit buffered non-GCR-SP group addressed BUs that will be delivered using MPDUs with an RA other than a SYNRA, before transmitting any individually addressed frames. The AP may additionally deliver these BUs using group AID as defined in 10.55.

The AP shall transmit a TIM with every Beacon frame except when the frame is scheduled for transmission in a TSBTT that is not a TBTT. Every dot11DTIMPeriod, a TIM of type *DTIM* is transmitted within a Beacon frame, rather than an ordinary TIM. An S1G AP with dot11ShortBeaconInterval equal to true may include a TIM in a Beacon frame that is scheduled for transmission in a TSBTT that is not a TBTT. An S1G AP with dot11ShortBeaconInterval equal to true may transmit a TIM of type DTIM in an S1G Beacon frame every dot11ShortBeaconDTIMPeriod.

Figure 11-11 illustrates the AP and STA activity under the assumptions that a DTIM is transmitted once every three TIMs. The top line in Figure 11-11 represents the time axis, with the beacon interval shown together with a DTIM Interval of three beacon intervals. The second line depicts AP activity. The AP schedules Beacon frames for transmission every beacon interval, but the Beacon frames may be delayed if there is traffic at the TBTT. This is indicated as "busy medium" on the second line. For the purposes of this figure, the important fact about Beacon frames is that they contain TIMs, some of which are DTIMs. Note that the second STA with ReceiveDTIMs equal to false does not power-on its receiver for all DTIMs.

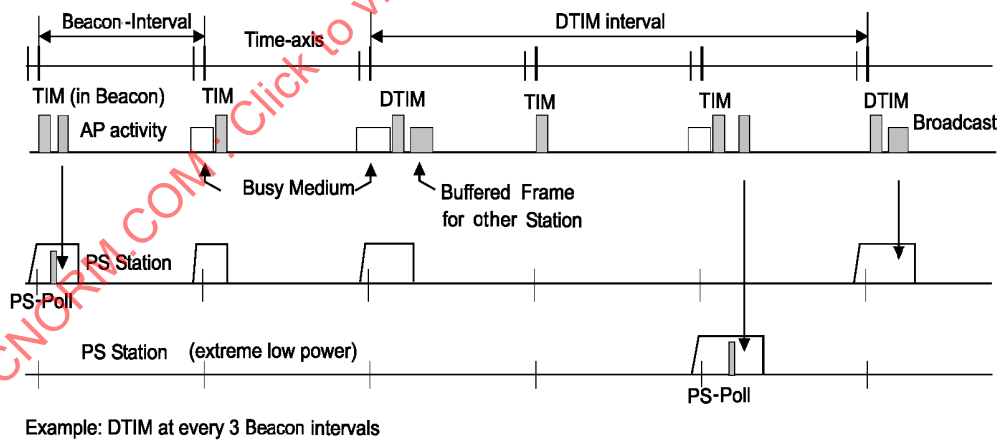

Figure 11-11—Infrastructure power management operation

The third and fourth lines in Figure 11-11 depict the activity of two STAs operating with different power management requirements. Both STAs power-on their receivers when they need to listen for a TIM. This is

[40] How the AP or mesh STA determines the traffic it is prepared to deliver is outside the scope of this standard.

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indicated as a rampup of the receiver power prior to the TBTT. The first STA, for example, powers up its receiver and receives a TIM in the first Beacon frame; that TIM indicates the presence of a buffered BU for the receiving STA. The receiving STA then generates a PS-Poll frame, which elicits the transmission of the buffered BU from the AP. Non-GCR-SP group addressed BUs are sent by the AP subsequent to the transmission of a Beacon frame containing a DTIM. The DTIM is indicated by the DTIM count field of the TIM element having a value of 0.

11.2.3.5 Power management with APSD

11.2.3.5.1 Power management with APSD procedures

QoS APs capable of supporting automatic power save delivery (APSD) shall signal this capability through the use of the APSD subfield in the Capability Information field in Beacon, Probe Response, and (Re)Association Response frames.

QoS STAs use the Power Management subfield in the Frame Control field of a frame to indicate whether it is in active or PS mode. As APSD is a mechanism for the delivery of BUs to power saving STAs, the frames transmitted by a STA in PS mode that is using APSD have the Power Management subfield in the Frame Control field set to 1, thereby causing buffering to take place at the AP.

APSD defines two delivery mechanisms, namely *unscheduled APSD* (U-APSD) and *scheduled APSD* (S-APSD). STAs may use U-APSD to have some or all of their BUs delivered during unscheduled SPs. STAs may use S-APSD to schedule delivery of some or all of their BUs during scheduled SPs.

If there is no unscheduled SP in progress, the unscheduled SP begins when the AP receives a trigger frame from a STA, which is a QoS Data or QoS Null frame using an AC the STA has configured to be trigger-enabled. An A-MPDU that contains one or more trigger frames acts as a trigger frame. An unscheduled SP ends after the AP has attempted to transmit at least one BU using a delivery-enabled AC and destined for the STA, but no more than the number indicated in the Max SP Length field of the QoS Capability element of the STA's (Re)Association Request frame if the field has a nonzero value.

NOTE 1—The transmission of one or more fragments of a BU counts as the transmission of one BU for the purposes of the constraint indicated by the Max SP Length field.

The last frame sent during the SP has the EOSP subfield set to 1. An unscheduled SP may be terminated before the maximum number of BUs in the SP has been reached. The times at which an AP may transmit during an unscheduled SP might be constrained by the U-APSD coexistence mechanism (see 11.2.3.5.2).

In order to configure an AP to deliver BUs during an unscheduled SP, a STA designates one or more of its ACs to be delivery-enabled and one or more of its AC to be trigger-enabled. A STA may configure an AP to use U-APSD using two methods. First, the STA may set individual U-APSD Flag bits in the QoS Info subfield of the QoS Capability element carried in (Re)Association Request frames. When a U-APSD Flag bit is 1, it indicates that the corresponding AC is both delivery- and trigger-enabled. When all four U-APSD Flag subfields are equal to 1 in (Re)Association Request frames, all of the ACs associated with the STA are trigger- and delivery-enabled during (re)association. When all four U-APSD Flag subfields are equal to 0 in (Re)Association Request frames, none of the ACs associated with the STA is trigger- or delivery-enabled during (re)association.

Alternatively, the STA may designate one or more AC as trigger-enabled and one or more AC as delivery-enabled by sending an ADDTS Request frame per AC to the AP with the APSD subfield set to 1 and the Schedule subfield set to 0 in the TS Info field in the TSPEC element. APSD settings in a TSPEC request take precedence over the static U-APSD settings carried in the QoS Capability element. In other words, a TSPEC request overwrites any previous U-APSD setting of an AC.

NOTE 2—Such an ADDTS Request frame can be sent regardless of the ACM setting of the AC.

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A STA may set an AC to be trigger- or delivery-enabled for its own use by setting up TSPECs with the APSD subfield set to 1 and the Schedule subfield set to 0 in the uplink or downlink direction, respectively. An uplink TSPEC plus a downlink TSPEC, or a bidirectional TSPEC with the APSD subfield equal to 1 and the Schedule subfield equal to 0, makes an AC both trigger- and delivery-enabled. An uplink TSPEC plus a downlink TSPEC, or a bidirectional TSPEC with the APSD and the Schedule subfields both equal to 0, makes an AC neither trigger- nor delivery-enabled.

A scheduled SP starts at fixed intervals of time specified in the Service Interval field.The following rules describe scheduled SP operation:

a) If the scheduled Service Interval field equals 0 (for example, with the GCR-A delivery method), the scheduled SP starts from the service start time without a fixed delivery interval.

b) To use a scheduled SP for a TS when the access policy is controlled channel access, a STA shall send an ADDTS Request frame to the AP with the APSD subfield of the TS Info field in the TSPEC element set to 1.

c) To use a scheduled SP for a TS for an AC when the access policy is contention based channel access, a STA shall send an ADDTS Request frame to the AP with the APSD and Schedule subfields of the TS Info field in the TSPEC element both set to 1. If the APSD mechanism is supported by the AP and the AP accepts the corresponding ADDTS Request frame from the STA, the AP shall respond to the ADDTS Request frame with a response containing the Schedule element indicating that the requested service can be accommodated by the AP.

d) When the access policy is contention based channel access for a GCR group addressed stream, a scheduled SP is set up according to 11.21.16.3.3. The first scheduled SP starts when the lower order 4 octets of the TSF timer equals the value specified in the Service Start Time field.

e) If the SI is nonzero, a STA using scheduled SP shall first wake up at the service start time to receive downlink individually addressed and/or GCR SP group addressed BUs buffered and/or to receive polls from the AP or HC. The STA shall wake up subsequently at a fixed time interval equal to the SI.

f) The AP may modify the non-GCR service start time by indicating so in the Schedule element in a successful ADDTS Response frame (which is sent in response to an ADDTS Request frame) and in Schedule frames (which are sent at other times).

g) The AP may modify the GCR service start time by indicating so in the Schedule element in the GCR Response subelements (see 9.4.2.88 and 11.21.16.3.4).

h) In both non-GCR and GCR cases, the service start time shall be updated (using the previously described service start time modification procedures) whenever the upper 4 octets of the TSF timer change.

A scheduled SP begins at the scheduled wakeup time that corresponds to the SI and the service start time indicated in the Schedule element sent in response to a TSPEC or GCR Request. If the SI is nonzero, the STA shall wake up at a subsequent time when the following is true:

$$(TSF - T_{service\text{-}start}) \bmod SI_{min} = 0$$

where

$T_{service\text{-}start}$ is the service start time

SI_{min} is the minimum SI

If the SI is nonzero, a scheduled SP for a GCR group ends after the AP has attempted to transmit at least one BU associated with the GCR group but no more than the number indicated in the Max SP Length field of the QoS Capability element of the STA's (Re)Association Request frame. The last frame of the GCR SP shall have the EOSP subfield set to 1.

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NOTE 3—The transmission of one or more fragments of a BU counts as the transmission of one BU for the purposes of the constraint indicated by the Max SP Length field.

If a scheduled SP overlaps the period during which the AP is required to transmit non-GCR-SP group addressed frames and individually addressed frames to STAs in PS mode that follow a DTIM beacon that has at least 1 bit set to 1 in the partial virtual bitmap of its TIM, the scheduled SP shall be deferred until the AP has transmitted all such buffered frames.

When the GCR-A delivery method is used, the scheduled Service Interval field is 0. If a STA has a GCR agreement with an AP for a group address using the GCR-A delivery method, there is no defined end of the scheduled SP. The STA in PS mode shall enter the awake state and shall remain awake in order to receive the buffered group addressed BUs until the AP changes the delivery method of the stream to a method other than GCR-A or until the GCR agreement is canceled.

If scheduled SPs are supported in a BSS, a STA may use both unscheduled and scheduled APSD on different ACs at the same time. The GCR-SP delivery method may be used on any AC, irrespective of any non-GCR unscheduled or scheduled APSD flows. When a STA establishes scheduled delivery for an AC the AP shall not transmit BUs using that AC during an SP that is initiated by a trigger frame, and it shall not treat BUs using the AC that are received from the STA as trigger frames. The AP shall decline any ADDTS Request frame that indicates the use of both scheduled and unscheduled APSD to be used on non-GCR-SP frames of the same AC at the same time.

APSD shall be used only to deliver individually addressed BUs and GCR-SP BUs to a STA. Non-GCR and non-GCR-SP group addressed BU delivery shall follow the frame delivery rules defined for group addressed BUs as defined in 11.2.3.6.

11.2.3.5.2 U-APSD coexistence

A non-AP STA that uses U-APSD might not be able to receive all AP transmitted frames during the service period due to interference observed at the non-AP STA. Although the AP might not observe the same interference, it is able to determine that the frames were not received correctly by the non-AP STA. The U-APSD coexistence capability enables the non-AP STA to indicate a requested transmission duration to the AP for use during U-APSD service periods. Use of the transmission duration enables the AP to transmit frames during the service period and improve the likelihood that the non-AP STA receives the frames when the non-AP STA is experiencing interference. The U-APSD coexistence capability reduces the likelihood that the AP transmits frames during the service period that are not received.

A STA with dot11UAPSDCoexistenceActivated equal to true shall support U-APSD coexistence and shall set to 1 the U-APSD Coexistence field of the Extended Capabilities elements that it transmits. Otherwise it shall set this field to 0.

A non-AP STA that is associated to an AP where both have previously advertised support for the U-APSD coexistence capability may transmit ADDTS Request frames including the U-APSD Coexistence element to the AP.

The content of the ADDTS Request frame excluding the U-APSD Coexistence element is referred to in subsequent text as the base ADDTS request. Upon reception of the ADDTS Request frame, the AP shall process the content of the base ADDTS request as described in 11.2.3.5. If the AP determines that the base ADDTS request cannot be granted it shall respond as described in 11.2.3.5, without processing the U-APSD Coexistence element. If the AP determines the base ADDTS request can be granted, it shall process the U-APSD Coexistence element. If the AP supports transmission of frames during the U-APSD service period for the duration value specified in the U-APSD Coexistence element Interval/Duration field, it shall grant the ADDTS request as described in 11.2.3.5. Otherwise, it shall deny the ADDTS Request.

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If the AP has previously granted an ADDTS request with U-APSD coexistence, a non-AP STA that continues using QoS services provided by an ADDTS Request frame without U-APSD coexistence may terminate the use of U-APSD coexistence by transmitting an ADDTS Request frame without the U-APSD Coexistence element. A non-AP STA may terminate use of all QoS services (including U-APSD coexistence) resulting from an ADDTS Request frame by transmitting a DELTS Request frame to the AP.

The non-AP STA may transmit multiple ADDTS Request frames to the AP where the last received ADDTS Request frame will override any previously received ADDTS Request frame.

An AP that supports U-APSD coexistence and accepts an ADDTS request limits the U-APSD coexistence service period according to the parameters specified in the ADDTS frame U-APSD Coexistence element, and shall transmit frames to the requesting non-AP STA according to the rules in 10.2.3.2 and the following rules:

— If the non-AP STA specified a nonzero TSF 0 Offset value in the U-APSD Coexistence element, the AP should not transmit frames to the non-AP STA outside of the U-APSD Coexistence Service Period, which begins when the AP receives the U-APSD trigger frame and ends after the transmission period specified by the result of the following calculation:

End of transmission period = T + (*Interval* – ((T – *TSF 0 Offset*) mod *Interval*))

where
T is the time the U-APSD trigger frame was received at the AP
Interval is the UAPSD Coexistence element Duration/Interval field value (see 9.4.2.90)

or upon the successful transmission of a frame with the EOSP subfield set to 1, whichever is earlier.

— If the non-AP STA specified a TSF 0 Offset value of 0 in the U-APSD Coexistence element, the AP should not transmit frames to the non-AP STA outside of the U-APSD coexistence service period, which begins when the AP receives a U-APSD trigger frame and ends after the transmission period specified by the result of the following calculation:

End of transmission period = T + *Duration*

where
T is the time the U-APSD trigger frame was received at the AP
Duration is the UAPSD Coexistence element Duration/Interval field value (see 9.4.2.90)

or upon the successful transmission of a frame with the EOSP subfield set to 1, whichever is earlier.

Throughout the U-APSD coexistence service period, the AP shall set the More bit to 1 if it has more frames to be transmitted and it can determine the frame might be received before the service period expires.

The AP should set the EOSP subfield to 1 in the frame that it expects to be the last frame transmitted to the non-AP STA during the U-APSD coexistence duration. If the last frame expected to be transmitted cannot be successfully transmitted to the non-AP STA before the termination of the U-APSD SP, or does not have QoS Control field, the AP should transmit a QoS Null frame with the EOSP subfield set to 1.

The non-AP STA may enter doze state at the end of the U-APSD coexistence service period.

11.2.3.6 AP operation

An AP shall maintain for each currently associated STA a Power Management status that indicates in which power management mode the STA is currently operating. APs that implement and signal their support of APSD shall maintain for each currently associated STA an APSD and an access policy status that indicates whether the STA is presently using APSD and shall maintain the schedule (if any) for the STA. An AP shall, depending on the power management mode of the STA, temporarily buffer BUs destined to the STA. An AP implementing APSD shall, if a STA is using APSD and is in PS mode, temporarily buffer BUs destined to that

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STA. No BUs addressed directly to STAs operating in the active mode shall be buffered for power management reasons.

The following rules describe the operation:

a) BUs destined for PS STAs shall be temporarily buffered in the AP. The algorithm to manage this buffering is beyond the scope of this standard, with the exception that if the AP is QoS-enabled, it shall preserve the order of arrival of frames on a per-TID, per-STA basis.

b) Nonbufferable MMPDUs and BUs destined for STAs in the active mode shall be directly transmitted to those STAs.

c) At every beacon interval, the AP shall assemble the partial virtual bitmap containing the buffer status per destination for STAs in the PS mode and shall send this out in the TIM element of the Beacon frame. At every beacon interval, the APSD-capable AP shall assemble the partial virtual bitmap containing the buffer status of nondelivery-enabled ACs (if there exists at least one nondelivery-enabled AC) per destination for STAs in PS mode and shall send this out in the TIM element of the Beacon frame. When all ACs are delivery-enabled, the APSD-capable AP shall assemble the partial virtual bitmap containing the buffer status for all ACs per destination. If FMS is enabled, the AP shall include the FMS Descriptor element in every Beacon frame. The FMS Descriptor element shall indicate all FMS group addressed frames that the AP buffers. An S1G AP should set the Duration field in the S1G Beacon frame to the estimated time required for all the S1G STAs that are indicated in the TIM elements and/or are allowed to access the first RAW immediately following the S1G Beacon frame as described in 10.23.5.4, to send the trigger or (NDP) PS-Poll frame and receive an acknowledgment from the AP. The operation described in this paragraph shall also be performed for every short beacon interval where a TIM is transmitted.

d) If a STA has set up a scheduled SP, it shall automatically wake up at each SP. Therefore, the APSD-capable AP shall transmit frames associated with admitted traffic with the APSD subfield equal to 1 in the TSPECs buffered for the STA during a scheduled SP. If the STA has set up to use unscheduled SPs, the AP shall buffer BUs using delivery-enabled ACs until it has received a trigger frame using a trigger-enabled AC from the non-AP STA, which indicates the start of an unscheduled SP. A trigger frame received by the AP from a STA that already has an unscheduled SP underway shall not trigger the start of a new unscheduled SP. The AP transmits BUs destined for the STA and using delivery-enabled ACs during an unscheduled SP. The bit for AID 0 (zero) in the Bitmap Control field of the TIM element shall be set to 1 when non-GCR-SP non-SYNRA group addressed traffic that is not to be delivered using group AID is buffered, according to 9.4.2.5.

NOTE 1—Transmission of BUs during an unscheduled SP is constrained by the max SP length.

NOTE 2—The AC for delivery of an MMPDU (see 10.2.3.2) determines whether it is transmitted using a delivery-enabled AC during an unscheduled SP.

e) If any associated non-GLK STAs are in PS mode, the AP shall buffer all non-GCR-SP group addressed BUs that arrive via the DS. If any GLK STA in its BSS is in PS mode, the AP shall not include any such STAs as a SYNRA destination and shall buffer all group addressed BUs destined to such STAs, delivering them with individually addressed MPDUs using power save delivery methods.

f) When dot11FMSActivated is false, the AP shall transmit all buffered non-GCR-SP non-SYNRA group addressed BUs immediately after every DTIM.

When dot11FMSActivated is true and the AP has established an FMS delivery interval for a multicast stream, the AP shall transmit all non-GCR-SP non-SYNRA group addressed BUs belonging to particular FMS stream immediately after the DTIM that has the Current Count field of the FMS Counter field set to 0 for that particular FMS stream.

The More Data subfield of each group addressed frame shall be set to indicate the presence of further buffered non-GCR-SP group addressed BUs that will be delivered using MPDUs with an RA

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other than a SYNRA. If the AP is unable, before the primary or secondary TBTT following the DTIM, to transmit all of the buffered non-GCR-SP group addressed BUs that will be delivered using MPDUs with an RA other than a SYNRA, then the AP shall set the bit for AID 0 (zero) in the TIM element to 1 for a single BSSID or set the corresponding group address bit to 1 for multiple BSSIDs, as defined in 9.4.2.5, and when dot11FMSActivated is true, shall set the appropriate bits in the FMS Descriptor element as described in 9.4.2.74 to indicate for which non-GCR-SP non-SYNRA group addresses there are still buffered BUs, until all buffered non-GCR-SP group addressed BUs that will be delivered using MPDUs with an RA other than a SYNRA have been transmitted.

When the AP transmits an STBC DTIM or TIM Beacon frame, the AP shall retransmit all non-GCR-SP group addressed BUs that will be delivered using MPDUs with an RA other than a SYNRA and that were transmitted following the non-STBC DTIM or TIM Beacon frame except that they are transmitted using the basic STBC MCS. It may be the case that a complete set of buffered non-GCR-SP non-SYNRA group addressed BUs is sent over a period of time during which non-STBC and STBC transmissions are interleaved, but the transition from non-STBC group addressed transmissions to STBC group addressed transmissions shall be preceded by the transmission of an STBC Beacon frame and the transition from STBC group addressed transmissions to non-STBC group addressed transmissions shall be preceded by the transmission of a non-STBC Beacon frame.

g) When the AP receives a PS-Poll frame from a STA that is in PS mode, it shall forward to the STA a buffered BU. The AP shall respond after a SIFS either with a Data or Management frame, or with an Ack frame; in which case the corresponding Data or Management frame is delayed. Until the transmission of this BU either has succeeded or is presumed failed (when maximum retries are exceeded), the AP shall acknowledge but ignore all PS-Poll frames from the same STA. This prevents a retried PS-Poll frame from being treated as a new request to deliver a buffered BU.

For a STA using U-APSD, the AP transmits one BU destined for the STA from any AC that is not delivery-enabled in response to PS-Poll frame from the STA. The AP should transmit the BU from the highest priority AC that is not delivery-enabled and that has a buffered BU. When all ACs associated with the STA are delivery-enabled, the AP transmits one BU from the highest priority AC that has a BU. Upon receiving a PS-Poll frame, the S1G AP that intends to respond with immediate Data frame may use the RTS/CTS scheme to protect the transmission of the frame.

An S1G AP that sends an acknowledgment frame of type (NDP) Ack or NDP PS-Poll-Ack in response to an (NDP)PS-Poll/Trigger frame that is received from an S1G STA shall set the More Data subfield of the acknowledgment frame to 0 when no BU is buffered for the STA; otherwise, it shall set it to 1. The reception of the acknowledgment frame provides the following indications to the S1G STA:

1) If the More Data subfield is equal to 0, it indicates that no service period starts for the STA and that it may enter the doze state,
2) If the More Data subfield is equal to 1, it indicates that a service period starts for the STA after a time T, starting from the end of the acknowledgment frame, after which the S1G STA shall remain in the awake state until a frame is received from the S1G AP that has the EOSP subfield equal to 1. The time T is equal to one of the following:
    i) 0 if the acknowledgment frame is an Ack frame or is an NDP (PS-Poll-)Ack frame with the Idle Indication subfield equal to 0.
    ii) The value indicated in the Duration field of the frame if the frame is an NDP (PS-Poll-)Ack frame with the Idle Indication subfield equal to 1.

For a STA in PS mode and not using U-APSD, the AP shall set the More Data subfield of the response Data or Management frame to 1 to indicate the presence of further buffered BUs (not including the BU currently being transmitted) for the polling STA.

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For a STA using U-APSD, the AP shall set the More Data subfield to 1 to indicate the presence of further buffered BUs (not including the BU currently being transmitted) that do not use delivery-enabled ACs. When all ACs associated with the STA are delivery-enabled, the AP shall set the More Data subfield to 1 to indicate the presence of further buffered BUs (not including the BU currently being transmitted) using delivery-enabled ACs.

If there are buffered BUs to transmit to the STA, the AP may set the More Data bit in a QoS +CF-Ack frame to 1 in response to a QoS Data frame to indicate that it has one or more pending BUs buffered for the PS STA identified by the RA in the QoS +CF-Ack frame. An AP may also set the More Data bit in an Ack frame to 1 in response to a QoS Data frame to indicate that it has one or more pending BUs buffered for the PS STA identified by the RA in the Ack frame, if that PS STA has set the More Data Ack subfield in the QoS Capability element to 1.

Unless indicated above, the AP shall set the More Data bit to 0.

h) At each scheduled APSD SP for a STA, the APSD-capable AP (i.e., an AP for which dot11APSDOptionImplemented is true) shall attempt to transmit at least one BU, using admitted TSPECs with the APSD and Schedule subfields both set to 1, that are destined for the STA. At each unscheduled SP for a STA, the AP shall attempt to transmit at least one BU, but no more than the value specified in the Max SP Length field in the QoS Capability element, from delivery-enabled ACs, that are destined for the STA.

NOTE 3—The transmission of one or more fragments of a BU counts as the transmission of one BU for the purposes of the constraint indicated by the Max SP Length field.

The AP shall set to 1 the More Data bit of an individually addressed MPDU containing all or part of a BU, using a delivery-enabled AC and destined for that STA, to indicate that more BUs (not including the BU currently being transmitted) are buffered for the delivery-enabled ACs. The AP shall set to 1 the More Data bit of an individually addressed MPDU containing all or part of a BU, using a nondelivery-enabled AC and destined for that STA, to indicate that more BUs (not including the BU currently being transmitted) are buffered for the nondelivery-enabled ACs.

In all frames except for the final frame of the SP, the AP shall set the EOSP subfield, if present, to 0 to indicate the continuation of the SP. An AP may also set the More Data bit to 1 in a QoS +CF-Ack frame in response to a QoS Data frame to indicate that it has one or more pending BUs buffered for the target STA identified by the RA in the QoS +CF-Ack frame. If the QoS Data frame is using a delivery-enabled AC, the AP shall set the More Data bit in the QoS +CF-Ack frame to 1 to indicate more BUs (not including the BU currently being transmitted) are buffered for the delivery-enabled ACs. If the QoS Data frame is not using a delivery-enabled AC, the AP shall set the More Data bit in the QoS +CF-Ack frame to 1 to indicate more BUs (not including the BU currently being transmitted) are buffered for the ACs that are not delivery-enabled.

Unless indicated above, the AP shall set the More Data bit to 0.

The AP considers an APSD STA to be in awake state after it has sent a QoS +CF-Ack frame, with the EOSP subfield equal to 0, to the APSD STA. If necessary, the AP may generate an extra QoS Null frame, with the EOSP subfield set to 1. When the AP has transmitted an individually addressed frame to the STA with the EOSP subfield set to 1 during the SP except for retransmissions of that frame, the AP shall not transmit any more frames to that STA using this mechanism until the next SP.

The AP shall set the EOSP subfield to 1 to indicate the end of the SP in APSD.

NOTE 4—Management frames do not have an EOSP subfield and so the end of the SP cannot be indicated in a Management frame. If the SP is to end after a Management, a QoS Null frame is used to indicate this.

The AP should not set the EOSP field to 1 in a frame that is not an individually addressed Data frame that requires immediate acknowledgment.

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i) If the AP does not receive an acknowledgment to an individually addressed MPDU containing all or part of a BU sent to a STA in PS mode following receipt of a PS-Poll frame from that STA, it may retransmit the frame for at most the lesser of the maximum retry limit and dot11QAPMissingAckRetryLimit times before the next Beacon frame, but it shall retransmit that frame at least once before the next Beacon frame, time permitting and subject to its appropriate lifetime limit. If an acknowledgment to the retransmission is not received, it may wait until after the next Beacon frame to further retransmit that frame subject to its appropriate lifetime limit.

j) If the AP does not receive an acknowledgment in response to a non-A-MPDU frame that is an individually addressed Data frame that is sent with the EOSP subfield equal to 1, and that requires immediate acknowledgment, it shall retransmit that frame at least once within the same SP, subject to applicable retry or lifetime limits. If the AP does not receive a BlockAck frame in response to an A-MPDU that contains one or more individually addressed Data frames that are sent with the EOSP subfield equal to 1, and that require immediate acknowledgment, it shall retransmit at least one of those frames at least once within the same SP, subject to applicable retry or lifetime limits. The maximum number of retransmissions within the same SP is the lesser of the maximum retry limit and dot11QAPMissingAckRetryLimit.

   If the AP does not receive an acknowledgment to an individually addressed Data or Management frame that requires immediate acknowledgment and that is not the initial attempt in this SP to send a frame with the EOSP subfield equal to 1, it may retransmit that frame in the next SP, subject to applicable retry or lifetime limits.

   An AP that transmits an A-MPDU containing Data frames in which the EOSP subfield is equal to 1 and that receives a BlockAck frame that does not acknowledge all of those MPDUs should not transmit any missed Data frames within the current service period because the destination STA might now be asleep.

k) An AP may delete buffered BUs for implementation dependent reasons (subject to 11.2.3.10), including the use of an aging function and availability of buffers. The AP may base the aging function on the listen interval indicated by the STA in its (Re)Association Request frame or the WNM sleep interval specified by the non-AP STA in the WNM Sleep Mode Request frame. In addition, the S1G AP may base the aging function on the listen interval indicated by the AP in the (Re)Association Response frame.

l) When an AP is informed that a STA has changed to the active mode, then the AP shall send buffered BUs (if any exist) to that STA without waiting for a PS-Poll frame. When an AP is informed that an APSD-capable STA is not using APSD, then the AP shall send buffered BUs (if any exist) to that STA according to the rules corresponding to the current PS mode of the STA.

11.2.3.7 Receive operation for STAs in PS mode

A STA in PS mode shall operate as follows to receive a BU from the AP.

The following rules describe operation of a STA in PS mode:

a) The STA with dot11NonTIMModeActivated equal to false shall wake up early enough to be able to receive the first Beacon frame scheduled for transmission at the time corresponding to the last TBTT or TSBTT for which the STA was awake plus the time interval indicated by the ListenInterval parameter of the MLME-ASSOCIATE.request or MLME REASSOCIATE.request primitive. The STA with dot11NonTIMModeActivated equal to true is not required to wake up to receive a Beacon frame and shall transmit at least one PS-Poll or trigger frame that is individually addressed to the associated AP every listen interval starting from the last known transition of the S1G STA in non-TIM mode in doze state unless it follows the TWT or NDP Paging procedure.

   NOTE—The STA might wake for a TBTT or TSBTT that is earlier than this deadline. In that case the previous requirement is reset based on a new “last TBTT or TSBTT”.

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b) When the STA detects that the bit corresponding to its AID is 1 in the TIM, the STA shall issue a PS-Poll frame, or a trigger frame if the STA is using U-APSD and all ACs are delivery-enabled, to retrieve the buffered BU. The PS-Poll or trigger frame shall be transmitted after a random delay uniformly distributed between zero and aCWmin slots following a DIFS.

c) The STA shall remain in the awake state until it receives the BU in response to its poll or it receives another Beacon frame whose TIM indicates that the AP does not have any BUs buffered for this STA. If the bit corresponding to the STA's AID is 1 in the subsequent TIM, the STA shall issue another PS-Poll frame to retrieve the buffered BU. When a STA that is using U-APSD and has all ACs delivery-enabled detects that the bit corresponding to its AID is 1 in the TIM, the STA shall issue a trigger frame or a PS-Poll frame to retrieve the buffered BU.

d) If the More Data subfield in the MPDU(s) containing the BU indicates that more traffic for that STA is buffered, the STA, at its convenience, shall poll until no more BUs are buffered for that STA.

e) When dot11FMSActivated is false and ReceiveDTIMs is true, the STA shall wake up early enough to be able to receive either every non-STBC DTIM or every STBC DTIM sent by the AP of the BSS.

When dot11FMSActivated is true and ReceiveDTIMs is true and the STA has been granted by the AP an alternate delivery interval for a multicast stream, the STA shall wake up before the non-STBC DTIM or STBC DTIM having Current Count of FMS Counter field set to 0 for that particular FMS stream.

A STA that stays awake to receive group addressed BUs shall elect to receive all group addressed non-STBC transmissions or all group addressed STBC transmissions and remain awake until the More Data subfield of the appropriate type (non-STBC or STBC) of group addressed BUs indicates there are no further buffered group addressed BUs of that type, or until a TIM is received indicating there are no more buffered group addressed BUs of that type, or until an FMS Descriptor element is received indicating that there are no further buffered group addressed BUs for which the STA has previously received an FMS Response element in a frame that has a value in Address 1 that matches its MAC address or that has an Address 1 value that is a group address corresponding to a group of which it is a member and that was transmitted by the AP with which it is associated and which had an Element Status value in the FMS Status subelement of "Accept". If a STA receives a QoS +CF-Ack frame from its AP with the More Data bit equal to 1, then the STA shall operate exactly as if it received a TIM with its AID bit equal to 1. If a STA has set the More Data Ack sub-field in QoS Capability element to 1, then if it receives an Ack frame from its AP with the More Data bit equal to 1, the STA shall operate exactly as if it received a TIM with its AID bit equal to 1. For example, a STA that is using the PS-Poll delivery method shall issue a PS-Poll frame to retrieve a buffered BU. See also 10.3.6.

11.2.3.8 Receive operation using APSD

A STA using APSD shall operate as follows to receive a BU from the AP:

a) If a scheduled SP has been set up, the STA wakes up at its scheduled start time. (The STA shall wake up early enough to receive transmissions at the scheduled SP.)

b) If the STA is initiating an unscheduled SP, the STA wakes up and transmits a trigger frame to the AP. When one or more ACs are not delivery-enabled, the STA may retrieve BUs using those ACs by sending PS-Poll frames to the AP.

c) The STA shall remain awake until it receives a QoS Data frame or QoS Null frame addressed to it, with the EOSP subfield equal to 1.

d) The STA may send additional PS-Poll frames if the More Data subfield is 1 in a downlink individually addressed MPDU containing all or part of a BU that does not use a delivery-enabled AC. The STA may send additional trigger frames if the More Data subfield is 1 in a downlink individually addressed MPDU containing all or part of a BU that uses a delivery-enabled AC.

For receive operation using the U-APSD coexistence mechanism, see additional procedures in 11.2.3.5.2.

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11.2.3.9 STAs operating in the active mode

A STA operating in this mode shall have its receiver activated continuously; such STAs do not need to interpret the TIM elements in Beacon frames.

11.2.3.10 AP aging function

Any AP aging function shall not cause the buffered BU to be discarded after any period that is shorter than that indicated by the STA for which the BUs are buffered, in the Listen Interval field of its (Re)Association Request frame. The exact specification of the aging function is beyond the scope of this standard.

NOTE—This aging function is independent of (i.e., in addition to) other causes of MSDU discard within the MAC, such as due to the operation of a per-TS MSDU lifetime, or related to dot11QAPEDCATableMSDULifetime.

11.2.3.11 PSMP power management

An AP transmits a PSMP frame containing a schedule only for STAs that are awake.

A STA with an established PSMP session (see 11.4.6) shall be awake at the start of the session's SP and shall remain awake until the end of the SP unless permitted to return to sleep as described in this subclause.

NOTE 1—A STA in power save mode can also be determined to be awake following receipt of a trigger frame according to the operation of the U-APSD protocol (as defined in 11.2.3.5), following receipt of a PS-Poll frame (as defined in 11.2.3.7), or following a DTIM Beacon (as defined in 11.2.3.7).

The AP may signal the end of the SP for all awake associated PSMP-capable STAs by setting the More PSMP field to 0 or by sending CF-End frame instead of the next PSMP frame.

NOTE 2—The AP can also signal the end of an SP on a per-STA basis using the EOSP subfield set to 1 in the QoS Control field, as defined in 9.2.4.5.3 and 11.2.3.6. This field remains set to 1 for any retransmissions of the same frame, and no more new frames are sent to this particular STA in the current SP.

NOTE 3—If a STA is awake at the start of a scheduled PSMP session, the operation of the More Data subfield in the Frame Control field and the TIM element are defined by the S-APSD rules in 11.2.3.5, 11.2.3.6, and 11.2.3.8.

A STA shall wake up at the start of the next PSMP frame if the More PSMP field is equal to 1 in the current PSMP frame, unless the STA has been permitted to return to sleep through the reception of a frame addressed to it with the EOSP subfield equal to 1 or the maximum SP interval has elapsed.

Within a PSMP sequence, a PPDU containing MPDUs addressed to a STA shall not start after the expiration of the STA's PSMP-DTT. A STA completes the reception of any PPDU that starts before the end of the PSMP-DTT. If no frames addressed to a STA begin within a PSMP-DTT, it can assume that no frame addressed to it will arrive during this PSMP sequence.

The STA shall be awake to receive at the start of the PSMP-DTT determined from a STA_INFO field that has the STA_INFO Type subfield equal to 2 and the AID field matching the STA's AID where the PSMP-DTT Duration subfield is not equal to 0.

11.2.3.12 TDLS peer power save mode

TDLS peer power save mode (TDLS peer PSM) is a power save mechanism that can be used between TDLS peer STAs, and which is based on a periodic wakeup schedule. A STA supports TDLS peer PSM if dot11TDLSPeerPSMActivated is true. A STA supporting this capability may indicate support through any TDLS Setup Request frame or TDLS Setup Response frame. A STA indicating this support shall signal this by setting the TDLS Peer PSM Support subfield in the Extended Capabilities element included in the TDLS Setup

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Request frame or TDLS Setup Response frame to 1. A station that signals support for this capability is capable of acting in both the TDLS peer PSM initiator and the TDLS peer PSM responder role.

A STA that intends to enter TDLS peer PSM (TDLS peer PSM initiator) shall send a TDLS Peer PSM Request frame to the TDLS peer STA (TDLS peer PSM responder), including a proposed periodic wakeup schedule. A TDLS Peer PSM Request frame shall not be transmitted to a STA that did not indicate support for TDLS peer PSM. When the TDLS peer PSM responder accepts the proposed wakeup schedule, it shall respond with a TDLS Peer PSM Response frame indicating status code SUCCESS. Otherwise, the TDLS peer PSM responder shall respond with a TDLS Peer PSM Response frame indicating the appropriate status code for rejecting the schedule. An alternative schedule shall be included in the TDLS Peer PSM Response frame when the status code is equal to TDLS_REJECTED_ALTERNATIVE_PROVIDED. The alternative schedule may be used by the TDLS peer PSM initiator to generate a new TDLS Peer PSM Request frame. After successfully transmitting or receiving a TDLS Peer PSM Response frame indicating status code SUCCESS, the TDLS peer PSM initiator and TDLS peer PSM responder have established a periodic wakeup schedule between them. The wakeup schedule remains valid until one of the following occurs:

— The TDLS direct link is torn down;
— The STAs explicitly update the existing wakeup schedule; or
— No MPDUs containing data have been exchanged for Idle Count consecutive Awake Windows.

A STA transmitting a TDLS Peer PSM Request frame shall remain in the awake state until it received the corresponding TDLS Peer PSM Response frame. A TDLS Peer PSM Request frame may be transmitted via the AP path or via the direct path (which is up to the implementer to decide). A TDLS Peer PSM Response frame shall be transmitted over the direct path.

The timing of the periodic schedule of the TDLS Peer PSM Awake Windows is based on the Offset field, the Interval field, the Awake Window Slots field, and the Maximum Awake Window Duration field of the Wakeup Schedule element that is contained in the TDLS Peer PSM Request frame that established TDLS peer PSM operation on the link.

Awake Windows begin at TSF values that satisfy the equation TSF mod Interval = Offset. The interval between the start of two successive Awake Windows is equal to the time in microseconds of the Interval field. The periodic wakeup schedule may be unrelated to the target beacon transmission time (TBTT) or the beacon interval.

Awake Windows end when the Awake Window Slot Counter reaches 0 or when the Maximum Awake Window Duration has been reached, whichever comes first.

The Awake Window Slot Counter counts down backoff slots that are determined using AIFS[AC_BE] in the same manner that normal backoff slots are determined according to 10.23.2.4.

The initial value of the Awake Window Slot Counter at the start of the Awake Window shall be equal to the value in the Awake Window Slots field of the Wakeup Schedule element that is contained in the TDLS Peer PSM Request frame that established TDLS peer PSM operation on the link.

The Awake Window Slot Counter begins counting at the beginning of the Awake Window and stops counting when it reaches 0.

A value of 0 in the Maximum Awake Window Duration field of the Wakeup Schedule element that is contained in the TDLS Peer PSM Request frame that established TDLS peer PSM operation on the link means that the end of the Awake Window duration is determined only by the Awake Window Slot Counter.

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A value of 0 in the Awake Window Slots field of the Wakeup Schedule element that is contained in the TDLS Peer PSM Request frame that established TDLS peer PSM operation on the link means that the duration of the Awake Window is determined only by the Maximum Awake Window Duration.

The Maximum Awake Window Duration field and the Awake Window Slots field shall not both be set to 0 in a TDLS Peer PSM Request frame.

The Awake Window Slots field in a TDLS Peer PSM Request frame should be set to a value that is larger than CWmin[AC_BE].

A TDLS peer PSM service period is a period of time during which one or more individually addressed frames are transmitted between two TDLS peer STAs when at least one STA employs TDLS peer PSM. A TDLS peer PSM service period may be initiated during an Awake Window. A TDLS peer STA in power save mode may enter a doze state when it has successfully transmitted to and received from the corresponding TDLS peer STA in power save mode a QoS frame with the EOSP subfield equal to 1, ending the TDLS peer PSM service period. A TDLS peer STA in power save mode may enter a doze state when it has received from the corresponding TDLS peer STA in active mode a QoS frame with the EOSP subfield equal to 1.

Either STA may update an existing schedule by initiating a TDLS Peer PSM Request/Response exchange. If the TDLS Peer PSM Response frame indicates status code SUCCESS, a new wakeup schedule is established for the TDLS direct link. Otherwise, the existing schedule still applies. The new schedule takes effect after the termination of the current TDLS peer PSM service period.

After the successful PSM setup, a STA informs its TDLS peer STA that it will enter power save mode per direct link by setting the Power Management subfield to 1 in an MPDU requiring immediate acknowledgment. The STA enters power save mode after successful transmission of the MPDU. The power save status on one direct link is independent of the power save status on other links (direct or with the AP) the STA may have.

If a TDLS peer STA enters power save mode when a wakeup schedule is active, it shall be awake at the beginning of each scheduled periodic Awake Window, and stay awake for the duration of the Awake Window or until the end of a TDLS peer PSM service period. Otherwise, it may enter a doze state, depending on the current requirements to be awake, imposed by other links. A TDLS peer STA that did not enter power save mode shall remain in the awake state.

When both TDLS peer STAs set the More Data Ack subfield in their QoS Capability element to 1, then the More Data subfield inside an Ack frame set to 0 shall have the same function as the EOSP subfield inside a QoS frame set to 1. Transmission of an Ack frame with the More Data subfield set to 0 under these conditions is equivalent to a successful transmission of a QoS frame with the EOSP subfield set to 1.

When waking up at the beginning of an Awake Window, if a STA has no buffered BU to send to a TDLS Peer STA that had the More Data Ack subfield in its QoS Capability element equal to 1 during the TDLS setup exchange, the TDLS STA may send a QoS Null frame with the EOSP subfield of the QoS Control field set to 1, and the More Data subfield of the Frame Control field set to 0. If the TDLS peer STA that is the recipient of this QoS Null frame also has no buffered BU to deliver either, and it had the More Data Ack subfield in its QoS Capability element equal to 1 during the TDLS setup exchange, then the TDLS peer STA shall respond with an Ack frame that has the More Data subfield set to 0. The STA may discard the QoS Null frame if it has not been successfully transmitted at the end of the Awake Window. Before the successful transmission of the QoS Null frame, if a Data or QoS Null frame with an EOSP subfield equal to 1 is received from the TDLS peer STA the STA may cancel the pending transmission of the QoS Null frame after the transmission of an Ack frame with the More Data subfield set to 0.

To keep track of the connectivity over the direct link and to maintain the wakeup schedule, a TDLS peer STA may start an acknowledged frame exchange at least once per Idle Count consecutive Awake Windows, as a keepalive. For instance a QoS Null frame may be used as a keepalive frame. When a TDLS Peer PSM

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Response frame was successfully transmitted or received and no subsequent TDLS peer PSM service period has started for Idle Count consecutive wakeup periods, a TDLS peer STA shall delete the wakeup schedule for this link, which means that the related periodic wakeup no longer occurs (i.e., the TDLS peer STA no longer has to wake up during this period) and that a wakeup schedule no longer exists for this link. When traffic arrives at a TDLS peer STA in TDLS peer PSM mode for a link with no existing wakeup schedule, the STA shall send a TDLS Peer PSM Request frame through the AP path to the TDLS peer STA to activate a new wakeup schedule. When both TDLS peer STAs enter active mode while a wakeup schedule is active, no more TDLS peer PSM service periods will occur, causing the wakeup schedule to be deleted.

If a TDLS peer STA does not receive an acknowledgment to an individually addressed QoS frame sent with the EOSP subfield equal to 1 that terminates a TDLS peer PSM service period, it shall retransmit that frame at least once within the same service period, subject to the applicable retry or lifetime limit. The maximum number of retransmissions within the same service period is the lesser of the maximum retry limit and dot11TDLSPeerSTAMissingAckRetryLimit. If an acknowledgment to the retransmission of this last frame in the same service period is not received, the TDLS peer STA may wait until the next Awake Window to further retransmit that frame, subject to its applicable retry or lifetime limit. When the TDLS peer STA has transmitted an individually addressed frame that terminates a TDLS peer PSM service period then, except for retransmissions of that frame, the TDLS peer STA shall not transmit any more frames to the TDLS peer STA until the next Awake Window.

A TDLS peer STA that has an active wakeup schedule shall not decrement a backoff count outside the Awake Windows, if that backoff precedes a frame that is destined for transmission on the related TDLS direct link.

At the start of an Awake Window, the backoff procedure shall be invoked at an EDCAF if there is a frame available for transmission at that EDCAF, and the backoff counter for that EDCAF has been 0 for at least one backoff slot.

Outside of its Awake Windows, and during Awake Windows when on the base channel, a TDLS peer STA can engage in communications with the AP.

11.2.3.13 TDLS peer U-APSD (TPU)

11.2.3.13.1 General

A STA supports the TPU buffer STA function if dot11TDLSPeerUAPSDBufferSTAActivated is true. dot11TDLSPeerUAPSDBufferSTAActivated is false in a non-QoS STA. A STA supporting this capability may indicate support through any TDLS Setup Request frame or TDLS Setup Response frame. A STA indicates support by setting the TPU Buffer STA Support subfield in the Extended Capabilities element included in the TDLS Setup Request frame or TDLS Setup Response frame to 1. Support for the TPU buffer STA function means that the STA has the capability to buffer BUs destined to the TPU sleep STA, and to deliver them during unscheduled service periods.

To operate as the TPU sleep STA in TPU, a STA shall configure its TPU capable TDLS peer STA by setting one or more U-APSD Flag subfields inside the QoS Info subfield of the QoS Capability element carried in a TDLS Setup Response frame to 1, or by setting one or more U-APSD Flag subfields inside the QoS Info subfield of the EDCA Parameter Set element carried in a TDLS Setup Confirm frame to 1.

A STA that configured TPU at a TDLS peer STA enters power save mode on a TDLS direct link after the successful transmission to the TDLS peer STA over the direct link of an acknowledged MPDU with the Power Management subfield equal to 1. The STA that transmitted the frame with the Power Management subfield equal to 1 is then referred to as a *TPU sleep STA*. The STA that received the frame with the Power Management subfield equal to 1 is referred to as a *TPU buffer STA*. A TPU sleep STA may be a TPU buffer STA at the same time and on the same link, by sending a frame to the TDLS peer STA with the Power Management subfield of the Frame Control field set to 1 (this transmission will be preceded by the

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transmission of a Peer Traffic Indication frame and the subsequent receipt of a trigger frame that starts a service period). The power save status on one direct link is independent of the power save status on other links (direct or with the AP) the STA may have.

The procedure to trigger and terminate an unscheduled SP between TPU buffer STA and a TPU sleep STA are described in 11.2.3.5 and 11.2.3.6, where the TPU buffer STA shall take the role of the AP and the TPU sleep STA shall take the role of the non-AP STA using U-APSD, except that a frame with the EOSP subfield equal to 1 shall not act as a trigger frame.

11.2.3.13.2 TPU at the TPU buffer STA

BUs at a TPU buffer STA destined for a TPU sleep STA shall be temporarily buffered at the TPU buffer STA. The algorithm to manage this buffering is beyond the scope of this standard, except that the TPU buffer STA shall preserve the order of buffered BUs on a per-TID, per-STA basis.

A TPU buffer STA shall transmit an individually addressed TDLS Peer Traffic Indication frame to a TPU sleep STA, through the AP, if and only if all of the following conditions are met:

— A BU destined for a TPU sleep STA was placed into a buffer at the TPU buffer STA;
— The buffer into which the BU was placed contained no other frames with the same RA; and
— One or more periods of dot11TDLSPeerUAPSDIndicationWindow beacon intervals have expired after the last service period.

The TDLS Peer Traffic Indication frame shall be transmitted through the AP path.

The transmitted TDLS Peer Traffic Indication frame shall indicate the nonempty AC(s), by setting the corresponding AC Traffic Available subfield of the TDLS Peer Traffic Indication frame to 1.

A PTI Control element may be included in the TDLS Peer Traffic Indication frame, to allow the TPU sleep STA to not start a service period when the indicated traffic has already been received by the TPU sleep STA.

The TID field contained in the PTI Control element (if included) shall be set to the TID of the latest MPDU that has been transmitted over the TDLS direct link to the TPU sleep STA that is the destination of the TDLS Peer Traffic Indication frame that contains the PTI Control element.

The Sequence Control field contained in the PTI Control element (if included) shall be set to the sequence number of the latest MPDU that has been transmitted over the TDLS direct link to the TPU sleep STA that is the destination of the TDLS Peer Traffic Indication frame that contains the PTI Control element.

After transmitting a TDLS Peer Traffic Indication frame without a PTI Control element, the TPU buffer STA shall stay awake at least until the corresponding or a subsequent TDLS Peer Traffic Response frame is received.

After transmitting a TDLS Peer Traffic Indication frame without a PTI Control element, the TPU buffer STA shall stay awake at least until the MPDU following the MPDU indicated in the Sequence Control field of the PTI Control element is successfully transmitted.

When no corresponding TDLS Peer Traffic Response frame has been received within dot11TDLSResponseTimeout after sending a TDLS Peer Traffic Indication frame, the STA shall tear down the direct link.

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11.2.3.13.3 TPU at the TPU sleep STA

When a TPU sleep STA receives a TDLS Peer Traffic Indication frame without a PTI Control element, the TPU sleep STA shall initiate a service period with the TPU buffer STA during which it shall transmit at least a TDLS Peer Traffic Response frame. The TDLS Peer Traffic Response frame shall echo the values of the Dialog Token and Link Identifier fields from the corresponding TDLS Peer Traffic Indication frame. The TDLS Peer Traffic Response frame shall be sent via the direct path.

When a TPU sleep STA receives a TDLS Peer Traffic Indication frame with a PTI Control element, and the TPU sleep STA has not received from the TPU buffer STA the MPDU following the MPDU that is indicated in the TDLS Peer Traffic Indication frame, the TPU sleep STA shall initiate a service period with the TPU buffer STA to retrieve the buffered traffic for the AC(s) for which no unscheduled SP is currently active.

11.2.3.14 FMS power management

11.2.3.14.1 General

Implementation of FMS is optional for a WNM STA. A STA with dot11FMSActivated equal to true shall support FMS and shall set to 1 the FMS field of the Extended Capabilities elements that it transmits.

11.2.3.14.2 FMS general procedures

When dot11FMSActivated is true at the AP, the AP shall include the FMS Descriptor element in every Beacon frame. The FMS Descriptor indicates the FMS group addressed buffered BUs at the AP. If there are no buffered BUs for FMS streams accepted by the AP, the AP shall set the Length field in the FMS Descriptor element to 1. The AP shall include the FMS Descriptor element for a nontransmitted BSSID in the corresponding Nontransmitted BSSID Profile subelement carried in the Multiple BSSID element sent in a Beacon frame.

When dot11FMSActivated is true at the AP, the AP shall support from one to eight different FMS stream delivery intervals for any number of FMS streams. Corresponding to these eight delivery intervals are eight FMS counters. More than one FMSID may have the same delivery interval and therefore will share the same FMS counter. An FMS counter corresponds to each unique delivery interval of one or more FMS streams.

Each FMS counter decrements once per DTIM beacon and when the FMS counter reaches 0, buffered group addressed BUs assigned to that particular interval are scheduled for delivery immediately following the next Beacon frame containing the DTIM transmission. After transmission of the buffered group addressed BUs, the AP shall reset the FMS counter to the delivery interval for the FMS streams associated with that FMS counter.

A non-AP STA that does not use FMS wakes every DTIM interval and follows group addressed BU reception rules as defined in 11.2.3.7.

A STA that supports FMS shall be capable of supporting a delivery interval of 1 for any stream.

11.2.3.14.3 FMS Request procedures

A non-AP STA that supports FMS may request use of FMS by sending an FMS Request frame or Reassociation Request frame that includes one or more FMS Request elements to an AP that supports FMS. Each FMS Request element includes one or more FMS subelements. Each FMS subelement identifies an FMS stream, the requested delivery interval and the maximum delivery interval for that stream. The FMS delivery interval shall be an integer multiple of the DTIM period.

Upon reception of an FMS Request frame or Reassociation Request frame, the AP shall transmit a corresponding single FMS Response frame or Reassociation Response frame that contains a corresponding

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FMS Response element for each FMS Request element in the same order received. Each FMS Response element shall contain an FMS Status subelement and zero or more other subelements drawn from Table 9-219 that corresponds to each FMS subelement in the FMS Request element, in the same order.

For each FMS subelement, the following rules apply:

If the AP accepts the FMS subelement and the requested delivery interval, the Element Status in the corresponding FMS Status subelement shall be set to "Accept" and the FMSID is assigned to a nonzero value. In addition:

- If the FMS stream identified in the FMS subelement matches a delivery interval already in use at the AP, the AP shall assign the FMS stream to use the FMS Counter ID assigned for that delivery interval.
- When an FMS stream is accepted by the AP, the Current Count value for that FMS stream is decremented by 1 for each DTIM Beacon frame in which the Current Count field appears.
- The AP may reschedule transmission of the FMS stream identified by an FMSID to align the transmission time of the FMS stream to the transmission time of other FMS streams that the STA is already receiving at the same delivery interval. The AP has the following two options:
  - Notify the STAs using that FMS stream. The AP shall keep the nonzero Current Count value the same across two consecutive Beacon frames in which the Current Count field appears. The algorithm by which the AP chooses to align or offset the different FMS counters is unspecified.
  - Transmit an unsolicited FMS Response frame to the group address included in the original FMS Response frame for the stream with the updated Delivery Interval field when the Current Count field value reaches 0. Since the AP transmits this FMS Response frame as a group addressed frame, the frame will be scheduled for delivery at the appropriate DTIM interval when all non-AP STAs are awake to receive the frame.
- An AP may terminate the use of FMS and resume default (non-FMS) transmission rules for any FMS stream identified by FMSID for any reason. To terminate the FMS stream, the AP shall send an unsolicited FMS Response frame to the group address included in the original FMS Response frame with Delivery Interval set to 0 and the Element Status in the FMS Status subelement set to one of "Terminate, due to AP policy change", "Terminate, due to lack of resources of AP," and "Terminate, due to other FMS stream with higher priority".
- If the FMS subelement contained a nonzero delivery interval and the non-AP STA specified a maximum delivery interval as part of the FMS request, the AP shall not modify the delivery interval for the stream greater than the maximum delivery interval specified by the non-AP STA.
- An AP shall transmit MSDUs belonging to the same FMSID in the same order that they were received at the MAC Data SAP. MSDUs belonging to the different FMSIDs are transmitted by the AP at the appropriate DTIM in the order received at the MAC data SAP based on the interval configured for the FMS stream.

If the AP denies the FMS subelement for any reason, including requested delivery interval, maximum delivery interval and TCLAS, the Element Status in the corresponding FMS Status subelement shall be set to one of "Deny, due to request format error or ambiguous classifier", "Deny, due to lack of resources on AP", "Deny, due to requested classifier(s) matching 2 or more existing streams on different intervals," "Deny, by policy, requested stream or filter is not permitted to participate in the service", and "Deny, reason unspecified".

If the AP selects an alternate delivery interval or alternate maximum delivery interval from the value specified in the FMS Request, the Element Status field in the corresponding FMS Status subelement shall be set to one of "Alternate proposed, due to existing stream with different delivery interval", "Alternate proposed, due to policy limits on AP", "Alternate proposed, because the AP changed the delivery interval", and "Alternate proposed, because the AP changed the maximum delivery interval" and the FMS subelement shall indicate the AP selected value(s).

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To terminate the use of FMS for an FMS stream identified by FMSID, the non-AP STA shall transmit an FMS Request frame with an FMS Request element and FMS subelement with the FMSID matching the FMS stream and the delivery interval set to 0.

The AP shall respond to a malformed FMS Request frame or Reassociation Request frame with an FMS Response frame or Reassociation Response frame that denies all FMS Request elements by including an FMS Status code "Deny, due to request format error or ambiguous classifier" in the Element Status field in each FMS Status subelement in the FMS Response element.

11.2.3.14.4 FMS Response procedures

Upon reception of an FMS Response element in a frame that has a value in Address 1 that matches its MAC address or that is a group address corresponding to a group of which it is a member and that was transmitted by the AP with which it is associated, a non-AP STA that supports FMS shall use the following procedures, based on the value of the Element Status value in the FMS Status subelement in the received FMS Response element.

- If the Element Status value in the FMS Status subelement is "Accept":
  - The AP has accepted the FMS subelement contained within the FMS Request element. If the FMS Request element specified a nonzero delivery interval, the AP will deliver the requested streams at the delivery interval as specified by the non-AP STA in the FMS Request element.
  - After receiving the FMS Response element, the non-AP STA shall be awake for the next DTIM beacon so that the non-AP STA can synchronize with the FMS Current Count for the requested FMS stream. Once synchronized with the FMS Current Count, the non-AP STA need not wake up at every DTIM interval to receive group addressed BUs.
- If the Element Status value in the FMS Status subelement is one of "Deny, due to request format error or ambiguous classifier", "Deny, due to lack of resources on AP", "Deny, due to requested classifier(s) matching 2 or more existing streams on different intervals", "Deny, by policy, requested stream or filter is not permitted to participate in the service", and "Deny, reason unspecified":
  - The AP does not deliver the requested streams at the delivery interval as specified by the non-AP STA in the FMS Request element. The AP delivers the requested stream at every DTIM interval.
- If the Element Status value in the FMS Status subelement is one of "Alternate proposed, due to existing stream with different delivery interval", "Alternate proposed, due to policy limits on AP", "Alternate proposed, because the AP changed the delivery interval", and "Alternate proposed, because the AP changed the maximum delivery interval":
  - The AP does not deliver the requested streams at the delivery interval and maximum delivery interval as specified by the non-AP STA in the FMS Request element. The FMS Status subelement specifies a delivery interval and a maximum delivery interval that the AP is willing to accept for the specified streams if the non-AP STA sends another FMS Request with that delivery interval and maximum delivery interval specified.
  - The non-AP STA may submit a new FMS Request that includes the delivery interval value received from the AP. If the AP accepts this new FMS Request, it shall respond as described in 11.2.3.14.2.
- If the Element Status value in the FMS Status subelement is "Alternate proposed, because the AP is unable to provide requested TCLAS-based classifiers":
  - The AP does not deliver the requested streams at the delivery interval as specified by the non-AP STA in the FMS Request element. The TCLAS element(s) or TCLAS Processing element in the TCLAS Status subelement contains one or more fields or subfields whose values have been modified by the AP. The AP may include fewer TCLAS elements in the FMS Response element than were present in the request; when the AP's response includes a single TCLAS element, it does not include a TCLAS Processing element. If the AP changes a TCLAS element's Classifier Type field in the FMS Response element but is unable to suggest a value

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for the Classifier Mask field, it shall set that field to 0. If the AP changes a TCLAS element's Classifier Type field or Classifier Mask field in the FMS Response element but is unable to suggest values for one or more Classifier Parameter subfields, it shall set those fields to 0.

  - A non-AP STA receiving a modified TCLAS element having a Classifier Mask field equal to 0 or Classifier Parameter subfields equal to 0 shall interpret these values as meaning that no suggested value has been provided by the AP.

- If the Element Status value in the FMS Status subelement is one of "Terminate, due to AP policy change", "Terminate, due to lack of resources of AP", and "Terminate, due to other FMS stream with higher priority":
  - The AP will terminate the use of FMS transmission rules for any FMS stream identified by FMSID. If the AP terminates the usage of FMS for a particular stream, the stream is transmitted at DTIM interval.
  - The non-AP STA shall wake up at every DTIM interval to receive group addressed BUs after receiving the FMS Response element.

11.2.3.15 TIM Broadcast

Implementation of TIM Broadcast is optional for a WNM STA. A STA that implements TIM Broadcast has dot11TIMBroadcastImplemented equal to true. When dot11TIMBroadcastImplemented is true, dot11WirelessManagementImplemented shall be true. A STA with dot11TIMBroadcastActivated equal to true shall support TIM Broadcast and shall set to 1 the TIM Broadcast field of the Extended Capabilities elements that it transmits. This subclause describes TIM broadcast procedures for STAs with dot11TIMBroadcastActivated equal to true.

TIM frames have shorter duration than Beacon frames and are potentially transmitted at a higher data rate. TIM Broadcast allows a non-AP STA to receive a TIM element without receiving a Beacon frame that may reduce the required wake time in a power save mode. The shorter receive time reduces the power consumption for non-AP STAs in a power save mode. The shorter receive time may reduce the power consumption for stations in a standby mode.

A non-AP STA may activate the TIM broadcast service by including a TIM Broadcast Request element in a TIM Broadcast Request frame, Association Request frame or Reassociation Request frame that is transmitted to the AP, which specifies the requested interval between TIM frame transmissions (the TIM broadcast interval). On receipt of a properly formatted TIM Broadcast Request element in a TIM Broadcast Request frame, Association Request frame or Reassociation Request frame, the AP shall include a TIM Broadcast Response element in the corresponding TIM Broadcast Response frame, Association Response frame or Reassociation Response frame, when dot11TIMBroadcastActivated is true. When the requested TIM broadcast interval is acceptable, the AP shall include a TIM Broadcast Response element specifying the requested TIM broadcast interval and a Status field indicating "Accept" when noTSF timestamp is present in the TIM frames, or "Accept, timestamp present in TIM frames" when a TSF timestamp is present in the TIM frames. When the AP overrides the requested TIM broadcast interval, it shall include a TIM Broadcast Response element specifying a different TIM broadcast interval and a Status field indicating "Overridden" when no TSF timestamp is present in the TIM frames, or "Overridden, timestamp present in TIM frames" when a TSF timestamp is present in the TIM frames, and include in the TIM Broadcast Response element the smallest TIM broadcast interval that is currently active. Otherwise, the AP shall include a TIM Broadcast Response element with a Status field indicating "Denied." The Status field in a TIM Broadcast Response element that is included in an Association Response frame or Reassociation Response frame has implications only for the TIM Broadcast negotiation.

NOTE 1—The STA might ignore the TIM Broadcast Interval field in the TIM Broadcast Response element if the Status field indicates "Accept" or "Accept, timestamp present in TIM frames", because the TIM broadcast interval is the requested one.

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If the AP accepted at least one TIM Broadcast Request with a nonzero TIM Broadcast Interval field, and at least one non-AP STA in PS mode still associated with the AP received in its latest TIM Broadcast Response a status field value equal to 0 (Accepted) in response to a TIM Broadcast Request with a nonzero TIM Broadcast Interval field, the AP shall transmit one or two TIM frames per TIM Broadcast Interval. The AP shall not transmit TIM frames otherwise. When TIM broadcast intervals overlap, a transmitted TIM frame serves both intervals and does not need to be duplicated.

If the AP transmits two TIM frames per TIM Broadcast Interval, the AP shall transmit the high data rate TIM frame first, followed by the low data rate TIM frame.

The AP shall transmit the low data rate TIM frame at the same data rate or MCS as the Beacon frame. The AP shall transmit the high data rate TIM frame at a higher data rate or using an MCS that corresponds to a higher data rate. For Clause 18 and Clause 19 PHYs, if the Beacon frame is transmitted using ERP-DSSS/CCK, the AP shall transmit the high data rate TIM frame and shall transmit it using ERP-OFDM. Otherwise, transmitting the high data rate TIM frame is optional. If the high data rate TIM is not transmitted, the AP shall set the High Rate TIM Rate field to 0 in the TIM Broadcast Response element.

The TIM Broadcast Interval field from the latest received TIM Broadcast Response element (N_TBI) together with dot11BeaconPeriod define a series of target TIM transmission times (TTTTs) N_TBI × dot11BeaconPeriod TUs apart. Time 0 is a TTTT. A non-AP STA may use the information in the High Rate TIM Rate and Low Rate TIM Rate fields to determine which of the two TIM frames they will be receiving. The first TIM frame per TIM broadcast interval is scheduled to be transmitted at the TTTT plus the indicated TIM broadcast offset. The offset may have a negative value that allows the TIM frame(s) to be transmitted before the TBTT. The value of the offset shall not be changed as long as an associated non-AP STA is using the TIM broadcast service.

The AP should accept new TIM broadcast interval requests if this implies transmitting TIM frames more frequently. For instance, if the AP currently transmits TIM frames every fourth beacon period and it receives a new request for every 3 beacon periods, then the AP should accept the new request and transmit TIM frames both every 3 and every 4 beacon periods. The AP may override incongruent requests once available resources (such as counters) have been depleted. An incongruent request is a request that contains an interval that is not an integer divide or a multiple of a currently active TIM Broadcast interval.

The AP shall accept a TIM broadcast interval of 1.

NOTE 2—The DTIM Period subfield in a TIM element in a TIM frame indicates the period for DTIM Beacon frames and is unrelated to any TIM Broadcast Interval(s).

The AP shall increase the value (modulo 256) of the Check Beacon field in the next transmitted TIM frame(s) when a critical update occurs to any of the elements inside the Beacon frame. The following events shall classify as a critical update:

a) Inclusion of a Channel Switch Announcement element
b) Inclusion of an Extended Channel Switch Announcement element
c) Modification of the EDCA parameters element
d) Inclusion of a Quiet element
e) Modification of the DSSS Parameter Set
f) Modification of the HT Operation element
g) Inclusion of a Wide Bandwidth Channel Switch element
h) Inclusion of a Channel Switch Wrapper element
i) Inclusion of an Operating Mode Notification element

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j) Inclusion of a Quiet Channel element
k) Modification of the VHT Operation element

An AP may classify other changes in the Beacon frame as critical updates.

The non-AP STA shall attempt to receive the next Beacon frame when it receives a Check Beacon field that contains a value that is different from the previously received Check Beacon field.

The Address 1 field of the TIM frame shall be set to the broadcast address.

In a multiple BSSID set, the APs that do not correspond to the transmitted BSSID shall not transmit a TIM frame.

11.2.3.16 WNM sleep mode

11.2.3.16.1 WNM sleep mode capability

Implementation of the WNM sleep mode capability is optional for a WNM STA. A STA that implements WNM sleep mode has dot11WNMSleepModeImplemented equal to true. When dot11WNMSleepModeImplemented is true, dot11WirelessManagementImplemented shall be true. A STA where dot11WNMSleepModeActivated is true is defined as a STA that supports WNM sleep mode. A STA supporting WNM sleep mode shall set the WNM Sleep Mode field of the Extended Capabilities element to 1. When dot11WNMSleepModeActivated is true, dot11TFSActivated shall be true.

A STA in which dot11WNMSleepModeActivated is true may send a WNM Sleep Mode Request or WNM Sleep Mode Response frame to a STA within the same infrastructure BSS whose last received Extended Capabilities element contained a value of 1 for the WNM Sleep Mode field in the Extended Capabilities field. WNM sleep mode is a service that may be provided by an AP to its associated STAs. The WNM sleep mode is not supported in an IBSS.

To prevent key reinstallation attacks, a non-AP STA in which dot11WNMSleepModeActivated is true shall maintain a copy of the most recent GTK, most recent IGTK and most recent BIGTK installed when exiting WNM sleep mode and shall not install a GTK, IGTK or BIGTK when the key to be set upon exiting WNM sleep mode matches either of the two maintained keys (see 6.3.19).

WNM sleep mode enables an extended power save mode for non-AP STAs in which a non-AP STA need not listen for every DTIM Beacon frame, and need not perform GTK/IGTK/BIGTK updates. A non-AP STA can sleep for extended periods as indicated by the WNM Sleep Interval field of the WNM Sleep Mode element, which is present in WNM Sleep Mode Request frames transmitted by the non-AP STA.

11.2.3.16.2 WNM sleep mode non-AP STA operation

To use the WNM sleep mode service, the non-AP STA's SME shall issue an MLME-SLEEPMODE.request primitive to send a WNM Sleep Mode Request frame. The MLME-SLEEPMODE.request primitive shall include a valid SleepMode parameter with a WNM Sleep Mode element. The Action Type field in the WNM Sleep Mode element shall be set to "Enter WNM sleep mode" and the WNM Sleep Interval field shall be included. The WNM Sleep Interval field shall be less than the BSS max idle period (see 11.21.13). The MLME-SLEEPMODE.request primitive shall also include a valid TFSRequest parameter as defined in the TFS Request element that the AP shall use as triggers to set the STA's TIM bit.

When a traffic filter for group addressed frames is enabled at the AP, the STA may request a notification frame (see 11.21.12.2) be sent when requesting the establishment of the traffic filtering agreement.

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On receiving a WNM Sleep Mode Response frame with Action Type field in the WNM Sleep Mode element set to "Exit WNM sleep mode", if dot11RSNAOperatingChannelValidationActivated is true and the AP's RSNE indicated OCVC capability, the STA shall validate the OCI information by ensuring that all the following are true:

— OCI element is present
— Channel information in the OCI matches current operating channel parameters (see 12.2.9)

Otherwise, the STA shall discard the frame.

The receipt of an MLME-SLEEPMODE.confirm primitive with a valid SleepMode parameter indicates to the STA's SME that the AP has processed the corresponding WNM Sleep Mode Request frame. The content of the WNM sleep mode parameter in the WNM Sleep Mode Response frame provides the status of WNM Sleep Mode elements processed by the AP. The non-AP STA shall delete the GTKSA if the response indicates success. If RSN is used with management frame protection, the non-AP STA shall delete the IGTKSA if the response indicates success. If RSN is used with beacon frame protection, the non-AP STA shall delete the BIGTKSA if the response indicates success.

While in WNM sleep mode, the non-AP STA need not wake up every DTIM interval for group addressed frames.

The STA wakes up at intervals not longer than the value indicated by the WNM Sleep Interval field to check whether the corresponding TIM bit is set or group addressed traffic is pending. The non-AP STA does not participate in GTK/IGTK/BIGTK updates.

To exit WNM sleep mode, the non-AP STA's SME shall issue an MLME-SLEEPMODE.request primitive to send a WNM Sleep Mode Request frame with an Action Type field in the WNM Sleep Mode element set to "Exit WNM sleep mode". If dot11RSNAOperatingChannelValidationActivated is true and the AP's RSNE indicated OCVC capability, the WNM Sleep Mode Request frame shall include an OCI element.

If a STA receives an unsolicited WNM Sleep Mode Response frame with the WNM Sleep Mode Response status value (see Table 9-226) equal to 1, and the frame is not discarded due to OCI validation, the STA exits WNM sleep mode. If the STA does not receive a WNM Sleep Mode Response frame after sending a WNM Sleep Mode Request frame, it shall issue an MLME-DEAUTHENTICATE.request primitive to deauthenticate from the current AP.

11.2.3.16.3 WNM sleep mode AP operation

On receiving a WNM Sleep Mode Request frame with Action Type field in the WNM Sleep Mode element set to "Exit WNM sleep mode", if dot11RSNAOperatingChannelValidationActivated is true and the non-AP STA's RSNE indicated OCVC capability, the AP shall validate the OCI information by ensuring that all the following are true:

— OCI element is present
— Channel information in the OCI fields matches current operating channel parameters (see 12.2.9)

Otherwise, the AP shall discard the frame.

When an AP's SME receives an MLME-SLEEPMODE.indication primitive with a valid SleepMode parameter and an Action Type in the WNM Sleep Mode element of "Enter WNM sleep mode" it shall issue an MLME-SLEEPMODE.response primitive with SleepMode parameters indicating the status of the request. The Action Type field of the WNM Sleep Mode element in the WNM Sleep Mode Response frame shall be set to "Enter WNM sleep mode".

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When WNM sleep mode is enabled for an associated STA, the AP shall stop sending all individually addressed MPDUs to the non-AP STA. The AP may disassociate or deauthenticate the STA at any time for any reason while the non-AP STA is in WNM sleep mode. An AP shall perform the TFS AP operation, as specified in 11.21.12 for non-AP STAs for which it has received TFS Request elements. The AP shall set the TIM bit corresponding to the AID of the associated STA for which the AP has queued either a TFS Notify frame or matching frame. An AP shall not perform GTK/IGTK/BIGTK updates for the STAs in WNM sleep mode.

When an AP's SME receives an MLME-SLEEPMODE.indication primitive with a valid SleepMode parameter and an Action Type in the WNM Sleep Mode element of "Exit WNM sleep mode", if the frame is not discarded due to OCI validation, the AP shall disable WNM sleep mode service for the requesting STA, and the AP's SME shall issue an MLME-SLEEPMODE.response primitive with a SleepMode parameter indicating the status of the associated request. When all traffic filter sets established for a STA are deleted upon frame matches, the AP shall also disable the WNM sleep mode service and transmit to the STA an unsolicited WNM Sleep Mode Response frame with the WNM Sleep Mode Response status value (see Table 9-226) set to 1. When an AP sends a WNM Sleep Mode Response frame with Action Type field in the WNM Sleep Mode element set to "Exit WNM sleep mode", if dot11RSNAOperatingChannelValidationActivated is true and the non-AP STA's RSNE indicated OCVC capability, the WNM Sleep Mode Response frame shall include an OCI element.

If RSN is used with management frame protection and a valid PTK is configured for the STA, the current GTK, IGTK, and BIGTK shall be included in the WNM Sleep Mode Response frame. If a GTK/IGTK/BIGTK update is in progress, the pending GTK, IGTK, and BIGTK shall be included in the WNM Sleep Mode Response frame. If RSN is used without management frame protection and a valid PTK is configured for the STA, the current GTK shall be sent to the STA using a group key handshake (see 12.7.7) immediately following the WNM Sleep Mode Response frame.

11.2.3.17 VHT TXOP power save

A VHT AP supports the operation of non-AP VHT STAs in TXOP power save mode in a BSS when dot11VHTTXOPPowerSaveOptionImplemented is true. Non-AP VHT STAs that are in active mode and have dot11VHTTXOPPowerSaveOptionImplemented equal to true operate in TXOP power save mode. A STA that has dot11VHTTXOPPowerSaveOptionImplemented equal to true shall set the TXOP PS field in the VHT Capabilities element to 1; otherwise, the STA shall set the field to 0. A VHT AP may allow non-AP VHT STAs in TXOP power save mode to enter the doze state during a TXOP, which the AP does by transmitting a VHT PPDU with the TXVECTOR parameter TXOP_PS_NOT_ALLOWED set to 0. The value of this parameter in the TXVECTOR of all VHT PPDUs transmitted by the VHT AP may be changed from 1 to 0 during the TXOP to enable TXOP power save mode for the remainder of the TXOP. The value of this parameter in the TXVECTOR of all VHT PPDUs transmitted by VHT AP shall not be changed from 0 to 1 during the TXOP. If dot11VHTTXOPPowerSaveOptionImplemented at VHT AP is false then the VHT AP shall set the TXOP_PS_NOT_ALLOWED to 1 in the TXVECTOR of the frames with FORMAT VHT.

If the AP allows non-AP VHT STAs to enter doze state during a TXOP, then a non-AP VHT STA that is in TXOP power save mode may enter the doze state until the end of that TXOP when one of the following conditions is met:

- On receipt of a VHT MU PPDU, the STA determines that it is not a member of the group indicated by the RXVECTOR parameter GROUP_ID.
- On receipt of an SU PPDU, the STA determines that the RXVECTOR parameter PARTIAL_AID is not equal to 0 nor does it match the STA's partial AID.
- The STA finds that the PARTIAL_AID in the RXVECTOR matches its partial AID but the RA in the MAC header of the corresponding frame that is received correctly does not match the MAC address of the STA.
- The STA receives a frame with an RXVECTOR parameter NUM_STS equal to 0 if it is a member of group indicated by RXVECTOR GROUP_ID.

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— In a received VHT NDP Announcement frame, the STA finds that the RXVECTOR parameter PARTIAL_AID is 0 and the AID in the STA Info field is not its AID.
— The STA receives a QoS Data frame intended for it with the More Data subfield equal to 0 and No Ack ack policy or sends an acknowledgment if the ack policy is not No Ack.

The VHT AP shall include a nav-set sequence (e.g., RTS/CTS) (see G.4 at the beginning of such a TXOP with the Duration/ID value set to the remainder of the TXOP duration. A VHT AP shall not transmit frames to a non-AP VHT STA that has been allowed to enter doze state according to the conditions above for the remainder of the TXOP.

NOTE 1—A VHT AP does not transmit VHT SU PPDUs in the current TXOP if the AP has already transmitted a VHT PPDU with the TXVECTOR parameter TXOP_PS_NOT_ALLOWED set to 0 in the same TXOP and does not want the STAs that are in awake state to enter the doze state.

If a VHT AP truncates the TXOP in which it allowed STAs to enter doze state, then the VHT AP shall not transmit frames to the STAs that were allowed to enter the doze state until the NAV set at the start of the TXOP has expired.

Under all of the following conditions:

— An AP transmitted a PPDU;
— The PPDU contains individually addressed frame that contains all or part of an MSDU, A-MSDU or MMPDU;
— The frame is addressed to a non-AP VHT STA that is in TXOP power save mode;
— The frame's More Data subfield is 0;
— The transmitted PPDU's TXVECTOR parameter TXOP_PS_NOT_ALLOWED is 0;
— The AP did not receive an acknowledgment to this transmission;

then the AP shall retransmit that frame one or more times within the same TXOP, subject to applicable transmission restrictions. These restrictions include retry and lifetime limits, the TXOP limit and the rules on TXOP sharing (see 10.23.2.7). If an acknowledgment to the retransmission of this last frame in the same TXOP is not received, it may wait until the next TXOP to further retransmit that frame, subject to its applicable retry or lifetime limit.

NOTE 2—An AP that receives from a VHT STA in TXOP power save mode a BlockAck frame that is a response to an A-MPDU containing MPDUs with the More Data subfield equal to 0 cannot expect to receive a response to subsequent MPDUs retransmitted in the same TXOP because the VHT STA might be in the doze state.

A VHT STA that is in TXOP power save mode and has entered doze state shall continue to operate its NAV during doze state and shall transition into awake state on the expiration of the NAV.

NOTE 3—The STA can contend for access to the medium immediately on the expiration of the NAV.

11.2.3.18 AP power management

This subclause describes AP power management procedure for an S1G AP.

An AP with dot11APPMActivated equal to false or not present shall operate in the Active mode. An AP with dot11APPMActivated equal to true may operate in the following Power Management modes:

— Active
— Power save

An AP in active mode shall be in awake state and may receive frames at any time.

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An AP with dot11APPMActivated equal to true in Power Save mode may be in any of the following two power states:

— Awake
— Doze

The AP with dot11APPMActivated equal to true may indicate that it is operating in Power Save mode by either:

— Setting the AP PM bit in the Frame Control field of the S1G Beacon frame to 1
— Including one or more RPS elements in the S1G Beacon frame that indicate AP PM RAWs (i.e., with the RAW Assignment Type equal to Simplex RAW and RAW Type Options equal to 0)

The AP shall operate in active mode during a beacon interval or short beacon interval if the AP PM subfield in the S1G Beacon frame transmitted at the TBTT or TSBTT is equal to 0. Similarly, the AP shall operate in active mode during one or more RAWs defined by an RPS element with the RAW Assignment type equal to generic RAW, sounding RAW, triggering frame RAW or simplex RAW with RAW Type Options equal to 1 or 2.

An AP that transmits an S1G Beacon frame with AP PM subfield equal to 1 may be in doze state at any time until the next TBTT or TSBTT, except that it shall be in awake state during any of the following intervals of time:

— Any RAW or PRAW intervals that are set up according to 10.23.5, except for RAWs that are defined by any RPS element with RAW Assignment Type equal to simplex RAW and RAW Type Options equal to 0
— Any TWT SPs that are negotiated according to 10.47

An AP that transmits an S1G Beacon frame whose AP PM subfield value is 1 should include an RPS element in the S1G Beacon frame that includes an omni RAW during which all STAs are allowed to access (i.e., the RPS element contains a RAW Assignment subfield with RAW Type field equal to 2 and RAW Type Options subfield equal to 2). The omni RAW may be used for association of new STAs. The AP that does not include the RPS element with the omni RAW, shall be awake for an amount of time not less than $bi - mad$ immediately following the S1G Beacon frame, where *bi* is the beacon interval if dot11ShortBeaconInterval is false and is the short beacon interval if dot11ShortBeaconInterval is true, and *mad* is the dot11MaxAwayDuration.

An AP shall not be in doze state for a duration of time that exceeds the value of the dot11MaxAwayDuration. The AP shall set dot11MaxAwayDuration to the lowest value obtained from the Max Away Duration field that is contained in the most recently received MAD elements from any of its associated STAs.

An AP may reject a (re)association of a STA if the Max Away Duration field in the MAD element in the (Re)Association Request frame transmitted by the STA is considered unacceptable. For example, an AP that schedules to be in doze state for 100 ms can reject association of a STA that indicates in the Association Request frame a value of 30 ms in its Max Away Duration field.

An AP may disassociate a STA based on the value indicated by Max Away Duration of the latest MAD element received from that STA.

An AP may include a MAD element in the (Re)Association Response frame or Probe Response frame that indicates the suggested maximum away duration during which the AP can be considered in doze state.

A STA may include a MAD element in the Probe Request or (Re)Association Requests frames.

Irrespective of the Power Management mode and Power States, an AP shall maintain the synchronization of the network by generating beacons as described in 11.1.3.

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A STA that is the intended receiver of a frame transmitted by an AP that has the PM Mode subfield equal to 0 shall consider the AP in active mode.

An AP that has previously sent a frame to one or a group of STAs with PM bit equal to 0, shall send a frame with PM bit equal to 1 to the same set of STAs before changing its operation mode to Power Save mode.

A STA that is the intended receiver of a frame transmitted by an AP that has the PM Mode subfield equal to 1 shall consider the AP in Power Save mode.

11.2.3.19 CMMG TXOP power save

A CMMG AP supports the operation of non-AP CMMG STAs in TXOP power save mode in a BSS when dot11CMMGTXOPPowerSaveOptionImplemented at the AP is true. Non-AP CMMG STAs that are in Active mode (see Table 11-3) and have dot11CMMGTXOPPowerSaveOptionImplemented equal to true operate in TXOP power save mode. A STA that has dot11CMMGTXOPPowerSaveOptionImplemented equal to true shall set the CMMG TXOP Power Save field in the CMMG Capabilities element to 1; otherwise, the STA shall set the field to 0. A CMMG AP may allow non-AP CMMG STAs in TXOP power save mode to enter the doze state during a TXOP. A CMMG AP shall indicate this by transmitting a CMMG PPDU with the TXVECTOR parameter TXOP_PS_NOT_ALLOWED set to 0. The value of this parameter in the TXVECTOR of all CMMG PPDUs transmitted by the CMMG AP may be changed from 1 to 0 during the TXOP to enable TXOP PS for the remainder of the TXOP. The value of this parameter in the TXVECTOR of all CMMG PPDUs transmitted by CMMG AP shall not be changed from 0 to 1 during the TXOP. If dot11CMMGTXOPPowerSaveOptionImplemented at CMMG AP is false then the CMMG AP shall set the TXOP_PS_NOT_ALLOWED to 1 in the TXVECTOR of the frames.

If the AP allows non-AP CMMG STAs to enter doze state during a TXOP, then a non-AP CMMG STA that is in CMMG TXOP power save mode may enter the doze state until the end of that TXOP when any of the following conditions is met:

— On receipt of a PPDU, the STA determines that the RXVECTOR parameter UPLINK_INDICATION is equal to 0 but the RXVECTOR parameter COLOR does not match the COLOR indicated by the AP to which the STA is associated.
— The STA finds that the COLOR in the RXVECTOR parameter matches the COLOR indicated by the AP to which the STA is associated but the RXVECTOR parameter PARTIAL_AID is not equal to 0 nor does it match the STA's partial AID.
— The STA finds that the PARTIAL_AID in the RXVECTOR matches its partial AID but the RA in the MAC header of the corresponding frame that is received correctly does not match the MAC address of the STA.
— In a received PSMP frame, the STA finds that the STA_AID field in the PSMP STA Info field is not its AID nor does the PSMP Group Address ID subfield match its group address.
— The STA receives a QoS Data frame intended for it with the More Data subfield equal to 0 and No Ack ack policy or sends an acknowledgment if the ack policy is not No Ack.
— On receipt of a PPDU, the non-AP STA determines that the RXVECTOR parameter UPLINK_INDICATION is equal to 1.

The CMMG AP shall include a NAV-set sequence (e.g., RTS/CTS) at the beginning of such a TXOP with the Duration/ID value set to the remainder of the TXOP duration. A CMMG AP shall not transmit frames to a non-AP CMMG STA that has been allowed to enter doze state according to the conditions above for the remainder of the TXOP.

NOTE 1—A CMMG AP does not transmit CMMG PPDUs in the current TXOP if the AP has already transmitted a CMMG PPDU with the TXVECTOR parameter TXOP_PS_NOT_ALLOWED set to 0 in the same TXOP and does not want the STAs that are in awake state to enter the doze state.

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If a CMMG AP truncates the TXOP in which it allowed STAs to enter doze state, then the CMMG AP shall not transmit frames to the STAs that were allowed to enter the doze state until the NAV set at the start of the TXOP has expired.

If the AP does not receive an acknowledgment after transmitting an individually addressed frame containing all or part of an MSDU, A-MSDU, or MMPDU sent with the More Data field equal to 0 to a non-AP CMMG STA that is in CMMG TXOP power save mode and the AP had set the TXVECTOR parameter TXOP_PS_NOT_ALLOWED to 0, it shall retransmit that frame at least once within the same TXOP, subject to applicable retry, lifetime limit, or TXOP limit. If an acknowledgment to the retransmission of this last frame in the same TXOP is not received, it may wait until the next TXOP to further retransmit that frame, subject to its applicable retry or lifetime limit.

NOTE 2—An AP that receives from a CMMG STA in TXOP power save mode a BlockAck frame that is a response to an A-MPDU containing MPDUs with the More Data field equal to 0 cannot expect to receive a response to subsequent MPDUs retransmitted in the same TXOP because the CMMG STA might be in the doze state.

A CMMG STA that is in TXOP power save mode and has entered doze state shall continue to operate its NAV timer during doze state and shall transition into awake state on expiry of the NAV timer.

NOTE 3—The STA can contend for access to the medium immediately on the expiry of the NAV timer.

11.2.4 Power management in an IBSS

11.2.4.1 Introduction

Subclause 11.2.4 specifies the power management mechanism for use within an IBSS. This mechanism is deprecated.

11.2.4.2 Basic approach

A STA can be in one of two power management modes:

— Active mode: The STA receives and transmits frames at any time. The STA remains in the awake state.

— Power save (PS) mode: The STA enters the awake state to receive or transmit frames. The STA remains in the doze state otherwise.

The basic approach is similar to the infrastructure case in that the STAs are synchronized, and group addressed BUs and the BUs that are to be transmitted to a power-conserving STA are first announced during a period when all STAs are awake. The announcement is done via an ATIM frame sent in an ATIM window. A STA in the PS mode shall listen for these announcements to determine if it needs to remain in the awake state. The presence of the ATIM window in the IBSS indicates if the STA may use PS mode. To maintain correct information on the power save state of other IBSS STAs, a STA needs to remain awake during the ATIM window. At other times the STA may enter the doze state except as indicated in the following procedures.

When a BU is to be transmitted to a destination STA that is in a PS mode, the transmitting STA first transmits an ATIM frame during the ATIM window, in which all of the STAs including those operating in a PS mode are awake. The ATIM window is defined as a specific period of time, defined by the ATIM Window field in the IBSS Parameter Set supplied to the MLME-START.request primitive, following a TBTT, during which only Control frames that are RTS, CTS, or Ack frames; Management frames that are Beacon or ATIM frames; or (QoS) Null frames shall be transmitted. ATIM frame transmission times are randomized, after a Beacon frame is either transmitted or received by the STA, using the backoff procedure with the CW equal to aCWmin. Individually addressed ATIM frames shall be acknowledged. If a STA transmitting an individually addressed ATIM frame does not receive an acknowledgment, the STA shall execute the backoff procedure for retransmission of the ATIM frame. Group addressed ATIM frames shall not be acknowledged.

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If a STA receives an individually addressed ATIM frame during the ATIM window, it shall acknowledge the individually addressed ATIM frame and stay awake to receive the announced BUs for the entire beacon interval or until it has completed successful transmission to and reception from the source STA of the received ATIM frame, a frame with the EOSP subfield equal to 1. If a STA does not receive an ATIM frame, it may enter the doze state at the end of the ATIM window. Transmissions of BUs announced by ATIM frames are randomized after the ATIM window, using the backoff procedure described in Clause 10.

It is possible that an ATIM frame may be received from more than one STA, and that a STA that receives an ATIM frame may receive more than one BU from the transmitting STA. ATIM frames are only addressed to the destination STA of the BU.

An ATIM frame for a BU shall have a destination address identical to that of the BU.

After the ATIM interval, only individually addressed BUs that have been successfully announced with an acknowledged ATIM frame and group addressed BUs that have been announced with an ATIM frame shall be transmitted to STAs in the PS mode. These frames shall be transmitted using the DCF (for non-QoS STAs) or EDCAF (for QoS STAs).

Figure 11-12 illustrates the basic PS operation.

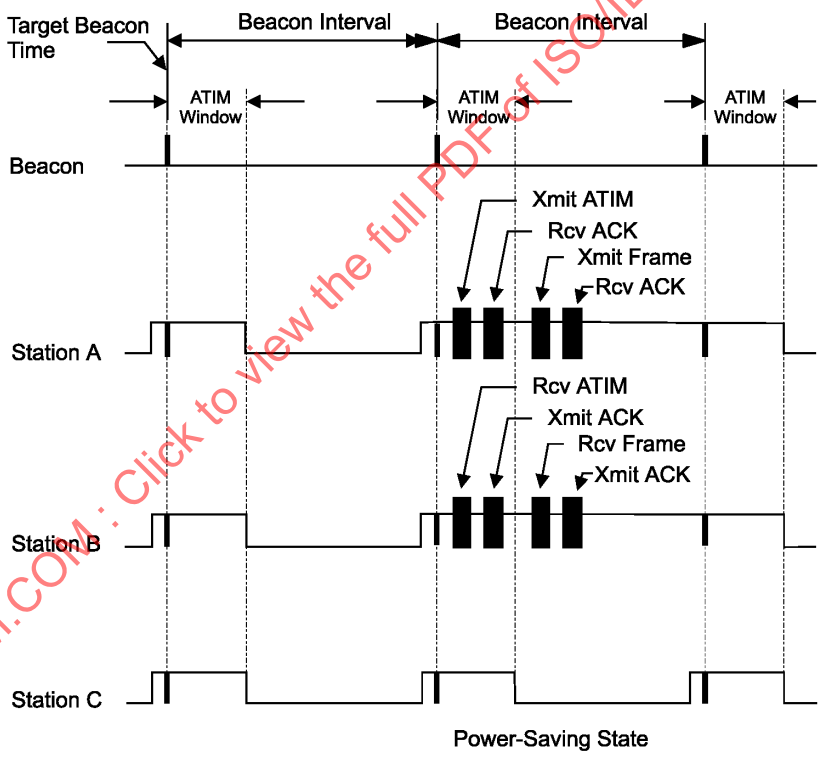

Figure 11-12—Power management in an IBSS—basic operation

The estimated power saving state of another STA may be based on the power management information transmitted by that STA and on additional information available locally, such as a history of failed transmission attempts. The use of RTS/CTS in an IBSS may reduce the number of transmissions to a STA that is in PS mode. If an RTS frame is sent and a CTS frame is not received, the transmitting STA may assume that the destination STA is in PS mode. The method of estimating the power management state of other STAs in the IBSS is outside the scope of this standard.

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11.2.4.3 Initialization of power management within an IBSS

The following procedure shall be used to initialize power management within a new IBSS, or to learn about the power management being used within an existing IBSS:

a) A STA joining an existing IBSS by the procedure in 11.1.4.4 shall update its ATIM window with the value contained in the ATIM Window field of the IBSS Parameter Set element within the Beacon or Probe Response frame received during the scan procedure.

b) A STA starting a new IBSS by the procedure in 11.1.4.4 shall set the ATIM Window field of the IBSS Parameter Set element within the Beacon frames transmitted to the value of its ATIM window.

c) The start of the ATIM window shall be the TBTT, defined in 11.1.3.5. The end of the ATIM window shall be defined as

   TSF timer mod dot11BeaconPeriod = ATIMWindow,
   where ATIMWindow is the ATIM Window field of the IBSS Parameter Set from the MLME-START.request or MLME-JOIN.request primitives.

d) The ATIM window period shall be static during the lifetime of the IBSS.

e) An ATIM window value of 0 shall indicate that power management is not usable within the IBSS.

11.2.4.4 STA power state transitions

A STA may enter PS mode if the value of the ATIM window in use within the IBSS is greater than 0. A STA shall not enter PS mode if the value of the ATIM window in use within the IBSS is equal to 0.

A STA shall indicate its power management mode in the Power Management subfield of the Frame Control field of frames containing all or part of a BU or individually addressed Probe Request frame, or (QoS) Null frames, that it transmits.

A STA in PS mode shall transition between awake state and doze state according to the following rules:

a) If a STA is operating in PS mode, it shall enter the awake state prior to each TBTT.

b) If a STA receives a group addressed ATIM frame during the ATIM window, the STA shall remain in the awake state until either the STA receives a group addressed frame from the source STA with the EOSP subfield equal to 1 or the end of the next ATIM window, whichever occurs first.

c) If a STA receives at least one individually addressed ATIM frame containing the STA's individual address in the RA field during the ATIM window then the STA shall remain in the awake state at least until the earlier of the completion of the successful transmission to and reception from the source STA of each received ATIM frame, a frame with the EOSP subfield equal to 1, and the end of the next ATIM window.

d) If a STA transmits at least one individually addressed ATIM frame containing a STA's individual address in the RA field during the ATIM window then the STA shall remain in the awake state at least until the earlier of the completion of the successful transmission to and reception from the destination STA of each transmitted ATIM frame, a frame with the EOSP subfield equal to 1, and the end of the next ATIM window.

e) If a STA transmits a Beacon, the STA shall remain in the awake state until the end of the next ATIM window.

f) If the STA has not transmitted an ATIM frame and does not receive either an individually addressed ATIM frame containing the STA's individual address, or a group addressed ATIM frame during the ATIM window, the STA may return to the doze state following the end of the current ATIM window.

11.2.5 Power management in an MBSS

Power management in an MBSS is described in 14.14.

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11.2.6 SM power save

A STA consumes power on all active receive chains, even though they are not necessarily required for the actual frame exchange. The SM power save feature allows a non-AP HT STA in an infrastructure BSS to operate with only one active receive chain for a significant portion of time.

The STA controls which receive chains are active through the PHY-RXCONFIG.request primitive specifying a PHYCONFIG_VECTOR parameter ACTIVE_RXCHAIN_SET that indicates which of its receive chains should be active.

In dynamic SM power save mode, the STA enables its multiple receive chains when it receives the start of a frame exchange sequence addressed to it. Such a frame exchange sequence shall start with a single-spatial stream individually addressed frame that requires an immediate response and that is addressed to the STA in dynamic SM power save mode. An RTS/CTS sequence may be used for this purpose. The STA shall, subject to its spatial stream capabilities (see 9.4.2.55.4 and 9.4.2.157.3) and operating mode (see 11.40), be capable of receiving a PPDU that is sent using more than one spatial stream a SIFS after the end of its response frame transmission. The STA switches to the multiple receive chain mode when it receives the frame addressed to it and switches back immediately when the frame exchange sequence ends.

NOTE—A STA in dynamic SM power save mode cannot distinguish between an RTS/CTS sequence that precedes a MIMO transmission and any other RTS/CTS and, therefore, always enables its multiple receive chains when it receives the RTS addressed to it.

The STA can determine the end of the frame exchange sequence through any of the following:

— It receives an individually addressed frame addressed to another STA.
— It receives a frame with a TA that differs from the TA of the frame that started the TXOP.
— The CS mechanism (see 10.3.2.1) indicates that the medium is idle at the TxPIFS slot boundary (defined in 10.3.7).

In static SM power save mode, the STA maintains only a single receive chain active.

The STA may use the SM Power Save frame to communicate its SM power save state. The STA may also use SM Power Save subfield in the HT Capabilities element of its (Re)Association Request frame to achieve the same purpose. The latter allows the STA to use only a single receive chain immediately after (re)association.

A STA that has one or more TDLS links shall not operate in SM power save mode.

Changes to the number of active receive chains are made only after the SM power save mode indication has been successfully delivered (i.e., by acknowledgment of a frame carrying the HT Capabilities element or by acknowledgment of a SM Power Save frame). The SM power save mode indication shall be transmitted using an individually addressed frame.

11.2.7 Power management in a PBSS and DMG infrastructure BSS

11.2.7.1 General

Power save mechanisms in this subclause enable non-AP STAs to sleep for one or more beacon intervals or for parts of a beacon interval.

The non-AP and non-PCP STA power save mechanisms defined in 11.2.7.2 enable a non-AP and non-PCP STA to sleep after signaling the AP or PCP, or to sleep according to a periodic schedule that is negotiated with the AP or PCP. A non-AP and non-PCP STA may use both mechanisms in conjunction to increase its power save opportunity.

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Similarly, the PCP power save mechanisms defined in 11.2.7.3 enable a PCP to sleep after signaling at least one non-AP and non-PCP STA, or to sleep according to a wakeup schedule that is available to all STAs associated with the PCP.

A non-AP STA can be in one of two power management modes:

— Active mode: The STA does not use any of the scheduled or unscheduled power save mechanisms defined in this subclause and operates in the awake state, except during time intervals that it determines it is not the target of any transmission by other STAs, where it may operate in doze state.

— Power save (PS) mode: The STA uses at least one of the scheduled or unscheduled power save mechanisms defined in this subclause and switches between awake and the doze states.

A non-AP STA shall be in active mode upon (re)association.

For scheduled power save, the DMG Wakeup Schedule element (9.4.2.130) is used to communicate the sleep and wakeup pattern of a DMG STA, referred to as the STA *wakeup schedule (WS)*. A STA wakeup schedule defines a periodic routine of cycling between a set of contiguous beacon intervals referred to as awake beacon intervals (A-BIs) and a set of contiguous beacon intervals referred to as doze beacon intervals (D-BIs). The rules for alternating between awake and doze power states during A-BIs and D-BIs are defined in 11.2.7.2.3 and 11.2.7.3.3. An overview of these rules is given in Table 11-3 and Table 11-4.

A STA in PS mode that is following a wakeup schedule and has also exercised unscheduled power save shall follow the D-BI rules in this subclause and shall follow the ATIM rules in 11.2.7.4 for a non-AP STA without wakeup schedule.

An AP or PCP keeps track of the wakeup schedules of all associated non-AP and non-PCP STAs. A non-AP and non-PCP STA keeps track of the wakeup schedule of all associated non-AP and non-PCP STAs that it is communicating with. There is no end time to a wakeup schedule. Once a STA enters PS mode according to its wakeup schedule it stays indefinitely in PS mode until it leaves the PS mode through mechanisms defined in this subclause. Once a STA is made aware of the wakeup schedule of another STA, it is able to keep track of the wakeup schedule on its own. Each STA delivers traffic to a peer STA only when the peer STA is in awake state.

A STA that has transmitted a frame to an AP or PCP with which it is not associated and from which it expects a response shall remain in the awake state until such a response is received or until the procedure has timed out.

An AP shall buffer BUs addressed to non-AP STAs in doze state. The buffered BUs shall be transmitted only at designated times (11.2.7.2). A non-AP STA shall defer delivery of BUs addressed to other non-AP STAs in doze state. The BUs shall be transmitted only at designated times (11.2.7.2).

If a PCP sets the BSS Type field within a transmitted DMG Beacon frame to PBSS or the AP or PCP includes a Nontransmitted BSSID Capability element in a transmitted DMG Beacon, Announce, or Probe Response frames and the BSS Type field within the Nontransmitted BSSID Capability element is equal to PBSS, then the AP or PCP shall follow the PCP power management rules described in 11.2.7.3 if the AP or PCP chooses to employ power management.

An AP or PCP may include an Antenna Sector ID Pattern element in Power Save Configuration Response and Probe Response frames transmitted to a non-AP and non-PCP STA. If a non-AP and non-PCP STA uses the information contained in the Antenna Sector ID Pattern element received from its AP or PCP, then during the BTI of an A-BI, the STA might stay awake just to receive DMG Beacon frames transmitted through specific DMG antenna and sector and switch to doze state during other periods in the BTI.

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Table 11-3 lists the power states for a non-AP and non-PCP STA in PS mode and a PCP in PS mode during an A-BI. Each entry indicates the state, either awake or doze, for the non-AP and non-PCP STA or the PCP in PS mode at various times during the A-BI.

Table 11-3—Power states for an A-BI

Portion of the beacon interval		PPS PCP	PS non-AP and non-PCP STA
BHI	BTI	Awake	Awake or doze
	A-BFT	Awake	Awake or doze
	ATI	Awake	Awake
DTI	CBAP with the PCP Active field set to 1 in the schedule	Awake or doze	Awake or doze
	CBAP with the PCP Active field set to 0 in the schedule	Doze	Awake or doze
	SP with Destination AID set to broadcast AID	Awake	Awake
	Nontruncatable or nonextensible SP with non-PCP STA as Source AID or Destination AID	Awake or doze	Awake or doze
	Truncatable SP or extensible SP with non-AP and non-PCP STA (excluding the PS STA) as Source AID or Destination AID	Awake	Awake or doze
	SPs allocated to itself	Awake or doze	Awake or doze
	All other SPs	Awake or doze	Awake or doze
	Awake window	Awake	Awake
	DTI with CBAP Only subfield set to 1	Awake or doze	Awake or doze
	Destination AID field of a CBAP equal to the broadcast AID in the schedule	Awake or doze	Awake or doze

Table 11-4 lists the power states for a non-AP and non-PCP STA in PS mode and a PCP in PS mode during a D-BI. Each entry indicates the state, either awake or doze, for the non-AP and non-PCP STA or the PCP in PS mode at various times during the D-BI.

The source DMG STA and the destination DMG STA of a nontruncatable SP or allocated CBAP with a destination AID that is not the broadcast AID may go to doze state within the SP or within the CBAP, respectively, after the source DMG STA transmitted a frame to the destination DMG STA of the SP or the CBAP, respectively, with the EOSP subfield set to 1 and received the following response frame from the destination DMG STA of the SP or the CBAP, respectively.

If the MM-SME Power Mode field within the MMS element sent by an MM-SME coordinated STA is 1, all STAs advertised in the MMS element shall switch to the doze state when the wakeup schedule of any one STA or a successful frame exchange as described in Annex G brings the STA to the doze state.

If the MM-SME Power Mode field within the MMS element sent by an MM-SME coordinated STA is 0, all STAs advertised in the MMS element shall switch to the awake state when the wakeup schedule of any one STA or a successful frame exchange as described in Annex G brings the STA to the awake state.

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Table 11-4—Power states for a D-BI

Portion of the beacon interval		PPS PCP	PS non-AP and non-PCP STA
BHI	BTI	N/A	Awake or doze
	A-BFT	N/A	Awake or doze
	ATI	Awake	Awake
DTI	CBAP with the PCP Active field set to 1 in the schedule	Doze	Doze
	CBAP with the PCP Active field set to 0 in the schedule	Doze	Doze
	SP with Destination AID set to broadcast AID	Doze	Doze
	SP with a destination AID that is not the broadcast AID	Doze	Awake
	Nontruncatable or nonextensible SP with non-PCP STA as Source AID or Destination AID	Doze	Doze
	Truncatable SP or extensible SP with non-AP and non-PCP STA (excluding the PS STA) as Source AID or Destination AID	Doze	Doze
	SPs allocated to itself	Doze	Doze
	All other SPs	Doze	Doze
	DTI with CBAP Only subfield set to 1	Doze	Doze
	Destination AID field of a CBAP equal to the broadcast AID in the schedule	Doze	Doze

11.2.7.2 Non-AP and non-PCP STA power management mode

11.2.7.2.1 General

The power management mode of a non-AP and non-PCP STA is selected by the PowerManagementMode parameter of the MLME-POWERMGT.request primitive. Once the STA updates its power management mode, the MLME shall issue an MLME-POWERMGT.confirm primitive indicating the result of the operation. While the STA is in PS mode it may exercise the unscheduled and scheduled power save mechanisms described in this subclause.

Figure 11-13 illustrates a finite state machine that shows the state transition of a STA in active and PS mode, and also the transition between active and PS modes when the non-AP and non-PCP STA has set up a wakeup schedule.

NOTE—In Figure 11-13, the notations PSC-REQ(X) and PSC-RSP(Y) indicate that the PSC-REQ and PSC-RSP frames, respectively, are transmitted with the setting as indicated by their corresponding X and Y parameters. The transitions shown “As per T1” are defined in Table 11-3. The transitions shown “As per T2” are defined in Table 11-4.

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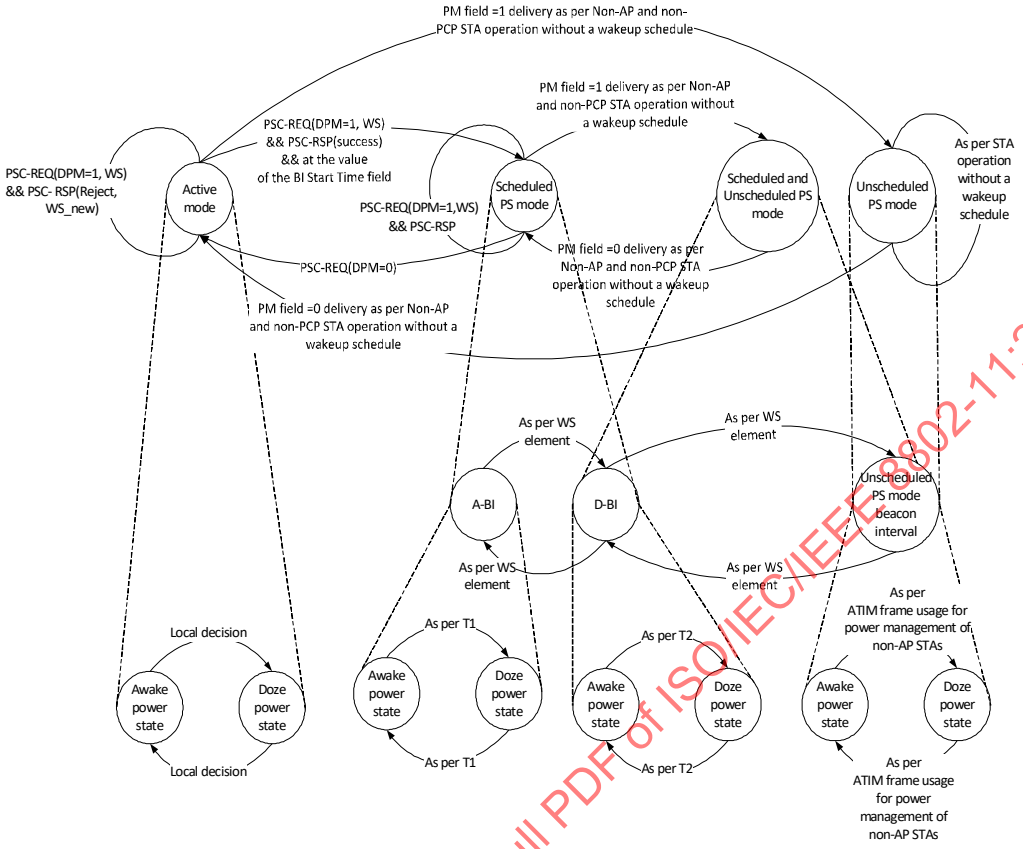

Figure 11-13—State transition diagram of non-AP and non-PCP STA in active and PS modes

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11.2.7.2.2 Non-AP and non-PCP STA operation without a wakeup schedule

To change its power state without a wakeup schedule, a non-AP and non-PCP STA shall inform the AP or PCP by completing a successful frame exchange (as described in Annex G) that is initiated by the STA and that includes a Management frame, Extension frame or Data frame, and also an Ack or a BlockAck frame from the AP or PCP. The Power Management subfield(s) in the Frame Control field of the frame(s) sent by the STA in this exchange that contain a BU or are QoS Null frame indicate the power state that the STA shall adopt upon successful completion of the entire frame exchange. A non-AP and non-PCP STA shall not change its power state using a frame exchange that does not receive an Ack or BlockAck frame from the AP or PCP, or using a BlockAckReq frame.

A non-AP and non-PCP STA in doze state shall limit the frames it transmits to the following:

— A Management, Extension or Data frame that triggers an Ack or a BlockAck frame from the AP or PCP, with the Power Management subfield in the Frame Control field of the frame set to 0, i.e., a frame to indicate the STA intent to transition out of unscheduled PS mode.

— A Management, Extension or Data frame that triggers an Ack or a BlockAck frame from the AP or PCP, plus Ack and BlockAck frames that respond to the frames sent by the AP or PCP during the reverse direction grant, if the following conditions apply:

  — The Power Management subfield in the Frame Control field of the frame sent by the non-AP and non-PCP STA is set to 1.

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— The AP or PCP has transmitted a Capability Information field in which the Triggered Unscheduled PS subfield is equal to 1.

— An RTS, DMG CTS-to-self, CF-End, Grant, BRP, SSW or SSW-Feedback frame.

NOTE 1—A DMG STA in doze state may need to perform beamforming to restore its links with other DMG STAs.

As long as there is at least one STA that has entered doze state through the unscheduled power save mechanism, the AP or PCP shall establish an awake window by transmitting an Awake Window element, and shall include a UPSIM element in every DMG Beacon and Announce frame it transmits. The AP or PCP may establish an awake window and/or include a UPSIM element in a DMG Beacon or Announce frame it transmits even if no STA is in doze state. The absence of a UPSIM element in a DMG Beacon or Announce frame is equivalent to presence of the UPSIM element in the frame with all bits of the Power Save Indication Bitmap field in the UPSIM element set to 0. The UPSIM element in every DMG Beacon or Announce frame transmitted by the AP or PCP shall indicate the power state of all STAs at the time of frame transmission.

NOTE 2—Transmitting a DMG Beacon frame with the Discovery Mode subfield set to 0, or an Announce frame, without including the UPSIM element in the frame, indicates that no STA is in unscheduled PS mode at the time of the frame transmission.

A non-AP and non-PCP STA may also indicate its power state to another non-AP and non-PCP STA through the Power Management subfield in the Frame Control field of any frame that contains all or part of a BU. The non-AP and non-PCP STA shall indicate its correct power state in the Frame Control field of any frame it transmits that contains all or part of a BU.

When a non-AP and non-PCP STA that has not set up a wakeup schedule with the AP or PCP enters PS mode, every beacon interval shall be an A-BI for that STA. A non-AP and non-PCP STA that has not set up a wakeup schedule with the AP or PCP and that is in PS mode shall be awake during any allocated SP for which the STA is either the source DMG STA or destination DMG STA during an A-BI. During an A-BI, a non-AP and non-PCP STA that has not set up a wakeup schedule with the AP or PCP and that is in PS mode shall be awake during any allocated CBAP for which the STA is the source DMG STA or destination DMG STA, or the source AID of the CBAP is equal to the broadcast AID or the destination AID of the CBAP is equal to the broadcast AID.

A non-PCP and non-AP STA that is in the doze state may offer an RDG to its AP or PCP if the following conditions apply:

— The AP or PCP has transmitted a Capability Information field in which the Triggered Unscheduled PS field is equal to 1.

— The non-AP and non-PCP has transmitted a Capability Information field in which the Reverse Direction subfield is equal to 1.

The AP or the PCP may use the offered RDG to transmit one or more BUs to the non-PCP and non-AP STA using the reverse direction protocol defined in 10.29.

The non-PCP and non-AP STA should continue to offer an RDG to the AP or to the PCP within the current TXOP while the Buffered AC subfield of the QoS Control field in frames transmitted by the AP or by the PCP indicates that one or more BUs are buffered for the AC for which the TXOP was gained.

11.2.7.2.3 Non-AP and non-PCP STA operation with a wakeup schedule

To transition from active mode to PS mode, a non-AP and non-PCP STA that is associated with an AP or PCP shall establish a wakeup schedule (WS) with the AP or PCP. A WS is established with the AP or PCP following the successful transmission of a PSC-REQ frame to the AP or PCP with the DPM field set to 1 and an acknowledged receipt of the corresponding PSC-RSP frame from the AP or PCP provided that the PSC-RSP frame contained a status code indicating success. After receiving a PSC-RSP frame from the AP or PCP

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with a status code indicating success and responding with an acknowledgment, the STA switches to the PS mode at the instant specified by the BI Start Time field of the DMG Wakeup Schedule element transmitted to the AP or PCP. In PS mode, the STA shall cycle between A-BIsand D-BIs following the WS that the STA has established with the AP or PCP.

As long as there is at least one STA that is in PS mode, the AP or PCP shall establish an awake window. The AP or PCP may include an Awake Window element in a DMG Beacon or Announce frame it transmits even if no STA in the BSS has entered PS mode.

A DMG Wakeup Schedule element shall be included in any PSC-REQ frame that the STA transmits to the AP or PCP as an explicit request for a WS. An Awake Window element may also be included in the same PSC-REQ frame to indicate a requested duration for the awake window. If the AP or PCP accepts the proposed WS and the optionally present awake window duration in the PSC-REQ frame, it shall reply with a PSC-RSP frame indicating a status code of SUCCESS. Otherwise, it shall respond with a PSC-RSP frame with a status code indicating the reason for rejecting the request. The AP or PCP may suggest an alternative WS and optionally an awake window duration in the PSC-RSP frame and set the status code to REJECT_WITH_SCHEDULE. If the STA accepts the alternative WS, it shall include this WS in a subsequently transmitted PSC-REQ frame. If the non-AP and non-PCP STA does not accept the alternative WS, it shall not send a PSC-REQ frame for dot11PSRequestSuspensionInterval beacon intervals following the receipt of the PSC-RSP frame from the AP or PCP.

NOTE 1—The AP or PCP can recommend an alternative WS, for example, to align the A-BIs of some or all non-AP and non-PCP STAs.

NOTE 2—The awake window duration sent by the AP or PCP in a PSC-RSP frame is to assist the STA for awake window planning. The awake window duration is always set by the Awake Window element in the most recent DMG Beacon or Announce frame received from the AP or PCP.

If a non-AP and non-PCP STA has established a WS with the AP or PCP and the non-AP and non-PCP STA is in PS mode, the non-AP and non-PCP STA shall have *m* successive A-BIs repeating every *n* beacon interval, where *n* is the Sleep Cycle field of the DMG Wakeup Schedule element contained in the PSC-RSP frame received from the AP or PCP during the frame exchange that established the WS, and *m* is the Number of Awake BIs field in the DMG Wakeup Schedule element contained in that PSC-RSP frame. During each of its A-BIs, the non-AP and non-PCP STA shall be awake during the awake window if it is present, and during all allocated SPs in which it is either the source or destination DMG STA.

An AP or PCP may send an unsolicited PSC-RSP frame without a WS and indicating a status code of success to a non-AP and non-PCP STA in PS mode. Upon receiving the unsolicited PSC-RSP frame meeting these conditions, the non-AP and non-PCP STA shall switch to active mode.

11.2.7.2.4 Non-AP and non-PCP STA operation with or without a wakeup schedule

A non-AP and non-PCP STA in PS mode shall stay awake for dot11MinBHIDuration starting from the beginning of each A-BI and may switch to the doze state after the expiration of this time. The only exception is when the Power Save Configuration Response or Probe Response frame received from the AP or PCP includes an Antenna Sector ID Pattern element, in which case the non-AP and non-PCP STA may use the Antenna Sector ID Pattern element to receive DMG Beacon frames transmitted through a specific DMG antenna and sector, and may switch to doze state during other periods in the BTI.

An AP or PCP shall transmit SP allocation announcements for STAs in PS mode during each of the STAs' A-BIs and may transmit those SP allocation announcements in other beacon intervals. New SPs shall be allocated to begin either within or after the later A-BI of the source DMG STA and destination DMG STA of the SP.

To transition from PS mode to active mode, a non-AP and non-PCP STA that has an established WS with the AP or PCP shall send a PSC-REQ frame with the DPM field set to 0 to the AP or PCP and enter active mode

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following the reception of the Ack frame response. The AP or PCP shall not send a PSC-RSP frame if the DPM field is 0 in the PSC-REQ frame.

In order for a STA to learn the WS of another STA within the BSS, the STA may send an Information Request frame to the other STA or to the AP or PCP as defined in 11.28.1. The AP or PCP maintains a WS distribution table for the lifetime of the BSS, and upon receiving an Information Request frame that contains a request for the WS of a STA identified by the Subject Address field within the frame, shall add an entry to the WS distribution table made up of the STA that transmitted the Information Request frame (the requesting STA) and the STA identified by the Subject Address field within the Information Request frame (the target STA). If the AP or PCP moves the TBTT, changes the duration of the beacon interval, or resets the TSF, the AP or PCP shall transmit an unsolicited Information Response frame with the updated DMG Wakeup Schedule element. When transmitting the DMG Wakeup Schedule element for a STA that is in PS mode, the transmitting STA shall use a value for the BI Start Time field that points to a TBTT that is earlier, but not more than 2^{31} µs minus aDMGDWSValidPeriod earlier, than the TBTT of the beacon interval during which the BI Start Time field is transmitted, so that the receiving STA can correctly identify the power management mode of the STA to which the WS belongs.

If the Information Request frame is transmitted to the AP or PCP and the STA indicated in the Information Request's Subject Address field does not have an established WS with the AP or PCP, the AP or PCP shall set the length of the DMG Wakeup Schedule element to 0 in the Information Response frame.

11.2.7.3 PCP power management mode

11.2.7.3.1 General

The power management mode of a PCP is selected by the PowerManagementMode parameter of the MLME-POWERMGT.request primitive. Once the PCP updates its power management mode, the MLME shall issue an MLME-POWERMGT.confirm primitive indicating the result of the operation. While the PCP is in PS mode it may exercise the unscheduled and scheduled power save mechanisms described in this subclause.

11.2.7.3.2 PCP operation without a wakeup schedule

To change its power state without a wakeup schedule, the PCP shall include a UPSIM element in or remove the UPSIM element from every DMG Beacon frame with the Discovery Mode subfield set to 0 and Announce frame that it transmits, and shall indicate its new power state in the UPSIM element if it is included in the frame

NOTE 1—The UPSIM element in a DMG Beacon frame with the Discovery Mode subfield set to 0, or in an Announce frame, includes the power state of the PCP at the time of the frame transmission. Transmitting a DMG Beacon frame with the Discovery Mode subfield set to 0 or an Announce frame, without including the UPSIM element in the frame, indicates that no STA (including the PCP) is in unscheduled PS mode at the time of the frame transmission.

Alternatively to change its power state without a wakeup schedule, the PCP shall inform all associated STAs by completing a successful frame exchange (as described in Annex G) that is initiated by the PCP and that includes a Management frame, Extension frame or Data frame, and also an Ack or a BlockAck frame from the associated STA. The Power Management subfield(s) in the Frame Control field of the frame(s) sent by the PCP in this exchange that contain a BU or are QoS Null frame indicate the power state that the PCP shall adopt upon successful completion of the entire frame exchange. The PCP shall not change its power state using a frame exchange that does not receive an Ack or BlockAck frame from the associated STA, or using a BlockAckReq frame.

The PCP shall not enter doze state unless it has received an Ack or BlockAck from each associated STA. The PCP shall enter awake state as soon as it receives an Ack or BlockAck from one associated STA.

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A PCP in doze state shall limit the frames it transmits to the following:

— A Management, Extension or Data frame that triggers an Ack or a BlockAck frame from a non-AP and non-PCP STA, with the Power Management subfield in the Frame Control field of the frame set to 0, i.e., a frame to indicate the PCP intent to transition out of unscheduled PS mode.

— A Management, Extension or Data frame that triggers an Ack or a BlockAck frame from a non-AP and non-PCP STA, plus Ack and BlockAck frames that respond to the frames sent by the non-AP and non-PCP STA during the reverse direction grant, if the following conditions apply:

  — The Power Management subfield in the Frame Control field of the frame sent by the PCP is set to 1.

  — The non-AP and non-PCP STA has transmitted a Capability Information field in which the Triggered Unscheduled PS subfield is equal to 1.

— An RTS, DMG CTS-to-self, CF-End, Grant, BRP, SSW or SSW-Feedback frame.

NOTE 2—A DMG STA in doze state may need to perform beamforming to restore its links with other DMG STAs.

The PCP shall indicate the correct power state in the Frame Control field of any frame it transmits to an associated STA that contains all or part of a BU.

11.2.7.3.3 PCP operation with a wakeup schedule

A PCP in PPS mode (PPS PCP) may enter the doze state for one or more consecutive beacon intervals in order to minimize its energy consumption. Figure 11-14 illustrates a finite state machine that shows the state transition of the PCP power management mode.

NOTE 1—Figure 11-14 uses the following terminology: "As per T1" means that the transitions are specified in Table 11-3, "As per T2" means that the transitions are specified in Table 11-4.

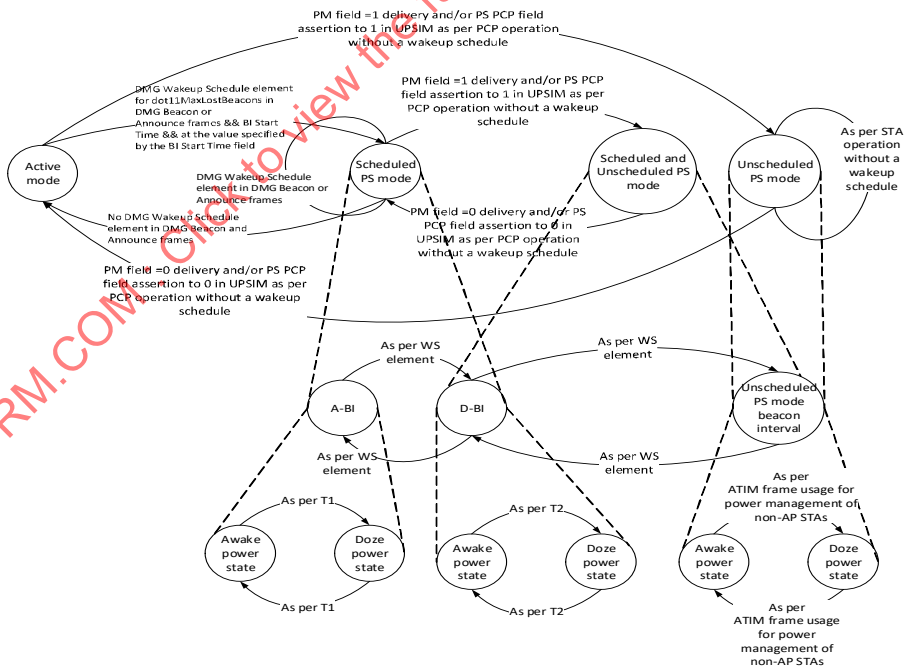

Figure 11-14—State transition diagram of PCP power management mode

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To enter PPS mode, or to modify an established WS, the PCP announces a WS through a DMG Wakeup Schedule element (9.4.2.130) included in a DMG Beacon, Announce, or any Action frame.

The PCP can assume that all associated STAs have received a WS and the Awake Window element that can optionally be transmitted with the WS at the earlier of the following events:

— The PCP has transmitted the DMG Wakeup Schedule element in DMG Beacon or Announce frames for at least dot11MaxLostBeacons successive beacon intervals.

— The PCP has confirmed that each associated STA has received the DMG Wakeup Schedule element by receiving an ACK or a response frame from each associated STA in response to a request frame that includes the DMG Wakeup Schedule element.

The first PCP A-BI of a sleep cycle in a WS starts at the instant specified by the BI Start Time field of the announced DMG Wakeup Schedule element, and the number of successive PCP A-BIs is specified by the Number of Awake BIs field of the DMG Wakeup Schedule element.Once in PPS mode, the PCP transitions between A-BI and D-BI according to the WS it has established.

NOTE 2—The PCP may need to behave as it is in active mode or in an A-BI to some associated STAs for a number of planned successive PCP D-BIs if it has not been able to confirm the reception of its WS by each associated STA, and it has not transmitted its WS through DMG Beacon or Announce frames over dot11MaxLostBeacons successive beacon intervals.

In order to transition from PPS mode to active mode, the PCP stops including the DMG Wakeup Schedule element in DMG Beacon and Announce frames. A DMG STA that receives a PCP WS shall assume the PCP WS is in effect until it either receives a DMG Beacon or Announce frame that does not include a DMG Wakeup Schedule element or receives a different PCP WS.

In a PCP D-BI, the PCP should schedule a BTI or ATI. If scheduling an ATI, the PCP should transmit an Announce frame during the ATI to associated STAs.

NOTE 3—The PCP provides the PBSS timing synchronization function (TSF). Transmitting frequent TSF information through DMG Beacon or Announce frames is important when there are non-PCP STAs in the PBSS that rely on TSF information to communicate directly with each other.

The PCP may include in the Extended Schedule element the schedule for the beacon intervals during the PCP D-BIs. The PCP may schedule an SP or CBAP within a D-BI by setting the Allocation Start field of the new SP or CBAP in the Extended Schedule element to a value within a D-BI. If the Extended Schedule element is transmitted, the PCP shall transmit it at least dot11MaxLostBeacons times before the PPS PCP enters the doze state.

The PCP shall check that the schedule of pseudo-static allocations transmitted in the last Extended Schedule element before the PCP entered PPS mode is valid during the PCP D-BIs. Thus, a STA participating in such a pseudo-static allocation assumes that the allocation is present during the following consecutive PCP D-BIs.

The PCP may enter and remain in the doze state for any portion of an SP if it is not a source or a destination of the SP. The PCP shall remain in the awake state for any portion of a truncatable or extendable SP (9.4.2.131). The CDMG PCP shall remain in the awake state for any portion of an extendable SP or a truncatable SP whose Truncation Type subfield is 0 (9.4.2.131). The availability of the PCP during a CBAP in the A-BI shall be announced by setting the PCP Active subfield within the Allocation Control field to 1 for a CBAP allocation made through the Extended Schedule element.

NOTE 4—A PCP that indicates availability during a CBAP that includes an awake window can exchange ATIM frames with non-AP and non-PCP STAs during the awake window and possibly enter the doze state for the remainder of the CBAP outside the awake window (see 11.2.7.4).

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Figure 11-15 shows an example of the basic operation of a PCP in PPS mode when the PCP sleep interval equals one beacon interval (i.e., PCP sleeps every other beacon interval) and the PCP sleep interval starts right after the first beacon interval. In this example, the first beacon interval and the second beacon interval have the same schedule, but the third beacon interval and the fourth beacon interval have different schedules. The first beacon interval is the A-BI in which the PPS PCP is in the awake state to serve non-PCP STAs. In the first beacon interval, the PCP transmits the Extended Schedule element for the current beacon interval with the pseudo-static subfield set to 1 for all allocations within the Extended Schedule element to indicate that the schedule of the first beacon interval also applies to the second beacon interval. In addition, the PCP transmits the DMG Wakeup Schedule element with the information of the start time and the length of the PCP sleep interval, and the STA Availability element to indicate the availability of the PCP for the CBAP of the A-BI. Following the CBAP of the first beacon interval, the PCP enters the doze state and sleeps for more than one beacon interval. The PCP switches from the doze state to the awake state after sleeping through the remainder of the first beacon interval and through the entire second beacon interval, which is the start of the third beacon interval in Figure 11-15. Since in this example the schedule of the third beacon interval and the fourth beacon interval are different, the PCP transmits the Extended Schedule element containing the individual allocations for the third beacon interval and fourth beacon interval. The PCP enters the doze state after it completes all exchanges in the third beacon interval and wakes up at the start of the fifth beacon interval.

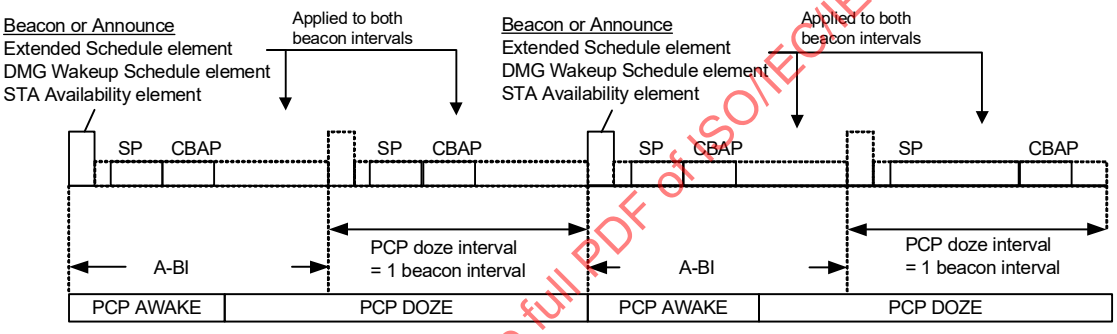

Figure 11-15—Example operation of PPS mode

11.2.7.4 ATIM frame usage for power management of non-AP STAs

An awake window is present within the first CBAP of a beacon interval that is scheduled through the Extended Schedule element and has the Source AID and Destination AID fields in that Extended Schedule element equal to the broadcast AID, or in a CBAP that is scheduled through the CBAP Only field in the DMG Parameters field (9.4.1.46) set to 1, for dot11MaxLostBeacons beacon intervals following the most recent transmission of the Awake Window element (9.4.2.137) by the AP or PCP with the Awake Window Duration field set to a nonzero value.

NOTE 1—Transmission rules during the awake window are the same as the transmission rules for the CBAP that the awake window belongs to.

A non-AP and non-PCP STA delivers the Awake Window element to an AP or PCP as defined in 11.2.7.2.3. An AP or PCP delivers the Awake Window element to a non-AP and a non-PCP STA as defined 11.2.7.3.

If present, the awake window starts from the beginning of a CBAP and has a duration that is defined by the Awake Window Duration field in the Awake Window element or the CBAP duration, whichever is smaller. During the awake window, a STA shall transmit only ATIM frames. A DMG STA in PS mode shall be in the awake state during each awake window that lies within each A-BI for that STA.

BUs that are to be transmitted to a STA that is in PS mode are first announced through ATIM frames during the awake window. A STA in PS mode that is awake during an awake window shall listen for these

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announcements to determine if it needs to change its power state. If during the awake window the STA does not receive or transmit an ATIM frame with BSSID equal to the BSSID of the BSS of which the STA is a member, then it may enter the doze state at the end of the awake window. If a STA receives an ATIM frame during the awake window, it shall acknowledge the ATIM frame. Any two STAs that successfully complete an ATIM frame exchange with each other during the awake window become peer STAs.

A STA that is in PS mode and following a wakeup schedule and is in the awake state and receives an ATIM frame during the awake window shall be awake during allocations within the current beacon interval that have the Source AID equal to broadcast AID or have a Source AID that identifies a STA whose MAC address is equal to the TA field of the received ATIM frame, or during any DTI that is scheduled through the CBAP Only field in the DMG Parameters field (9.4.1.46) set to 1. If a STA transmits an ATIM frame during the awake window, it shall attempt to deliver its BUs during allocations within the current beacon interval that have a Destination AID equal to broadcast AID or have a Destination AID that identifies a STA whose MAC address is equal to the RA field of the transmitted ATIM frame, or during any DTI that is scheduled through the CBAP Only field in the DMG Parameters field (9.4.1.46) set to 1. A STA that receives or transmits an ATIM frame during the awake window may enter the doze state when it has successfully transmitted to and received from all corresponding peer STAs for this beacon interval a QoS Data frame with the EOSP subfield set to 1; otherwise it shall stay active until the end of the current beacon interval. ATIM frame transmissions and MSDU transmissions follow the rules defined in 11.2.8.

NOTE 2—A STA is in the doze state and receives an ATIM frame during an awake window can leave the doze state following the procedure in 11.2.7.2.2or 11.2.7.3.2.

Figure 11-16 illustrates an example of a DMG STA response to an ATIM frame. For illustration purposes the 5 beacon intervals shown in the figure are numbered from 0 to 4. The PCP is following a wakeup schedule, with 1 A-BI out of every 4 beacon intervals. The non-PCP STA A is also following a wakeup schedule, with 1 A-BI out of every 2 beacon intervals. In addition, STA A performs unscheduled power save during beacon interval 0, and also during beacon interval 2 to beacon interval 4. STA A is required to stay awake during the following CBAP after receiving an ATIM frame in beacon interval 2. An ATIM frame received during beacon interval 4, however, serves as a traffic indication and PCP will transmit frames to STA A only after STA A is in the awake state.

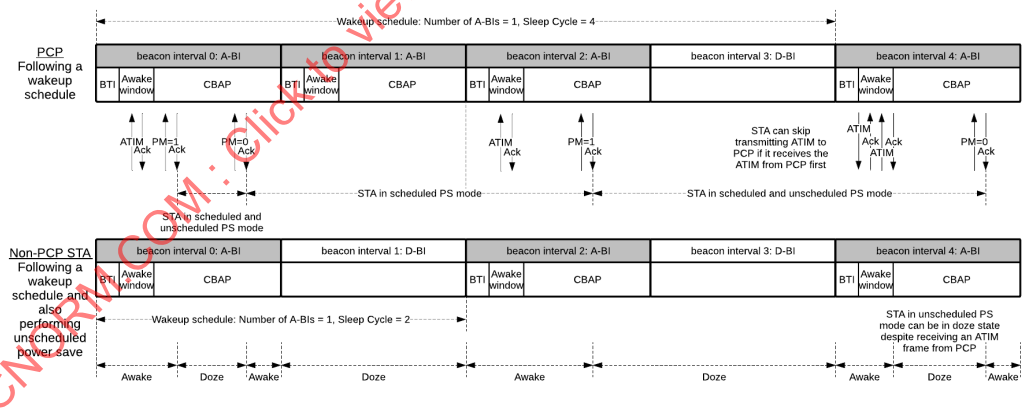

Figure 11-16—Example of ATIM frame response behavior in PS mode

The ATIM frame transmission result and EOSP notification result between a MAC address pair can be used for other MAC pairs that are members of the same MMSL cluster.

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11.2.8 ATIM frame and frame transmission in IBSS, DMG infrastructure BSS, and PBSS

Power management in an IBSS is deprecated. If power management is in use within an IBSS, a STA shall buffer individually addressed BUs for STAs that are known to be in PS mode.

The following rules describe operation of the ATIM frame and frame transmission to STAs in PS mode in an IBSS, DMG infrastructure BSS and PBSS:

a) Following the reception or transmission of the Beacon frame in a non-DMG IBSS, during the ATIM window, the STA shall queue for transmission an individually addressed ATIM frame to each STA for which it has one or more buffered individually addressed BUs and for which an ATIM frame is not already queued. Following the BTI or ATI in a DMG BSS, during the Awake Window, the STA shall queue for transmission an individually addressed ATIM frame to each STA for which it has one or more buffered individually addressed BUs and for which an ATIM frame is not already queued. If the STA has one or more buffered group addressed MSDUs or has one or more buffered group addressed MMPDUs, it shall queue for transmission an appropriately addressed group addressed ATIM frame if such an ATIM frame is not already queued.

b) In a non-DMG IBSS, a STA shall use the backoff procedure defined in 10.3.4.3 for transmission of the first ATIM frame following the Beacon frame. In a DMG BSS, a STA shall use the backoff procedure defined in 10.3.4.3 for transmission of the first ATIM frame following the BTI or ATI. All remaining ATIM frames shall be transmitted using the DCF (for non-QoS STAs) or the EDCAF (for QoS STAs).

c) ATIM frames shall be transmitted only during the the ATIM window (for an IBSS STA) or Awake Window (for a non-IBSS DMG STA).

d) A non-DMG STA shall transmit no frame types other than RTS, CTS, Ack, Beacon, ATIM and (QoS) Null frames during the ATIM window.

e) Individually addressed ATIM frames shall be acknowledged. If no acknowledgment is received, the ATIM frame shall be retransmitted using either the DCF (for non-QoS STAs) or the EDCAF (for QoS STAs). Group addressed ATIM frames shall not be acknowledged.

f) If a STA is unable to transmit an ATIM frame during the the ATIM window (for an IBSS STA) or Awake Window (for a non-IBSS DMG STA), for example due to contention with other STAs, the STA should retain the buffered BUs and either discard the ATIM frame or attempt to transmit the ATIM frame during the next the ATIM window (for an IBSS STA) or Awake Window (for a non-IBSS DMG STA).

g) Immediately following the ATIM window (for an IBSS STA) or Awake Window (for a non-IBSS DMG STA), a STA shall begin transmission of any buffered group addressed frames for which an ATIM frame was previously transmitted. Following the transmission of any group addressed frames, any BUs addressed to STAs for which an acknowledgment for a previously transmitted ATIM frame was received shall be transmitted. A STA shall use the backoff procedure defined in 10.3.4.3 for transmission of the first frame following the the ATIM window (for an IBSS STA) or Awake Window (for a non-IBSS DMG STA). All remaining frames shall be transmitted using either the DCF (for non-QoS STAs) or the EDCAF (for QoS STAs).

h) If a buffered BU is transmitted using fragmentation and if the BU has been partially transmitted when the next Beacon frame is sent in a non-DMG IBSS or when the next beacon interval begins in a DMG BSS, the STA shall retain the buffered BU and announce the remaining fragments by transmitting an ATIM frame during the next the ATIM window (for an IBSS STA) or Awake Window (for a non-IBSS DMG STA).

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i) If a STA is unable to transmit a buffered BU during the beacon interval in which it was announced, for example due to contention with other STAs, the STA shall retain the buffered BU and announce the BU again by transmitting an ATIM frame during the next the ATIM window (for an IBSS STA) or Awake Window (for a non-IBSS DMG STA).

j) Following the transmission of all buffered BUs, a STA may transmit BUs without announcement to STAs that are known to be in the awake state for the current beacon interval.

k) A STA may discard BUs buffered for later transmission to power saving STAs if the STA determines that the BU has been buffered for an excessive amount of time or if other conditions internal to the STA implementation make it desirable to discard buffered BUs (e.g., buffer starvation). A BU should not be discarded that has been buffered for less than dot11BeaconPeriod. The algorithm to manage this buffering is beyond the scope of this standard.

l) In order to indicate its intent to change power management modes, a STA shall transmit individually addressed or group addressed (QoS) Null frames within the ATIM window.

The STA shall not transition into or out of PS mode unless it has received acknowledgments from all recipients to which individually addressed (QoS) Null frames have been transmitted or after it has transmitted a sufficient number of group addressed (QoS) Null frames.

NOTE—The choice between individually addressed and group addressed transmissions, the peer STAs addressed for individually addressed transmissions, and the number of transmissions for group addressed transmissions are implementation choices outside the scope of the standard. A STA might base its choices on factors such as the number of peer STAs it is aware of in the IBSS, the expected traffic from each of these peer STAs, and the reliability of frame exchanges with these peer STAs.

11.2.9 Power management with general links

GLK STAs that have established general links (associations) have additional power management behaviors to support Data frames with a SYNRA and GLK GCR. These behaviors are in addition to the GLK STA behaviors listed in the previous subclauses.

NOTE 1—It is suggested that a STA using a general link that carries unknown traffic loads on behalf of other endpoints not use PS mode, due to the increased delay and jitter it would cause. However, GLK STAs that find PS mode useful may utilize PS mode while performing behaviors in this subclause.

Data frames with a SYNRA are queued for normal (nonbuffered) transmission to associated GLK STAs that are not in PS mode. A SYNRA shall not be used to address GLK STAs in PS mode.

NOTE 2—The net effect of the above is that any GLK non-AP STA in PS mode will, for all traffic for which the PS STA is a recipient, result in MPDUs that are buffered and, if there are multiple receivers, potentially duplicated. The IEEE 802.1Q bridge at the AP should use higher-layer facilities to filter traffic being sent to the STA so as to limit the amount of buffered traffic.

A GLK STA that has enabled GLK-GCR on its general link shall not enter PS mode. GLK STAs shall not use the FMS, TFS nor WNM-Sleep procedures applied to group addressed frames.

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11.3 STA authentication and association

11.3.1 State variables

A STA (local) for which dot11OCBActivated is false keeps an enumerated state variable for each STA (remote) with which direct communication via the WM is needed. In this context, direct communication refers to the transmission of any Class 2 or Class 3 frame with an Address 1 field that matches the MAC address of the remote STA.

A STA for which dot11MeshActivated is true (i.e., a mesh STA) does not use procedures described in 11.3.5. Instead, a mesh STA uses a mesh peering management protocol (MPM) or a authenticated mesh peering exchange (AMPE) to manage states and state variables for each peer STA. See 14.3 and 14.5 for details.

A STA for which dot11OCBActivated is true does not use MAC sublayer authentication or association and does not keep this state variable.

For nonmesh STAs, this state variable expresses the relationship between the local STA and the remote STA. It takes on the following values:

— *State 1*: Initial start state for non-DMG STAs and for DMG STAs that perform IEEE 802.11 authentication. Unauthenticated and unassociated.
— *State 2*: Initial start state for DMG STAs that do not perform IEEE 802.11 authentication. Authenticated (except DMG STAs that do not perform IEEE 802.11 authentication, which are unauthenticated) but unassociated.
— *State 3*: Authenticated (except DMG STAs that did not perform IEEE 802.11 authentication, which are unauthenticated) and associated (Pending RSNA Authentication). The IEEE 802.1X Controlled Port is blocked.
— *State 4*: Authenticated (except DMG STAs that did not perform IEEE 802.11 authentication, which are unauthenticated) and associated (RSNA Established or Not Required). The IEEE 802.1X Controlled Port is unblocked, or not present.

The state variable is kept within the MLME (i.e., is written and read by the MLME). The SME may also read this variable using the MLME-GETAUTHASSOCSTATE.request primitive.

Mesh STAs manage the state variable as described in 14.3.2.

11.3.2 State transition diagram for nonmesh STAs

Figure 11-17 shows the state transition diagram for nonmesh STA states. Note that only events causing state changes are shown. The state of the sending STA given by Figure 11-17 is with respect to the intended receiving STA.

NOTE—A transition to State 1 might occur for other reasons such as no frames having been received from a STA for a period of time.

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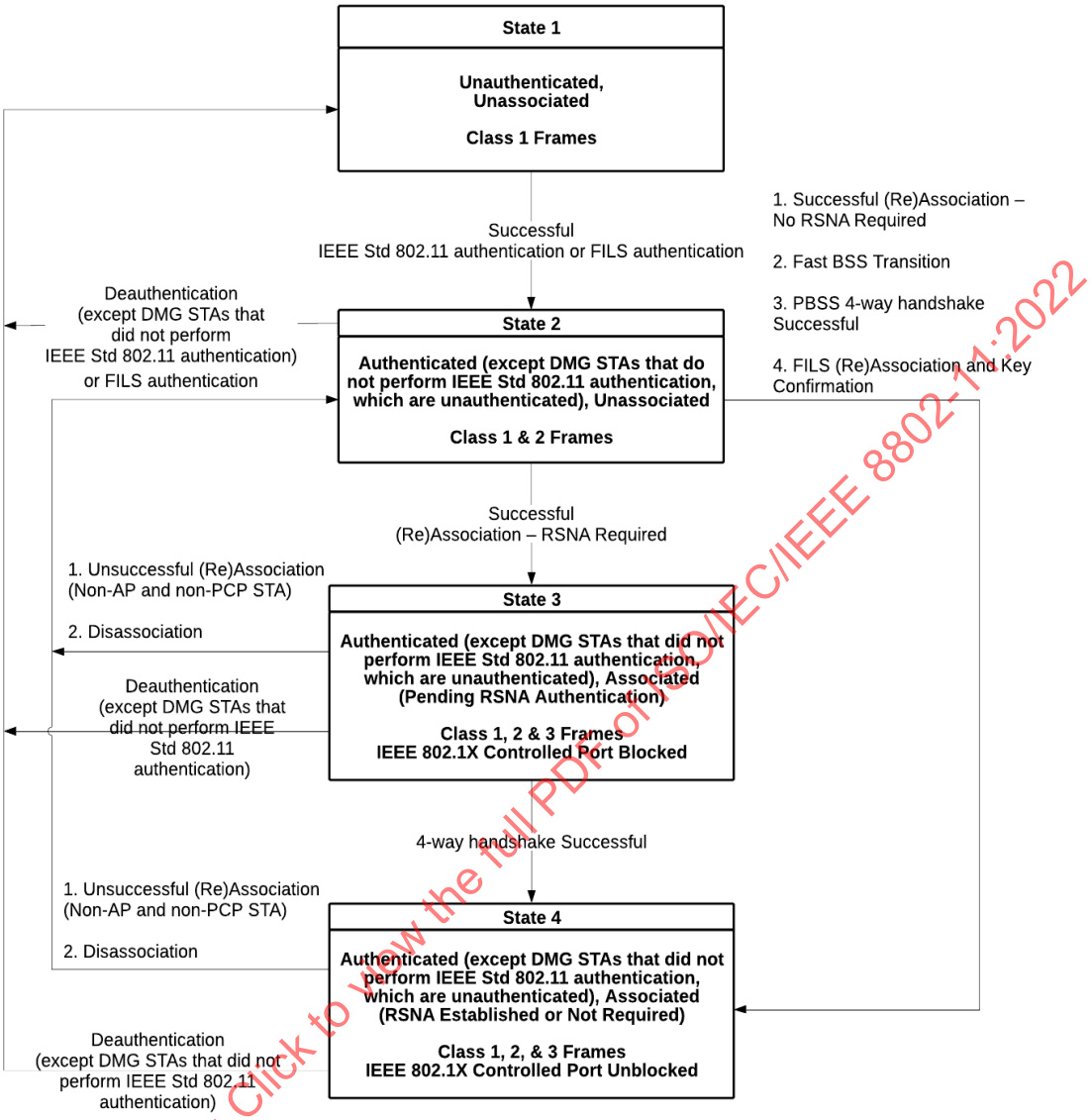

Figure 11-17—Relationship between state and services between a given pair of nonmesh STAs

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11.3.3 Frame filtering based on STA state

The current state existing between the transmitter and receiver STAs determines the IEEE 802.11 frame types that may be exchanged between that pair of STAs (see Clause 9). A unique state exists for each pair of transmitter and receiver STAs. The allowed frame types are grouped into classes and the classes correspond to the STA state. In State 1, only Class 1 frames are allowed. In State 2, only Class 1 or Class 2 frames are allowed. In State 3 and State 4, all frames are allowed (Classes 1, 2, and 3). In the definition of frame classes, the following terms are used:

— Within an infrastructure BSS: both the transmitting STA and the recipient STA participate in the same infrastructure BSS

— Within a PBSS: both the transmitting STA and the recipient STA participate in the same PBSS

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— Within an IBSS: both the transmitting STA and the recipient STA participate in the same IBSS
— dot11RSNAActivated: reference to the setting of dot11RSNAActivated at the STA that needs to determine whether a transmission or reception is permitted.

NOTE—The phrase "within a BSS" comprises "within a PBSS," "within an IBSS," "within an MBSS," or "within an infrastructure BSS."

STA A participates in the same infrastructure BSS as STA B if at least one of the following conditions is met:

— STA A is associated with STA B, and either STA A or STA B is an AP.
— STA A receives a frame with the value of its TA field equal to the MAC address of STA B and with the value of its BSSID field equal to the BSSID of the BSS of which STA A is a member.
— STA A receives an Information Response frame from the AP with which it is associated containing an explicit indication that STA B is a member of the same BSS as STA A.

STA A participates in the same PBSS as STA B if at least one of the following conditions is met:

— STA A is associated with STA B, and either STA A or STA B is a PCP.
— STA A receives a frame with the value of its TA field equal to the MAC address of STA B and with the value of its BSSID field equal to the BSSID of the PBSS that STA A has joined or started.
— STA A receives a frame, i.e., an Information Response frame, from its PCP containing an explicit indication that STA B is a member of the PBSS that STA A has joined.

STA A participates in the same IBSS as STA B if STA A receives a frame with the value of its TA field equal to the MAC address of STA B and with the value of its BSSID field equal to the BSSID of the IBSS that STA A has joined or started.

The frame classes are defined as follows:

a) Class 1 frames
    1) Control frames
        i) RTS
        ii) CTS
        iii) DMG Clear to send (DMG CTS)
        iv) Ack
        v) Grant
        vi) SSW
        vii) SSW-Feedback
        viii) SSW-Ack
        ix) Grant Ack
        x) CF-End
        xi) In an IBSS and in a PBSS when dot11RSNAActivated is false, Block Ack (BlockAck)
        xii) In an IBSS and in a PBSS when dot11RSNAActivated is false, Block Ack Request (BlockAckReq)
    2) Management frames
        i) Probe Request/Response
        ii) Beacon
        iii) Authentication
        iv) Deauthentication
        v) ATIM

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vi) Public Action
vii) Self-protected Action
viii) In an IBSS, all Action frames and all Action No Ack frames
ix) Unprotected DMG Action frames
x) In a PBSS when dot11RSNAActivated is false, all Action and Action No Ack frames except the following frames:
1) ADDTS Request
2) ADDTS Response
3) DELTS

3) Data frames
i) Data frames between IBSS STAs
ii) Data frames within a PBSS

4) Extension frames
i) DMG Beacon

b) Class 2 frames
1) Management frames
i) Association Request/Response
ii) Reassociation Request/Response
iii) Disassociation

c) Class 3 frames
1) Data frames
i) Data frames between STAs in an infrastructure BSS or in an MBSS

2) Management frames
i) In an infrastructure BSS, an MBSS, or a PBSS, all Action and Action No Ack frames except those that are declared to be Class 1 or Class 2 frames

3) Control frames
i) PS-Poll
ii) Poll
iii) SPR
iv) DMG DTS
v) Block Ack (BlockAck), except those that are declared to be Class 1
vi) Block Ack Request (BlockAckReq), except those that are declared to be Class 1 (above)

Class 2 and Class 3 frames are not allowed in an IBSS. If an IBSS STA receives a Class 2 or Class 3 frame, it shall ignore the frame.

A STA shall not transmit Class 2 frames unless in State 2 or State 3 or State 4.

A STA shall not transmit Class 3 frames unless in State 3 or State 4.

A multi-band capable device that uses OCT to move from State 2 to either State 3 or State 4 shall not transmit frames before the transmitting STA becomes over-the-WM enabled (see 11.31.5).

The use of the word “receive” in 11.3 refers to a frame that meets all of the filtering criteria specified in Clause 12 and Clause 10.

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11.3.4 Authentication and deauthentication

11.3.4.1 General

This subclause describes the procedures used for IEEE 802.11 authentication and deauthentication. The states used in this description are defined in 11.3.1.

Successful authentication sets the state for a STA to State 2, if it was in State 1. Unsuccessful authentication leaves the state for the STA unchanged.

Deauthentication notification sets the state for a STA to State 1. Deauthentication notification when in State 3 or 4 implies disassociation as well. A STA may deauthenticate a peer STA at any time, for any reason.

If STA A in an infrastructure BSS receives a Class 2 or Class 3 frame from STA B that is not authenticated with STA A (i.e., the state for STA B is State 1), STA A shall discard the frame. If the frame has an individual address in the Address 1 field, the MLME of STA A shall send a Deauthentication frame to STA B.

Authentication is optional in an IBSS. In a non-DMG infrastructure BSS, authentication is required. In a DMG infrastructure BSS and PBSS, the Open System authentication algorithm is not used (see 12.3.3.1). APs and PCPs do not initiate authentication.

11.3.4.2 Authentication—originating STA

Upon receipt of an MLME-AUTHENTICATE.request primitive that is part of an on-channel tunneling (see 11.31.5), the originating STA shall follow the rules in 11.31.5 in addition to the authentication procedure described below.

Upon receipt of an MLME-AUTHENTICATE.request primitive, the originating STA shall authenticate with the indicated STA using the following procedure:

a) If the STA is in an IBSS, the SME shall delete any PTKSA, GTKSA, IGTKSA and temporal keys held for communication with the indicated STA by using the MLME-DELETEKEYS.request primitive (see 12.6.18).

b) The STA shall execute one of the following:
   1) For the Open System or Shared Key authentication algorithm, the authentication mechanism described in 12.3.3.2 or 12.3.3.3, respectively.
   2) For the fast BSS transition (FT) authentication algorithm in an ESS, the authentication mechanism described in 13.5, or, if resource requests are included, 13.6.
   3) For SAE authentication in an infrastructure BSS, IBSS, or MBSS, the authentication mechanism described in 12.4.
   4) For FILS authentication, the authentication mechanism described in 12.11. An AP or PCP may provide estimated association response latency to a non-AP and non-PCP STA using the Association Delay Info field in the Association Delay Info element (9.4.2.174). The value of the Association Delay Info field shall be larger than dot11HLPWaitTime.

c) If the authentication was successful within the AuthenticateFailureTimeout, the state for the indicated STA shall be set to State 2 if it was State 1; the state shall remain unchanged if it was other than State 1.

d) The MLME shall issue an MLME-AUTHENTICATE.confirm primitive to inform the SME of the result of the authentication.

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11.3.4.3 Authentication—destination STA

Upon receipt of an Authentication frame with authentication transaction sequence number equal to 1, the destination STA shall authenticate with the originating STA using the following procedure:

a) If Open System or Shared Key authentication algorithm is being used, the STA shall execute the procedure described in 12.3.3.2 or 12.3.3.3, respectively. These result in the generation of an MLME-AUTHENTICATE.indication primitive to inform the SME of the authentication request.

b) If FT authentication is being used, the MLME shall issue an MLME-AUTHENTICATE.indication primitive to inform the SME of the authentication request, including the FT Authentication Elements, and the SME shall execute the procedure as described in 13.5 or 13.6.

c) If SAE authentication is being used in an infrastructure BSS, IBSS, or MBSS, the MLME shall issue an MLME-AUTHENTICATE.indication primitive to inform the SME of the authentication request, including the SAE authentication elements, and the SME shall execute the procedure as described in 12.4.

d) If FILS authentication is being used, the MLME shall issue an MLME-AUTHENTICATE.indication primitive to inform the SME of the authentication request, and the SME shall execute the procedure described in 12.11.

e) If the STA is in an IBSS and management frame protection was not negotiated when the PTKSA(s) were created, the SME shall delete any PTKSA, GTKSA, IGTKSA and temporal keys held for communication with the originating STA by using the MLME-DELETEKEYS.request primitive (see 12.6.18).

f) Upon receipt of an MLME-AUTHENTICATE.response primitive, if the ResultCode is not SUCCESS, the MLME shall transmit an Authentication frame with the corresponding status code, as defined in 9.4.1.9, and the state for the originating STA shall be left unchanged. The Authentication frame is constructed using the appropriate procedure in 12.3.3.2, 12.3.3.3, 13.5, or 13.6.

g) Upon receipt of an MLME-AUTHENTICATE.response primitive, if the ResultCode is SUCCESS, the MLME shall transmit an Authentication frame that is constructed using the appropriate procedure in 12.3.3.2, 12.3.3.3, 13.5 or 13.6, with a status code of SUCCESS, and the state for the originating STA shall be set to State 2 if it was in State 1; the state shall remain unchanged if it was other than State 1.

NOTE—If management frame protection was negotiated, the SME does not change the state for the originating STA and does not delete any of the previously created SAs or temporal keys as a part of this authentication procedure.

If the STA is in an IBSS, if the SME decides to initiate an RSNA, and if the SME does not know the security policy of the peer, it may issue an individually addressed Probe Request frame to the peer by invoking an MLME-SCAN.request primitive to discover the peer's security policy.

When a non-AP and non-PCP STA receives an Authentication frame that includes an Association Delay Info element, it sets dot11AssociationResponseTimeOut equal to or larger than the Association Delay Info field.

11.3.4.4 Deauthentication—originating STA

The originating STA shall deauthenticate with the indicated STA using the following procedure:

a) The SME shall generate an MLME-DEAUTHENTICATE.request primitive containing the appropriate reason code for the STA deauthentication, as defined in Table 9-49 of 9.4.1.7.

b) On receipt of the MLME-DEAUTHENTICATE.request primitive, if the state for the indicated STA is State 2, State 3, or State 4, the MLME shall generate a Deauthentication frame to be transmitted to the indicated STA.

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NOTE—As the Deauthentication frame is a bufferable MMPDU, the transmission of this frame might be delayed by the operation of a power saving protocol. The AID and the PTKSA are maintained (when applicable) until the frame is acknowledged or attempts to transmit the frame are abandoned.

c) The state for the indicated STA shall be set to State 1.

d) Once the Deauthentication frame is acknowledged or attempts to transmit the frame are abandoned, the MLME shall issue an MLME-DEAUTHENTICATE.confirm primitive to inform the SME of the deauthentication.

e) The SME, upon receipt of an MLME-DEAUTHENTICATE.confirm primitive, shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA and temporal keys held for communication with the indicated STA by using the MLME-DELETEKEYS.request primitive (see 12.6.18) and by generating an MLME-SETPROTECTION.request(None) primitive.

f) If the STA is contained within an AP or PCP, its SME, upon receipt of an MLME-DEAUTHENTICATE.confirm primitive, shall release the AID assigned for the indicated STA, if the state for the indicated STA was State 3 or State 4.

g) If the STA is contained within an AP, its SME shall inform the DS of the disassociation, if the state for the indicated STA was State 3 or State 4.

h) If the STA is a mesh STA, its SME shall inform the mesh peering instance controller (see 14.3.4) of the deauthentication.

11.3.4.5 Deauthentication—destination STA

A DMG STA in State 2, State 3 or State 4 that receives a Deauthentication frame shall remain in the same state if it did not perform an IEEE 802.11 authentication exchange.

Otherwise, upon receipt of a Deauthentication frame from a STA for which the state is State 2, State 3, or State 4, the destination STA shall deauthenticate with the originating STA using the following procedure:

a) If management frame protection was not negotiated when the PTKSA(s) were created, or if management frame protection is in use and the frame is not discarded per management frame protection processing, the MLME shall issue an MLME-DEAUTHENTICATE.indication primitive to inform the SME of the deauthentication, and set the state for the originating STA to State 1.

b) Upon receiving an MLME-DEAUTHENTICATE.indication primitive, the SME shall

   1) Delete any PTKSA, GTKSA, IGTKSA, BIGTKSA and temporal keys held for communication with the originating STA by using the MLME-DELETEKEYS.request primitive (see 12.6.18) and by generating an MLME-SETPROTECTION.request(None) primitive.

   2) If the STA is contained within an AP or PCP, release the AID assigned for the indicated STA.

   3) If the STA is contained within an AP, inform the DS of the disassociation, if the state for the originating STA was State 3 or State 4.

   4) If the STA is a mesh STA, inform the mesh peering instance controller (see 14.3.4) of the deauthentication.

11.3.5 Association, reassociation, and disassociation

11.3.5.1 General

Subclause 11.3.5 describes the procedures used for IEEE 802.11 association, reassociation, and disassociation.

The states used in this description are defined in 11.3.1.

Successful association enables a STA to exchange Class 3 frames. Successful association sets the state for a non-FILS STA to State 3 or State 4. Successful association sets the state for FILS STAs to State 4.

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Successful reassociation enables a STA to exchange Class 3 frames. Unsuccessful reassociation when not in State 1 leaves the state for a STA state unchanged [with respect to the AP or PCP that was sent the Reassociation Request (which may be the current STA)]. Successful reassociation sets the state for a non-FILS STA to State 3 or State 4 (with respect to the AP or PCP that was sent the Reassociation Request frame). Successful reassociation when not in State 1 sets the state for a STA to State 2 (with respect to the current AP or PCP, if this is not the AP or PCP that was sent the Reassociation Request frame). Successful reassociation sets the state for a FILS STA to State 4 (with respect to the AP or PCP that was sent the Reassociation Request frame) and enables it to exchange Class 3 frames. Reassociation shall be performed only if the originating STA is already associated in the same ESS.

Disassociation notification when not in State 1 sets the state for a non-FILS STA to State 2. Disassociation notification when not in State 1 sets the state for a FILS STA to State 1. The STA shall become associated again prior to sending Class 3 frames. A STA may disassociate a peer STA at any time, for any reason.

If non-DMG STA A in an infrastructure BSS receives a Class 3 frame from STA B that is authenticated but not associated with STA A (i.e., the state for STA B is State 2), STA A shall discard the frame. If the frame has an individual address in the Address 1 field, the MLME of STA A shall send a Disassociation frame to STA B.

If DMG STA A in an infrastructure BSS receives a Class 3 frame from STA B that is not associated with STA A (i.e., the state for STA B is State 2), STA A shall discard the frame. If the frame has an individual address in the Address 1 field, the MLME of STA A shall send a Disassociation frame to STA B.

If an MM-SME coordinated STA receives an Association Response frame with a result code equal to SUCCESS and with the Single AID field within MMS element equal to 1, then

— For each of its MAC entities advertised within the MMS element and for which dot11RSNAActivated is true, the state is set to State 3. Progress from State 3 to State 4 occurs independently in each such MAC entity.
— For each of its MAC entities advertised within the MMS element and for which dot11RSNAActivated is false, the state is set to State 4.

If the MM-SME coordinated STA in State 3 is assigned an AID for only the MAC entity identified by the RA field of the Association Response frame with result code equal to SUCCESS, the MM-SME may repeat the association procedure for any other MAC entity coordinated by the MM-SME.

Association is not applicable in an IBSS. In an infrastructure BSS, association is required. In a PBSS, association is optional. APs and PCPs do not initiate association.

11.3.5.2 Non-AP and non-PCP STA association initiation procedures

The SME shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA and temporal keys held for communication with the AP or PCP by using MLME-DELETEKEYS.request primitive (see 12.6.18) before invoking MLME-ASSOCIATE.request primitive.

If dot11InterworkingServiceActivated is true, the STA is associating with an AP but does not have credentials for the AP, and the STA is initiating an emergency services association procedure, the SME shall submit the MLME-ASSOCIATE.request primitive with EmergencyServices parameter set to true.

The MM-SME of a non-AP and non-PCP STA may include an MMS element in an MLME-ASSOCIATE.request primitive. The MM-SME shall include in the MMS element the MAC address associated with the MLME SAP instance to which the primitive is submitted.

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Upon receipt of an MLME-ASSOCIATE.request primitive that is part of an on-channel tunneling (see 11.31.5), a non-AP and non-PCP STA shall follow the rules in 11.31.5 in addition to the association procedures described below.

Upon receipt of an MLME-ASSOCIATE.request primitive, a non-AP and non-PCP STA shall associate with an AP or PCP using the following procedure:

a) If the state for the AP or PCP is State 1, the MLME shall inform the SME of the failure of the association by issuing an MLME-ASSOCIATE.confirm primitive, and this procedure ends.

b) All the states, agreements and allocations listed in both numbered lists in 11.3.5.4 item c) are deleted or reset to initial values.

c) The MLME shall transmit an Association Request frame to the AP or PCP. The RSNE contained in the MLME-ASSOCIATE.request primitive shall be included in the Association Request frame. The RSNE shall specify exactly one pairwise cipher suite and exactly one AKM suite. If the MLME-ASSOCIATE.request primitive contained the EmergencyServices parameter equal to true, an Interworking element with the UESA field set to 1 shall be included in the Association Request frame.

d) If an Association Response frame is received with a status code of SUCCESS, a DMG STA shall write to each of the following MIB attributes the corresponding subfield of the DMG BSS Parameter Configuration field of the DMG Operation element received from the AP or PCP to which it requested association:

   1) dot11PSRequestSuspensionInterval from the PSRequestSuspensionInterval subfield
   2) dot11MinBHIDuration from the MinBHIDuration subfield
   3) dot11BroadcastSTAInfoDuration from the BroadcastSTAInfoDuration subfield
   4) dot11AssocRespConfirmTime from the AssocRespConfirmTime subfield
   5) dot11MinPPDuration from the MinPPDuration subfield
   6) dot11SPIdleTimeout from the SPIdleTimeout subfield
   7) dot11MaxLostBeacons from the MaxLostBeacons subfield

e) If an Association Response frame is received with a status code of SUCCESS, the state for the AP or PCP shall be set to State 4 or, if dot11RSNAActivated is true, State 3. The state for any other AP or PCP which is State 3 or State 4 prior to the association request shall be set to State 2, and the MLME shall issue an MLME-ASSOCIATE.confirm primitive to inform the SME of the successful completion of the association.

f) If an Association Response frame is received with a status code of SUCCESS at an MM-SME coordinated STA and the Single AID field within the MMS element is equal to 1, then

   — For each of its MAC entities advertised within the MMS element and for which dot11RSNAActivated is true, the state is set to State 3. Progress from State 3 to State 4 occurs independently in each such MAC entity.
   — For each of its MAC entities advertised within the MMS element and for which dot11RSNAActivated is false, the state is set to State 4.
   — For each of its MAC entities advertised within the MMS element the state for any other AP or PCP which is State 3 or State 4 prior to the association request shall be set to State 2.

g) If an Association Response frame is received with a status code other than SUCCESS or the association fails to complete within dot11AssociationResponseTimeout the state for the AP or PCP shall be set to State 2, and the MLME shall issue an MLME-ASSOCIATE.confirm primitive to inform the SME of the failure of the association. The status code returned in the Association Response frame indicates the cause of the failed association attempt. Any misconfiguration or parameter mismatch, e.g., data rates required as basic rates that the STA did not indicate as supported in the STA's Supported Rates and BSS Membership Selectors element, shall be corrected before the SME issues an MLME-ASSOCIATE.request primitive for the same AP or PCP. If the

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status code indicates the association failed because of a reason that is not related to configuration (e.g., the AP or PCP is unable to support additional associations) and the Association Response frame does not include a Timeout Interval element with Timeout Interval Type equal to 3 the SME shall not issue an MLME-ASSOCIATE.request primitive for the same AP or PCP until a period of at least 2 s has elapsed. If the status code indicates the association failed and the Association Response frame contains a Timeout Interval element with Timeout Interval Type equal to 3, the SME shall not issue an MLME-ASSOCIATE.request primitive for the same AP or PCP until the period specified in the Timeout Interval element has elapsed.

h) If an MLME-ASSOCIATE.confirm primitive is received with a ResultCode of SUCCESS, and RSNA is required, and FILS authentication was not used, then the SME shall perform a 4-way handshake to establish an RSNA. As a part of a successful 4-way handshake, the SME shall enable protection by generating an MLME-SETPROTECTION.request(Rx_Tx) primitive. If an MLME-ASSOCIATE.confirm primitive is received with a ResultCode of SUCCESS, and FILS authentication was used, then the SME shall enable protection by generating an MLME-SETPROTECTION.request(Rx_Tx) primitive.

i) Upon receipt of the MLME-SETPROTECTION.request(Rx_Tx) primitive, the MLME shall set the state of the STA to State 4.

11.3.5.3 AP or PCP association receipt procedures

Upon receipt of an Association Request frame from a STA the AP or PCP shall use the following procedure:

a) The MLME shall issue an MLME-ASSOCIATE.indication primitive to inform the SME of the association request. The SME shall issue an MLME-ASSOCIATE.response primitive addressed to the STA identified by the PeerSTAAddress parameter of the MLME-ASSOCIATE.indication primitive. If the association is not successful, the SME shall indicate a specific reason for the failure to associate in the ResultCode parameter. Upon receipt of the MLME-ASSOCIATE.response primitive, the MLME shall transmit an Association Response frame.

b) If the state for the STA is 1 and the STA is a non-DMG STA, the SME shall refuse the association request by issuing an MLME-ASSOCIATE.response primitive with ResultCode NOT_AUTHENTICATED.

c) AP with dot11InterworkingServiceActivated true only: If the MLME-ASSOCIATE.indication primitive has the EmergencyServices parameter set to true and the RSN parameter does not include an RSNE, the SME shall not reject the association request on the basis that dot11RSNAActivated is true, thereby granting access, using unprotected frames (see 9.2.4.1.9), to the network for emergency services purposes.

d) Otherwise, in an RSNA the SME shall check the values received in the RSN parameter to see whether the values received match the security policy. If they do not, the SME shall refuse the association by issuing an MLME-ASSOCIATE.response primitive with a ResultCode indicating the security policy mismatch.

e) Otherwise, if the state for the STA is 4, the STA has a valid security association, the STA has negotiated management frame protection, the STA has not performed a successful SAE authentication after the current association was established, and there has been no earlier, timed out SA Query procedure with the STA (which would have allowed a new association process to be started, without an additional SA Query procedure):

   1) The SME shall refuse the association request by issuing an MLME-ASSOCIATE.response primitive with ResultCode REFUSED_TEMPORARILY and TimeoutInterval containing a Timeout Interval element with the Timeout Interval Type field set to 3 (Association Comeback time). If the SME is in an ongoing SA Query with the STA, the Timeout Interval Value field shall be set to the remaining SA Query period, otherwise it shall be set to dot11Association-SAQueryMaximumTimeout.

   2) The state for the STA shall be left unchanged.

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3) Following this, if the SME is not in an ongoing SA Query with the STA, the SME shall issue one MLME-SA-QUERY.request primitive addressed to the STA every dot11AssociationSAQueryRetryTimeout TUs until an MLME-SA-QUERY.confirm primitive for the STA is received or dot11AssociationSAQueryMaximumTimeout TUs from the beginning of the SA Query procedure have passed. The SME shall increment the TransactionIdentifier by 1 for each MLME-SA-QUERY.request primitive, rolling it over the value to 0 after the maximum allowed value is reached.

4) If no MLME-SA-QUERY.confirm primitive for the STA is received within the dot11AssociationSAQueryMaximumTimeout period, the SME shall allow a subsequent association process with the STA to be started without starting an additional SA Query procedure, except that the SME may deny a subsequent association process with the STA if an MSDU was received from the STA within this period.

NOTE 1—Reception of an MSDU implies reception of a valid protected frame, which obviates the need for the SA Query procedure.

f) The SME shall refuse an association request from a STA that does not support all of the rates in the BSSBasicRateSet parameter and all of the membership selectors in the BSSMembershipSelectorSet parameter in the MLME-START.request primitive.

g) The SME shall refuse an association request from an HT STA that does not support all of the MCSs in the Basic HT-MCS Set field of the HT Operation parameter in the MLME-START.request primitive.

h) The SME shall refuse an association request from a VHT STA that does not support all of the <VHT-MCS, NSS> tuples indicated by the Basic VHT-MCS And NSS Set field of the VHT Operation parameter in the MLME-START.request primitive.

i) An AP or PCP may refuse GLK association based on local policy and, if so, shall return the GLK_NOT_AUTHORIZED ResultCode.

NOTE 2—For example, there might be a list of authorized GLK peers or clients or a limit on the number of GLK peers or clients and the peer or client is not on that list or its acceptance would exceed the limit.

j) The SME shall generate an MLME-ASSOCIATE.response primitive with the PeerSTAAddress parameter set to the MAC address of the STA identified by the PeerSTAAddress parameter of the MLME-ASSOCIATE.indication primitive. If the ResultCode in the MLME-ASSOCIATE.response primitive is SUCCESS, the SME has an existing SA with the STA, and an SA Query procedure with that STA has failed to receive a valid response (i.e., has not received an MLME-SA-QUERY.confirm primitive within the dot11AssociationSAQueryMaximumTimeout period), the SME shall issue an MLME-DISASSOCIATE.request primitive addressed to the STA with ReasonCode INVALID_AUTHENTICATION.

NOTE 3—This MLME-DISASSOCIATE.request primitive generates a protected Disassociation frame. If the association request was genuine, the STA has deleted the PTKSA by this point and so the protected Disassociation frame is ignored. The purpose is to inform a STA which has for some reason failed to respond to an SA Query procedure triggered by a forged association request.

k) If the ResultCode in the MLME-ASSOCIATE.response primitive is SUCCESS, all the states, agreements and allocations pertaining to the associating STA and listed in both numbered lists in 11.3.5.4 item c) are deleted or reset to initial values.

l) If the ResultCode in the MLME-ASSOCIATE.response primitive is SUCCESS, the SME shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA and temporal keys held for communication with the STA by using the MLME-DELETEKEYS.request primitive (see 12.6.18).

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m) If the MLME-ASSOCIATE.indication primitive includes an MMS parameter, the AP or PCP shall generate the MLME-ASSOCIATE.response primitive directed to the MLME of the STA identified by the PeerSTAAddress parameter of the MLME-ASSOCIATE.request primitive and take the following additional action, as appropriate:

1) If the Single AID field in the MMS parameter of the MLME-ASSOCIATE.indication primitive is equal to 1, the AP or PCP may allocate a single AID for all of the STAs included in the MMS element. If the AP or PCP allocates the same AID to each STA whose MAC address was included in the MMS element, it shall include the MMS element received from the MM-SME coordinated STA in the MLME-ASSOCIATE.response primitive.

2) If the Single AID field is 0, the AP or PCP shall allocate a distinct AID for each STA specified in the MMS element.

NOTE 4—When the Single AID field is 0, a separate association request/response exchange is performed for each STA specified in the MMS element, and this assigns the multiple AIDs for the STAs.

n) If an Association Response frame with a status code of SUCCESS is acknowledged by the STA, the state for the STA shall be set to State 4 or, if dot11RSNAActivated is true, State 3.

o) If the ResultCode in the MLME-ASSOCIATE.response primitive is not SUCCESS and management frame protection is in use the state for the STA shall be left unchanged. If the ResultCode is not SUCCESS and management frame protection is not in use the state for the STA shall be set to State 3 if it was State 4.

p) If the ResultCode in the MLME-ASSOCIATE.response primitive is SUCCESS and RSNA establishment is required, and FILS authentication was not used, the SME shall attempt a 4-way handshake. Upon a successful completion of the 4-way handshake, the SME shall enable protection by issuing an MLME-SETPROTECTION.request(Rx_Tx) primitive. If FILS authentication was used, the SME shall enable protection by generating an MLME-SETPROTECTION.request(Rx_Tx) primitive. In either case, upon receipt of the MLME-SETPROTECTION.request(Rx_Tx) primitive, the MLME shall set the state for the STA to State 4.

q) AP only: The SME shall inform the DS of any changes in the state of the STA.

11.3.5.4 Non-AP and non-PCP STA reassociation initiation procedures

Except when the association is part of a fast BSS transition, the SME shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA and temporal keys held for communication with the AP or PCP by using the MLME-DELETEKEYS.request primitive (see 12.6.18) before invoking an MLME-REASSOCIATE.request primitive.

If dot11InterworkingServiceActivated is true and the STA was associated to the ESS for unsecured access to emergency services, the SME shall submit the MLME-REASSOCIATE.request primitive with EmergencyServices parameter set to true.

The MM-SME of a non-AP and non-PCP STA may include an MMS element in an MLME-REASSOCIATE.request primitive. The MM-SME shall include in the MMS element the MAC address associated with the MLME SAP instance to which the primitive is submitted.

Upon receipt of an MLME-REASSOCIATE.request primitive that is part of an on-channel tunneling (see 11.31.5), a non-AP and non-PCP STA shall follow the rules in 11.31.5 in addition to the reassociation procedures described below.

Upon receipt of an MLME-REASSOCIATE.request primitive, a non-AP and non-PCP STA shall reassociate with an AP or PCP using the following procedure:

a) If the STA is not associated in the same ESS or the state for the new AP or PCP is State 1, the MLME shall inform the SME of the failure of the reassociation by issuing an MLME-REASSOCIATE.confirm primitive, and this procedure ends.

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b) The MLME shall transmit a Reassociation Request frame to the new AP or PCP. The RSNE contained in the MLME-ASSOCIATE.request primitive shall be included in the Reassociation Request frame. The RSNE shall specify exactly one pairwise cipher suite and exactly one AKM suite. If the MLME-REASSOCIATE.request primitive contained the EmergencyServices parameter equal to true, an Interworking element with the UESA field set to 1 shall be included in the Reassociation Request frame.

c) If a Reassociation Response frame is received with a status code of SUCCESS, the state variable for the new AP or PCP shall be set to State 4 or to State 3 if dot11RSNAActivated is true and the FT protocol is not used with respect to the new AP or PCP and, unless the old AP or PCP and new AP or PCP are the same, to State 2 with respect to the old AP or PCP, and the MLME shall issue an MLME-REASSOCIATE.confirm primitive to inform the SME of the successful completion of the reassociation.

   If the MLME-REASSOCIATION.request primitive has the new AP's or PCP's MAC address in the CurrentAPAddress parameter (reassociation to the same AP or PCP), the following states, agreements, and allocations shall be deleted or reset to initial values:

   1) All EDCAF state
   2) Any block ack agreements that are not GCR agreements
   3) Sequence number
   4) Packet number
   5) Duplicate detection caches
   6) Anything queued for transmission
   7) Fragmentation and reassembly buffers
   8) Power management mode
   9) WNM sleep mode
   10) TPKSAs established with any peers
   11) TSPECs
   12) DMG TSPECs
   13) GLK-GCR agreement
   14) MSCS
   15) SCS

   If the reassociation is to the same AP (as described above), the following states, agreements, and allocations are not affected by the reassociation procedure:

   1) PSMP sessions
   2) Enablement/Deenablement
   3) GDD enablement
   4) TDLS agreements
   5) MMSLs
   6) GCR agreements that are not GLK-GCR agreements
   7) DMS agreements
   8) TFS agreements
   9) FMS agreements
   10) Triggered autonomous reporting agreements
   11) FTM sessions
   12) DMG SP and CBAP allocations
   13) PTP TSPECs

   In the case of reassociation to a different AP or PCP (the CurrentAPAddress parameter is not the new AP's or PCP's MAC address), all the states, agreements and allocations listed above are deleted or reset to initial values.

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d) If a Reassociation Response frame is received with a status code of SUCCESS, a DMG STA shall write to each of the following MIB attributes the corresponding subfield of the DMG BSS Parameter Configuration field of the DMG Operation element received from the AP or PCP to which it requested reassociation:

   1) dot11PSRequestSuspensionInterval from the PSRequestSuspensionInterval subfield
   2) dot11MinBHIDuration from the MinBHIDuration subfield
   3) dot11BroadcastSTAInfoDuration from the BroadcastSTAInfoDuration subfield
   4) dot11AssocRespConfirmTime from the AssocRespConfirmTime subfield
   5) dot11MinPPDuration from the MinPPDuration subfield
   6) dot11SPIdleTimeout from the SPIdleTimeout subfield
   7) dot11MaxLostBeacons from the MaxLostBeacons subfield

e) If an Association Response frame is received with a status code of SUCCESS at an MM-SME coordinated STA and the Single AID field within the MMS element is equal to 1, then

   — For each of its MAC entities advertised within the MMS element and for which dot11RSNAActivated is true, the state is set to State 3. Progress from State 3 to State 4 occurs independently in each such MAC entity.
   — For each of its MAC entities advertised within the MMS element and for which dot11RSNAActivated is false, the state is set to State 4.
   — For each of its MAC entities advertised within the MMS element the state for any other AP or PCP which is State 3 or State 4 prior to the association request shall be set to State 2.

f) If a Reassociation Response frame is received with a status code other than SUCCESS or the reassociation fails to complete within dot11AssociationResponseTimeout:

   1) Except when the association is part of a fast BSS transition, the state for the AP or PCP shall be set to State 2 with respect to the new AP or PCP.
   2) The MLME shall issue an MLME-REASSOCIATE.confirm primitive to inform the SME of the failure of the reassociation. The ResultCode returned in the MLME-REASSOCIATE.confirm primitive indicates the cause of the failed reassociation attempt. Any misconfiguration or parameter mismatch, e.g., data rates required as basic rates that the STA did not indicate as supported in the STA's Supported Rates and BSS Membership Selectors element, shall be corrected before the SME issues an MLME-REASSOCIATE.request primitive for the same AP or PCP. If the status code indicates the reassociation failed because of a reason that is not related to configuration (e.g., the AP or PCP is unable to support additional associations) and the Reassociation Response frame does not include a Timeout Interval element with Timeout Interval Type equal to 3 the SME shall not issue an MLME-REASSOCIATE.request primitive for the same AP or PCP until a period of at least 2 s has elapsed. If the status code indicates the reassociation failed and the Reassociation Response frame contains a Timeout Interval element with Timeout Interval Type equal to 3, the SME shall not issue an MLME-REASSOCIATE.request primitive for the same AP or PCP until the period specified in the Timeout Interval element has elapsed.

g) If an MLME-REASSOCIATE.confirm primitive is received with a ResultCode of SUCCESS, and RSNA is required, and FILS authentication was not used, and the STA is in State 3, then the SME shall perform a 4-way handshake to establish an RSNA. As a part of a successful 4-way handshake, the SME shall enable protection by generating an MLME-SETPROTECTION.request(Rx_Tx) primitive. If an MLME-REASSOCIATE.confirm primitive is received with a ResultCode of SUCCESS, and FILS authentication was used, and the STA is in State 3, then the SME shall enable protection by generating an MLME-SETPROTECTION.request(Rx_Tx) primitive.

h) Upon receipt of the MLME-SETPROTECTION.request(Rx_Tx) primitive, the MLME shall set the state of the STA to State 4.

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11.3.5.5 AP or PCP reassociation receipt procedures

Upon receipt of a Reassociation Request frame from a STA the AP or PCP shall use the following procedure:

a) The MLME shall issue an MLME-REASSOCIATE.indication primitive to inform the SME of the reassociation request. The SME shall issue an MLME-REASSOCIATE.response primitive addressed to the STA identified by the PeerSTAAddress parameter of the MLME-REASSOCIATE.indication primitive. If the reassociation is not successful, the SME shall indicate a specific reason for the failure to reassociate in the ResultCode parameter. Upon receipt of the MLME-REASSOCIATE.response primitive, the MLME shall transmit a Reassociation Response frame.

b) If the state for the STA is 1 and the STA is a non-DMG STA, the SME shall refuse the reassociation request by issuing an MLME REASSOCIATE.response primitive with ResultCode NOT_AUTHENTICATED.

c) AP with dot11InterworkingServiceActivated true only: If the MLME-REASSOCIATE.indication primitive has the EmergencyServices parameter set to true and the RSN parameter does not include an RSNE, the SME shall not reject the reassociation request on the basis that dot11RSNAActivated is true and dot11PrivacyInvoked is true thereby granting access, using unprotected frames (see 9.2.4.1.9), to the network for emergency services purposes.

d) Otherwise, in an RSNA the SME shall check the values received in the RSN parameter to see whether the values received match the security policy. If they do not, SME shall refuse the reassociation by issuing an MLME-REASSOCIATE.response primitive with a ResultCode indicating the security policy mismatch.

e) Otherwise, if the state for the STA is 4, the STA has a valid security association, the STA has negotiated management frame protection, the reassociation is not a part of a fast BSS transition, the STA has not performed a successful SAE authentication after the current association was established, and there has been no earlier, timed out SA Query procedure with the STA (which would have allowed a new reassociation process to be started, without an additional SA Query procedure):

   1) The SME shall refuse the reassociation request by issuing an MLME-REASSOCIATE.response primitive with ResultCode REFUSED_TEMPORARILY and TimeoutInterval containing a Timeout Interval element with the Timeout Interval Type field set to 3 (Association Comeback time). If the SME is in an ongoing SA Query with the STA, the Timeout Interval Value field shall be set to the remaining SA Query period, otherwise it shall be set to dot11AssociationSAQueryMaximumTimeout.

   2) The state for the STA shall be left unchanged.

   3) Following this, if the SME is not in an ongoing SA Query with the STA, the SME shall issue one MLME-SA-QUERY.request primitive addressed to the STA every dot11AssociationSAQueryRetryTimeout TUs until an MLME-SA-QUERY.confirm primitive for the STA is received or dot11AssociationSAQueryMaximumTimeout TUs from the beginning of the SA Query procedure have passed. The SME shall increment the TransactionIdentifier by 1 for each MLME-SA-QUERY.request primitive, rolling it over to 0 after the maximum allowed value is reached.

   4) If no MLME-SA-QUERY.confirm primitive for a STA is received within the dot11AssociationSAQueryMaximumTimeout period, the SME shall allow a subsequent reassociation process to be started without starting an additional SA Query procedure, except that the SME may deny a subsequent reassociation process with the STA if an MSDU was received from the STA within this period.

   NOTE 1—Reception of an MSDU implies reception of a valid protected frame, which obviates the need for the SA Query procedure.

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f) The SME shall refuse a reassociation request from a STA that does not support all the rates in the BSSBasicRateSet parameter and all of the membership selectors in the BSSMembershipSelectorSet parameter in the MLME-START.request primitive.

g) The SME shall refuse a reassociation request from an HT STA that does not support all of the MCSs in the Basic HT-MCS Set field of the HT Operation parameter in the MLME-START.request primitive.

h) The SME shall refuse a reassociation request from a VHT STA that does not support all of the <VHT-MCS, NSS> tuples indicated by the Basic VHT-MCS And NSS Set field of the VHT Operation parameter in the MLME-START.request primitive.

i) If the ResultCode in the MLME-REASSOCIATE.response primitive is SUCCESS, the SME has an existing SA with the STA, and an SA Query procedure with that STA has failed to receive a valid response (i.e., has not received an MLME-SA-QUERY.confirm primitive within the dot11AssociationSAQueryMaximumTimeout period), the SME shall issue an MLME-DISASSOCIATE.request primitive addressed to the STA with ReasonCode INVALID_AUTHENTICATION.

NOTE 2—This MLME-DISASSOCIATE.request primitive generates a protected Disassociation frame. If the reassociation request was genuine, the STA has deleted the PTKSA by this point and so the protected Disassociation frame is ignored. The purpose is to inform a STA which has for some reason failed to respond to an SA Query procedure triggered by a forged reassociation request.

j) If the ResultCode in the MLME-REASSOCIATE.response primitive is SUCCESS and the reassociation is not part of a fast BSS transition, the SME shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA and temporal keys held for communication with the STA by using the MLME-DELETEKEYS.request primitive (see 12.6.18).

k) If the MLME-REASSOCIATE.indication primitive includes an MMS parameter, the AP or PCP shall take the following additional action, as appropriate:

1) If the Single AID field in the MMS parameter of the MLME-REASSOCIATE.indication primitive is equal to 1, the AP or PCP may allocate a single AID for all of the STAs included in the MMS element. If the AP or PCP allocates the same AID to all STAs whose MAC address was included in the MMS element, it shall include the MMS element received from the MM-SME coordinated STA in the MLME-REASSOCIATE.response primitive.

2) If the Single AID field is 0, the AP or PCP shall allocate a distinct AID for each STA specified in the MMS element.

NOTE 3—When the Single AID field is 0, a separate reassociation request/response exchange is performed for each STA specified in the MMS element, and this assigns the multiple AIDs for the STAs.

l) If a Reassociation Response frame with a status code of SUCCESS is acknowledged by the STA, the state for the STA shall be set to State 4, or to State 3 if dot11RSNAActivated is true and the reassociation is not part of a fast BSS transition.

m) If the ResultCode in the MLME-REASSOCIATE.response primitive is not SUCCESS and management frame protection is in use the state for the STA shall be left unchanged. If the ResultCode is not SUCCESS, management frame protection is not in use, and the reassociation is part of a fast BSS transition, the state for the STA shall be left unchanged. If the ResultCode is not SUCCESS, management frame protection is not in use, and the reassociation is not part of a fast BSS transition, the state for the STA shall be set to State 3 if it was State 4.

n) If the ResultCode in the MLME-REASSOCIATE.response primitive is SUCCESS, RSNA establishment is required, and the reassociation is not part of a fast BSS transition, and FILS is not in use, the SME shall attempt a 4-way handshake. Upon a successful completion of a 4-way handshake, the SME shall enable protection by issuing an MLME-SETPROTECTION.request(Rx_Tx) primitive. If FILS authentication was used, the SME shall enable protection by generating an MLME-SETPROTECTION.request(Rx_Tx) primitive. In either case, upon receipt of the MLME-SETPROTECTION.request(Rx_Tx) primitive, the MLME shall set the state for the STA to State 4.

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o) AP only: The SME shall inform the DS of any changes in the state of the STA.

p) If the ResultCode in the MLME-REASSOCIATE.response primitive is SUCCESS and the CurrentAPAddress parameter in the MLME-REASSOCIATION.indication primitive is this AP's or PCP's MAC address (reassociation to the same AP or PCP), the AP or PCP shall match the non-AP STA's treatment of the listed agreements and allocations as described in 11.3.5.4 item c). The AP or PCP deletes or resets to initial values those items that the non-AP STA is required in 11.3.5.4 item c) to delete or reset to initial values, and the AP or PCP does not modify the states, agreements and allocations that are listed as not affected by the reassociation procedure.

q) If the ResultCode in the MLME-REASSOCIATE.response primitive is SUCCESS and the CurrentAPAddress parameter in the MLME-REASSOCIATION.indication primitive is not this AP's or PCP's MAC address (reassociation to a different AP or PCP), all the states, agreements and allocations pertaining to the associating STA and listed in both numbered lists in 11.3.5.4 item c) are deleted or reset to initial values.

11.3.5.6 Non-AP and non-PCP STA disassociation initiation procedures

The SME shall issue an MLME-DISASSOCIATE.request primitive that includes an appropriate Reason Code as defined in Table 9-49 of 9.4.1.7.

Upon receipt of an MLME-DISASSOCIATE.request primitive, a non-AP and non-PCP STA's MLME shall disassociate from an AP or PCP using the following procedure:

a) If the state for the AP or PCP is State 3 or State 4, the MLME shall transmit a Disassociation frame to the AP or PCP.

b) The state for the AP or PCP shall be set to State 2 if it was not State 1. In the case of an MM-SME coordinated STA, the MLME shall perform this for each STA whose address was included in the MMS parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive that established the association.

c) The MLME shall issue an MLME-DISASSOCIATE.confirm primitive to inform the SME of the successful completion of the disassociation.

d) Upon receiving an MLME-DISASSOCIATE.confirm primitive, the SME shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA and temporal keys held for communication with the AP or PCP by using the MLME-DELETEKEYS.request primitive (see 12.6.18) and by invoking an MLME-SETPROTECTION.request(None) primitive. In the case of an MM-SME coordinated STA, the MLME shall perform this for each STA whose address was included in the MMS parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive that established the association.

11.3.5.7 Non-AP and non-PCP STA disassociation receipt procedure

Upon receipt of a Disassociation frame from an AP or PCP for which the state is State 3 or State 4, if management frame protection was not negotiated when the PTKSA(s) were created, or if management frame protection is in use and the frame is not discarded per management frame protection processing, a non-AP and non-PCP STA shall disassociate from the AP or PCP using the following procedure:

a) The state for the AP or PCP shall be set to State 2.

b) The MLME shall issue an MLME-DISASSOCIATE.indication primitive to inform the SME of the disassociation.

c) Upon receiving the MLME-DISASSOCIATE.indication primitive, the SME shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA and temporal keys held for communication with the AP or PCP by using the MLME-DELETEKEYS.request primitive (see 12.6.18) and by invoking an

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MLME-SETPROTECTION.request(None) primitive. The MM-SME shall perform this process for each STA whose address was included in the MMS parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive that established the association.

d) If the reason code indicates a configuration or parameter mismatch as the cause of the disassociation, the SME shall not attempt to associate or reassociate with the AP or PCP until the configuration or parameter mismatch has been corrected.

e) If the reason code indicates the STA was disassociated for a reason other than configuration or parameter mismatch, the SME shall not attempt to associate or reassociate with the AP or PCP until a period of 2 s has elapsed.

11.3.5.8 AP or PCP disassociation initiation procedure

The SME shall issue an MLME-DISASSOCIATE.request primitive that includes an appropriate Reason Code as defined Table 9-49 of 9.4.1.7.

Upon receipt of an MLME-DISASSOCIATE.request primitive, an AP or PCP shall disassociate a STA using the following procedure:

a) If the state for the STA is State 3 or State 4, the AP or PCP shall generate a Disassociation frame to be transmitted to the indicated STA.

NOTE—As the Disassociation frame is a bufferable MMPDU, the transmission of this frame might be delayed by the operation of a power saving protocol. The AID and the PTKSA are maintained (when applicable) until the frame is acknowledged or attempts to transmit the frame are abandoned.

b) The state for the STA shall be set to State 2, if it was not State 1. The MM-SME shall perform this process for each STA whose address was included in the MMS parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive that established the association.

c) Once the Disassociation frame is acknowledged or attempts to transmit the frame are abandoned, the MLME shall issue an MLME-DISASSOCIATE.confirm primitive to inform the SME of the disassociation.

d) Upon receiving an MLME-DISASSOCIATE.confirm primitive, the SME shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA and temporal keys held for communication with the STA by using the MLME-DELETEKEYS.request primitive (see 12.6.18) and by invoking an MLME-SETPROTECTION.request(None) primitive. The MM-SME shall perform this process for each STA whose address was included in the MMS parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive that established the association.

e) Upon receiving an MLME-DISASSOCIATE.confirm primitive, the SME shall release the AID assigned for the indicated STA, if the state for the indicated STA was State 3 or State 4.

f) AP only: The SME shall inform the DS of the disassociation.

11.3.5.9 AP or PCP disassociation receipt procedure

Upon receipt of a Disassociation frame from a STA for which the state is State 3 or State 4, if management frame protection was not negotiated when the PTKSA(s) were created, or if management frame protection is in use and the frame is not discarded per management frame protection processing, the AP or PCP shall disassociate the STA using the following procedure:

a) The state for the STA shall be set to State 2. The MM-SME shall perform this process for each STA whose address was included in the MMS parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive that established the association.

b) The MLME shall issue an MLME-DISASSOCIATE.indication primitive to inform the SME of the disassociation.

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c) Upon receiving an MLME-DISASSOCIATE.indication primitive the SME shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA and temporal keys held for communication with the STA by using the MLME-DELETEKEYS.request primitive (see 12.6.18) and by invoking an MLME-SETPROTECTION.request(None) primitive. The MM-SME shall perform this process for each STA whose address was included in the MMS parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive that established the association.

d) AP only: The SME shall inform the DS of the disassociation.

e) The SME shall release the AID assigned for the indicated STA.

11.3.5.10 PBSS procedures for nonassociated STAs

In a PBSS, there are four types of relationships between a PCP and the members of a PBSS:

— Nonassociated, non-RSNA (when dot11RSNAActivated is false)
— Associated, non-RSNA (when dot11RSNAActivated is false)
— Associated, RSNA (when dot11RSNAActivated is true)
— Nonassociated, RSNA (when dot11RSNAActivated is true)

The following rules apply in the last case:

a) In a PBSS, when a STA is in State 2 and dot11RSNAActivated is true, successful RSNA establishment changes the STA to State 4. Unsuccessful RSNA establishment leaves the state unchanged.

b) In a PBSS, when a STA is in State 4, the STA's receipt of a disassociation notification changes the state to State 2.

11.3.5.11 Service characteristic indication during association

A sensor service is the service that a sensor STA is capable of provisioning that is usually delivered using small payload Data frames. Non-sensor services include offloading and critical services. Different service characteristics may have different requirements on QoS, frame length, duty cycle, etc. An AP can optimize the system operating parameters with the knowledge of the service characteristic of each associated STA or place a high priority on association/reassociation for a STA that provides critical services such as health care, home, industrial, alarm monitoring or emergency service.

A non-AP STA may indicate to the AP its service characteristic information during association by including the Service Characteristic field in the AID Request element in the (Re)Association Request frame. The AP may assign a particular AID to the STA taking into account the received service characteristic information from the STA.

11.3.6 Additional mechanisms for an AP collocated with a mesh STA

If a STA to AP mapping is added to the DS with the STA being a non-AP STA in an infrastructure BSS and the AP being an access point that interconnects through a DS with a mesh gate (that is, AP and mesh gate are collocated; see Figure 4-10), this mesh gate shall verify that the MAC address of the STA does not belong to a mesh STA in the MBSS. See 4.5.3.3 and Clause 7 for association and STA to AP mapping in the DS. If the mesh gate determines that the authenticated STA has a MAC address that is a MAC address of a mesh STA in the MBSS, then the collocated access point shall deauthenticate the STA with Reason Code UNSPECIFIED_REASON or MACADDRESS-ALREADY-EXISTS-IN-MBSS.

The mechanism for verifying the MAC address of the authenticated STA depends on the active path selection protocol and might be vendor specific. See 14.10.13 when HWMP is the active path selection protocol.

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11.3.7 Communicating PBSS information

Following the association or security association of a STA with a PCP, the PCP shall send an unsolicited Information Response frame (9.6.19.5 to all STAs associated with the PCP. The PCP shall send a broadcast Information Response frame and/or shall send individually addressed Information Response frames to each STA associated with the PCP. The PCP shall set the Subject Address field of the Information Response frame to the broadcast address and shall include in the Information Response frame the DMG Capabilities element for the PCP and each STA associated with the PCP. This process is referred to as *PBSS information distribution*.

The PCP shall perform a PBSS information distribution at least once every dot11BroadcastSTAInfoDuration beacon intervals.

11.3.8 Neighbor report information upon rejection with suggested BSS transition

An AP may provide neighbor report information to a STA that requests authentication or association by responding with an Authentication or (Re)Association Response frame that has the Status Code field set to REJECTED_WITH_SUGGESTED_BSS_TRANSITION and that includes one or more Neighbor Report elements.

11.3.9 Authentication control

11.3.9.1 General

In infrastructure mode, an S1G AP can use the Authentication Control element to alleviate WM contention when a large number of STAs are trying to or are expected to send Authentication Request frames to the AP at about the same time.

11.3.9.2 Centralized authentication control

When dot11S1GCentralizedAuthenticationControlActivated is true, an S1G STA shall set the Centralized Authentication Control subfield to 1 in the S1G Capabilities Information field of the S1G Capabilities element. Otherwise, the STA shall set it to 0. A STA that transmits the Centralized Authentication Control subfield of the S1G Capabilities Information field set to 0 is not constrained by the requirements specified in this subclause.

A centralized authentication controller access point (CAC AP) shall set the Control subfield to 0 in the Authentication Control element in all transmitted Beacons and Probe Responses frames. A non-CAC AP shall not include an Authentication Control element with the Control field equal to 0 in a Beacon or Probe Response frame.

A CAC AP may include an Authentication Control element with the Control subfield equal to 0 and the Deferral subfield equal to 0 in a Beacon or a Probe Response frame to attempt to limit the number of STAs that can transmit an Authentication Request frame to it. The AP may transmit a different value in the Authentication Control Threshold subfield in the Authentication Control element included in each of Beacon and Probe Response frames that it transmits.

A CAC AP may include, within an individually addressed Probe Response frame that is transmitted in response to a Probe Request frame from a STA, an Authentication Control element that has the Control subfield equal to 0, the Deferral subfield equal to 1 and the Authentication Control Threshold subfield equal to a deferred channel access time. During the deferred channel access time that begins immediately following the reception of the Probe Response, a centralized authentication controlled station (CAC STA) shall not transmit an Authentication Request frame to the AP that transmitted the Probe Response frame.

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A non-CAC STA is not constrained by the Authentication Control rules specified in this subclause when it transmits an Authentication Request frame to the AP. A CAC STA sets the MAC variable AuthenticationRequestTransmission to true when it is initialized.

A CAC STA shall generate a random number *v* when it is initialized. The generated random number *v* shall be uniformly distributed between 0 and 1022. The STA may generate a new random value for *v* after receiving an Authentication Response frame from an AP.

A CAC STA shall compare *v* with the Authentication Control Threshold subfield value in the most recently received Authentication Control element from the AP to which it intends to send an Authentication Request frame if the Control and the Deferral subfields are equal to 0. If *v* is less than the Authentication Control Threshold subfield, the STA may transmit an Authentication Request frame to the AP and shall set the MAC variable AuthenticationRequestTransmission to true. Otherwise, the STA shall set the MAC variable AuthenticationRequestTransmission to false and the STA shall not transmit an Authentication Request frame to the AP. A CAC STA shall update its MIB values of the CAC parameters based on the values received in the Authentication Control element.

A CAC STA shall set the MAC variable AuthenticationRequestTransmission to false and shall defer the transmission of an Authentication Request frame to an AP from which it has received an individually addressed probe response if the Probe Response frame contains an Authentication Control element with the Control subfield equal to 0 and the Deferral subfield equal to 1. The deferral begins at the end of the reception of the Probe Response frame and extends for a period of time equal to the value contained in the Authentication Control Threshold subfield value in the Probe Response frame. At the end of the deferral time period, the STA shall set the MAC variable AuthenticationRequestTransmission to true and may transmit an Authentication Request frame to the AP.

A CAC STA shall set the MAC variable AuthenticationRequestTransmission to true when it receives a Beacon or Probe Response frame that does not include an Authentication Control element from the AP that it intends to join.

An S1G AP shall not set the Deferral subfield in the Authentication Control element of the Beacon frames or the broadcast Probe Response frames to 1.

An S1G STA does not follow the Authentication Control rules defined in this subclause if it receives a Beacon or Probe Response frame that includes an Authentication Control element from the AP that it does not intend to join, or is not intended to the STA.

11.3.9.3 Distributed authentication control

When dot11S1GDistributedAuthenticationControlActivated is true, an S1G AP shall set the Distributed Authentication Control subfield to 1 in the S1G Capabilities Information field of the S1G Capabilities element. Otherwise, the subfield is set to 0.

When an S1G STA receives an S1G Capabilities element with the Distributed Authentication Control field equal to 1, the STA shall determine when it is permitted to access the medium to transmit an Authentication Request frame to the AP from which it received the S1G Capabilities element based on the following procedure:

a) The STA maintains the following distributed authentication control (DAC) parameters:
   1) Authentication control slot duration (T_{ac}) in TUs. The default value is set to 10 TUs.
   2) Minimum transmission interval (TI_{min}) in units of a beacon interval. The default value is set to 8 beacon intervals.
   3) Maximum transmission interval (TI_{max}) in units of a beacon interval. The default value is set to 256 beacon intervals.

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b) The STA maintains a transmission interval (TI) in units of a beacon interval.

c) The TI is initialized to TI_{min}.

d) The STA chooses a random number *m* from [0, TI].

e) The STA chooses a random number *l* from [0, L], where $L = \lfloor (bi)/T_{ac} \rfloor$, *l*=0 is the first authentication control slot, and *bi* is the beacon interval.

f) The STA may initiate normal EDCA access procedures for the transmission of the Authentication Request frame beginning at the authentication control slot *l* in the beacon interval *m*, where *m*=0 is the current beacon interval.

g) If the transmission of the Authentication Request frame fails, the TI is increased as follows: $TI = \min\{2 \times TI, TI_{max}\}$.

An S1G AP may assign DAC parameters different from the default values by sending to the STA an Authentication Control element with the Control subfield equal to 1. An S1G STA receiving such an Authentication Control element shall update its MIB values of the DAC parameters based on the values received in the Authentication Control element.

11.4 TS operation

11.4.1 Introduction

There are three types of traffic specifications: the TSPEC, the DMG TSPEC, and the PTP TSPEC.

A TSPEC describes the traffic characteristics and the QoS requirements of a TS. The main purpose of the TSPEC is to reserve resources within the HC and, in the case of HCCA and HEMM access policies, to modify the HC's scheduling behavior. It also allows other parameters to be specified that are associated with the TS, such as a traffic classifier and ack policy.

The DMG TSPEC (9.4.2.133) describes an allocation (also known as DMG allocation) within either a PBSS or a DMG infrastructure BSS. The purpose of the DMG TSPEC is to create or modify an allocation for the transmission of frames between DMG STAs that are members of a PBSS or that are members of an infrastructure BSS (10.39.6).

To communicate between STAs in a PBSS or between non-AP DMG STAs in an infrastructure BSS, a TSPEC (as defined in 9.4.2.29) is used to create or modify a TS between those STAs. This TSPEC is referred to as a *PTP TSPEC*.

In a DMG BSS, a TSPEC includes parameters that are associated with the TS such as maximum MSDU size, delay bound, and optionally the allocation carrying the TS. A single allocation can carry multiple TSs. Each TS is carried in one allocation, except when

— The TS has an access policy of EDCA, where it can use all CBAP allocations with Source AID equal to the broadcast AID, all CBAP allocations with Source AID matching the source STA of the TS, and all CBAP allocations with Destination AID matching the destination STA of the TS; or

— The TS has an access policy of SEMM, where it can use exactly one SP allocation as well as all CBAP allocations with Source AID equal to the broadcast AID, all CBAP allocations with Source AID matching the source STA of the TS, and all CBAP allocations with Destination AID matching the destination STA of the TS.

A TS may have one or more TCLAS (within the discretion of the STA that sets up the stream) associated with it. A DMG STA or AP uses the parameters in the TCLAS elements to filter the MSDUs belonging to this TS for delivery as part of the TS. An Intra-Access Category Priority element may be associated with a TS by the inclusion of an Intra-Access Category Priority element in an ADDTS Request frame. The User Priority

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subfield of the Intra-Access Category Priority element shall be set to the same UP as specified in the User Priority subfield of the TS Info field. If dot11AlternateEDCAActivated is true, the Alternate Queue subfield is used to select the appropriate EDCA transmit queue when the Access Policy subfield of the TS Info field in the TSPEC is EDCA or HEMM. When an Intra-Access Category Priority element is associated with a TS, the Drop Eligibility subfield is used to indicate the drop eligibility of the MSDUs of this TS.

TS may have zero or one Expedited Bandwidth Request (EBR) elements associated with it. An AP uses the parameters in the EBR to understand the precedence level requested by a non-AP STA (see R.5.4). For example, the precedence level may be used to convey to the AP that the requested TS is for the purposes of placing an emergency call. Support for precedence levels greater than 18 is optional for STAs.

TSPEC, PTP TSPEC, optional TCLAS, optional EBR, and optional Intra-Access Category Priority elements are transported over the WM by the ADDTS Request frame and the ADDTS Response frame, and across the MLME SAP by the MLME-ADDTS primitives. In addition, a TS could be created if a STA sends a resource request to an AP or PCP prior to initiating a transition to that AP or PCP, as part of performing FST (11.31), or in the Reassociation Request frame to that AP or PCP.

The DMG TSPEC is transported over the air within DMG ADDTS Request and DMG ADDTS Response frames and across the MLME SAP by the MLME-ADDTS primitives.

Following a successful negotiation, a TS is created, identified within the non-AP STA by its TSID and direction, and identified within the HC by a combination of TSID, direction, and STA address.

Following a successful negotiation of a DMG TSPEC in a PBSS or in a DMG infrastructure BSS, a new allocation is created, or an existing allocation is modified. Within a PBSS or infrastructure BSS, each allocation is uniquely identified by a combination of allocation ID, source AID, and destination AID.

Following a successful negotiation of a PTP TSPEC or a TSPEC in a DMG BSS, the frames corresponding to the PTP TSPEC or TSPEC are identified within the STA by the combination of TSID, requesting non-AP DMG STA address, and responding non-AP DMG STA address and direction.

It is always the responsibility of the non-AP STA to initiate the creation of a TS regardless of its direction. A STA that is not a DMG STA shall not transmit a PTP TSPEC or a DMG TSPEC. A non-AP DMG STA that is not the source DMG STA of a specific TS shall not initiate the exchange of a TSPEC to the AP DMG STA or PCP DMG STA to create that TS. Any non-AP DMG STA can issue a PTP TSPEC to any other non-AP DMG STA to create a TS.

In the TDLS direct-link case, it is the responsibility of the STA that is going to send the data to create the TS. In this case, the STA negotiates with the HC to gain TXOPs that it uses to send the data. There is no negotiation between the originator and recipient STAs concerning the TS: the originator can discover the capabilities of the recipient (rates, Block Ack) using the TDLS.

In the case of traffic relayed by an AP or PCP, the sending and receiving non-AP and non-PCP STAs may both create individual TS for the traffic. In an infrastructure BSS, any traffic classifier created for the downlink TS applies equally regardless of whether the source is in the same BSS or reached through the DS.

In a non-DMG infrastructure BSS, a non-AP STA may simultaneously support up to eight TSs from the HC to itself and up to eight TSs from itself to other STAs, including the HC. The actual number it supports may be less due to implementation restrictions.

In a non-DMG infrastructure BSS, an HC may simultaneously support up to eight downlink TSs and up to eight uplink TSs per associated STA. The actual number it supports may be less due to implementation restrictions.

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In a DMG BSS there may be up to 16 TSs from a source DMG STA to a destination DMG STA. An additional 16 TSs may be created between the two DMG STAs by reversing the roles of source and destination. The actual number supported in any direction may be less due to implementation restrictions in either the source or destination DMG STA.

In a non-DMG BSS, the traffic admitted in the context of a TSPEC can be sent using EDCA, HCCA, or HEMM. This depends on the access policy set in the TS Info field in the TSPEC. A TSPEC request may be set so that both HCCA and EDCA mechanisms (i.e., HEMM) are used.

In a DMG BSS, the traffic admitted in the context of a PTP TSPEC or TSPEC is sent according to the access policy set in the TS Info field of the PTP TSPEC or TSPEC, respectively. Specifically, the traffic is sent during one or more CBAP allocations if the access policy is EDCA, during an SP allocation if the access policy is SPCA, and during one SP allocation as well as zero or more CBAP allocations if the access policy is SEMM.

A DMG STA transmitting a DMG TSPEC shall set the LP SC Used subfield within the DMG TSPEC to 1 to indicate that the low-power SC mode described in 21.7 is used during the allocation. All frames sent during such an allocation shall use the low-power SC mode. The STA shall set the LP SC Used subfield to 1 only if the STA identified in the Destination AID field within the DMG TSPEC supports the low-power SC mode (9.4.2.127.2). In all other cases, the LP SC Used subfield shall be set to 0.

When dot11SSPNInterfaceActivated is true, TSPEC processing by the HC may be subject to limitations received from the SSPN interface. The SSPN may limit access to certain QoS priorities, and further restrict the data rate and delay used with any priority.

11.4.2 TSPEC construction

TSPECs and DMG TSPECs are constructed at the SME, from application requirements supplied via the SME, and with information specific to the MAC layer.

The value of the Minimum PHY Rate in a TSPEC shall satisfy the following constraints:

a) For an uplink TS, it
   - Is included in dot11SupportedDataRatesTxTable and in the AP's operational rate set, or
   - Corresponds to an HT-MCS included in dot11SupportedHTMCSTxTable, if present, and in the AP's operational HT-MCS set, if defined, at a bandwidth and guard interval supported by the non-AP STA on transmission and permitted in the BSS, or
   - Corresponds to a VHT-MCS and NSS for which support is indicated by the combination of
     - The Tx VHT-MCS Map subfield in the VHT Operation parameter of the MLME-(RE)ASSOCIATE.request primitive, if present, and
     - The AP's operational VHT-MCS and NSS set, if defined, and
     - The VHT Capabilities Information field

     at a bandwidth and guard interval supported by the non-AP STA on transmission and permitted in the BSS.

b) For a downlink TS, it
   - Is included in the OperationalRateSet parameter of the MLME-JOIN.request primitive and supported by the AP on transmission,[41] or
   - Corresponds to an HT-MCS included in dot11SupportedHTMCSRxTable, if present, and supported by the AP on transmission, at a bandwidth and guard interval supported by the non-AP STA on reception and permitted in the BSS,[42] or

[41] How a non-AP STA determines an AP's non-HT rate transmission support is implementation dependent. The non-AP STA might conservatively use the basic rate set, or it might use knowledge of past transmissions by the AP, or it might use other means.

[42] How a non-AP STA determines an AP's HT-MCS transmission support, if the Tx MCS Set subfield in the HT Capabilities element advertised by the AP is equal to 0 or if the Tx Rx MCS Set Not Equal subfield in that element is equal to 1, is implementation dependent. The non-AP STA might conservatively use the basic HT-MCS set, or it might use knowledge of past transmissions by the AP, or it might use other means.

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— Corresponds to a VHT-MCS and NSS for which support is indicated by the combination of
  — The Rx VHT-MCS Map subfield in the VHT Operation parameter of the MLME-(RE)ASSOCIATE.request primitive, if present, and
  — The Tx VHT-MCS Map subfield of the VHT Operation element advertised by the AP, if present, and
  — The VHT Capabilities Information field

  at a bandwidth and guard interval supported by the non-AP STA on reception and permitted in the BSS.

c) For a bidirectional TS, it satisfies both a) and b) above.

See K.4 for a description of the parameter choice for the TSPEC.

NOTE—This standard states no requirements on how a DMG TSPEC is to be generated.

11.4.3 TS life cycle

Figure 11-18 summarizes the TS life cycle (using the HMSC syntax defined in ITU-T Recommendation Z.120 (2004).

Initially a TS is inactive. A STA shall not transmit any QoS Data frames in which the TID subfield of the QoS Control field matches an inactive TS.

A TS may be established by a Resource Request appearing in a message as part of a fast BSS transition from a STA. Such a TS is created in the accepted state. If the STA subsequently reassociates with this AP, then the TS becomes active. If the STA does not reassociate prior to the expiration of the reassociation timeout, then the TS becomes inactive.

Unless stated otherwise, in a DMG BSS, the owner of an SP is the source DMG STA for that SP, and the owner of a TXOP is the TXOP holder. A STA that owns an SP or a TXOP is said to have the ownership of the SP or the TXOP, respectively. The rules applicable to an SP or TXOP owner are defined in 10.39 and 11.4.

Following a successful TS setup initiated by a non-AP STA, the TS becomes active, and either the non-AP STA or the HC may transmit QoS Data frames whose TID contains this TSID (according to the Direction field). In the case of EDCA, the TID contains the UP value.

While the TS is active, the non-AP STA can attempt to renegotiate the parameters of the TSPEC characterizing the TS or the parameters of the DMG TSPEC characterizing the allocation carrying the TS.

An active TS becomes inactive following a TS deletion process initiated at either non-AP STA or HC. It also becomes inactive following a TS timeout detected at the HC, or if the HC within an AP when dot11SSPNInterfaceActivated is true determines as defined in 11.22.5 that the non-AP STA's TS has exceeded the transmitted MSDU limit for the access category in which the TS was admitted. In a DMG BSS, a TS timeout is detected at a non-AP STA and causes the TS deletion process to be initiated at the non-AP STA. When an active TS becomes inactive, all of the resources allocated for the TS are released.

An active TS may become suspended if no activity is detected for a duration of a suspension interval. Upon detection of activity, the TS may be reinstated. While the TS is in the suspended state, the HC shall not reclaim the resources assigned to the TS. In a DMG BSS, a TS in which both the source and destination are non-AP and non-PCP STAs shall not be suspended.

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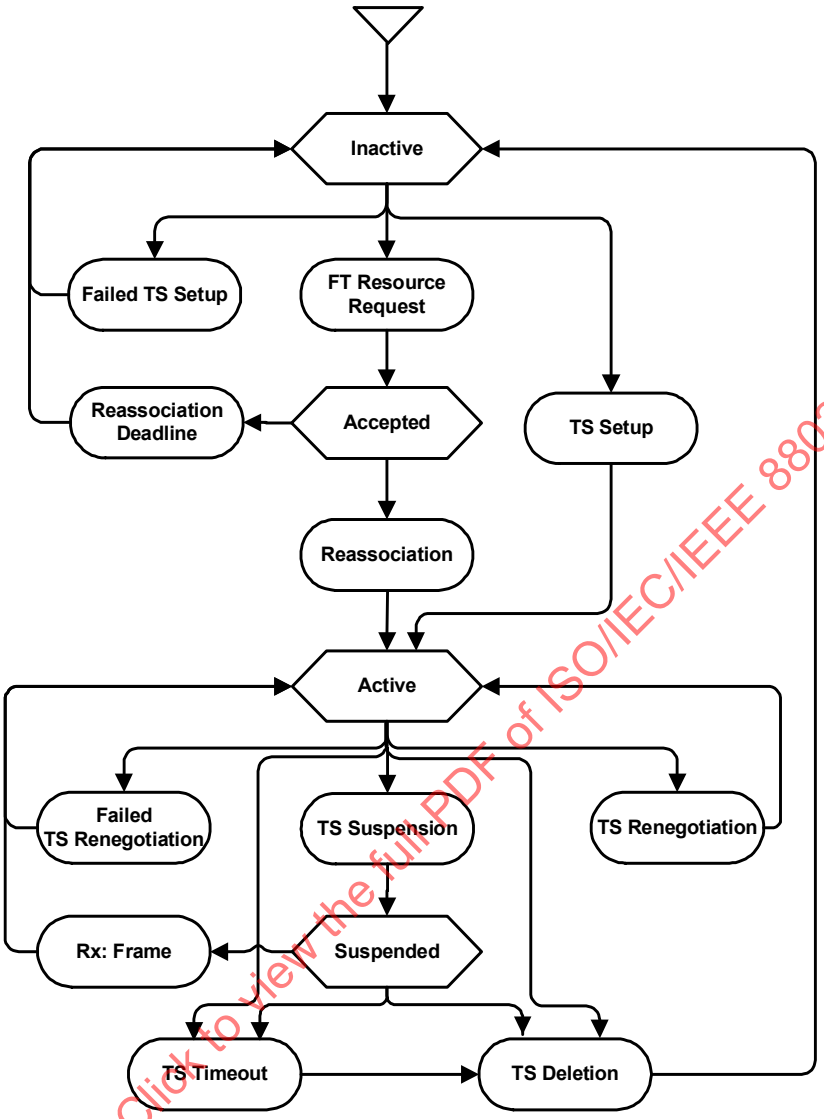

Figure 11-18—TS life cycle

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11.4.4 TS setup

11.4.4.1 General

A TS setup may be initiated by a non-AP STA or an AP.

11.4.4.2 Non-AP-STA-initiated TS setup

Figure 11-19 shows the sequence of messages occurring at a TS setup initiated by a non-AP STA. This message sequence in this figure and in the subsequent figures does not show the acknowledgment.

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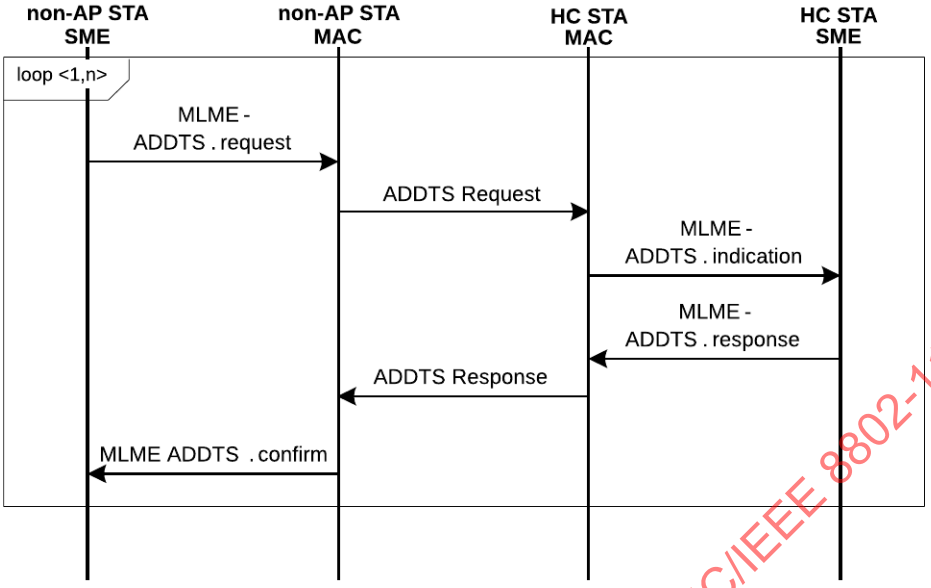

Figure 11-19—TS setup

11.4.4.3 AP-initiated TS setup

Figure 11-20 shows the sequence of messages occurring at a TS setup initiated by the AP. This message sequence in this figure and in the subsequent figures does not show the acknowledgments.

TS setup may be initiated by an AP in response to a request originating from higher layer protocols. An AP in which dot11RobustAVStreamingImplemented is true shall not send ADDTS Reserve Request frames to an associated STA that has set the RobustAVStreaming bit in the Extended Capabilities element in its (Re)Association Request frame to 0.

The higher layer stream ID is defined by the higher layer protocol. The Higher Layer Stream ID element shall be included in the ADDTS Reserve Request frame sent by the AP to the non-AP STA. This element is used in the TS setup procedure between the AP and the non-AP STA.

The AP initiates the TS setup by sending an ADDTS Reserve Request frame that includes the Higher Layer Stream ID element to the non-AP STA. On receipt of the ADDTS Reserve Request frame from the AP, the non-AP STA shall perform one of the following:

a) Complete the AP-initiated TS setup procedure by sending an ADDTS Reserve Response frame that includes the Higher Layer Stream ID element corresponding to the AP-initiated TS setup procedure and with the status code set to SUCCESS.

b) Send an ADDTS Reserve Response frame with a status code not equal to SUCCESS and abort the AP-initiated TS setup. The Higher Layer Stream ID element in this ADDTS Reserve Response frame shall be set to the higher layer stream ID corresponding to the AP-initiated TS setup procedure.

c) Send an ADDTS Request frame to the AP. There might be multiple ADDTS Request/ADDTS Response exchanges between the non-AP STA and the AP, as described in 11.4.4.4, to negotiate the TSPEC parameters. The Higher Layer Stream ID element shall be included in all frames corresponding to the AP-initiated TS setup procedure that are exchanged between the non-AP STA and the AP. The AP-initiated TS setup procedure is completed by sending an ADDTS Reserve Response frame that includes the Higher Layer Stream ID element corresponding to the AP-initiated TS setup procedure and with the status code set to indicate the result of the TSPEC negotiation.

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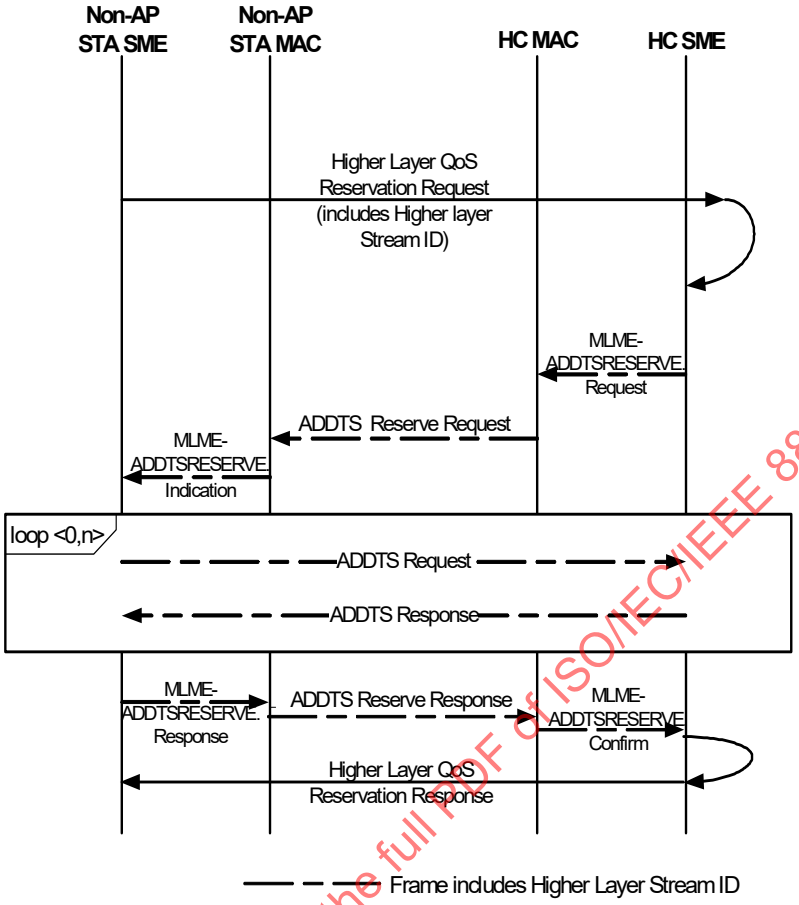

Figure 11-20—TS setup when initiated by the AP

NOTE 1—Stream Reservation Protocol (SRP) as described in IEEE Std 802.1Q is an example of a higher layer protocol. The IEEE 802.11 subsystem at a non-AP STA does not interpret the SRP reservation request but simply sends it to the AP with which it is associated. A higher layer agent called *Designated Multiple Stream Registration Protocol (MSRP) Node (DMN)* is co-located with the AP in the device that supports SRP. All incoming SRP reservation requests are forwarded to the MSRP DMN. The MSRP DMN interprets the SRP reservation request and invokes appropriate IEEE 802.11 primitives in order for the AP to invoke the MLME-ADDTSRESERVE.request primitive. The MSRP DMN responds to the originator of the SRP Reservation request with the outcome of the AP-initiated TS setup procedure. The procedures performed by the MSRP DMN are described in IEEE Std 802.1Q.

NOTE 2—If the higher layer SRP Reservation Request message is lost within the IEEE 802.11 subsystem, the corresponding retry/recovery procedure is the responsibility of the SRP protocol. These procedures are described in IEEE Std 802.1Q.

11.4.4.4 TS setup procedures for both AP and non-AP STA initiation

The non-AP STA's SME decides that a TS needs to be created. How it does this, and how it selects the TSPEC or DMG TSPEC parameters, is beyond the scope of this standard. The SME generates an MLME-ADDTS.request primitive containing a TSPEC or DMG TSPEC. A TSPEC or DMG TSPEC may also be generated autonomously by the MAC without any initiation by the SME.

NOTE—Such a TPSEC or DMG TPSEC might be overridden as a result of a subsequent MLME-ADDTS.request primitive from the SME (see 11.4.4.5)

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The STA's MLME transmits the TSPEC or DMG TSPEC in an ADDTS Request frame to the HC STA. If the non-AP STA's MLME is in power save mode, the STA shall include its DMG Wakeup Schedule element in the ADDTS Request frame variant and in the DMG ADDTS Request frame variant.

The HC STA's MLME receives this Management frame and generates an MLME-ADDTS.indication primitive to its SME containing the TSPEC or DMG TSPEC.

The SME in the HC STA decides whether to admit the TSPEC or DMG TSPEC with its associated TCLAS element(s) (if present) and TCLAS Processing element (if present), as specified, refuse the TSPEC or DMG TSPEC, or not admit but suggest an alternative TSPEC, DMG TSPEC, or TCLAS element(s), or TCLAS Processing element.

A DMG STA that responds with an ADDTS Response frame and an HC may change the value of parameters that have been set unspecified by the STA to any value that it deems appropriate, including leaving them unspecified.

If the TSPEC or DMG TSPEC is received from a non-AP STA by an AP when dot11SSPNInterfaceActivated is true, the HC shall use the permissions stored in dot11InterworkingEntry for that STA in the decision to admit or deny the request (see 11.22.5.3). The SME then generates an MLME-ADDTS.response primitive containing the TSPEC or DMG TSPEC, zero or more TCLAS element(s) (only if present in the request) and TCLAS Processing element (only if present in the request) and a ResultCode value. The contents of the TSPEC or DMG TSPEC field, TCLAS element(s) (if present), TCLAS Processing element (if present), and ResultCode field contain values specified in 6.3.25.5.2. The SME may include fewer TCLAS elements in the MLME-ADDTS.response primitive than were present in the request; when the SME's response includes a single TCLAS element, it shall not include a TCLAS Processing element. If the SME changes a TCLAS element's Classifier Type field in the MLME-ADDTS.response primitive but is unable to suggest a value for the Classifier Mask field, it shall set that field to 0. If the SME changes a TCLAS element's Classifier Type field or Classifier Mask field in the MLME-ADDTS.response primitive but is unable to suggest values for one or more Classifier Parameter subfields, it shall set those subfields to 0.

When the HC in an AP that has dot11SSPNInterfaceActivated equal to true receives a TSPEC, the AP shall inspect it to determine the requested access policy, user priority, and mean data rate as follows:

a) The access category shall be determined from the user priority according to Table 10-1. For a TS to be admitted when the requested access policy is EDCA, both of the following shall be true:
   1) The field corresponding to this access category in dot11NonAPStationAuthAccessCategories from the non-AP STA's dot11InterworkingEntry is equal to 1.
   2) The sum of the mean data rate of all of the requesting STA's active TSs in this access category plus the mean data rate in the TSPEC is less than or equal to the non-AP STA's dot11InterworkingEntry for dot11NonAPStationAuthMaxVoiceRate, dot11NonAPStationAuthMaxVideoRate, dot11NonAPStationAuthMaxBestEffortRate, or dot11NonAPStationAuthMaxBackgroundRate depending on whether the derived access category is AC_VO, AC_VI, AC_BE or AC_BK, respectively.

b) For a TS to be admitted when the requested access policy is HCCA, all of the following shall be true:
   1) The dot11NonAPStationAuthHCCAHEMM value is true.
   2) The sum of the mean data rate of all of the requesting STA's active TSs having access policy set to HCCA plus the mean data rate in the TSPEC is less than or equal to dot11NonAPStationAuthMaxHCCAHEMMRate in the non-AP STA's dot11InterworkingEntry.
   3) The delay bound that will be provided by the HC in the TSPEC response is less than or equal to dot11NonAPStationAuthHCCAHEMMDelay in the non-AP STA's dot11InterworkingEntry.

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If the DMG TSPEC is admitted, the AP or PCP shall set the ResultCode to SUCCESS_STA_IN_PS_MODE if the STA identified by destination AID is in power save mode and shall include in the ADDTS Response frame the DMG Wakeup Schedule element of the destination DMG STA if one is established. In this case, the AP or PCP should defer including the TS schedule in the Extended Schedule element until both source DMG STA and destination DMG STA are in active mode.

The HC STA's MLME transmits an ADDTS Response frame containing this TSPEC or DMG TSPEC and status. The encoding of the ResultCode values to Status Code field values is defined in Table 9-50. The AP or PCP shall transmit the ADDTS Response frame to the STAs identified as source and destination AID of the DMG TSPEC contained in the ADDTS Request frame if the ADDTS request is sent by a non-AP and non-PCP STA. If the ResultCode is SUCCESS, the AP or PCP shall announce the creation of the allocation by setting the Allocation ID subfield in the TSPEC element sent in the ADDTS Response frame to a nonzero value and also by delivering the Extended Schedule element as defined in 10.39.6. In an AP when dot11SSPNInterfaceActivated is true, the HC shall set dot11NonAPStationAddtsResultCode in the non-AP STA's dot11InterworkingEntry equal to the ResultCode.

The STA's MLME receives this Management frame. It generates an MLME-ADDTS.confirm primitive to its SME containing the TSPEC or DMG TSPEC and status.

The SME decides whether the response meets its needs. How it does this is beyond the scope of this standard. An SME receiving a modified TCLAS element having a Classifier Mask field equal to 0 or Classifier Parameter subfields equal to 0 should regard these values as meaning that no suggested value has been provided by the HC.

— If the result code is SUCCESS, the TS enters into an active state.
— If the result code is REJECTED_WITH_SUGGESTED_BSS_TRANSITION, the non-AP STA may try to transition to other BSSs. In case that the non-AP STA is recommended to transition to other BSSs, it should do so according to the process defined in 11.21.7. Once the transition is completed, it should proceed with a TS setup process with the new HC.
— Otherwise, the whole process can be repeated using the same TSID and direction, a modified TSPEC or DMG TSPEC, optional TCLAS element(s), and an optional TCLAS Processing element until the SME decides that the granted medium time is adequate or inadequate and cannot be improved.

The above rules also apply to the negotiation of the PTP TSPEC and to the negotiation of the DMG TSPEC.

The parameters that are set for a TS may be renegotiated in a similar manner (see 11.4.4.5).

If the HC or PCP grants medium time for an ADDTS Request frame with the TS Info Ack Policy subfield equal to Block Ack and the Direction field equal to either downlink or bidirectional, then it shall initiate a block ack negotiation by sending an ADDBA Request frame to the STA that originated the ADDTS Request frame. If a non-DMG STA is granted medium time for an ADDTS Request frame with the TS Info Ack Policy subfield equal to Block Ack and the Direction field equal to other than downlink, then it shall initiate a block ack negotiation by sending an ADDBA Request frame to the recipient of the TS.

In a non-DMG BSS, the combination of the TSID and Direction subfields identify the TS, in the context of the STA, to which the TSPEC applies. A bidirectional link request is equivalent to a downlink TS and an uplink TS, each with the same TSID and parameters. In a DMG BSS, the combination of the TSID, source DMG STA AID, destination DMG STA AID, and Direction subfields identifies the TS, in the context of the non-AP STA, to which the TSPEC applies.

The same TSID may be used for multiple TSs at different STAs. A STA can use the same TSID subfield value for a downlink TSPEC and either an uplink or a direct-link TSPEC at the same time. In a non-DMG BSS, a non-AP STA shall not use the same TSID for both uplink and direct-link TS. In a DMG BSS, a non-AP STA as

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a source DMG STA can use the TSID subfield value for an uplink PTP TSPEC, and at the same time the non-AP STA as a destination DMG STA can use the same TSID subfield value for a downlink PTP TSPEC.

If the TS Info Ack Policy subfield of a TSPEC or DMG TSPEC element is Block Ack and the type of Block Ack policy is unknown to the HC, the HC assumes, for TXOP scheduling, that the immediate block ack policy is being used (see 10.25).

An HC shall be capable of receiving an ADDTS Request frame that contains a TCLAS element and capable of generating an indication that contains this as a parameter.

When a STA requests service at a higher priority than authorized by its dot11InterworkingTableEntry, the HC may provide a suggested TSPEC or DMG TSPEC with a data rate and lower priority that would be authorized. Usage of the TSPEC in an Interworking environment is described in Annex K.

A STA may include a U-PID element in ADDTS Request, DMG ADDTS Request, ADDTS Response and DMG ADDTS Response frames it transmits. The U-PID element is used to indicate the upper layer protocol responsible for handling MSDUs corresponding to the TID indicated within the frame carrying the U-PID element. If a U-PID element is not included in an ADDTS Request, DMG ADDTS Request, ADDTS Response or DMG ADDTS Response frame, MSDUs corresponding to the TID contain an LLC header that is used for upper layer protocol identification.

A U-PID element shall not be included in an ADDTS Response or DMG ADDTS Response frame if a U-PID element was not included in the corresponding ADDTS Request or DMG ADDTS Request frame. If a U-PID element was included in an ADDTS Request or DMG ADDTS Request frame, the same U-PID element shall be included in the corresponding ADDTS Response or DMG ADDTS Response frame if that frame has a Status Code of SUCCESS. The Status Code field shall be set to REJECT_U-PID_SETTING in the ADDTS Response or DMG ADDTS Response frame if the request is rejected frame due to the setting of the U-PID element received; this frame may contain an alternative U-PID element that is acceptable to the STA sending the ADDTS Response or DMG ADDTS Response frame.

11.4.4.5 TS renegotiation

A non-AP STA may attempt to modify the parameters of a TSPEC or DMG TSPEC by transmitting an ADDTS Request or DMG ADDTS Request frame. If the Status Code in the corresponding ADDTS Response or DMG ADDTS Response frame is SUCCESS, then any TSPEC with the same TSID or DMG TSPEC with the same allocation ID is overridden with the TSPEC or DMG TSPEC in that frame, the HC and non-AP STA shall reset the inactivity interval timer, and the HC shall reset the suspension interval timer.

11.4.5 TS setup by resource request during a fast BSS transition

A QoS STA may transmit a TSPEC as part of a RIC-Request in a resource request message. The SME in the hybrid coordinator (HC) decides whether to accept the TSPEC as specified, or refuse the TSPEC, or not accept but suggest an alternative TSPEC. It then generates a RIC-Response, according to the procedures given in 13.11.

Each TS established by this resource request is placed in the accepted state. This state is an intermediate state between inactive and active. In the accepted state, the inactivity and suspension timers shall not be started for the TS. For a TS based on hybrid coordination function (HCF) controlled channel access (HCCA), the HC shall not generate CF-Poll for the TS.

The SME may take the resource/timing requirements of the TS in the accepted state into consideration before assigning any further resources to any other admitted or accepted TS, and in calculating the available admission capacity for the BSS Load element.

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The TS is moved to the active state once the STA performs a reassociation to the AP (see 13.11.3). Once the TS becomes active, the inactivity and suspension timers are started. In an AP when dot11SSPNInterfaceActivated is true, the HC shall set dot11NonAPStationAddtsResultCode in the non-AP STA's dot11InterworkingEntry equal to the Status Code in the corresponding RDE.

If the reassociation timer times out and the TS is not yet in the active state, the TS goes back to the inactive state.

11.4.6 PSMP management

A STA may attempt to create a scheduled PSMP session with its AP only if the AP has the S-PSMP Support field in the Extended Capabilities element equal to 1.

The TSPEC reserves resources within the AP and modifies the AP's scheduling behavior. The parameters in the TSPEC can be grouped into two categories: PSMP scheduling and PSMP reservation. The scheduling parameters are used by the AP to schedule a suitable SI. The reservation parameters are used by the AP to reserve time in the PSMP-UTT and PSMP-DTT.

The service start time and SI specify the PSMP schedule in the response's Schedule element. All other parameters result in a reservation for the PSMP-UTT and PSMP-DTT within the scheduled PSMP sequence.

An AP shall terminate the PSMP session only when the last TS associated with the particular PSMP session is terminated.

Once created, a PSMP session can be extended by another TSPEC setup. A STA that has an established PSMP session may issue an additional TSPEC request with the following:

— The Aggregation field set to 1
— The Scheduled field set to 1 and APSD field set to 0 (S-PSMP)
— The Minimum Service Interval and Maximum Service Interval fields both set to the Service Interval field value from the Schedule element specified when the PSMP session was established

The AP shall return an identical Schedule element for all TSPEC response frames related to the same PSMP session.

NOTE—A STA that does not have an established PSMP session might send a TSPEC request specifying S-PSMP session with the same SI. The AP is free to choose between aggregating this request with an existing PSMP session of the same SI or creating a new PSMP session.

The parameters of a TS already associated with the PSMP session may be changed; however, the SI shall not be changed. The start time of existing STAs in the PSMP schedule shall not be changed by the addition of a TSPEC from a new STA.

A TSPEC that reserves resources for a STA under scheduled PSMP shall have the APSD and Scheduled fields set to indicate Scheduled PSMP as defined in Table 9-161.

The non-AP STA's SME decides that a PSMP session needs to be established. How it makes this decision and how it selects the related TSPEC parameters are beyond the scope of this standard.

The Minimum Service Interval field of the TSPEC element of an ADDTS Request frame shall be a multiple of the SI granularity indicated by the AP in its Extended Capabilities element.

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11.4.7 Failed TS setup

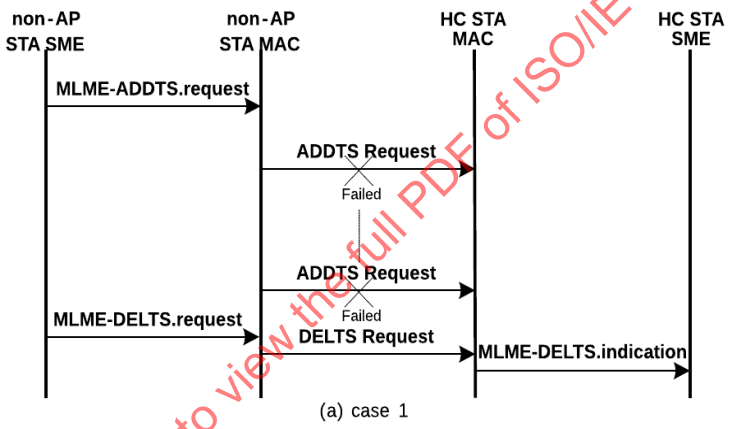
There are three possible types of failed TS setup:

a) The transmission of ADDTS Request frame failed.

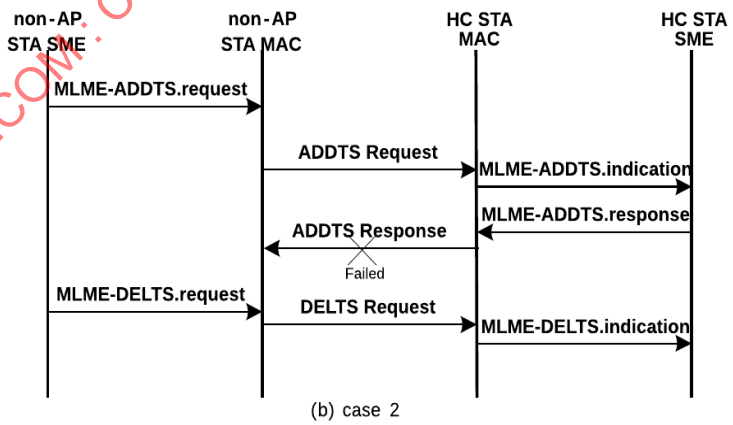
b) No ADDTS Response frame is received from the HC STA (e.g., because of delay due to congestion or because the response frame cannot be transmitted).

c) An ADDTS Response frame is received that contains the Status Code field equal to REJECTED_FOR_DELAY_PERIOD. In this case, if the Delay field of the TS Delay element of the ADDTS Response frame is nonzero, the STA that transmitted the ADDTS Request frame shall not transmit another ADDTS Request frame to the same AP until the time indicated by the Delay field has elapsed.

Figure 11-21 summarizes the two cases. In either case in a non-DMG BSS, if the request is not for an existing TS, the SME shall issue a DELTS.request primitive to the HC specifying the TSID and direction of the failed request just in case the HC had received the request and it was the response that was lost. In either case in a DMG BSS, if the request is not for an existing allocation or TS, the SME shall issue a DELTS.request primitive to the non-AP STA specifying the allocation ID or TSID and destination DMG STA of the failed request just in case the AP or PCP had received the request and it was the response that was lost.



(a) case 1



(b) case 2

Figure 11-21—Failed TS setup detected within non-AP STA's MLME

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11.4.8 Data transfer

After the setup of a TSPEC or PTP TSPEC, MSDUs are classified above the MAC and are sent to the MAC through the MAC SAP using the MA-UNITDATA.request primitive with the priority parameter encoded to the TID.

In a DMG BSS, MSDUs are transmitted using QoS Data frames. During each CBAP allocation, the MAC delivers MSDUs based on the priority of the transmitted QoS Data frames. The MAC can transmit all MSDUs having a TSID with an associated TSPEC with an access policy of EDCA or SEMM, provided that the source AID of the CBAP allocation is equal to the source AID of the TS, or the source AID of the CBAP allocation is equal to broadcast AID, or the destination AID of the CBAP matches the destination AID of the TS.

During each SP allocation, the MAC delivers MSDUs whose TSIDs identify TSPECs that have been set up to use the SP allocation. Relative prioritization of multiple TSPECs mapped to the same SP allocation is implementation dependent and outside the scope of this standard.

When an MSDU arrives from the MAC SAP with a TSID for which there is no associated TSPEC, the MSDUs shall be sent using EDCA with the access category AC_BE.

The generation of the associated TID is done by a classifier above the MAC and it may use the associated TCLAS elements if any are present. When there are multiple TCLAS elements and if the Processing subfield of TCLAS Processing element is 0, the priority parameter in the associated MA-UNITDATA.request primitive is set to TID if the classifier matches the parameters in all of the TCLAS elements associated with the TS. When there are multiple TCLAS elements and if the Processing subfield of the TCLAS Processing element is 1, the priority parameter in the associated MA-UNITDATA.request primitive is set to TID if the classifier matches the parameters in at least one of the TCLAS elements associated with the TS. When there is no TCLAS element and if the Processing subfield of the TCLAS Processing element is 2, the priority parameter in the associated MA-UNITDATA.request primitive is set to TID if the classifier cannot match the parameters to any of the TCLAS elements. An incoming MSDU that is not classified to a particular TS may be classified to another active TS based on the frame classifier for that TS. If, however, all of the frame classifiers for the active TS have been exhausted, the MSDU does not belong to any active TS and is classified to be a best-effort MSDU. See 5.1.1.3 for the treatment of an MSDU with a TSID for which there is no associated TSPEC.

When an MSDU is classified using a TCLAS element, the original UP cannot be recovered by the receiver.

If dot11AlternateEDCAActivated is true, if an Intra-Access Category Priority element was provided when the TS was created, and if the Access Policy subfield of the TS Info field in the TSPEC is EDCA or HEMM, the value from the Alternate Queue subfield is used to select the appropriate EDCA transmit queue.

If an Intra-Access Priority element was provided when the TS was created, the Drop Eligibility subfield is used to determine the drop eligibility of the MSDU.

11.4.9 TS deletion

11.4.9.1 Deletion of a TS established between an HC, DMG AP, or PCP and a non-AP and non-PCP STA

The STA may delete a TS in either of two ways: using non-PCP and non-AP STA initiation or using HC, DMG AP or PCP initiation. In both methods, the SME entity above the MAC generates an MLME-DELTS.request primitive specifying the TS to be deleted and the reason for deleting the TS. This causes the MAC to send a DELTS frame. The encoding of ReasonCode values to Reason Code field values is defined in Table 9-49.

Having transmitted a DELTS frame, the initiating MAC deletes the TS identified in the DELTS frame when it receives an Ack frame that responds to this DELTS frame. There is no Management frame response.

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Figure 11-22 shows the case of TS deletion initiated by a non-PCP and non-AP STA and the case of TS deletion initiated by an HC, DMG AP, or PCP.

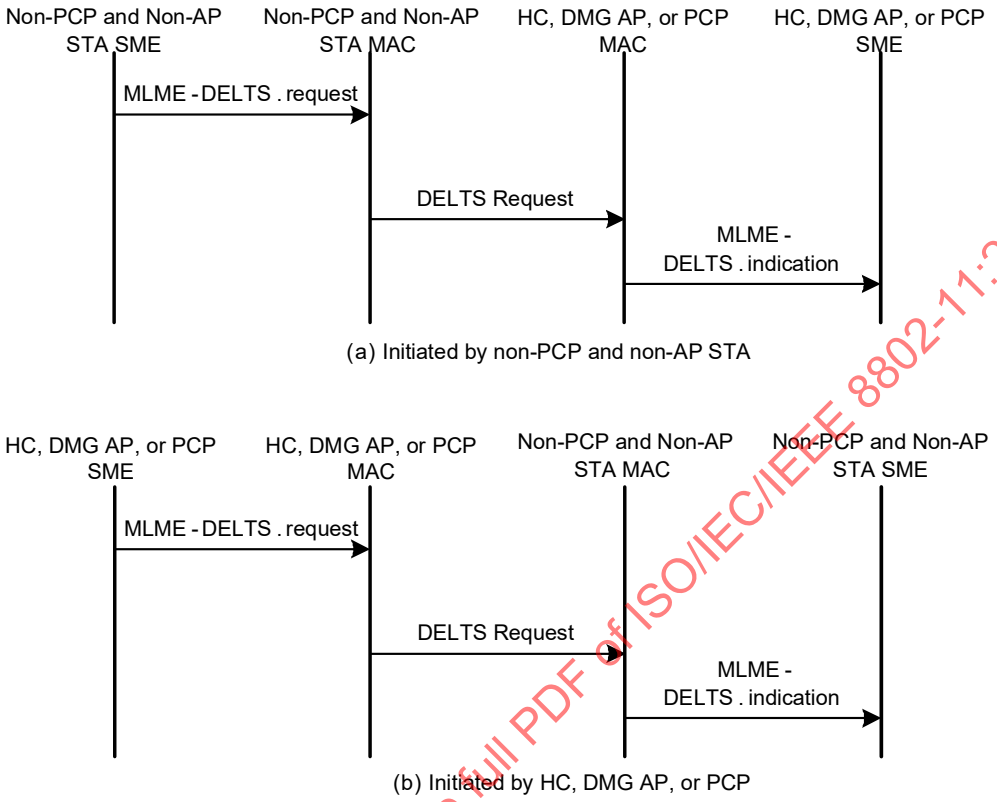

Figure 11-22—TS deletion

An HC should not delete a TSPEC without a request from the SME, except for inactivity (see 11.4.10) or an HC service change that precludes the HC from continuing to meet the requirements of the TSPEC.

All TSPECs that have been set up shall be deleted upon disassociation and reassociation. Reassociation causes the non-PCP and non-AP STA and HC, DMG AP, or PCP to clear their states, and the non-PCP and non-AP STA may then reinitiate the setup.

11.4.9.2 Peer-to-peer TS deletion and deletion of an allocation

This subclause describes deletion of a TS established between non-AP and non-PCP DMG STAs (i.e., established using a PTP TSPEC) and deletion of an allocation (i.e., established using a DMG TSPEC).

In this subclause the following procedures for deletion of an allocation or TS are described:

— Deletion of a TS established using a PTP TSPEC by either source or destination STAs
— Deletion of an allocation by either source or destination STAs of that allocation, which might result in the deletion of one or more associated TSs
— Deletion of an allocation (either SP or CBAP) by the AP or PCP

The SME entity above the MAC generates an MLME-DELTS.request primitive specifying either the TS or the allocation to be deleted and the reason for deleting the TS or allocation, respectively. If generated within a

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non-AP and non-PCP STA, this primitive causes the MAC to send a single DELTS frame. If generated within an AP or PCP, this primitive causes the MAC to send one or two DELTS frames, as described below. The encoding of ReasonCode values to Reason Code field (see 9.4.1.7) values is defined in Table 9-49.

A STA that receives an MLME-DELTS.request primitive for a TS that was established using a PTP TSPEC causes the MAC to send a DELTS frame to the peer STA of the TS. This is shown in Figure 11-23.

NOTE 1—The AP or PCP is unaware of the deletion of the TS.

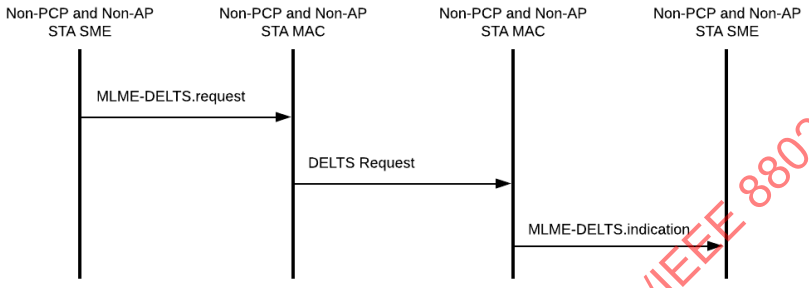

Figure 11-23—Deletion of a TS established using a PTP TSPEC

A non-AP and non-PCP STA that receives an MLME-DELTS.request primitive for an allocation causes the MAC to send a DELTS frame to the AP or PCP. If it is transmitted by the STA identified by the Source AID of the allocation and if the Destination AID of the allocation is different from the broadcast AID, the AP or PCP shall send a DELTS frame to the STA identified by the Destination AID of the allocation. If it is transmitted by the STA identified by the Destination AID of the allocation and if the Source AID of the allocation is different from the broadcast AID, the AP or PCP shall send a DELTS frame to the STA identified by the Source AID of the allocation. The AP or PCP shall also delete the scheduling information corresponding to the allocation, identified by the DMG Allocation Info field of the DELTS frame.

Figure 11-24 shows the deletion of an allocation in which both Source AID and Destination AID are not the broadcast AID.

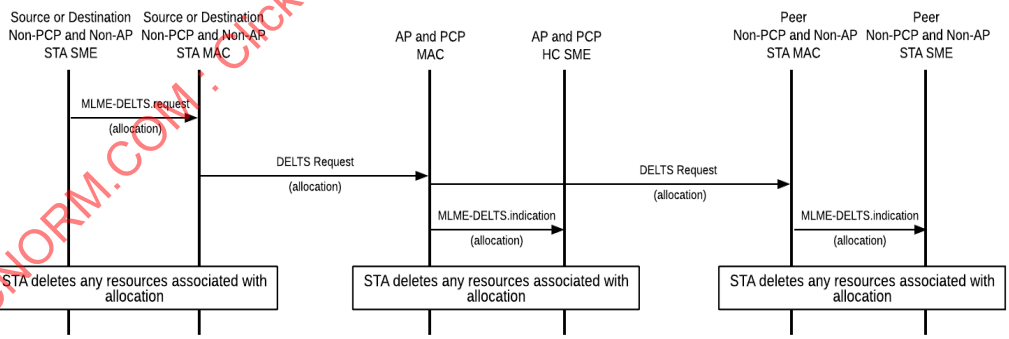

Figure 11-24—Deletion of an allocation in which both Source AID and Destination AID are not the broadcast AID

An AP or PCP that receives an MLME-DELTS.request primitive for an allocation causes the MAC to send one or two DELTS frames. If the Destination AID of the allocation is different from the broadcast AID, the AP or PCP shall send a DELTS frame to the STA identified by the Destination AID of the allocation. If the Source AID of the allocation is different from the broadcast AID, the AP or PCP shall send a DELTS frame to the STA

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identified by the Source AID of the allocation. The AP or PCP shall also delete the scheduling information corresponding to the allocation, identified by the DMG Allocation Info field of the DELTS frame.

An SME that deletes an allocation (using an MLME-DELTS.request primitive) or is notified that an allocation has been deleted (by receiving an MLME-DELTS.indication primitive) also locally deletes (i.e., updates it own resources, but does not cause any MAC frames to be transmitted) any TS that is dependent on that allocation as follows:

— Deleting an SP allocation shall also locally delete any TS with access policy SPCA or SEMM using the allocation.
— Deleting a CBAP allocation with Source AID different from the broadcast AID shall also locally delete any TS with access policy EDCA using the allocation.
— Deleting a CBAP allocation with Source AID equal to the broadcast AID shall also locally delete any TS with access policy EDCA using the allocation, unless there is another CBAP allocation the TS could use.

A non-AP and non-PCP STA that associates, disassociates or reassociates (except for reassociation to the same AP) shall locally delete all existing allocations and all TSs that have been established using a PTP TSPEC.

An AP or PCP that receives an MLME-ASSOCIATE.indication, MLME-REASSOCIATE.indication (except when the MLME-REASSOCIATE.indication primitive has this AP's MAC address in the CurrentAPAddress parameter) or MLME-DISASSOCIATE.indication primitive from a STA (the "resetting" STA) with which it has an existing association shall locally delete all allocations that have been established by the resetting STA using a PTP TSPEC. When deleting an allocation in which the Source AID or Destination AID correspond to the resetting STA and the peer STA is not identified by the broadcast AID, the AP or PCP shall send a DELTS to the peer STA to delete that allocation.

NOTE 2—If both Source AID and Destination AID are equal to the broadcast AID, the AP or PCP transmits no DELTS frames. It deletes scheduling information corresponding to the allocation, which is reflected in its subsequent transmission of frames containing an Extended Schedule element.

A STA that generates an MLME-ASSOCIATE.request, MLME-REASSOCIATE.request (except when the MLME-REASSOCIATE.request primitive has the target AP's MAC address in the CurrentAPAddress parameter) or MLME-DISASSOCIATE.request primitive shall locally delete all allocations and all TSs that have been established using a PTP TSPEC.

NOTE 3—Reassociation causes a STA to clear any state related to allocations and TSs that have been established using a PTP TSPEC. A non-PCP and non-AP STA might need to repeat the establishment of any allocations or TSs after reassociation needed to support applications active before the reassociation.

In all of the cases listed above, the TS or allocation is deleted within the initiating MAC when the Ack frame to the Action frame is received. No Action frame response is generated.

11.4.10 TS timeout

TS timeout is detected within the HC STA's MAC when no traffic is detected on the TS within the inactivity timeout specified when the TS was created.

For an uplink TS in a non-DMG BSS or for a TS that has the AP or PCP as the destination DMG STA in a DMG BSS, the timeout is based on the arrival of received MSDUs that belong to the TS, after any decryption and reassembly.

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For a downlink TS in a non-DMG BSS or for a TS that has the AP or PCP as the source DMG STA in a DMG BSS, the timeout is based on the following:

— Arrival of valid MA-UNITDATA.request primitives using this TS at the MAC SAP when the QoS Data frames are sent with No Ack ack policy
— Confirmation of correctly sent MSDUs that belong to the TS within the MAC when the QoS Data frames are sent with ack policy other than No Ack

In a DMG BSS and in the case of a TS that is established between non-AP STAs (PTP TSPEC), the timeout of the recipient is based on the arrival of MSDUs that belong to the TS within the MAC after any decryption, A-MSDU unpacking, and reassembly.

In a TS established between non-AP STAs (PTP TSPEC), the timeout of the originator is based on the following:

— Arrival of valid MA-UNITDATA.request primitives using this TS at the MAC SAP when the QoS Data frames are sent with No Ack ack policy
— Confirmation of correctly sent MSDUs that belong to the TS within the MAC when the QoS Data frames are sent with ack policy other than No Ack

In a direct-link TS in a non-DMG BSS, inactivity is considered to have happened if one of the two following events occurs:

— The HC transmits a QoS CF-Poll frame and the polled STA returns a QoS Null immediately after a SIFS that contains a QoS Control field in which the Queue Size subfield contains 0.
— The HC transmits a QoS CF-Poll frame, and no QoS Null frame is received within the granted TXOP duration that indicates the queue size for the related TSID. This is to confirm that the STA is actually using the assigned TXOP for the given TSID.

In a non-DMG BSS, any other use of a polled TXOP delivered to the STA is considered to be activity on all direct-link TS associated with that STA. Detection of inactivity of this type is optional.

In response to an inactivity timeout, an HC shall send a DELTS frame to the STA with the Reason Code set to TIMEOUT and inform its SME using the MLME-DELTS.indication primitive. In response to an inactivity timeout, a DMG AP shall send a DELTS frame to the non-AP DMG STA with the result code set to TIMEOUT and inform its SME using the MLME-DELTS.indication primitive. In response to an inactivity timeout, a PCP shall send a DELTS frame to the non-PCP DMG STA with the result code set to TIMEOUT and inform its SME using the MLME-DELTS.indication primitive.

In a DMG BSS when a TS is established between non-AP STAs (PTP TSPEC), then in response to a TS timeout detected within the originator non-AP STA the non-AP STA shall send a DELTS frame to the recipient non-AP STA with the result code set to TIMEOUT and inform its SME using the MLME-DELTS.indication primitive. If the TS timeout is detected within the recipient non-AP STA, the STA shall send a DELTS frame to the originator non-AP STA with the result code set to TIMEOUT and inform its SME using the MLME-DELTS.indication primitive.

The case of uplink TS timeout is shown in Figure 11-25.

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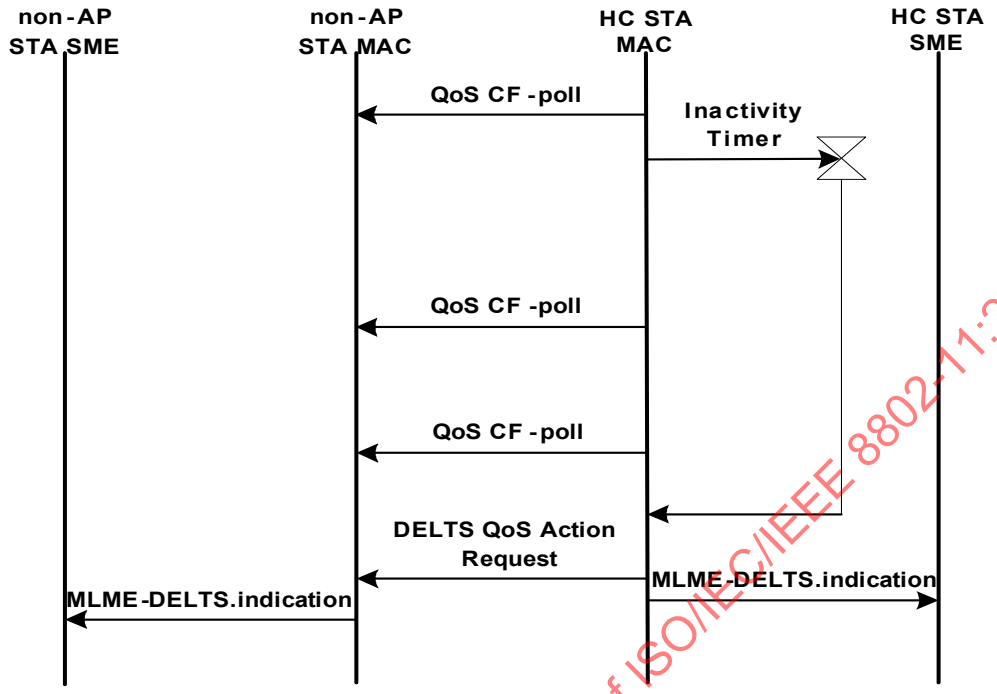
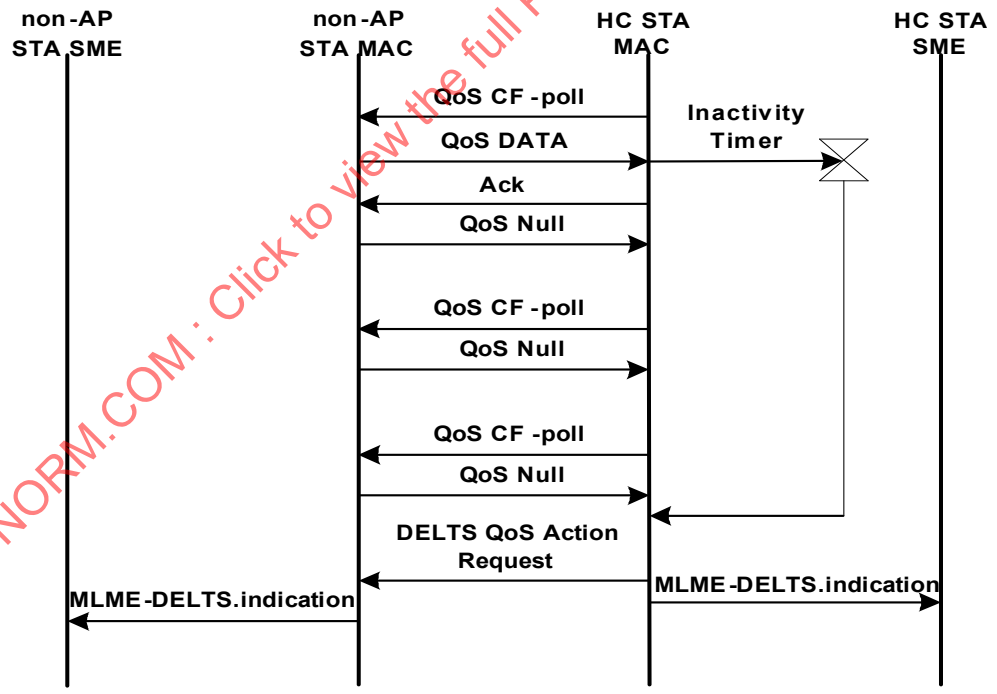


(a) No response from STA



(b) No Data frames from STA

Figure 11-25—TS timeout

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11.4.11 TS suspension

TS suspension occurs within the HC's MAC when no traffic is detected on the TS within the suspension interval specified when the TS was created. In the suspended state, the generation of QoS (+)CF-Poll frames is stopped for the related TS.

11.4.12 TS reinstatement

A suspended TS may be reinstated following activity for that TS.

For uplink and direct link, a suspended TS may be reinstated by a STA by sending a QoS Data or QoS Null frame. This frame may be sent at the highest priority using EDCA. The generation of successive QoS (+)CF-Poll frames shall then be resumed by the HC.

For downlink, a suspended TS is reinstated by the HC when the AP receives an MSDU from a higher layer.

11.4.13 DMG allocation formats

11.4.13.1 General

A DMG STA manages allocations and TSs as described in 11.4.1 to 11.4.14. Using the DMG TSPEC, a DMG STA can indicate two types of allocation scheduling: isochronous and asynchronous. It should establish an isochronous allocation if it needs periodic access to the channel and does not expect to change the amount of time allocated frequently. It should establish an asynchronous allocation if it expects to make requests for channel time and wishes to reserve a minimum amount of channel time to satisfy for those requests when they occur.

11.4.13.2 Isochronous allocations

In order to request the setup of an isochronous allocation, a DMG STA shall set the Allocation Format field in the DMG TSPEC element to 1.

Following the successful admittance of a DMG TSPEC with an isochronous allocation, the AP or PCP should allocate time in the beacon interval to meet the periodicity and minimum allocation requirements specified in the DMG TSPEC element.

Referring to fields in the DMG TSPEC element, the AP or PCP should check that over each Allocation Period the sum of the time allocations is at least the Minimum Allocation. In addition, the AP or PCP should check that each individual allocation has a minimum duration of at least Minimum SP Duration. See 9.4.2.133, 10.39.6, and 10.39.6.4.

With an isochronous DMG TSPEC, the allocation period defines the period over which the channel time allocation repeats. The scheduler should check that at least the minimum allocation is made within each allocation period. The allocation may be composed of multiple SPs. The scheduler also checks that each SP making up the allocation is no shorter than the minimum SP duration. The scheduler is free to position the SPs that make up the allocation anywhere in the allocation period. The scheduler may allocate up to the maximum allocation each allocation period if resources permit.

11.4.13.3 Asynchronous allocations

A DMG STA uses the SPR frame to request channel time for asynchronous traffic.

For each TID, source DMG STA, and destination DMG STA tuple, the AP or PCP can maintain the amount of outstanding channel time that needs to be allocated. Each time it receives an SPR frame, the amount

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of outstanding channel time is set to the value received in the SPR frame from the source DMG STA for the identified TID and destination DMG STA. The amount of outstanding channel time is decreased by the amount allocated when channel time is scheduled for that TID, source DMG STA, and destination DMG STA tuple.

A DMG STA may also use a DMG TSPEC to reserve resources for asynchronous traffic. In this case, the STA shall set the Allocation Format field in the DMG TSPEC element to 0. The AP or PCP should admit an asynchronous DMG TSPEC only if it is able to meet the minimum allocation requirements specified in the DMG TSPEC element.

With an asynchronous DMG TSPEC, a DMG STA registers the minimum allocation it expects within the allocation period while an SP request is in effect that is greater than the minimum allocation specified. In addition, the STA expects that each allocation is at least of duration specified by the Minimum Duration field of the DMG TSPEC, provided the outstanding SP request is at least that long. In admitting a DMG TSPEC, the AP or PCP should check that there are sufficient resources available to meet the TSPEC requirements.

11.4.14 PTP TS operation

The ADDTS Request frame containing the PTP TSPEC may be sent to the peer non-AP DMG STA directly or through a DMG AP or PCP.

A non-AP DMG STA may add TSs to an existing allocation with a peer non-AP DMG STA. To do this, the non-AP DMG STA transmits an ADDTS Request frame to the peer STA to include the additional TS. The ADDTS Request frame shall contain a PTP TSPEC with the Allocation ID subfield set to indicate the allocation for the additional TS. A TS with EDCA access policy does not need to be added to any CBAP allocation and can use any CBAP allocation as long as the source AID of the CBAP allocation matches the source AID of the TS, or the source AID of the CBAP allocation is equal to the broadcast AID, or the destination AID of the CBAP matches the destination AID of the TS.

A non-AP DMG STA transmits an ADDTS Request frame to a peer non-AP DMG STA to add a TS to an existing allocation and to possibly communicate traffic-specific parameters such as A-MSDU subframe and Maximum MSDU Size with the peer non-AP DMG STA. The non-AP DMG STA may transmit the ADDTS Request frame directly to the peer STA or to the AP or PCP. In the latter case, the ADDTS Request frame shall contain a TCLAS element with the classifier type set to Ethernet parameters; the Source Address field shall contain the address of the STA that sends the ADDTS Request frame; and the Destination Address field shall contain the address of the peer STA, which is used by the AP or PCP to forward to the peer STA.

The AP or PCP STA shall forward the received ADDTS Request frame to the STA with Address equal to the Destination Address field of the Classifier. If an ADDTS Response frame is received by the AP or PCP STA in response to the forwarded ADDTS Request frame, then the AP or PCP STA shall forward the ADDTS Response frame to the STA with Address equal to the Source Address field of the Classifier. The AP DMG STA and the PCP DMG STA shall not change the content of the elements included in the ADDTS Request and ADDTS Response frames.

If a STA sets the Direction field to a value equal to downlink in the PTP TSPEC included in the ADDTS Request frame, the parameters apply to the STA as the destination DMG STA of that TS. For example, in this case, the Maximum MSDU Size field indicates that the STA is not able to receive MSDUs longer than the value presented in the MSDU Size field. Similarly, if the Direction field indicates uplink, the parameters apply to the STA as the source DMG STA of that TS. In this case, the STA that issued the ADDTS Request frame does not send MSDUs longer than the value of the Maximum MSDU Size field.

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11.5 Block ack operation

11.5.1 Introduction

Block ack may be set up at the MAC (see 10.25.2) or by the initiation of SME. The setup and deletion of block ack at the initiation of the SME is described in this subclause.

11.5.2 Setup and modification of the block ack parameters

11.5.2.1 General

The procedures for setting up and modifying the block ack parameters are described in 11.5.2.2 and 11.5.2.3, respectively, and illustrated in Figure 11-26.

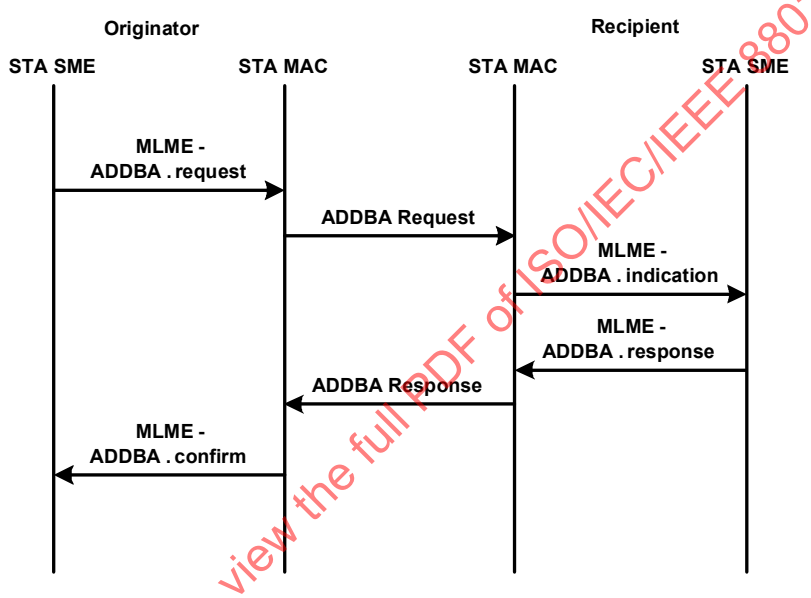

Figure 11-26—Block ack setup

11.5.2.2 Procedure at the originator

Upon receipt of an MLME-ADDBA.request primitive, an initiating STA that intends to send QoS Data frames under the block ack mechanism shall set up the block ack agreement using the following procedure:

a) If the initiating STA is an HT STA, is an IBSS STA, and has no block ack agreement with the recipient STA, then the initiating STA shall transmit a Probe Request frame to the recipient STA and shall not transmit an ADDBA Request frame unless it receives a Probe Response frame from the recipient.

NOTE—When the block ack agreement is being established between a non-AP STA and its AP, then the originator and the recipient have exchanged capability information during the association exchange that allows them to determine whether the other STA is an HT STA.

b) If the peer STA is an S1G STA, the S1G originator shall send an NDP ADDBA Request to indicate that it expects only NDP BlockAck frames during the block ack agreement with the following exceptions:

1) If the S1G originator's dot11BATImplemented is true and the BAT Support subfield in the most recently received S1G Capabilities element from the S1G recipient is 1 and a TWT has been set up with the S1G recipient as described in 10.47, then the S1G originator shall send a

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BAT ADDBA Request to indicate that it expects only BAT frames during the block ack agreement.

2) When any of the conditions below is satisfied then the S1G originator may send an ADDBA request to indicate that it expects only BlockAck frames during the block ack agreement:
   i) The value of the Buffer Size field in the ADDBA Request, carried in an S1G_LONG or S1G_SHORT PPDU, is greater than 16.
   ii) The value of the Buffer Size field of the ADDBA Request, carried in an S1G_1M PPDU, is greater than 8.
   iii) The dot11AsymmetricBlockAckActivated is true and Asymmetric BA Supported field in the most recently received S1G Capabilities element from the S1G recipient is 1.

c) If the recipient is capable of participating, the originator sends an ADDBA Request frame indicating the TID and the buffer size. If the recipient is capable of participating and the GCRGroupAddress parameter of the MLME-ADDBA.request primitive is present, the originator sends an ADDBA Request frame that includes a GCR Group Address element. All DMG STAs are capable of participating in the block ack mechanism.

d) If an ADDBA Response frame is received with the matching dialog token and the TID and with a status code equal to SUCCESS, the STA has established a block ack mechanism with the recipient STA; and the MLME shall issue an MLME-ADDBA.confirm primitive indicating the successful completion of the setup of the block ack agreement.

e) If an ADDBA Response frame is received with the matching dialog token and the TID and with a status code not equal to SUCCESS, the STA has not established a block ack mechanism with the recipient STA; and the MLME shall issue an MLME-ADDBA.confirm primitive indicating the failure of the setup of the block ack agreement.

11.5.2.3 Procedure at the recipient

A recipient shall operate as follows in order to support block ack agreement set up and modification:

a) When an ADDBA Request frame is received from another STA, the MLME shall issue an MLME-ADDBA.indication primitive.

b) Upon receipt of the MLME-ADDBA.response primitive, the STA shall respond by an ADDBA Response frame with a result code as defined in 9.6.4.3.
   1) If the result code is SUCCESS, the block ack agreement is considered to be established with the originator. Contained in the frame are the type of Block Ack agreement, the type of BlockAck frames, and the number of buffers that have been allocated for the support of this block. If the recipient STA is an S1G non-AP STA and it has received from the AP a frame containing an S1G Capabilities element with the Asymmetric BA Supported equal to 1, the Originator Preferred MCS field may be contained in the ADDBA Response frame.
   2) If the result code is REFUSED, the block ack agreement is not considered to have been established.

The encoding of ResultCode values to Status Code field values is defined in Table 9-50.

For S1G STA, the ADDBA Response frame refers to

1) An NDP ADDBA Response if the value of the Buffer Size field of the NDP ADDBA Response is not greater than the value of the maximum number of MSDUs and A-MSDUs that can be acknowledged with the selected NDP BlockAck frame and no TWT has already been set up with the S1G originator as described in 10.47. This value is 8 for NDP 1M BlockAck frames and 16 for NDP_2M BlockAck frames as described in 23.3.12.2.6. The NDP ADDBA Response frame shall be carried in an S1G_1M PPDU to indicate the use of NDP_1M BlockAck frames and shall be carried in an S1G_SHORT or S1G_LONG PPDU to indicate the use of NDP_2M BlockAck frames.

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2) Otherwise, a BAT ADDBA Response as a response to a BAT ADDBA Request if a TWT has already been set up with the S1G originator as described in 10.47. The value of the Buffer Size field in the BAT ADDBA Response shall not be greater than 32.

Otherwise, an ADDBA Response indicating the use of BlockAck frames. The MCS subfield in the Originator Preferred MCS field shall be set to 15 unless the dot11AsymmetricBlockAckActivated is true and the Asymmetric BA Supported field in the most recently received S1G Capabilities element from the S1G originator is 1, in which case the MCS subfield may indicate the value of the preferred MCS if asymmetric BA operation is used. The preferred MCS implicitly indicates the MCSDifference value, which is the difference between the preferred MCS and the MCS at which the ADDBA Response is sent.

11.5.2.4 Procedure common to both originator and recipient

Once a block ack agreement has been successfully established between two STAs, the type of agreement thus established is dependent on the capabilities of the STAs and the contents of the ADDBA Request and ADDBA Response frames used to establish this agreement as defined in Table 11-5 for non-DMG STAs and in Table 11-6 for DMG STAs.

Table 11-5—Types of block ack agreement based on capabilities and ADDBA conditions for non-DMG STAs

Capabilities condition	ADDBA condition	Type of block ack agreement
Both STAs are HT STAs.	Block Ack Policy subfield equal to 1	HT-immediate
Both STAs are robust AV streaming STAs, and the agreement was established using ADDBA Request/Response frames that included GCR Group Address elements.	Block Ack Policy subfield equal to 1	GCR Block Ack
Both STAs are S1G STAs	Block Ack Policy subfield equal to 1	HT-immediate

Table 11-6—Types of block ack agreement based on capabilities and ADDBA conditions for DMG STAs

Capabilities condition	ADDBA condition	Type of BlockAckReq and BlockAck variant	Type of block ack agreement
Both STAs have the BlockAck with Flow Control field in the DMG Capabilities element equal to 1.	Block Ack Policy subfield set to 0	Compressed	HT-immediate
At least one of the STAs has the BlockAck with Flow Control field in the DMG Capabilities element equal to 0.	Block Ack Policy subfield set to 0	Compressed	HT-immediate
At least one of the STAs has the BlockAck with Flow Control field in the DMG Capabilities element equal to 0.	Block Ack Policy subfield set to 1	Extended Compressed	HT-immediate
Both STAs have the BlockAck with Flow Control field in the DMG Capabilities element equal to 1.	Block Ack Policy subfield set to 1	Extended Compressed	HT-immediate + flow control

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NOTE—If the BlockAckReq and BlockAck variant is Extended Compressed and the Type of block ack agreement is HT-immediate, use of the RBUFCAP field is implementation dependent.

11.5.3 Teardown of the block ack mechanism

11.5.3.1 General

The procedure at the two STAs is described in 11.5.3.2 and 11.5.3.3 and illustrated in Figure 11-27.

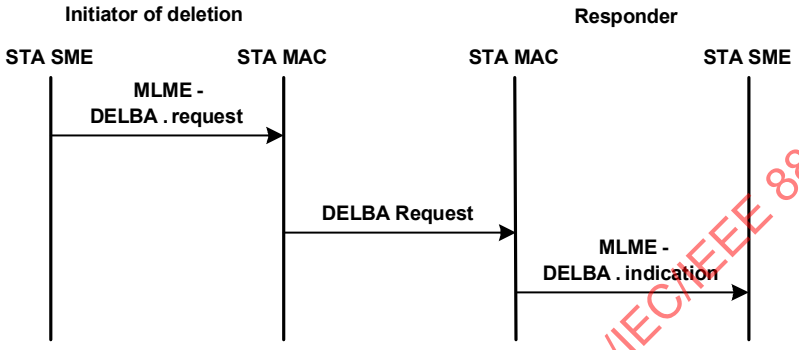

Figure 11-27—Block ack deletion

11.5.3.2 Procedure at the initiator of the block ack teardown

Upon receipt of an MLME-DELBA.request primitive, the MLME shall tear down the block ack by transmitting a DELBA frame.

The encoding of ReasonCode values to Reason Code field (see 9.4.1.7) values is defined in Table 9-49.

11.5.3.3 Procedure at the recipient of the DELBA frame

A STA shall issue an MLME-DELBA.indication primitive with the parameter ReasonCode having a value of REQUESTED when a DELBA frame is received.

11.5.4 Error recovery upon a peer failure

Every STA shall maintain an inactivity timer for every negotiated block ack setup, unless the block ack agreement is set up for a GCR group address. The inactivity timer at a recipient is reset when MPDUs with the TID for the block ack agreement are received and the ack policy is Block Ack or Implicit BAR. The inactivity timer is not reset when MPDUs corresponding to other TIDs are received. The inactivity timer at the recipient is also reset when a BlockAckReq frame with the TID for the block ack agreement is received. The inactivity timer at the originator is reset when a BlockAck frame with the TID for the block ack agreement is received. When a timeout of BlockAckTimeout is detected, the STA shall send a DELBA frame to the peer STA with the Reason Code field set to TIMEOUT and shall issue an MLME-DELBA.indication primitive with the ReasonCode parameter having a value of TIMEOUT. The procedure is illustrated in Figure 11-28.

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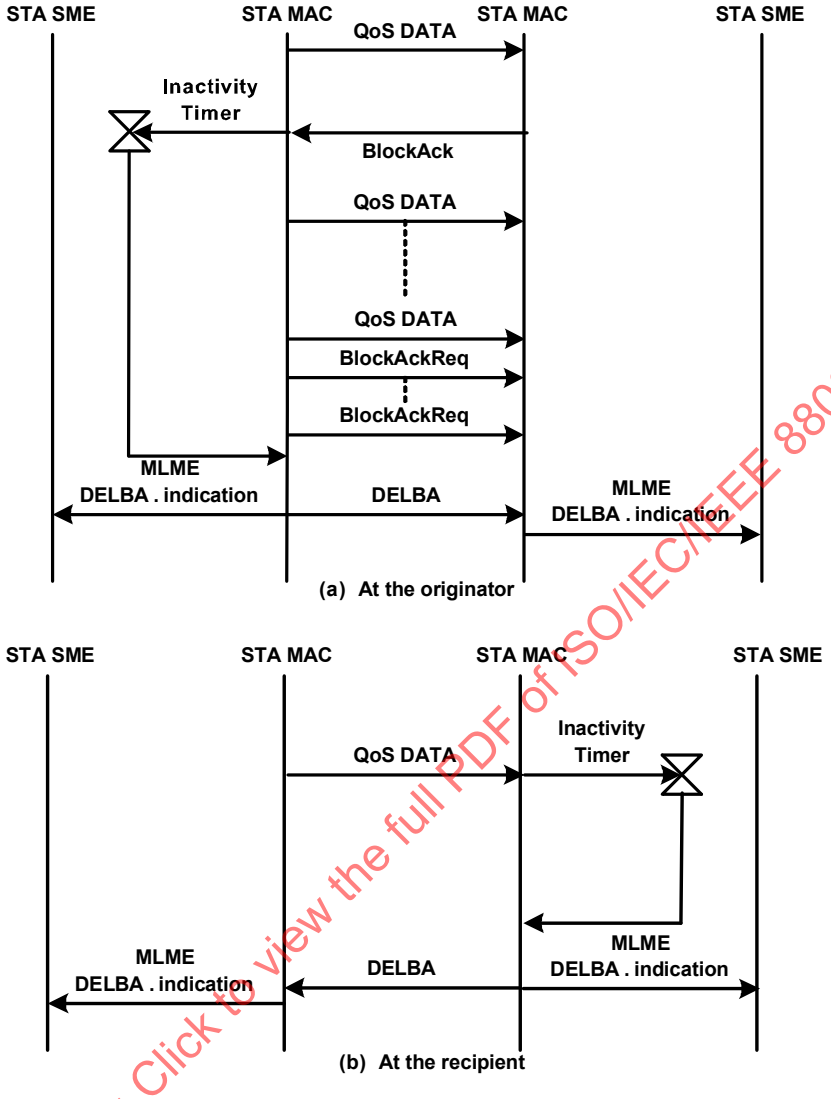

Figure 11-28—Error recovery by the receiver upon a peer failure

When a recipient does not have an active block ack for a TID, but receives QoS Data frames with Block Ack ack policy, it shall discard them and shall send a DELBA frame within its own TXOP. If such a STA receives a BlockAckReq frame, it may respond with an Ack frame and shall respond with a DELBA frame within its own TXOP. The originator may attempt to set up the use of block ack or may send the MPDUs using an alternative acknowledgment mechanism. When the recipient transmits a DELBA frame, it shall set the last sequence number received value to the sequence number of the last received MPDU, regardless of the ack policy used in that frame. When the originator receives a DELBA frame, it shall

a) Discard any MPDU that has been transmitted and not acknowledged, with the possible exception if it was the last MPDU to be sent and it was not a retransmission, and

b) Set the sequence number to either that of the last MPDU that is sent if it intends to retransmit or one beyond the last MPDU sent.

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11.6 Higher layer timer synchronization

11.6.1 Introduction

Higher layer timer synchronization is beyond the scope of this standard. However, explanation of how the constructs in this standard might be used to support such capabilities might be useful to the designer.

One way to accomplish synchronization across a BSS is by multicasting synchronization (sync) packets from the higher layers containing a time stamp and a sequence number. These packets would be opaque to the MAC and would be transported in the same way as any other MSDU (most likely addressed to the group address). Sync packets would be treated as a type of management packet by the higher layers. The time stamp in the sync packet would contain the higher layer clock value at the time when the previous sync packet was transmitted. The sequence number parameter has a value equal to the sequence number of the MSDU in which the time stamp is provided.

The reason the packet would contain the time stamp for the previous sync packet (rather than the current packet) is that hardware and layering constraints would prohibit the ability to provide a time stamp for the exact instant the current packet is transmitted within that packet. However, an MLME-HL-SYNC.indication primitive allows the transmitting STA to know exactly when each sync packet is transmitted. A receiving STA might note the time when each sync packet is received as well as the sequence number for that frame. The receiving STA would save this receive time indication for each packet along with its sequence number and compare the indication of the previously received sync packet to the time stamp in the most currently received packet. This comparison allows the STA to compute an offset, which can be used to adjust its time reference to match that of the synchronization source. A check of the sequence number verifies that the correct packet is being used for time stamp comparison. It is possible a packet is lost; in this case, the received time stamp for the lost packet should be discarded.

The last symbol of the sync packet is indicated by the PHY using the PHY-TXEND.confirm and PHY-RXEND.indication primitives in the transmitter and receiver of the sync packet, respectively. Practical limits on the coincidence of this indication and the last symbol of the sync packet are implementation dependent. The accuracy of this technique also depends on the propagation delay between the source and receiving channel. However, both the time difference (between the PHY indication and the last symbol of the sync packet) and the propagation delay can be considered as fixed-delay components. Therefore, they contribute only to the fixed time difference between the transmitter and receiver STAs' clocks and do not contribute to jitter. An implementation dependent scheme might be used to cancel or minimize this fixed time difference.

The sync packet may also be relayed through the AP. In this case, the STA that generates the time stamps notes the reception of the group addressed sync packet from the AP as the indication to save the higher clock value for the next sync packet. Receiving STAs would also similarly note the time when each sync packet is received from the AP. The sequence number would include a value corresponding to the frame received from the AP.

This is an example implementation using the higher layer timer synchronization feature. Other implementations are possible.

11.6.2 Procedure at the STA

In order to determine whether to provide an MLME-HL-SYNC.indication primitive for a particular Data frame, a MAC that supports MLME-HL-SYNC primitives compares the Address 1 field in a Data frame's MAC header to a list of group addresses previously registered by an MLME-HL-SYNC.request primitive.

When the MAC transmits a Data frame with an Address 1 match, the MLME-HL-SYNC.indication shall occur when the last symbol of the PPDU carrying the Data frame is transmitted. When the MAC receives a Data frame with an Address 1 match, the MLME-HL-SYNC.indication shall occur when the last symbol of the PPDU carrying the matching Data frame is received. In both cases, the MLME-HL-SYNC.indication primitive

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provided is simultaneous (within implementation dependent delay bounds) with the indication provided to other STAs within the BSS for the same Data frame.

11.7 TPC procedures

11.7.1 General

Regulations that apply to the 5 GHz band in most regulatory domains require RLANs operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel. This standard describes such a mechanism, referred to as *transmit power control (TPC)*.

This subclause describes TPC procedures intended to satisfy needs in many regulatory domains and other frequency bands. These procedures might be useful for other purposes (e.g., reduction of interference, range control, reduction of power consumption).

A STA shall use the TPC procedures defined in 11.7 if dot11SpectrumManagementRequired is true. dot11SpectrumManagementRequired shall be set to true when regulatory authorities require TPC. It may also be set to true in other circumstances. The TPC procedures provide for the following:

- Association of STAs with an AP or PCP in a BSS based on the STAs' power capability (see 11.7.2)
- Peering of mesh STAs based on the mesh STAs' power capability (see 11.7.3)
- Specification of regulatory and local maximum transmit power levels for the current channel (see 11.7.5)
- Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory and local requirements (see 11.7.6)
- Adaptation of transmit power based on a range of information, including path loss and link margin estimates (see 11.7.7)

If dot11SpectrumManagementRequired is true, a non-DMG STA shall not join an infrastructure BSS, MBSS or IBSS unless the Spectrum Management bit is 1 in the Capability Information field in Beacon frames and Probe Response frames or in the Condensed Capability Information field in Measurement Pilot frames received from other STAs in the BSS, with the following exceptions:

- A STA may operate when the Spectrum Management bit is 0 if the STA determines that it is in a regulatory domain that does not require TPC or determines that it meets regulatory requirements even if TPC is not employed. Potential methods for determining the regulatory domain include receiving a country indication in the Beacon frame, Measurement Pilot frame, user confirmation, or configuration information within the device. Potential methods to meet regulations even if TPC is not employed include using a transmit power that is below the legal maximum (including any mitigation factor).
- A STA shall set dot11SpectrumManagementRequired to true before associating with a BSS in which the Spectrum Management bit is 1 in the Capability Information field in Beacon frames and Probe Response frames or in the Condensed Capability Information field in Measurement Pilot frames received from the BSS.
- An AP may allow association of devices that do not have the Spectrum Management bit equal to 1 in the Capability Information field in Association Request frames and Reassociation Request frames received from the STA to account for the existence of legacy devices that do not support TPC, but do meet regulatory requirements.

A mesh STA shall set dot11SpectrumManagementRequired to true before becoming a member of an MBSS in which the Spectrum Management bit is equal to 1 in the Capability Information field in Beacon frames and Probe Response frames received from the MBSS.

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11.7.2 Association based on transmit power capability

A STA shall inform an AP or PCP of its minimum and maximum transmit power capability for the current channel when associating or reassociating, using a Power Capability element in (Re)Association Request frames.

An AP or PCP might use the minimum and maximum transmit power capability of associated STAs as an input into an algorithm used to determine the local transmit power constraint for any BSS it maintains. The specification of the algorithm is beyond the scope of this standard.

An AP or PCP may reject a (re)association request from a STA if it considers the STA's minimum or maximum transmit power capability to be unacceptable. For example, a STA's power capability might be unacceptable if it violates local regulatory constraints or increases the probability of hidden STAs by a significant degree. The criteria for accepting or rejecting a (re)association on the basis of transmit power capability are beyond the scope of this standard.

If a STA sends a Country element, a Power Constraint element, and a Transmit Power Envelope element, where the interpretation of the Maximum Transmit Power Level field in the Country element for a 20 MHz or 40 MHz Subband Triplet field is the same as the Local Maximum Transmit Power Unit Interpretation subfield, then at least one of local power constraints indicated by the Local Maximum Transmit Power For 20 MHz and Local Maximum Transmit Power For 40 MHz fields in the Transmit Power Envelope element shall be the same as the indicated local power constraint expressed by the combination of Country element and Power Constraint element.

NOTE—An example of the interpretation of the Maximum Transmit Power Level field in the Country element for a 20 MHz or 40 MHz Subband Triplet field being the same as the Local Maximum Transmit Power Unit Interpretation subfield is when both are EIRP.

11.7.3 Peering based on transmit power capability

A mesh STA shall provide a candidate peer mesh STA with its minimum and maximum transmit power capability for the current channel when becoming a member of an MBSS, using a Power Capability element in Mesh Peering Open frames.

A mesh STA may use the minimum and maximum transmit power capability of a neighbor peer mesh STA as an input into the algorithm used to determine the local transmit power constraint. The specification of the algorithm is beyond the scope of this standard.

A mesh STA may reject a Mesh Peering Open request from a candidate mesh STA if it considers the candidate mesh STA's minimum or maximum transmit power capability to be unacceptable. For example, a candidate mesh STA's power capability might be unacceptable if it violates local regulatory constraints. The criteria for establishing or rejecting a Mesh Peering Open request on the basis of transmit power capability are beyond the scope of this standard.

If a STA sends a Country element, a Power Constraint element, and a Transmit Power Envelope element, where the interpretation of the Maximum Transmit Power Level field in the Country element for a 20 MHz or 40 MHz Subband Triplet field is the same as the Local Maximum Transmit Power Unit Interpretation subfield, then at least one of the local power constraints indicated by a) the Local Maximum Transmit Power For 20 MHz field or b) Local Maximum Transmit Power For 40 MHz field in the Transmit Power Envelope element shall be the same as the indicated local power constraint expressed by the combination of Country element and Power Constraint element.

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11.7.4 Interpretation of transmit power capability

As regards the units of the Minimum Transmit Power Capability and Maximum Transmit Power Capability fields within the Power Capability element sent in a STA's (Re)Association Request frame to an AP, if all of the following apply:

— The STA is extended spectrum management capable.

— The STA has dot11SpectrumManagementRequired or dot11RadioMeasurementActivated equal to true.

— A Beacon or Probe Response frame has been received from the AP by the STA.

— The Beacon or Probe Response frame includes one or more Transmit Power Envelope elements.

then

— The units shall be interpreted according to the Local Maximum Transmit Power Unit Interpretation subfield in the Transmit Power Information field in the Transmit Power Envelope element (see 9.4.2.161) sent in the most recently received Beacon or Probe Response frame.

Otherwise

— The units shall be interpreted as EIRP.

If the Beacon or Probe Response frame most recently received from a neighbor mesh STA by a mesh STA that is extended spectrum management capable and that has dot11SpectrumManagementRequired or dot11RadioMeasurementActivated equal to true includes one or more Transmit Power Envelope elements, then the units of the Minimum Transmit Power Capability and Maximum Transmit Power Capability fields within the Power Capability element sent in the Mesh Peering Open frame to the neighbor mesh STA shall be interpreted according to the Local Maximum Transmit Power Unit Interpretation subfield in the Transmit Power Information field in the Transmit Power Envelope element (see 9.4.2.161) sent in the most recently received Beacon or Probe Response frame. Otherwise, the units of the Minimum Transmit Power Capability and Maximum Transmit Power Capability fields within the Power Capability element sent in the mesh STA's Mesh Peering Open frame to the neighbor mesh STA shall be interpreted as EIRP.

11.7.5 Specification of regulatory and local maximum transmit power levels

A STA shall determine a regulatory maximum transmit power for the current channel by selecting the minimum of the following:

— Any regulatory maximum transmit power received in a Country element from the AP in its BSS, PCP in its PBSS, another STA in its IBSS, or a neighbor peer mesh STA in its MBSS

— Any regulatory maximum transmit power for the channel in the current regulatory domain known by the STA from other sources

A STA shall determine a local maximum transmit power for the current channel by selecting the minimum of the following:

— Unless the STA is extended spectrum management capable and has received a Transmit Power Envelope element for a channel width of 20 MHz and 40 MHz, any local maximum transmit power received in the combination of a Country element and a Power Constraint element from the AP in its BSS, PCP in its PBSS, another STA in its IBSS, or a neighbor peer mesh STA in its MBSS

— If the STA is extended spectrum management capable, any local maximum transmit power received in a Transmit Power Envelope element from the AP in its BSS, another STA in its IBSS, or a neighbor peer mesh STA in its MBSS

— Any local maximum transmit power for the channel regulatory domain known by the STA from other sources

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The Local Power Constraint field of any transmitted Power Constraint element and each Local Maximum Transmit Power For *X* MHz field (where *X* = 20, 40, 80, or 160/80+80) in the Transmit Power Envelope element shall each be set to its respective value that allows the mitigation requirements to be satisfied in the current channel.

NOTE 1—The local maximum transmit power for the channel needs to meet the mitigation requirements for the channel in the current regulatory domain. The conservative approach is to set the local maximum transmit power level equal to the regulatory maximum transmit power level minus the mitigation requirement. However, it might be possible to satisfy the mitigation requirement using a higher local maximum transmit power level. A lower local maximum transmit power level might be used for other purposes (e.g., range control, reduction of interference).

The regulatory and local maximum transmit powers may change in a STA during the life of an infrastructure BSS and an MBSS. However, network stability needs to be considered when deciding how often or by how much these maximums are changed. The regulatory and local maximum transmit powers shall not change during the life of an IBSS.

An AP, IBSS STA, or mesh STA shall advertise the regulatory maximum transmit power for that STA's operating channel in Beacon frames and Probe Response frames using a Country element. An AP, IBSS STA or mesh STA shall advertise the local maximum transmit power for that STA's operating channel in Beacon frames and Probe Response frames using the combination of a Country element and a Power Constraint element.

If an AP, IBSS STA, or mesh STA is extended spectrum management capable, it shall advertise the local maximum transmit power for that STA's operating channel in Beacon frames and Probe Response frames using one Transmit Power Envelope element for each distinct value of the Local Maximum Transmit Power Unit Interpretation subfield that is supported by the BSS, IBSS, or MBSS, respectively. Each Transmit Power Envelope element shall include a local power constraint for all channel widths supported by the BSS.

STAs that are extended spectrum management capable and have dot11RadioMeasurementActivated equal to true should be able to reduce their EIRP to 0 dBm.

NOTE 2—When the local maximum transmit power is set by an AP for radio resource management, a typical low value for the local power constraint is 0 dBm. A STA that cannot reduce its transmit power to this level or below will not be able to associate to the AP.

The PCP in a PBSS shall advertise both the regulatory maximum transmit power and the local maximum transmit power for its operating channel in Announce and Probe Response frames (using a Country element for the regulatory maximum and a combination of a Country element and a Power Constraint element for the local maximum). In addition, it should advertise both regulatory and local maximum transmit power in DMG Beacon frames.

When dot11SpectrumManagementRequired is false and dot11RadioMeasurementActivated is true, an AP or a PCP may include a Power Constraint element and a Transmit Power Envelope element in Beacon, DMG Beacon, Announce, and Probe Response frames.

11.7.6 Transmit power selection

A STA may select any transmit power for transmissions in a channel within the following constraints:

- A STA shall determine a regulatory maximum transmit power and a local maximum transmit power for a channel in the current regulatory domain before transmitting in the channel.
- An AP shall use a transmit power less than or equal to the regulatory maximum transmit power level for the channel. The AP shall also meet any regulatory mitigation requirement.
- A non-AP STA shall use a transmit power less than or equal to the local maximum transmit power level for the channel.

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11.7.7 Transmit power adaptation

A STA may use any criteria, and in particular any path loss and link margin estimates, to dynamically adapt the transmit power for transmissions of an MPDU to another STA. The adaptation methods or criteria are beyond the scope of this standard.

A STA may use a TPC Request frame to request another STA to respond with a TPC Report frame reporting link margin and transmit power information. A STA that receives a TPC Request frame shall respond with a TPC Report frame that contains a TPC Report element in which the Transmit Power field indicates the power used to transmit the response and the Link Margin field indicates the estimated link margin. A DMG STA may also use the link measurement procedure and the DMG Link Margin element to exchange TPC information.

An AP, PCP, or IBSS STA shall autonomously include a TPC Report element with the Link Margin field set to 0 in Beacon frames, DMG Beacon frames, Announce frames, or Probe Response frames.

11.8 DFS procedures

11.8.1 General

Regulations that apply to the 5 GHz band in most regulatory domains require RLANs operating in the 5 GHz band to implement a mechanism to avoid co-channel operation with radar systems and to uniformly utilize available channels. This standard describes such a mechanism, referred to as *dynamic frequency selection (DFS)*.

This subclause describes DFS procedures that can be used to satisfy these and similar future regulatory requirements. The procedures might also satisfy comparable needs in other frequency bands and might be useful for other purposes. For example, some of the procedures described in this subclause could be used for channel selection in a DMG BSS.

A STA shall use the DFS procedures defined in 11.8.1 to 11.8.9 if dot11SpectrumManagementRequired is true.

A STA shall use the DFS procedures defined in 11.8.10 if dot11SpectrumManagementRequired and dot11FutureChannelGuidanceActivated are true.

Attribute dot11SpectrumManagementRequired shall be set to true when regulatory authorities require DFS. It may also be set to true in other circumstances. The DFS procedures provide for the following:

- Associating STAs with an AP based on the STAs' supported channels (see 11.8.2).
- Quieting the current channel so it can be tested for the presence of radar with less interference from other STAs (see 11.8.3).
- Testing channels for radar before using a channel and while operating in a channel (see 11.8.4).
- Discontinuing operations after detecting radar in the current channel to avoid further interference with radar (see 11.8.5).
- Detecting radar in the current and other channels, based on regulatory requirements (see 11.8.6).
- Requesting and reporting measurements in the current and other channels (see 11.8.7).
- Selecting and advertising a new channel to assist the migration of a BSS after radar is detected (see 11.8.8).
- Guiding STAs about the likely future channel should the AP leave this channel (see 11.8.10).

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In a DMG BSS, the following DFS procedures apply:

- Associating a STA with an AP or a PCP based on the STA's supported channels (see 11.8.2).
- Quieting the current channel so it can be tested for interference with less interference from associated STAs (see 11.8.3).
- Requesting and reporting measurements in the current and other channels (see 11.8.7).
- Selecting and advertising a new channel to assist the migration of an infrastructure BSS, IBSS, or PBSS (see 11.8.8).

For the purposes of DFS in a non-DMG BSS, the following statements apply:

- A STA with dot11SpectrumManagementRequired true shall not operate in a BSS unless the Spectrum Management bit is 1 in the Capability Information field in Beacon frames and Probe Response frames received from other STAs in the BSS, with the following exception.
  - A STA may operate when the Spectrum Management bit is 0 if the STA determines that it is in a regulatory domain that does not require DFS or determines that it meets regulatory requirements even if DFS is not employed. Potential methods for determining the regulatory domain include receiving a country indication in the Beacon frame, user confirmation, or configuration information within the device. Potential methods to enable regulations to be met even if DFS is not employed include independently detecting radar and ceasing operation on channels on which radar is detected.
- A STA shall set dot11SpectrumManagementRequired to true before associating with an infrastructure BSS, IBSS, or MBSS in which the Spectrum Management bit is 1 in the Capability Information field in Beacon frames and Probe Response frames received from the infrastructure BSS, IBSS, or MBSS.
- An AP may allow association of devices that do not have the Spectrum Management bit equal to 1 in the Capability Information field in Association Request frames and Reassociation Request frames received from a STA to account for the existence of legacy devices that do not support DFS, but do meet regulatory requirements.

11.8.2 Association based on supported channels

11.8.2.1 Association based on supported channels in a non-DMG BSS

A STA shall provide an AP with a list of the channels in which the STA can operate when associating or reassociating by including a Supported Channels element in its (Re)Association Request frames.

An AP may use the supported channels list for associated STAs as an input into an algorithm used to select a new channel for the BSS. The specification of this algorithm is beyond the scope of this standard.

An AP may reject an (re)association request from a STA if it considers the STA's supported channel list to be unacceptable. For example, a STA's supported channel list might be unacceptable if it can operate only in a limited number of channels. The criteria for accepting or rejecting (re)associations are beyond the scope of this standard.

11.8.2.2 Providing supported channels upon association in a DMG BSS

An AP or PCP may advertise the regulatory domain in which it is located via a Country element in the DMG Beacon, Announce, or Information Response frames if dot11MultiDomainCapabilityActivated is true.

When it (re)associates, the STA shall provide to the AP or PCP a list of channels in which the STA can operate. The STA does this by including a Supported Channels element in the Information Request or (Re)Association Request frames that it transmits. An AP or PCP can use the supported channels list for associated STAs as an

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input into an algorithm used to select a new channel for the BSS. The specification of this algorithm is beyond the scope of this standard.

The AP or PCP may advertise the supported channels of associated STAs via an Information Response frame with Subject Address field set to the broadcast address and a Supported Channels element that lists the intersection of channels supported by STAs associated with the BSS, as indicated by their Supported Channels elements.

11.8.3 Quieting channels for testing

When the AP Quiet Mode field of a Quiet Channel element has the value 1, the Quiet Channel element is called a *mode set Quiet Channel element*.

An AP may schedule quiet intervals by transmitting one or more mode set Quiet Channel elements (VHT AP only) and/or one or more Quiet elements in Beacon frames and Probe Response frames.

A mesh STA may schedule quiet intervals by transmitting one or more Quiet elements in Beacon frames and Probe Response frames. A mesh STA shall not transmit mode set Quiet Channel elements.

A non-VHT AP shall not transmit a Quiet Channel element. An AP shall not transmit a Quiet Channel element with the AP Quiet Mode field value equal to 0 in frames that do not include at least one Quiet element. An AP shall not transmit more than one Quiet Channel element with the AP Quiet Mode field equal to 0. An AP shall not transmit a Quiet Channel element if the BSS bandwidth is neither 160 MHz nor 80+80 MHz.

An AP may stop scheduling quiet intervals, or may transmit Quiet elements with changes in the Quiet Period, Quiet Duration and Quiet Offset fields, or may (VHT AP only) transmit Quiet Channel elements (with changes in the Quiet Period, Quiet Duration and Quiet Offset fields in the case of mode set Quiet Channel elements). A mesh STA may stop scheduling quiet intervals, or may transmit Quiet elements with changes in the Quiet Period, Quiet Duration and Quiet Offset fields, or may transmit (VHT mesh STA only) Quiet Channel elements that are not mode set Quiet Channel elements. Only the most recently received Beacon frame or Probe Response frame defines all future quiet intervals; therefore, all schedules for quiet intervals based on older Beacon frames or Probe Response frames shall be discarded.

An AP or PCP in a DMG BSS may measure one or more channels itself, or the AP or PCP may request associated non-AP and non-PCP STAs in the same BSS to measure one or more channels, either in a dedicated measurement interval or during normal operation. The AP or PCP in a DMG BSS may schedule a service period allocated to itself to quiet the associated STAs and use the self-allocated SP for measurement.

An IBSS STA may schedule quiet intervals only if it is the DFS owner. In order to set a quiet interval schedule, the STA transmits one or more Quiet elements in the first Beacon frame establishing the IBSS. All IBSS STAs shall continue these quiet interval schedules by including appropriate Quiet elements in any transmitted Beacon frames or Probe Response frames. An IBSS STA shall not transmit Quiet Channel elements.

NOTE—This means the quiet interval schedules, if any, are defined by the IBSS STA that starts the IBSS. They cannot subsequently be changed, or initiated, by any STA in the IBSS (including the STA that started the BSS and the DFS owner).

Multiple independent quiet intervals may be scheduled, so that not all quiet intervals have the same timing relationship to TBTT, by including multiple Quiet elements or, in an infrastructure BSS, mode set Quiet Channel elements in Beacon frames or Probe Response frames.

Control of the channel is lost at the start of a quiet interval, and the following quieting rules apply:

— The NAV is set by all of the non-VHT STAs in the BSS for the length of the quiet interval established by a Quiet element.

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— The NAV is set by all of the VHT STAs in the BSS for the duration of the quiet interval established by a Quiet element if a Quiet Channel element was not sent or received with the Quiet element.
— A VHT STA in the BSS shall not transmit PPDUs that occupy the secondary 80 MHz channel or, in an infrastructure BSS, transmit PPDUs to the AP during the quiet interval established by a Quiet element if a Quiet Channel element with the AP Quiet Mode field equal to 0 was sent or received with the Quiet element.
— A VHT STA in an infrastructure BSS shall not transmit PPDUs that occupy the secondary 80 MHz channel during the quiet interval established by a Quiet Channel element with the AP Quiet Mode field in the Quiet Channel element equal to 1.
— Transmission by any non-VHT STA in the BSS of any MPDU and any associated acknowledgment within either the primary channel or the secondary channel (if present) shall complete before the start of the quiet interval.
— Transmission by any VHT STA in the BSS of any MPDU and any associated acknowledgment of the BSS shall complete before the start of the quiet interval established by a Quiet element if a Quiet Channel element was not sent or received with the Quiet element.
— Transmission by any VHT STA in the BSS of any PPDUs that occupy the secondary 80 MHz channel or, in an infrastructure BSS, are directed to the AP, and any associated acknowledgment of the BSS, shall complete before the start of the quiet interval established by a Quiet element if a Quiet Channel element with the AP Quiet Mode field equal to 0 was sent or received with the Quiet element.
— Transmission by any VHT STA in the infrastructure BSS of any PPDUs that occupy the secondary 80 MHz channel and any associated acknowledgment of the BSS shall complete before the start of the quiet interval established by a Quiet Channel element with the AP Quiet Mode field in the Quiet Channel element equal to 1.

Before starting transmission of an MPDU, a STA shall check if there is enough time for the exchange to complete within the time allowed by the quieting rules. If there is not enough time, the STA shall defer the transmission by selecting a random backoff count using the present CW (without advancing to the next value in the series). The short retry count and long retry count for the MSDU or A-MSDU are not affected.

11.8.4 Testing channels for radar

A STA does not transmit in a channel unless the channel has been tested for the presence of radar transmissions according to regulatory requirements.

11.8.5 Discontinuing operations after detecting radar

If a STA is operating in a channel and detects radar operating in the channel or accepts that another STA has detected radar operating in the channel, then the STA discontinues transmissions according to regulatory requirements.

11.8.6 Detecting radar

The methods that satisfy regulatory requirements to detect radar transmissions are beyond the scope of this standard.

11.8.7 Requesting and reporting of measurements

The response to a Basic request is a Basic report. A STA in an infrastructure BSS or PBSS shall generate a Basic report in response to a Basic request if the request is received from the AP or PCP with which it is associated, except as specified in this subclause.

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A STA may measure one or more channels itself or a STA may request other STAs in the same BSS to measure one or more channels on its behalf. These measurements may occur either during a quiet interval or during normal operation.

In order to request other STAs to measure one or more channels, a STA shall use a Spectrum Measurement Request frame containing one or more Measurement Request elements. The measurement request may be sent to an individual or group destination address. Addressing requests to multiple STAs should be used with care to avoid a reply storm.

The measurement requests effectively allowed by these rules are shown in Table 11-7.

Table 11-7—Allowed measurement requests

Service set	Source of request	Destination of request	Type of measurement request allowed
BSS	AP	STA	Individual or group
	STA	AP	Individual only
	STA	STA	None
IBSS, MBSS	STA	STA	Individual or group
PBSS	PCP	Non-PCP STA	Individual or group
	Non-PCP STA	PCP	Individual
	Non-PCP STA	Non-PCP STA	None

A STA that successfully requests another STA to perform a measurement on another channel should not transmit MSDUs, A-MSDUs, or MMPDUs to that STA during the interval defined for the measurement plus any required channel switch intervals. In determining this period, a STA shall assume that any required channel switches take dot11ChannelSwitchTime per switch.

A STA that receives an individually addressed Spectrum Measurement Request frame from a STA in its BSS shall parse the frame's Measurement Request elements in order, with measurements starting at the times specified by the Measurement Request elements.

Any result of a measurement request shall be returned without undue delay to the requesting STA in Measurement Report elements using one or more Spectrum Measurement Report frames. The result may be the completed measurement or an indication that the STA is unable to complete the measurement request.

A STA shall report it is too late to undertake a measurement request if it receives the request after the specified starting time for the measurement.

A STA shall report it is refusing a measurement request if all of the following conditions exist:

— The STA is capable of undertaking a measurement request.
— The STA does not want to undertake the measurement request at this time.
— The measurement request is not mandatory.

NOTE—Measurements are specified as mandatory or optional in 9.4.2.20.

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A STA shall report it is incapable of performing a measurement request if any of the following conditions exists:

— The STA is incapable of undertaking an optional measurement request.
— The STA does not support the channel specified in a mandatory measurement request.
— The STA does not support any requested parallel measurements in the same or different channels.

A Spectrum Measurement Report frame shall contain the same value in its Dialog Token field as the Dialog Token field in the corresponding Spectrum Measurement Request frame, and each Measurement Report element shall contain the same value in its Measurement Token field as the Measurement Token field in the corresponding Measurement Request element.

A STA may autonomously report measurements to another STA in its BSS by transmitting a Spectrum Measurement Report frame that includes a Dialog Token field set to 0 and one or more Measurement Report elements. An IBSS STA may also autonomously report measurements to other STAs in the IBSS using the Channel Map field in the IBSS DFS element in a Beacon frame or Probe Response frame.

A STA may enable or disable measurement requests or autonomous measurement reports from another STA by transmitting Measurement Request elements with the Enable bit set to 1 and the Request bit and Report bit set to 0 or 1, as appropriate. These elements do not require a corresponding Measurement Report element in a Spectrum Measurement Report frame. All measurement requests and reports shall be enabled by default. An AP or PCP may ignore a request to disable a mandatory measurement request. All other such requests shall be honored.

The measurement request and report procedures are defined in 11.10.

11.8.8 Selecting and advertising a new channel

11.8.8.1 General

A channel switch is an attempt to move a BSS to a new operating channel. It is an objective that disruption to the BSS be minimized in this process, although it should be recognized that a channel switch might not successfully move all STAs.

Two procedures are defined for switching channels: the channel switching procedure, which is defined in 11.8.8 and 11.8.9, and the extended channel switching procedure, which is defined in 11.9.

It should also be stressed that both the channel switching procedure and the extended channel switching procedure are distinct from the regulatory requirement to cease transmission on a particular channel in the presence of radar.

The Address 1 field of a Channel Switch Announcement frame shall be set to the broadcast address.

11.8.8.2 Selecting and advertising a new channel in a non-DMG infrastructure BSS

This subclause describes operation in an infrastructure BSS that is a non-DMG BSS. For a DMG infrastructure BSS, see 11.8.8.6.

The decision to switch to a new operating channel in an infrastructure BSS shall be made only by the AP. An AP may make use of the information in Supported Channel elements and the results of measurements undertaken by the AP and other STAs in the BSS to assist the selection of the new channel. The algorithm to choose a new channel is beyond the scope of this standard. The AP shall attempt to select a new channel that is supported by all associated STAs.

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An AP shall inform associated STAs that the AP is moving to a new channel and shall maintain the association by advertising the switch using Channel Switch Announcement elements in Beacon frames, Probe Response frames, and Channel Switch Announcement frames until the intended channel switch time. The AP may force STAs in the BSS to stop transmissions until the channel switch takes place by setting the Channel Switch Mode field in the Channel Switch Announcement element to 1. The channel switch should be scheduled so that all STAs in the BSS, including STAs in power save mode, have the opportunity to receive at least one Channel Switch Announcement element before the switch. The AP may send the Channel Switch Announcement frame in a BSS without performing a backoff, after determining the WM is idle for one PIFS (see 10.3.2.3).

When the AP sets the Channel Switch Count field of a Channel Switch Announcement element to a nonzero value in a Beacon frame, it should include a Max Channel Switch Time element in that Beacon frame.

When the AP includes the Max Channel Switch Time element with the Channel Switch Announcement element in the Beacon frame, the AP shall transmit the first Beacon frame in the new channel no later than the time indicated in the Switch Time field of the Max Channel Switch Time element after the last Beacon frame transmitted in the current channel, unless the AP determines that it is unable to operate on the new channel.

When the AP sets the Channel Switch Count field of the Channel Switch Announcement element to 0, it shall not include the Max Channel Switch Announcement element into the Beacon frame.

If a Channel Switch Announcement element in a Beacon or Probe Response frame is used to announce a switch to a 20 MHz BSS bandwidth, then a Wide Bandwidth Channel Switch subelement in a Channel Switch Wrapper element shall not be present in the same frame.

If a Channel Switch Announcement element in a Beacon or Probe Response frame is used to announce a switch to a 40 MHz BSS bandwidth, then a Wide Bandwidth Channel Switch subelement in a Channel Switch Wrapper element shall also be present in the same frame if the STA sending the frame is extended spectrum management capable.

A Channel Switch Wrapper element shall not be included in Beacons and Probe Response frames if the element contains zero subelements.

A STA that receives a Channel Switch Announcement element may choose not to perform the specified switch, but to take alternative action. For example, it may choose to move to a different BSS. An AP shall deauthenticate non-AP STAs that have indicated OCVC capability, are not in WNM Sleep, and have failed to send an SA query within an implementation specific timeout following a channel switch. An AP should pause the transmission and reception of Data frames until the SA query procedure has completed successfully for additional protection.

If dot11RSNAOperatingChannelValidationActivated is true and a channel switch is requested while the handshake is in progress, the handshake should be aborted.

A non-AP STA in an infrastructure BSS shall not transmit the Channel Switch Announcement element.

11.8.8.3 Selecting and advertising a new channel in an IBSS

DFS in an IBSS is complicated by the following:

- There is no central AP function for collating measurements or coordinating a channel switch. If STAs make independent decisions to switch channel in the presence of radar, there is a danger that all STAs announce switches to different channels if several of them detect the radar.
- There is no association protocol that can be used to
  - Exchange supported channel information
  - Determine membership of the IBSS at a given instant for requesting measurements.

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— Beaconing is a shared process; therefore, there is no guarantee that a STA that has something to send (e.g., a channel switch message) will be the next STA to transmit a Beacon frame.
— A 20/40 MHz IBSS cannot be changed to a 20 MHz IBSS, and a 20 MHz IBSS cannot be changed to a 20/40 MHz IBSS.

The DFS owner service, IBSS DFS element, and Channel Switch Announcement frame address these complications:

— The DFS owner service provides a central point of coordination for a channel switch. It attempts to minimize the probability that multiple STAs concurrently decide to switch to different channels. The DFS Owner field and DFS Recovery Interval field in the IBSS DFS element support the DFS owner service.
— Each STA shall include a Channel Map field in the IBSS DFS elements that it transmits. The channel map communicates the STA-supported channel set and basic measurement reports for that STA.
— Each STA shall have the ability to send a Channel Switch Announcement element in a Management frame other than a Beacon frame or Probe Response frame.

The potential for hidden nodes within an IBSS means that an IBSS channel switching procedure might not move all STAs. In some regulatory domains, each STA in an IBSS is required by regulation to detect radar and cease transmission, after a required interval, on any channel on which the presence of radar is detected.

A STA at which an IBSS is started shall be a DFS owner in that IBSS. That STA shall include its MAC address in the DFS Owner field of the IBSS DFS element and DFS Recovery Interval field from the MLME.START.request primitive parameter. The purpose of the DFS owner is to coordinate a channel switch. All STAs in an IBSS shall have the ability to become DFS owner.

Each IBSS STA shall adopt the DFS Owner field and the DFS Recovery Interval field from any valid IBSS DFS element when the received frame contains a matching SSID and the value of the timestamp is later than the STA's TSF timer. The STA shall include the adopted values in the IBSS DFS elements it transmits. Because all IBSS STAs participate in sending Beacon frames, this process always, over a number of beacon intervals, results in a unified view of one DFS owner throughout the IBSS.

In order to attempt a channel switch using the DFS owner, a STA that detects radar shall broadcast one or more Spectrum Measurement Report frames indicating the presence of the radar.

A DFS owner receiving a Spectrum Measurement Report frame indicating the presence of radar in the current channel shall select and advertise a new operating channel (including the possibility of no change). The DFS owner may make use of information received in Channel Map fields and from measurements undertaken by other members of the IBSS to assist the selection of the new channel. The algorithm to choose a new channel is beyond the scope of this standard, but shall satisfy any regulatory requirements, including uniform spreading rules and channel testing rules. The DFS owner shall attempt to select a new channel that is supported by all members of the IBSS. Note that this process might be imperfect in that the DFS owner might have incomplete knowledge and there might not be a suitable channel.

The DFS owner shall attempt to make the members of the IBSS aware of the new operating channel by broadcasting at least one Channel Switch Announcement frame. The DFS owner may transmit the Channel Switch Announcement frame in an IBSS without performing a backoff, after determining that the WM is idle for one PIFS (see 10.3.2.3). The DFS owner shall also include the Channel Switch Announcement element in all Beacon frames, Probe Response frames, or Channel Switch Announcement frames until the intended channel switch time. A STA that receives a valid Channel Switch Announcement element that is not a superseded Channel Switch Announcement element (see 11.15.3.3) shall repeat this element in all Beacon frames and Probe Response frames that it transmits. The DFS owner may attempt to silence STAs in the IBSS until the channel switch takes place using the Channel Switch Mode field in the Channel Switch

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Announcement element. If possible, the channel switch should be scheduled so that all STAs in the IBSS, including STAs in power save mode, have the opportunity to receive at least one Channel Switch Announcement element before the switch.

If a STA does not receive a valid Channel Switch Announcement element from the DFS owner within the DFS recovery time, then it shall enter DFS recovery mode. DFS recovery time is measured from the end of the frame that first announced radar presence, whether that frame was transmitted by the STA or received from another STA. In DFS recovery mode the STA shall assume the role of DFS owner, shall select a new operating channel, and shall advertise the new channel by transmitting a Channel Switch Announcement frame using the contention resolution algorithm defined for beacon transmission at TBTT in 11.1.3.5. The STA shall also include the Channel Switch Announcement element in all Beacon frames and Probe Response frames until the intended channel switch time. A STA that is not the DFS owner shall not initiate a channel switch.

If the STA receives a valid Channel Switch Announcement element that is not a superseded Channel Switch Announcement element (see 11.15.3.3) from another member of the IBSS, the STA shall leave DFS owner recovery mode prior to the channel switch and adopt the received channel switch information. If the Channel Switch Announcement element was in a Beacon frame or Probe Response frame, the STA shall also adopt the STA identified by the DFS owner address of the IBSS DFS element as the DFS owner. If the Channel Switch Announcement element was in a Channel Switch Announcement frame, the receiving STA shall adopt the STA that transmitted the frame as the DFS owner.

There are several circumstances when DFS owner recovery is needed (e.g., if the original DFS owner has left the network or if the original measurement report was not received by the initial DFS owner). Note that DFS owner recovery might temporarily give rise to more than one DFS owner in the IBSS. This risk is mitigated by the random nature of the IBSS DFS recovery mechanism. However, because all IBSS STAs participate in sending Beacon frames, over a number of beacon periods, there will be convergence from multiple DFS owners to one DFS owner.

11.8.8.4 MBSS channel switching

11.8.8.4.1 General

A mesh channel switch might be triggered by the need to avoid interference to a detected radar signal, or to reassign mesh STA channels to maintain MBSS connectivity.

A mesh STA may make use of the information in Supported Channel elements, Supported Operating Classes elements, and the results of measurements undertaken by the mesh STAs in the MBSS to assist the selection of the new channel. The algorithm for choosing a new channel is beyond the scope of this standard.

A 20/40 MHz MBSS may be changed to a 20 MHz MBSS and a 20 MHz MBSS may be changed to a 20/40 MHz MBSS.

When an MBSS switches from a 20 MHz MBSS to a 20/40 MHz MBSS or switches from a 20/40 MHz MBSS to a 20 MHz MBSS, a mesh STA might need to do path maintenance to find an optimized path.

11.8.8.4.2 Initiating MBSS channel switch

A mesh STA shall not initiate a new channel switch attempt if there is an ongoing channel switch attempt by this mesh STA.

A mesh STA shall inform each of the peer mesh STAs that the mesh STA is moving to a new channel while maintaining mesh peerings by including Channel Switch Announcement elements together with the Mesh Channel Switch Parameters element in all Beacon frames, Probe Response frames, and Channel Switch Announcement frames that it transmits until the intended channel switch time. The channel switch should be

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scheduled so that all mesh STAs in the MBSS, including mesh STAs in power save mode, have the opportunity to receive at least one Channel Switch Announcement element before the switch.

The fields in the Channel Switch Announcement element are set as follows:

— The Channel Switch Count field shall be set to the time period until the mesh STA sending the Channel Switch Announcement element switches to the new channel.

— The Channel Switch Mode field is reserved.

— The New Channel Number field shall be set to the number of the channel to which the mesh STA is moving.

The fields in the Mesh Channel Switch Parameters element are set as follows:

— The Precedence Value field shall be set to a random value selected from a uniform distribution in the range 0 to 65 535.

— The mesh STA may force mesh STAs in the MBSS to stop transmissions of frames (except frames containing Channel Switch Announcement element) until the channel switch takes place by setting the Transmit Restrict subfield of the Flags field to 1.

— The Reason subfield in the Flags field shall be set to 1 to indicate that the content of the Reason Code field (as defined in Table 9-49) is valid. The Reason Code field shall be set to MESH-CHANNEL-SWITCH-REGULATORY-REQUIREMENTS when the channel switch is initiated to meet regulatory requirement; otherwise, the Reason Code field shall be set to MESH-CHANNEL-SWITCH-UNSPECIFIED.

— The Initiator subfield of the Flag field shall be set to 1.

— The Time To Live field should be set to the maximum number of hops (e.g., dot11MeshHWMPnetDiameter) for which this Channel Switch attempt is intended.

11.8.8.4.3 Processing channel switch announcement

Upon receipt of a Channel Switch Announcement frame or Extended Channel Switch Announcement frame, a mesh STA shall not accept and shall not process the received Channel Switch Announcement element or Extended Channel Switch Announcement element, if any of the following is true:

— The Mesh Channel Switch Parameters element is not present in the received frame containing the Channel Switch Announcement element or the Extended Channel Switch Announcement element.

— The Time To Live field in the received Mesh Channel Switch Parameters element is 0.

— A mesh channel switch is already running and the mesh STA has not yet moved into the new channel and/or operating class and the current precedence value is greater than or equal to the received Precedence Value field.

A mesh STA that receives a Channel Switch Announcement element may choose not to perform the specified switch, but to take alternative action. For example, it may choose to move to a different MBSS.

If dot11RSNAOperatingChannelValidationActivated is true and a channel switch is requested while the handshake is in progress, the handshake should be aborted.

When a mesh STA accepts a channel switch, it shall adopt the information received in the Channel Switch Announcement element and the Mesh Channel Switch Parameters element. The mesh STA shall schedule the channel switch according to this information. If the Time To Live field value in the received Mesh Channel Switch Parameters element is greater than 1, the mesh STA shall transmit a Channel Switch Announcement frame and shall include a Channel Switch Announcement element together with a Mesh Channel Switch Parameters element in the Beacon and Probe Response frames until the intended channel switch time. The Channel Switch Mode and New Channel Number fields in the transmitted Channel Switch Announcement element(s) are set to the same values as in the received Channel Switch Announcement element. The Channel

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Switch Count field is set to indicate the time remaining until the channel switch, as specified in 9.4.2.18. The Reason Code and Precedence Value fields in the transmitted Mesh Channel Switch Parameters element(s) are set to the same values as in the received Mesh Channel Switch Parameters element. The Time to Live and Flags fields are set as specified in 9.4.2.102. The Time To Live field shall be set to the received Time To Live field minus 1. The Initiator field shall be set to 0. The Transmit Restrict field shall be set to 1 when the mesh STA requires neighboring mesh STAs not to transmit (until the scheduled channel switch occurs) further frames that do not contain the Channel Switch Announcement element on the current channel. The Transmit Restrict subfield shall be set to 0 otherwise.

It is possible that a channel switch is not successful in moving all of the mesh STAs in MBSS to the new operating channel. Transitioning to a new channel does not tear down mesh peerings and, as long as the mesh peers move to the new operating channel, their peerings are maintained in the new channel.

After moving into a new operating channel, the mesh STA shall perform CCA until a frame is detected by which it can set its NAV, or until a period of time indicated by the NAVSyncDelay parameter from the most recent MLME-START.request primitive has transpired.

11.8.8.4.4 Channel switch across an operating class

When dot11OperatingClassesImplemented is true and the mesh STA is capable of operation in more than one operating class, the mesh STA shall include the Supported Operating Classes element within its Mesh Peering Open frames. The Supported Operating Classes element announces the operating classes that the mesh STA supports.

When dot11OperatingClassesImplemented is true, a mesh STA may switch from the operating channel to a channel in a different operating class.

11.8.8.5 HT-greenfield transmissions in operating classes that include a behavior limit of DFS_50_100_Behavior

The requirements described in this subclause apply only when an HT STA is operating in an operating class for which the behavior limits set listed in Annex E includes the value DFS_50_100_Behavior; i.e., the operating class is subject to DFS with 50–100 μs radar pulses.

A non-HT OBSS scan operation is a passive or active scan of the primary channel and of the secondary channel if the STA conducting the scan is in a 20/40 MHz BSS that the STA currently uses or intends to use. During a non-HT OBSS scan operation, the channel scan duration shall be a minimum of dot11OBSSScanPassiveTotalPerChannel TUs when scanning passively and a minimum of dot11OBSSScanActiveTotalPerChannel TUs when scanning actively.

Before an HT STA starts a BSS with the OBSS Non-HT STAs Present field of the HT Operation element equal to 0, the HT STA shall perform a non-HT OBSS scan in order to search for any existing non-HT OBSSs.

When an HT STA detects that there are one or more non-HT OBSSs, and if the HT STA starts a BSS on that channel, then the HT STA shall set to 1 the OBSS Non-HT STAs Present field of the HT Operation element it transmits; otherwise, the HT STA may set to 0 the OBSS Non-HT STAs Present field of the HT Operation element it transmits.

NOTE 1—Detection of a non-HT OBSS can be achieved by the reception of a Beacon or Probe Response frame that does not contain an HT Capabilities element or HT Operation element.

An HT AP shall not transmit a PPDU with the FORMAT parameter of the TXVECTOR set to HT_GF if the OBSS Non-HT STAs Present field of the HT Operation element is equal to 1 in the most recently transmitted Management frame that contained that element.

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An HT non-AP STA shall not transmit a PPDU with the FORMAT parameter of the TXVECTOR set to HT_GF if the most recent frame received from its AP containing an HT Operation element has the OBSS Non-HT STAs Present field equal to 1.

NOTE 2—This requirement applies also to PPDUs transmitted on a direct link between two non-AP STAs.

When moving the BSS to a new channel or set of channels and before completing a non-HT OBSS scan of the new channel or set of channels, an HT AP shall set to 1 the OBSS Non-HT STAs Present field of the HT Operation element it transmits. After the HT AP completes one non-HT OBSS scan of the new channel or set of channels and if the HT AP has detected that there are zero non-HT OBSSs, then the HT AP may set to 0 the OBSS Non-HT STAs Present field of the HT Operation element it transmits.

11.8.8.6 Selecting and advertising a new channel in a DMG BSS

The decision to switch to a new operating channel in a DMG BSS shall be made only by an AP or PCP. An AP or PCP may make use of the information in received Supported Channel elements and the results of measurements undertaken by the AP or PCP and other STAs in the BSS to assist the selection of the new channel. The algorithm to choose a new channel is beyond the scope of this standard.

An AP or PCP shall inform associated STAs that the AP or PCP is changing to a new channel and shall maintain the association by advertising the switch using the Extended Channel Switch Announcement element in its transmitted DMG Beacon frames, Announce frames, and Information Response frames until the intended channel switch time. The channel switch should be scheduled so that all non-AP and non-PCP STAs in the BSS, including STAs in power save mode, have the opportunity to receive at least one Extended Channel Switch Announcement element before the switch. A STA may ignore the Channel Switch Mode field and either cease transmissions or attempt new transmissions in the operating channel until the channel change occurs.

A STA that receives an Extended Channel Switch Announcement element may choose not to perform the specified switch, but to take alternative action. For example, it may choose to move to a different BSS. A non-AP and non-PCP STA in an infrastructure BSS or PBSS shall not transmit the Extended Channel Switch Announcement element.

11.8.9 Channel Switch Announcement element operation

If a non-DMG STA in a BSS that is not an IBSS receives a Channel Switch Mode field that has the value 1, it shall not transmit any more frames on the channel until the scheduled channel switch occurs. An IBSS STA may treat a Channel Switch Mode field equal to 1 as advisory. A Channel Switch Mode equal to 0 does not impose any requirement on the STA that receives the Channel Switch Announcement frame.

11.8.10 Future Channel Guidance operation

This subclause defines a mechanism to create, communicate and act on the Future Channel Guidance element.

When dot11FutureChannelGuidanceActivated is true, a STA shall follow these procedures for future channel guidance operation.

A STA transmitting Beacon frames transmits the Future Channel Guidance element in (Re)Association Response frames and optionally in Beacon frames.

In some bands, the channel clearing time will be much less than one second for all STAs, and future channel guidance permits all STAs know what channels will be used if the current channels are cleared.

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In some bands, Beacon frames are an enabling signal, and some STAs are not allowed to transmit in the band before receiving an enabling signal. When Beacon frame reception stops, some STAs are no longer enabled to transmit in the band. In these bands, when Beacon frame reception stops, it is an implicit message to switch from current channels to other channels according to prior future channel guidance.

Future channel guidance indicates future channels that the Beaconing STA switches to while maintaining associations and mesh peering relationships (see 11.8.8.2, 11.8.8.3, 11.8.8.4.2, 11.8.8.6, 11.9.3.2, 11.9.3.3, and 11.9.3.4).

A STA receiving the Future Channel Guidance element shall retain the information until it receives a different Future Channel Guidance element from the same STA, it receives a Channel Switch Announcement element or a Channel Switch Announcement frame from the same STA, or it chooses alternative action. For example, it may choose to move to a different BSS.

11.9 Extended channel switching (ECS)

11.9.1 General

This subclause describes ECS procedures that change the BSS operating channel frequency and bandwidth. When the STA's dot11ExtendedChannelSwitchActivated value is true, the enabling STAs (see 11.11), APs, DFS owners, and mesh STAs may construct and transmit frames that contain Extended Channel Switch Announcement elements.

A STA shall use the ECS procedures defined in this subclause if dot11ExtendedChannelSwitchActivated is true. To indicate that it can perform ECS procedures, a STA shall set dot11ExtendedChannelSwitchActivated, dot11MultiDomainCapabilityActivated and dot11OperatingClassesRequired to true and shall set to 1 the Extended Channel Switching field in the Extended Capabilities elements it transmits. When dot11ExtendedChannelSwitchActivated is false, the STA shall not use ECS procedures. When an AP is switching to a different channel and one or more of its associated STAs do not support extended channel switching capability, then both the Extended Channel Switch Announcement and the Channel Switch Announcement elements and frames may be used.

If dot11ExtendedChannelSwitchActivated and dot11LCIDSERequired are true, frames containing Channel Switch Announcement elements shall not be transmitted.

An enabling STA may send frames containing Extended Channel Switch Announcement elements to dependent STAs (see 11.11.5). If dot11DSERequired is true, a STA shall perform ECS procedures to switch at the time indicated by the channel switch count, or the STA shall change its enablement state for the enabling STA to unenabled.

The Address1 field of an Extended Channel Switch Announcement frame shall be set to the broadcast address.

11.9.2 Advertising supported operating classes

When dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true, the Current Operating Class field in the Supported Operating Classes element shall indicate the operating class in use for transmission and reception. The Operating Classes field shall list all operating classes with which the STA is capable of operating for the country that is specified in the Country element (9.4.2.8).

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11.9.3 Selecting and advertising a new channel and/or operating class

11.9.3.1 General

An attempt may be made to move a BSS to a new operating channel and/or new operating class using extended channel switching. An objective during this process is to minimize disruption to the BSS. It is possible, however, that an extended channel switch is not successful in moving all STAs to the new channel and/or operating class.

11.9.3.2 Selecting and advertising a new channel in an infrastructure BSS

When an AP with dot11DSERequired true receives frames containing Extended Channel Switch Announcement elements from the enabling STA, it shall advertise an extended channel switch with the same channel switch mode, new operating class, new channel number, and channel switch count as received in the Extended Channel Switch Announcement elements.

The decision to switch to a new operating channel and/or operating class in an infrastructure BSS is made by the AP when dot11DSERequired is false. An AP may make use of the information in the Supported Channels element, Supported Operating Classes element, and the results of measurements undertaken by the AP and other STAs in the BSS to assist the selection of the new channel and/or operating class. A method to make the decision and to select a new channel is defined in 11.8.8.2.

When an AP is switching to a different operating class and dot11ExtendedChannelSwitchActivated is true, then the AP shall use the Extended Channel Switch Announcement element and frame. In addition, the AP may also send Channel Switch Announcement elements and frames when the requirements signified by the new operating class are met by all associated STAs.

When an AP is switching to a new channel within the same operating class and dot11ExtendedChannelSwitchActivated is true, then the AP shall send the Extended Channel Switch Announcement element and frame, or both the Extended Channel Switch Announcement and the Channel Switch Announcement elements and frames. If dot11ExtendedChannelSwitchActivated is false, the AP shall send the Channel Switch Announcement element and frame.

When dot11ExtendedChannelSwitchActivated is true, an AP shall inform associated STAs that the AP is moving to a new channel and/or operating class and maintain the association by advertising the switch using Extended Channel Switch Announcement elements in any transmitted Beacon frames, Probe Response frames, and Extended Channel Switch Announcement frames until the intended channel switch time. The AP may request STAs in the BSS to stop transmissions until the channel switch takes place by setting the Extended Channel Switch Mode field to 1 in the Extended Channel Switch Announcement element. If possible, the channel switch should be scheduled so that all STAs in the BSS, including STAs in power save mode, have the opportunity to receive at least one Extended Channel Switch Announcement element before the switch. The AP may send the Extended Channel Switch Announcement frame without performing a backoff, after determining the WM is idle for one PIFS (see 10.3.2.3). When both the Extended Channel Switch Announcement and the Channel Switch Announcement elements are transmitted in Action frames, they shall be sent in separate frames.

When the AP sets the Channel Switch Count field of an Extended Channel Switch Announcement element to a nonzero value in a Beacon frame, it should include a Max Channel Switch Time element in that Beacon frame.

When the AP includes the Max Channel Switch Time element with the Extended Channel Switch Announcement element in the Beacon frame, the AP shall transmit the first Beacon frame in the new channel no later than the time indicated in the Switch Time field of the Max Channel Switch Time element after the last Beacon frame transmitted in the current channel, unless the AP determines that it is unable to operate on the new channel.

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When the AP sets the Channel Switch Count field of the Extended Channel Switch Announcement element to 0, it shall not include the Max Channel Switch Announcement element into the Beacon frame.

If an Extended Channel Switch Announcement element in a Beacon or Probe Response frame is used to announce a switch to a 40 MHz BSS bandwidth, then a Wide Bandwidth Channel Switch subelement in a Channel Switch Wrapper element may be present in the same frame if the STA sending the frame is extended spectrum management capable.

When a STA with dot11DSERequired equal to false receives an Extended Channel Switch Announcement element, it may choose not to perform the specified switch, but to take alternative action. For example, it might choose to move to a different BSS.

If dot11RSNAOperatingChannelValidationActivated is true and a channel switch is requested while a security handshake is in progress, the handshake should be aborted.

If the STA chooses to perform the specified switch and dot11RSNAOperatingChannelValidationActivated is true and the AP has indicated OCVC capability, after switching to the new channel the STA shall wait a random delay uniformly-distributed in the range between zero and 5000 μs, and then initiate the SA query procedure once any applicable conditions for transmitting on the new channel are met (e.g., channel access procedures, DFS or enablement procedures). This procedure shall be initiated whether or not the switch was based on a protected Management frame that contained the new operating channel information. The STA may pause Data frame transmission and may drop any received Data frames until the SA query procedure has completed successfully for additional protection.

If a STA initiates SA query procedure to validate a channel switch, any existing SA query procedure for channel switch validation shall be abandoned.

A non-AP STA in an infrastructure BSS shall not transmit the Extended Channel Switch Announcement element.

11.9.3.3 Selecting and advertising a new channel in an IBSS

When a DFS owner with dot11DSERequired true receives frames containing Extended Channel Switch Announcement elements from the enabling STA, it shall advertise an extended channel switch with the same channel switch mode, new operating class, new channel number, and channel switch count as received in the Extended Channel Switch Announcement elements.

The DFS owner that advertises a channel switch shall follow the rules defined in 11.8.8.3 with the following extensions:

a) If a DFS owner is switching to a new channel or to the same channel in a different operating class and dot11ExtendedChannelSwitchActivated is true, then the DFS owner shall use the Extended Channel Switch Announcement element and frame. Alternatively, both the Extended Channel Switch Announcement and the Channel Switch Announcement elements and frames may be used when Channel Switch Announcement elements and frames are permitted for operation in the band signified by the new operating class.

b) If a DFS owner is switching to a new channel within the same operating class and dot11ExtendedChannelSwitchActivated is true, then the DFS owner shall send the Extended Channel Switch Announcement element and frame, or both the Extended Channel Switch Announcement and the Channel Switch Announcement elements and frames. If dot11ExtendedChannelSwitchActivated is false, the DFS owner shall send the Channel Switch Announcement element and frame, or both the Extended Channel Switch Announcement and the Channel Switch Announcement elements and frames.

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c) If both the Extended Channel Switch Announcement and the Channel Switch Announcement elements are transmitted in Public Action frames, they shall be sent in separate frames.

The DFS owner may transmit the Extended Channel Switch Announcement frame in an IBSS without performing a backoff, after determining that the WM is idle for one PIFS (see 10.3.2.3).

11.9.3.4 Selecting and advertising a new channel in an MBSS

A mesh STA may make use of the information in the Supported Channels element, Supported Operating Classes element, and the results of measurements undertaken by this mesh STA and other mesh STAs in the MBSS to assist the selection of the new channel and/or operating class.

If dot11ExtendedChannelSwitchActivated is true, the mesh STA that advertises a channel switch shall follow the rules defined in 11.8.8.4 with the following extensions:

a) If a mesh STA is switching to a different operating class, then the mesh STA shall use the Extended Channel Switch Announcement element and frame. Alternatively, both the Extended Channel Switch Announcement and the Channel Switch Announcement elements and frames may be used when Channel Switch Announcement elements and frames are permitted for operation in the band signified by the new operating class.

b) If a mesh STA is switching to a new channel within the same operating class, then the mesh STA shall send the Channel Switch Announcement element and frame, or both the Extended Channel Switch Announcement and the Channel Switch Announcement elements and frames.

c) If both the Extended Channel Switch Announcement and the Channel Switch Announcement elements are transmitted in Public Action frames, they shall be sent in separate frames.

d) The Extended Channel Switch Announcement element shall be included in the Beacon and Probe Response frames until the intended channel switch time.

11.10 Radio measurement procedures

11.10.1 General

This subclause describes the radio measurements and the procedures for requesting and reporting radio measurements between STAs. When a STA implements support for one or more of the procedures described in this subclause, it shall set dot11RadioMeasurementActivated to true. When dot11RadioMeasurementActivated is true, dot11MultiDomainCapabilityImplemented, dot11MultiDomainCapabilityActivated, dot11OperatingClassesImplemented, and dot11OperatingClassesRequired shall be true.

NOTE—A key issue in radio measurement is network operation and management, considering each STA's service load, power state, and operating conditions. Timely measurement reports might be more important than percentage of wireless capacity or STA capacity used by radio measurements. The measurement requester might consider traffic load and application requirements, regulatory requirements, and specific measurement states from every STA in support of wireless network management. There are no typical scenarios that describe IEEE 802.11 operation in all bands. Off-channel measurements are desirable to gather timely information about the channel to which to switch BSS operation, and the noisier the operating environment, the more urgent the need for radio measurements off the serving channel. In any case, the measuring STA might refuse any measurement request.

11.10.2 Measurement on operating and nonoperating channels

Measurements on nonoperating channels might need the measuring STA to interrupt its data services on the operating channel, switch channels, and make measurements. Measurements on the operating channel might not require the STA to interrupt its data services.

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All stations are responsible for maintaining data services and an association or membership with the BSS on the operating channel while performing measurements on nonoperating channels.

A STA shall determine the time between successive nonoperating channel measurements. This time may be a fixed length, or it may be determined by the STA using application-specific (or other) knowledge.

11.10.3 Measurement start time

A Radio Measurement Request frame may contain a single Measurement Request element or a sequence of Measurement Request elements. A STA that accepts the first or only measurement request within a Radio Measurement Request frame shall start the measurement as soon as practical after receiving the request. Subsequent measurement requests in the Radio Measurement Request frame that are accepted shall start as soon as practical after processing the previous request in the frame. Such measurement start times shall be subject to any specified randomization interval.

The radio measurement category permits a randomization interval to be specified for measurement start times. The intent of this is to avoid traffic storms that could arise with synchronized group addressed measurements. Prior to making each measurement in the requested sequence, the STA shall calculate a random delay distributed uniformly in the range 0 to the randomization interval specified in the measurement request. The STA shall not start the measurement until this delay has expired. Randomization interval is specified in units of TUs. A randomization interval field value of 0 in a measurement request indicates that no random delay is to be used.

NOTE—It is important that designers recognize the need for statistical independence of the random number streams between STAs.

A number of repetitions may be specified in the Radio Measurement Request frame. In this case, the measurements in the frame are repeated as detailed further in 11.10.7. Each time a measurement is repeated, the STA shall recalculate the random delay as described above.

When a Measurement Start Time field is present in a measurement report, the measuring STA shall report the value of its TSF timer at the time the measurement started to an accuracy of ± 1 TU.

11.10.4 Measurement duration

The values of Request Measurement Duration and Duration Mandatory in the received measurement request and the dot11RMMaxMeasurementDuration setting in the receiving STA determine if the receiving STA accepts the measurement request and for how long the measurement is performed. dot11RMMaxMeasurementDuration indicates a measurement duration using the following formula:

$$\text{Maximum Measurement Duration in TUs} = 2^{(\text{dot11RMMaxMeasurementDuration} - 4)} \times \text{BeaconInterval}$$

Table 11-8 describes how a STA responds to a measurement request depending on the values of dot11RMMaxMeasurementDuration, Measurement Duration, and Duration Mandatory.

Measurement duration on nonoperating channels is defined by dot11RMNonOperatingChannelMaxMeasurementDuration. If this attribute is 0, the STA does not support RM measurements on nonoperating channels; on receipt of a Radio Measurement Request frame requesting a measurement on nonoperating channels, the STA shall reject the measurement request by returning a Measurement Report element in which the Incapable bit in the Measurement Report Mode field is 1. The interpretation rules defined in Table 11-8 also apply for all nonzero values of dot11RMNonOperatingChannelMaxMeasurementDuration for measurements on nonoperating channels.

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Table 11-8—Measurement Duration

dot11RMMaxMeasurementDuration	Measurement Duration in the Measurement Request	Duration Mandatory	Notes
0	Any value	1	The STA shall perform measurements for the requested measurement duration.
0	Any value	0	The STA may perform measurements for a duration shorter than the requested measurement duration.
Nonzero	Any value	0	The STA shall perform measurements for a maximum duration that is equal to the minimum of the requested measurement duration and the dot11RMMaxMeasurementDuration.
Nonzero	Requested measurement duration > Maximum Measurement Duration in TUs	1	The STA shall reject the measurement request with the Measurement Report Mode set to "refused."
Nonzero	Requested measurement duration ≤ Maximum Measurement Duration in TUs	1	The STA shall perform the measurement for the requested duration.

NOTE—Measurement duration on nonoperating channels is subject to further limitations due to maximum off-operating channel time.

If the Duration Mandatory bit is 1 in the Measurement Request mode field of a measurement request, the requested STA, if it accepts the request, shall perform the measurement over the Measurement Duration specified in the request. If the STA is unable to commit to making the measurement over the requested duration, it shall refuse the request by sending a measurement report in which the refused bit in the Measurement Report Mode field is set to 1. The measurement duration in the measurement report is equal to the requested measurement duration.

If the Duration Mandatory bit is 0 in the Measurement Request mode field of a measurement request, the requested STA, if it accepts the request, shall attempt a measurement using the requested duration as a maximum measurement duration, and may report results with an actual measurement duration less than the requested duration. The duration over which the measurement was made will be included in the measurement duration field of the measurement report.

Each separate measurement within the Radio Measurement Request frame shall be performed over a continuous measurement time period. In Radio Measurement Request frames the requested Measurement Duration value shall not be set to 0 except when the request frame is a Beacon request in which the Measurement Mode field value is Beacon Table, or is a STA Statistics request, or is a request for triggered autonomous measurements.

11.10.5 Station responsibility for conducting measurements

A radio measurement-capable STA shall decode and interpret each Radio Measurement Request frame that it receives and shall assess the contents against its capabilities and the impact on its own performance. A measurement request may be refused by the receiving STA by sending a Radio Measurement Report frame in which the refused bit in the Measurement Report Mode field is set to 1. The reasons for refusing a

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measurement request are outside the scope of this standard but may include reduced quality of service, unacceptable power consumption, measurement scheduling conflicts, or other significant factors.

In assessing the performance impact of each Measurement Request element, a STA may use application-specific knowledge or other knowledge to limit the time it spends away from the operating channel. In doing so, the STA may either:

— Reject any Measurement Request element in which the Duration Mandatory bit is 1 and that has a mandatory measurement duration exceeding the maximum allowed off-operating channel time, or
— Measure for a reduced duration if the Duration Mandatory bit is 0.

A STA shall cancel all in-process radio measurements and shall delete all pending, unprocessed radio measurement requests upon receipt of a Disassociation frame or upon (re)association with a BSSID different from its most recent association.

11.10.6 Requesting and reporting of measurements

A STA may perform radio measurements on one or more channels itself or a STA may request STAs in the same BSS to perform measurements on its behalf.

A STA advertises its radio measurement capability using the RM Enabled Capabilities element. If a STA advertises that it is capable of a measurement, it shall not reject a request for the corresponding measurement by sending a Radio Measurement Report frame in which the Incapable bit in the Measurement Report Mode field is set to 1, except as specified in 11.10.9.7. Measurement requests for radio measurements that the STA has advertised it is not capable of shall be rejected, and the corresponding report shall have the Incapable bit in the Measurement Report Mode field set to 1.

When requesting other STAs to measure one or more channels, a STA shall use a Radio Measurement Request frame containing one or more Measurement Request elements. The measurement request may be sent to an individual or group destination address. The permitted measurement requests are shown in Table 11-9.

Table 11-9—Allowed measurement requests

Service set	Source of request	Destination of request	Receiver address of Radio Measurement Request frame
Infrastructure BSS	AP	Non-AP STA	Individual or group
	Non-AP STA	AP	Individual only
	Non-AP STA	Non-AP STA	Individual only for Direct Link within a BSS served by QoS AP, otherwise not allowed
IBSS	Non-AP STA	Non-AP STA	Individual or group
PBSS	PCP	STA	Individual or group
	STA	PCP	Individual only
	STA	STA	None

The source and destination of a measurement request shall both be a member of the same infrastructure BSS, a member of the same PBSS, or a member of the same IBSS. Measurement requests with an individual Receiver Address shall be sent only to STAs that have indicated radio measurement capability.

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The set of requested measurements received in the most recently received Radio Measurement Request frame of highest precedence is active. The precedence order for measurement requests shall be as follows (highest precedence first):

— Measurement requests received in individually addressed Radio Measurement Request frames
— Measurement requests received in multicast-group addressed Radio Measurement Request frames
— Measurement requests received in broadcast Radio Measurement Request frames

The Measurement Request elements shall be processed in sequence by default, with certain Measurement Request elements processed in parallel according to the parallel bit field setting: see 9.4.2.20. A STA shall accept a measurement request with the parallel bit field enabled if dot11RMParallelMeasurementsActivated is true; otherwise, the STA shall reject the Measurement Request by returning a Measurement Report with the Incapable bit in the Measurement Report Mode field set to 1.

If dot11RMParallelMeasurementsActivated is true and if measurement resources are available, the STA processes each element by setting up and making the specified measurement. If measurement resources are not available to perform the requested parallel measurements, the STA shall return a Measurement Report with the Refused bit in the Measurement Report Mode field set to 1.

The Measurement Request elements within a Radio Measurement Request frame may specify multiple measurement types across multiple channels.

A STA may receive another Radio Measurement Request frame while the measurements requested in a previous Radio Measurement Request frame are pending or in progress. If this request is accepted, the set of measurement requests in the new frame supersedes any previous requests received in a Radio Measurement Request frame of the same or lower precedence. The measuring STA shall report the results of any completed measurements and terminate any pending or in-progress measurements. Results from a terminated in-progress measurement may be valid and reported if Duration Mandatory was not equal to 1 in the corresponding request. It is permissible for the superseding Radio Measurement Request frame to contain no new measurement requests. This has the effect of canceling all pending or in-progress measurements of the same or lower priority. If a station receives a Radio Measurement Request frame with lower precedence than the currently active Radio Measurement Request frame, the station shall discard the measurement requests in the new Radio Measurement Request frame. Measurement Request elements that have the Enable bit equal to 1 shall be processed in all received Radio Measurement Request frames regardless of these precedence rules.

If a STA receives a Spectrum Measurement Request frame with Measurement Type field equal to 0 (Basic request), this shall take priority over any pending or in-progress radio measurements.

A STA that issues a radio measurement request to another STA to perform a measurement on the operating channel may continue to transmit MPDUs and MMPDUs to that STA while the measurement is being processed.

A STA that issues a radio measurement request to another STA to perform a measurement on a nonoperating channel is not required to take any special action to suspend traffic to that STA. All stations shall maintain state information such that data services and association or membership with the BSS continue when returning from a nonoperating channel measurement.

A single Measurement Request element may generate a large quantity of measurement report data. The measurement report data may be reported using multiple measurement report elements in multiple measurement report frames. The result of each measurement requested in a Measurement Request element shall be reported in one or more Measurement Report elements of type corresponding to the request. Each Measurement Report element returned shall have the same Measurement Token as in the corresponding Measurement Request element, and the same Actual Measurement Start Time field, if present, as in the first

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returned Measurement Report element. The results of each measurement should be returned without undue delay to the requesting STA.

Measurement Report elements shall be returned to the requesting STA in one or more Radio Measurement Report frames. Each Radio Measurement Report frame shall contain the same Dialog Token field value as the corresponding Radio Measurement Request frame, and the same Actual Measurement Start Time field, if present, as in the first returned Measurement Report element.

When a STA is permanently unable to make a requested measurement, the STA shall respond to such a measurement request received within an individually addressed Radio Measurement Request frame with a measurement report indicating that it is incapable of completing the measurement request. A STA shall not respond to requests received in group addressed frames in this manner. Examples of when a response of incapable is appropriate are

— The requested measurement type is not supported.
— The measuring STA cannot support requested parallel measurements due to the requests relating to different channels.

A STA that receives a response with an incapable indication shall not make the same request to the responding STA during the lifetime of the current association, or IBSS membership. This is logically the same as the responding STA using the Enable and Request bits in a measurement request to indicate that it does not accept measurement requests of a certain type. A STA that has indicated an incapable response to a requesting STA may discard further requests of the same type from that STA without responding.

A STA may refuse to make any requested measurement. A STA refusing a measurement request within an individually addressed Radio Measurement Request frame shall respond with a measurement report indicating that it is refusing the measurement request. A STA shall not respond to measurement requests received in group addressed Radio Measurement Request frames in this manner.

By default, a STA may send a radio measurement request of any defined measurement type. A STA that receives a Measurement Request element with the Enable bit equal to 1 and the Request bit equal to 0 shall not issue a measurement request of the type specified in the request to the STA from which the element was received.

Since measurements on nonoperating channels interrupt normal operation on the operating channel, the requesting STA should consider each STA's service load, power state, and operating conditions. Since measurements on the operating channel execute concurrently with normal traffic processing, operating channel measurements can be requested more frequently and for longer durations.

11.10.7 Repeated Measurement Request frames

Radio Measurement Request frames contain a field specifying the number of repetitions for the Radio Measurement Request frame.

If the Radio Measurement Request frame includes a nonzero value for the Number of Repetitions and dot11RMRepeatedMeasurementsActivated is false, the STA shall reject the measurement request by returning a Measurement Report with the Incapable bit in the Measurement Report Mode field set to 1.

If the Radio Measurement Request frame includes a nonzero value for the Number of Repetitions and dot11RMRepeatedMeasurementsActivated is true, the STA shall iterate (repeat) the processing of all of the Measurement Request elements in the frame as specified by the value in the Number of Repetitions field. A value of 0 in the Number of Repetitions field indicates Measurement Request elements are executed once without repetition; a value of 1 in the Number of Repetitions field indicates Measurement Request elements are executed twice, one initial execution and one repetition; and so on. When completing the initial processing of

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the last Measurement Request element in the frame, the STA shall begin processing of the first Measurement Request element in the frame to repeat the frame until the number of iterations reaches the value in the Number of Repetitions field. Measurement Request elements with the Enable bit equal to 1 shall be processed once regardless of the value in the Number of Repetitions in the measurement request.

Each repeated measurement result shall include the same Measurement Token value as in the Measurement Token field of the corresponding Measurement request element and the same Dialog Token field as in the Dialog Token field of the corresponding Radio Measurement Request frame.

Measurement results shall be reported for each repetition of a repeated measurement request subject to any conditional reporting requirement.

STAs responding with incapable or refused indications to measurement requests within a Radio Measurement Request frame with a nonzero value for Number of Repetitions shall respond only once.

11.10.8 Triggered autonomous reporting

Autonomous reporting is defined for spectrum management measurements supporting DFS; see 11.8.7. It allows a STA to report the results of measurements to a peer STA for which there was no explicit measurement request. In this case, the transmission of autonomous reports shall be entirely the decision of the STA at which such reporting has been enabled. An example of this use would be to report a change in conditions at the STA observed as a result of background measurement, e.g., the presence of a radar signal.

In radio measurement, triggered autonomous reporting shall be subject to trigger conditions set by the enabling STA that determine when measurement reports are issued. Triggered autonomous reporting provides a method for conditional reporting during continuous background measurements. An example of the use of triggered autonomous measurement is for reporting problem conditions in continuous, noninvasive statistical monitoring.

Triggered autonomous reporting is defined for the Transmit Stream/Category Measurement measurement type; see 11.10.9.8. When dot11MulticastDiagnosticsActivated is true, triggered autonomous reporting is used for Multicast Diagnostics reports (11.10.19). When dot11TriggerSTAStatisticsActivated is true, triggered autonomous reporting is used for STA Statistics reports (11.10.9.5).

If dot11RMTriggeredTransmitStreamCategoryMeasurementActivated is true, a STA indicates that it wishes to accept triggered autonomous reports by sending a Measurement Request element with the Enable and Report bits set to 1; see 9.4.2.20. The type of measurement is indicated in the Measurement Type field. Trigger conditions that determine when measurement reports are to be generated shall be specified in the Measurement Request field. A Measurement Request element that is being used to control triggered autonomous reporting shall be sent within a Radio Measurement Request frame. Measurement Request elements being used to request measurements may also appear in the same Radio Measurement Request frame. The Radio Measurement Request frame may be sent to a group receiver address to enable triggered autonomous reports at more than one STA.

A STA shall not send autonomous reports for radio measurement types having triggered autonomous reporting enabled without a requested trigger condition having been met.

If a request to enable triggered autonomous reporting is sent to an individual address and the recipient STA does not support measurements of the type indicated or the recipient STA has dot11RMTriggeredTransmitStreamCategoryMeasurementActivated equal to false, a Measurement Report element shall be returned to the requesting STA with the Incapable bit set to 1. A STA may also refuse to enable triggered autonomous reporting. In this case a Measurement Report element shall be returned to the requesting STA with the refused bit set to 1. Such responses shall not be issued if the request to enable triggered autonomous reporting was sent to a group address.

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A STA receiving a request to enable triggered autonomous reporting from another STA may send reports of the appropriate type, addressed to the individual address of the STA that sent the enable request. Autonomous reports shall be sent only to the individual addresses of STAs from which a valid enable request has been received and shall be issued only when a requested trigger condition has been met. The Measurement Token in each Measurement Report element and the Dialog Token field in the Radio Measurement Report frame shall both be set to 0 in a triggered autonomous report.

A STA may update the trigger conditions set for triggered autonomous reports by issuing a new Measurement Request element with the Enable and Report bits both set to 1, the Measurement Type field set to the appropriate type and the Measurement Request field indicating the new trigger conditions. A STA disables all triggered autonomous measurement reports by sending a Measurement Request element with the Enable bit set to 1 and the Report bit set to 0; see 9.4.2.20.

A STA in an infrastructure BSS or PBSS shall cease all triggered autonomous reporting if it disassociates, or reassociates to a different BSS (reassociation to the same BSS shall not affect triggered reporting). An IBSS STA shall cease all triggered autonomous reporting if it leaves the BSS.

Triggered autonomous reporting and requested measurements are independent. A STA may request measurements from another STA even if it has enabled triggered autonomous reporting from that STA. All Measurement Request elements received in Radio Measurement Request frames that have the Enable bit equal to 1 shall be processed without regard for the measurement precedence rules for requested measurements in 11.10.6.

A number of triggered measurements may run concurrently at a non-AP STA. The number of simultaneous triggered measurements supported is outside the scope of the standard. Each triggered measurement is logically separate; reporting conditions such as Trigger Timeout periods apply only to the measurement for which they are established.

11.10.9 Specific measurement usage

11.10.9.1 Beacon report

If a STA accepts a Beacon request it shall respond with a Radio Measurement Report frame containing Beacon reports for all observed BSSs matching the BSSID and SSID in the Beacon request, at the level of detail requested in the Reporting Detail. If the Reporting Detail is 1 and the optional Request subelement is included in the Beacon request, the corresponding Beacon report shall include the list of elements listed in the Request subelement. The RCPI in the Beacon report indicates the power level of the received Beacon, Measurement Pilot, or Probe Response frame. For repeated measurements (when the Radio Measurement Request frame contains a nonzero value for the Number of Repetitions field), the transmission of the Beacon report may be conditional on the measured RCPI or RSNI value. If the Radio Measurement Request frame contains a 0 value for the Number of Repetitions field, the Beacon Reporting subelement shall not be included in the Beacon request. If the Radio Measurement Request frame contains a nonzero value for the Number of Repetitions field, and if both dot11RMBeaconMeasurementReportingConditionsActivated and dot11RMRepeatedMeasurementsActivated are true, and if a Beacon Reporting subelement is included in a Beacon request, the STA shall respond with a Beacon report if the indicated Beacon reporting condition is true. Otherwise, the STA shall not respond with a Beacon report. Table 9-105 lists the reporting conditions that are based on the measured RCPI or RSNI levels.

If the requested Beacon report includes the Supported Operating Classes element, then the channel number, operating class, and/or reported frame information for that measurement may be included in the beacon report; otherwise these fields shall be set to 255 in the beacon report. The STA shall use the Reporting Detail specified in the measurement request to determine the data to be included in the measurement report. If the STA has no beacon information available then the STA may either refuse the request or send an empty Beacon report.

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If dot11RMBeaconPassiveMeasurementActivated is true and the Measurement Mode in the measurement request is Passive, the measuring STA shall perform the following procedure (or an equivalent procedure) on the requested channel:

— Set a measurement duration timer.
— At the end of the measurement duration, process all received Beacons or Probe Response frames with the requested SSID and BSSID to compile the measurement report. The STA shall use the Reporting Detail specified in the measurement request to determine the data to be included in the measurement report. If no Beacon or Probe Response frames with the requested SSID and BSSID were received in the measurement duration, then process all Measurement Pilot frames with the requested BSSID to compile the measurement report. Otherwise, compile an empty Beacon report.

If dot11RMBeaconPassiveMeasurementActivated is false and the Measurement Mode in the measurement request is Passive, the measuring STA shall reject the measurement request by returning a Beacon report with the Incapable bit in the Measurement Report Mode field set to 1.

If dot11RMBeaconActiveMeasurementActivated is true and the Measurement Mode in the measurement request is Active, the measuring STA shall perform the following procedure (or an equivalent procedure) on the requested channel:

— If the channel is not the operating channel, wait for dot11RMMeasurementNavSync, or until a PHY-RXSTART.indication primitive has been received.
— Using the basic access protocol in 10.3.4.2, send a Probe Request frame to the broadcast destination address (DA). The BSSID field in the Probe Request frame shall be set to the BSSID field in the measurement request. The SSID element in the Probe Request frame shall be set to the SSID element in the measurement request.
— Set a measurement duration timer.
— At the end of the measurement duration, process all received Probe Response and Beacon frames with the requested SSID and BSSID to compile the measurement report. The STA shall use the Reporting Detail specified in the measurement request to determine the data to be included in the measurement report. If no Beacons or Probe Response frames were received in the measurement duration and Measurement Pilot frames with the requested BSSID were received in the measurement duration, then process all these Measurement Pilot frames to compile the measurement report. Otherwise, compile an empty Beacon report.

If dot11RMBeaconActiveMeasurementActivated is false and the Measurement Mode in the measurement request is Active, the measuring STA shall reject the measurement request by returning a Beacon report with the Incapable bit set in the Measurement Report Mode field.

When more than one Beacon or Probe Response from a BSS is received in the measurement duration, the contents of the Beacon report shall be based on the latest received. If only Measurement Pilot frames were received in the measurement duration, the contents of the Beacon report shall be based on the latest Measurement Pilot frame received.

If the BSSID field in the Measurement Request contains a wildcard BSSID, all observed BSSs with the requested SSID shall be reported in a separate Beacon report for each BSSID. If the SSID subelement is not included in the Beacon request, all observed BSSs shall be reported in a separate Beacon report for each BSSID. In active mode, Probe Response frames shall be evaluated regardless of whether the Probe Response frame was triggered by the measuring STA's Probe Request.

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On accepting an active or passive mode Beacon request, a STA shall conduct measurements as follows:

- If the Channel Number is 0 and the Operating Class identifies the location of the primary channel, then a STA shall conduct iterative measurements on all supported channels in the specified Operating Class where the measurement is permitted on the channel and the channel is valid for the current regulatory domain.
- If the Channel Number is 0 and if the Operating Class encompasses a primary channel but does not identify the location of the primary channel, then a STA shall conduct iterative measurements on all primary channel positions within all requested and supported channels where the measurement is permitted on the channel and the channel is valid for the current regulatory domain.
- If the Channel Number is 255, the Operating Class identifies the location of the primary channel, and the Beacon request includes AP Channel Report subelements, a STA shall conduct iterative measurements on all supported channels listed in the AP Channel Report subelements that are valid for the current regulatory domain. If there is no AP Channel Report subelement included in the Beacon request, a STA shall conduct iterative measurements on all supported channels listed in the latest AP Channel Report received from the serving AP that are valid for the current regulatory domain. If there are no AP Channel Report subelements included in the Beacon request, and no AP Channel Report included in last received AP Beacon frame, the STA shall reject the Beacon request.
- If the Channel Number is 255, the Operating Class encompasses a primary channel but does not identify the location of the primary channel, and the Beacon request includes AP Channel Report subelements, then a STA shall conduct iterative measurements on all primary channel positions within all requested (in the AP Channel Report) and supported channels that are valid for the current regulatory domain. If there are no AP Channel Report subelements included in the Beacon request, the STA shall reject the Beacon request.
- If the Channel Number is a value other than 0 or 255, a STA shall conduct iterative measurements on the requested channel, where the measurement is permitted on the channel and the channel is valid for the current regulatory domain.

Except when the Measurement Mode field is equal to Beacon Table, measurements shall be made using the specified Measurement Duration with the time between each consecutive measurement as defined in 11.10.2. Iterative measurements shall cease when all channels have been measured. While the STA is processing a Beacon request for iterative channel measurements, the STA shall not begin processing the next measurement request in the Radio Measurement Request frame.

If dot11RMBeaconTableMeasurementActivated is true and the Measurement Mode in the measurement request is Beacon Table, the measuring STA shall return a Beacon report containing the current contents of any stored beacon information for any supported channel with the requested SSID and BSSID without performing additional measurements. The receiving STA shall ignore the channel and measurement duration specified in the Beacon request when the Measurement Mode field contains Beacon Table. The beacon information accumulated may be the result of any operation that caused the STA to acquire these results. If the stored beacon information is based on a measurement made by the reporting STA, and if the actual measurement start time, measurement duration, and Parent TSF are available for this measurement, then the beacon report shall include the actual measurement start time, measurement duration, and Parent TSF; otherwise the actual measurement start time, measurement duration, and Parent TSF shall be set to 0. The RCPI and RSNI for that stored beacon measurement may be included in the beacon report; otherwise the beacon report shall indicate that RCPI and RSNI measurements are not available.

If dot11RMBeaconTableMeasurementActivated is false and the Measurement Mode in the measurement request is Beacon Table, the measuring STA shall reject the measurement request by returning a Beacon report with the Incapable bit set in the Measurement Report Mode field.

For repeated measurements, the Beacon request may include a Beacon Reporting subelement that determines when the measuring STA is to send a Beacon report for a measured Beacon, Measurement Pilot, or Probe

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Response frame with the requested SSID and BSSID. When the requested Reporting Condition value is nonzero, and dot11RMBeaconMeasurementReportingConditionsActivated is true, the STA shall create and transmit a Beacon report for that measured frame if the condition indicated in Table 9-105 is true. Otherwise, the STA shall not transmit a Beacon report for that measured frame. If multiple Beacon, Measurement Pilot, or Probe Response frames with the requested specific BSSID are received during the measurement duration, the reporting condition shall be applied only to the latest received Beacon, Measurement Pilot, or Probe Response frame. If multiple Beacon, Measurement Pilot, or Probe Response frames are received during the measurement duration when a wildcard BSSID is requested, the STA shall generate one Beacon report for each BSSID occurring in frames that satisfy the reporting condition; the Beacon report shall be based on the latest received Beacon, Measurement Pilot, or Probe Response frame for that specific BSSID. For reporting conditions 5–10, the serving AP's reference RCPI level and the serving AP's reference RSNI level referred to in Table 9-105 are average values of the RCPI or RSNI of the 16 most recent Beacon frames received from the measuring STA's serving AP. The serving AP's reference RCPI level and the serving AP's reference RSNI level are so averaged to provide a more accurate and stable indication of the signal level from the serving AP. For reporting conditions 5–10, the STA shall use the serving AP's reference RCPI level or reference RSNI level (with offset, if any) to test the measured RCPI or RSNI to determine whether to create and send a Beacon report for this measured Beacon, Measurement Pilot, or Probe Response frame.

The STA shall return a Beacon report with the Incapable bit set in the Measurement Report Mode field in the following cases:

— Reporting Condition in the Beacon request is nonzero and dot11ReportingConditionsActivated is false,

— Reporting Condition in the Beacon request is nonzero and the Number of Repetitions in the Radio Measurement Request frame is 0.

NOTE 1—Reporting conditions described here for repeated Beacon request measurements are distinct from the conditions defined elsewhere for triggered measurements.

A STA that is not extended spectrum management capable shall not include a Wide Bandwidth Channel Switch subelement in a Beacon request or Beacon report. A STA shall not include a Wide Bandwidth Channel Switch subelement in a Beacon request or Beacon report sent to a STA that is not extended spectrum management capable. If the Wide Bandwidth Channel Switch subelement is included in a Beacon request or Beacon report, then the Operating Class shall indicate a 40 MHz channel spacing.

If N (where $N \geq 1$) AP Channel Report subelements containing an Operating Class with an 80+ behavior limit (the 80+ behavior limit is defined in Table D-2, the operating classes that might use this limit are defined in E.1) are included contiguously in a Beacon request, then the N subelements shall be followed by one AP Channel Report subelement containing an Operating Class without an 80+ behavior limit (as defined in Annex E). All N+1 Channel List fields in each of these subelements shall contain the same number L of channel numbers. This sequence of N+1 AP Channel Report subelements indicates a list of L noncontiguous channels comprising N+1 frequency segments, where the lth channel number in the nth Channel List field identifies the channel center frequency of the nth frequency segment.

NOTE 2—To identify the BSS bandwidth, the Beacon request might include a Request subelement listing the element IDs of the HT Operation and VHT Operation elements. The Beacon report would then include the requested elements, which contain fields defining the BSS bandwidth.

When a Beacon request includes a Last Beacon Report Indication Request subelement with the Data field equal to 1, the reporting STA shall include a Last Beacon Report Indication subelement in the Beacon report, and set the Data field of the subelement to 1 when that is the last frame of the sequence of frames generated as a response to a Beacon request. Otherwise the Data field is set to 0.

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11.10.9.2 Frame report

If dot11RMFrameMeasurementActivated is true, and a station accepts a Frame request, it shall respond with a Radio Measurement Report frame containing one or more Measurement Report elements with the Measurement Type field set to Frame. (See 9.4.2.21.8.)

If the MAC Address field included in the Frame request was not set to the broadcast address, the measuring station shall report, in one or more Frame reports, only those Data or Management frames received during the measurement duration with a TA field matching the MAC Address field of the Frame request, if at least one such frame was received. If the MAC address field included in the Frame request was set to the broadcast address, the measuring station shall report all Data or Management frames received during the measurement duration in one or more Frame reports.

If the Frame Request Type of the corresponding Frame request equals 1, then each Frame report contains one Frame Count subelement that contains in turn one or more Frame Report Entries.The measuring station shall count the number of individually addressed Data and Management frames received from one transmitter address during the measurement duration and shall summarize this traffic in a frame report entry.

The reported Average RCPI shall be an average of the RCPI values of frames received and counted in the Frame Report Entry field. If there are up to 32 frames, then the Average RCPI indicates the mean of the RCPI of each of the frames. If there are more than 32 frames, then the Average RCPI indicates an exponentially weighted average, initialized by the mean RCPI of the first 32 frames and exponentially updated by new RCPI values. The averaging is calculated as depicted as follows.

If the number of frames received is less than or equal to 32:

Average RCPI = Sum of RCPI values / Number of frames

For 33 received frames and above:

Average RCPI = (Last Average RCPI × 31 / 32) + (Current frame RCPI / 32)

The Last RCPI shall be the RCPI value of the most recently received frame counted in the Frame Report Entry field. The Antenna ID field contains the identifying number for the antenna(s) or DMG antenna used to receive the most recently received frame included in this Frame Report Entry field as defined in 9.4.2.39. If different antennas are used to receive the frame preamble and the frame body, this antenna ID or DMG antenna ID shall contain the identifying number for the antenna(s) used to receive the frame body.

If dot11RMFrameMeasurementActivated is false, a station shall reject the received Frame request by returning a Frame report in which the Incapable bit in the Measurement Report Mode field is 1.

A STA that is not extended spectrum management capable shall not include a Wide Bandwidth Channel Switch subelement in a Frame request or Frame report. A STA shall not include a Wide Bandwidth Channel Switch subelement in a Frame request or Frame report sent to a STA that is not extended spectrum management capable. If the Wide Bandwidth Channel Switch subelement is included in a Frame request or Frame report, then the Operating Class shall include a 40 MHz channel spacing.

11.10.9.3 Channel load report

If dot11RMChannelLoadMeasurementActivated is true and a station accepts a Channel Load request, it shall respond with a Radio Measurement Report frame containing one Measurement (Channel Load) Report element. The Channel Load field is defined as the percentage of time, linearly scaled with 255 representing 100%, the STA sensed the medium was busy, as indicated by either the virtual carrier sense mechanism or the

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physical carrier sense mechanism over the requested channel width (together referred to as the *CS mechanism*). This percentage is computed using the following formula:

$$\text{Channel Load} = \left\lfloor \frac{\text{channel busy time}}{\text{MeasurementDuration} \times 1024} \times 255 \right\rfloor$$

where channel busy time is defined to be the number of microseconds during which the CS mechanism, as defined in 10.3.2.1, has indicated a channel busy indication for the requested channel width.

If dot11RMChannelLoadMeasurementActivated is false, a station shall reject the received Channel Load request by returning a Channel Load report with the Incapable bit in the Measurement Report Mode field set to 1.

If dot11RMChannelLoadMeasurementActivated is true and if a Channel Load Reporting subelement is included in a Channel Load request, the STA shall respond with a Channel Load report if the indicated channel load reporting condition is true. Otherwise, the STA shall not respond with a Channel Load report.

A STA that is not extended spectrum management capable shall not include a Wide Bandwidth Channel Switch subelement in a Channel Load request or Channel Load report. A STA shall not include a Wide Bandwidth Channel Switch subelement in a Channel Load request or Channel Load report sent to a STA that is not extended spectrum management capable. If the Wide Bandwidth Channel Switch subelement is included in a Channel Load request or a Channel Load report, then the Operating Class shall indicate a 40 MHz channel spacing.

11.10.9.4 Noise Histogram report

If dot11RMNoiseHistogramMeasurementActivated is true and a station accepts a Noise Histogram request, it shall respond with a Radio Measurement Report frame containing one Measurement (Noise Histogram) Report element. The Noise Histogram report shall contain the IPI densities observed in the channel for the IPI levels defined in Table 9-128.

To compute the IPI densities, a STA shall measure the amount of time, in microseconds, during which the IPI is in each IPI range specified in Table 9-128. These IPI measurements shall be taken over the entire associated channel bandwidth, and during the requested measurement duration except for those time intervals during which the NAV is not equal to 0 (when virtual CS mechanism indicates channel busy), or during which frame transmission or reception is occurring. The IPI densities are then computed for each of the nine possible IPI values using:

$$\text{IPI Density} = \text{Integer}\left[\frac{255 \times D_{IPI}}{(1024 \times D_M) - T_{NAV} - T_{TX} - T_{RX}}\right]$$

where

D_{IPI} is the duration receiving at the specified IPI value (μs)
D_M is the measurement duration (TU)
T_{NAV} is the total time that NAV is nonzero during the Measurement Duration (μs)
T_{TX} is the frame transmission time during the Measurement Duration (μs)
T_{RX} is the frame reception time during the Measurement Duration (μs)

The sum of the IPI densities is approximately 255. If either the NAV is nonzero, or if there is frame transmission, or if there is frame reception throughout the entire measurement duration period, no reportable IPI values are measured, and all IPI Densities shall be set to 0 in the Measurement Report element.

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A STA shall include in the Noise Histogram report an average noise power indicator (ANPI) value representing the average noise plus interference power on the measured channel at the antenna connector during the measurement duration. The STA may use Noise Histogram IPI density values to calculate ANPI. The IPI densities in the Noise Histogram report may be used to calculate an average noise power for the channel during the measurement duration. This calculated average IPI power value may be reported as the value for ANPI. Any equivalent method to measure ANPI may also be used. ANPI power is defined in dBm using the same accuracy as defined for RCPI.

ANPI may be calculated in any period and at any time by filtering all PHY IPI values in a MAC filter to exclude IPI values received when NAV is nonzero. These filtered IPI values represent idle channel noise and may be stored in a first-in-first-out (FIFO) buffer to facilitate ANPI calculation over a fixed number of IPI samples. ANPI may be so calculated upon receipt of any frame and may be used with RCPI to calculate RSNI for any received frame. Any equivalent method to measure ANPI may also be used to calculate RSNI for any received frame.

If dot11RMNoiseHistogramMeasurementActivated is false, a station shall reject the received Noise Histogram request by returning a Noise Histogram report with the Incapable bit in the Measurement Report Mode field set to 1.

If dot11RMNoiseHistogramMeasurementActivated is true and if a Noise Histogram Reporting subelement is included in a Noise Histogram request, the STA shall respond with a Noise Histogram report if the indicated noise histogram reporting condition is true. Otherwise the STA shall not respond with a Noise Histogram report.

A STA that is not extended spectrum management capable shall not include a Wide Bandwidth Channel Switch subelement in a Noise Histogram request or Noise Histogram report. A STA shall not include a Wide Bandwidth Channel Switch subelement in a Noise Histogram request or Noise Histogram report sent to a STA that is not extended spectrum management capable. If the Wide Bandwidth Channel Switch subelement is included in a Noise Histogram request or a Noise Histogram report, then the Operating Class shall indicate a 40 MHz channel spacing.

11.10.9.5 STA Statistics report

If dot11RMStatisticsMeasurementActivated is true and a station accepts a STA Statistics request, it shall respond with a Radio Measurement Report frame including one STA Statistics report. If the Requested Measurement Duration value is 0, the STA shall report the current values for the requested Statistics Group Data. If the Requested Measurement Duration value is greater than 0, the STA Statistics report reports the change in the requested Statistics Group Data measured within that nonzero Measurement Duration. The reported change in data value shall be the value of the data at the end of the actual Measurement Duration minus the value of the data at the beginning of the actual Measurement Duration. If a STA accepts a STA Statistics request measurement with nonzero, positive Measurement Duration, the STA shall perform the measurement over the requested Measurement Duration without regard to the Duration Mandatory bit in the Measurement Request Mode field. If a STA cannot measure over the requested Measurement Duration, the STA shall refuse the Statistics request measurement.

If dot11RMStatisticsMeasurementActivated is false, a station shall reject the received STA Statistics request by returning a Statistics Measurement Report with the Incapable bit in the Measurement Report Mode field set to 1.

A STA may request that a STA Statistics report be sent when statistics of interest reach a threshold as defined in the Measurement Request element of the STA Statistics request frame (see 9.4.2.20.9). This is termed a triggered STA Statistics measurement. Implementation of Triggered STA Statistics Reporting is optional for a WNM STA. A STA that implements Triggered STA Statistics Reporting has

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dot11TriggerSTAStatisticsImplemented equal to true. When dot11TriggerSTAStatisticsImplemented is true, dot11WirelessManagementImplemented shall be true.

A triggered STA Statistic measurement shall be requested by setting the Enable and Report bits to 1 within a Measurement Request element with the Measurement Type field set to STA Statistics. The Measurement Request field shall contain a STA Statistics request with the trigger conditions specified in the Triggered Reporting subelement, as defined in 9.4.2.20.9. One or more trigger conditions shall be set with specified thresholds. See 11.10.8. To prevent generation of too many triggered reports, the value of the Trigger Timeout field shall be set to greater or equal to dot11MinTriggerTimeout. If the Trigger Timeout field is less than dot11MinTriggerTimeout, the STA shall reject the measurement request by returning a report where the Measurement Report Mode field is "Incapable."

A STA accepting a triggered STA Statistics measurement shall measure the requested statistics. If a trigger condition occurs, the measuring STA shall send a STA Statistics measurement report to the requesting STA. The measuring STA shall not send further triggered STA Statistics reports for that trigger condition to the requesting STA until the Trigger Timeout period specified in the request frame has expired. The STA Statistics measurement report is defined in 9.4.2.20.9. If the number of MPDUs or MSDUs indicated in the Measurement Count field are transmitted or received without any of the counted statistics meeting the corresponding trigger threshold then the measuring STA shall restart measuring for another measurement count window.

If a STA receives a STA Statistics request from the same STA for which a triggered STA Statistics measurement is in progress, the in-progress triggered measurement shall be terminated.

STA Statistics reported in a triggered STA Statistics report shall be the values accumulated over the number of transmitted or received MSDUs or MPDUs before the trigger condition is met. Measurement duration shall not be specified when requesting a triggered STA statistics measurement and the Measurement Duration field in the corresponding Measurement Request shall be set to 0.

All triggered STA Statistics measurements shall be terminated at a measuring STA by receiving a STA Statistics request with the Enable bit equal to 1 and the Report bit equal to 0. A STA requesting a triggered STA Statistics measurement may update the trigger conditions by sending a STA Statistics request specifying the new trigger conditions.

Once accepted by a measuring STA, a triggered STA Statistics measurement continues to be active until the measurement request is superseded by a STA Statistics request from the requesting STA or the measuring STA disassociates or reassociates.

11.10.9.6 LCI report (Location configuration information report)

If dot11RMLCIMeasurementActivated is true, a STA that receives an LCI request for location information that is not available shall respond with a Radio Measurement Report frame including a Radio Measurement Report element with the Refused bit set to 1. If dot11RMLCIMeasurementActivated is true and a STA accepts an LCI request that does not include an azimuth request, it shall respond with a Radio Measurement Report frame including one LCI subelement (LCI report). If both dot11RMLCIMeasurementActivated and dot11RMLCIAzimuthActivated are true, and the STA accepts an LCI request that includes an azimuth request, it shall respond with a Radio Measurement Report frame that includes one LCI subelement (LCI report) and the requested Azimuth Report, if available. If dot11RMLCIAzimuthActivated is false, a STA that receives an LCI request that includes an azimuth request shall respond with a Radio Measurement Report frame including an Radio Measurement Report element with the Incapable bit set to 1.

The Datum value shall be 1 (World Geodetic System 1984), unless another datum is required for operation in the regulatory domain.

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If the Altitude Type is 2 (Floors of Altitude), the value reported shall be as required for operation in the regulatory domain.

An LCI request shall indicate a location request for the requesting STA, the reporting STA, or a third STA with the MAC address specified in the Target MAC Address subelement, by setting the LCI request Location Subject field to indicate a Local, a Remote, or a third-party request, respectively. Local LCI request is used by the requesting STA to obtain its own location by asking "Where am I?" Remote LCI request is used by requesting STA to obtain location of reporting STA by asking "Where are you?" Third-party location request is used by requesting STA to obtain location of a STA with the MAC address specified in the Target MAC Address subelement.

The Latitude, Longitude, and Altitude fields of the LCI report shall be reported at their best known resolutions unless otherwise configured.

If the STA receiving an LCI request has no location information about the requested LCI subject's physical location, the STA shall send a LCI subelement indicating an unknown LCI (see 9.4.2.21.10). If the STA receiving an LCI request has no location information about the requested Azimuth, the STA shall omit the Azimuth Report subelement. If the STA receiving an LCI request that contains a Maximum Age subelement has already determined the requested LCI within the indicated maximum age, the STA may respond with its already determined LCI; otherwise, the STA shall update its LCI before the STA responds with its LCI. The method by which the physical location and azimuth information in the LCI report is generated is outside the scope of this standard.

A STA that receives an LCI report that contains a Usage Rules/Policy subelement shall process the LCI information in compliance with the retransmission and retention permissions in the Usage-rules subelement.

NOTE 1—A STA that requested an LCI including an Azimuth Request, and received an LCI report in which the Incapable bit is 1 might alternatively request the LCI with no Azimuth requested.

If dot11RM3rdPartyMeasurementActivated is false, a STA that receives an LCI request that includes an LCI request with the Location Subject field equal to 2 shall respond with a Radio Measurement Report frame including an Radio Measurement Report element with the Incapable bit set to 1.

It is optional for a STA to support an LCI request and an LCI report with the Location Subject field equal to 2. If dot11RM3rdPartyMeasurementActivated is true and a STA supports LCI request and LCI report, the following procedure shall be followed:

— When a non-AP STA requests the geospatial location of a STA with the MAC address specified in the Target MAC Address field, it shall also include its own MAC address in the Originator Requesting STA MAC address field. When an AP receives an LCI request with the Location Subject field value equal to 2, the AP shall generate an LCI request to the STA with the MAC address specified in the Target MAC Address field. If the AP does not have an association with the STA with the MAC address specified in the Target MAC Address field, the AP shall reject the received LCI request by returning an LCI report where the Incapable bit is set in the MeasurementReport Mode field. The AP shall copy the Originator Requesting STA MAC address and Target MAC Address fields into the request from the received LCI request.

— When a STA receives an LCI request with the Location Subject field value equal to 2, the STA may generate an LCI report if the MAC address in the Target MAC Address field is its own MAC address; it shall not generate an LCI report otherwise. When an LCI report is generated, the reporting STA shall include its MAC address into the Target MAC Address field and the MAC address present in the Originator Requesting STA MAC address field of the corresponding LCI request into the Originator Requesting STA MAC address field. When an AP receives an LCI report with an Originator Requesting STA MAC address field present, the AP shall generate an LCI report to the associated STA with the MAC address specified in the Originator Requesting STA MAC

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address field. The AP shall copy the Originator Requesting STA MAC address and Target MAC Address fields into the LCI report being transmitted to the originating requesting STA.

If dot11RMLCIMeasurementActivated is false, a station shall reject the received LCI request by returning an LCI report with the Incapable bit in the Measurement Report Mode field set to 1.

If dot11RMLCIMeasurementActivated is true and a STA has its own location configured in LCI format excluding an unknown LCI as defined in 9.4.2.20.10, the STA shall set dot11RMLCIConfigured to true.

NOTE 2—It is recommended that User Applications not send location information to other stations without the express permission of the user. User agents acquire permission through a user interface, unless they have prearranged trust relationships with users. Those permissions that are acquired through the user interface and that are preserved beyond the current browsing session (i.e., beyond the time when the BSS connection is terminated) are revocable and receiving stations should respect revoked permissions. Some user applications might have prearranged trust relationships that do not require such user interfaces. For example, while a social networking application might present a user interface when a friend performs a location request, a VOIP telephone might not present any user interface when using location information to perform an E911 function.

11.10.9.7 Measurement pause

A measurement pause is used within a Radio Measurement Request frame to provide a time delay between the processing of two other Measurement Request elements within the sequence of Measurement Request elements in that frame.

If a STA accepts a Measurement Pause request it shall delay processing of the next measurement request in the Radio Measurement Request frame. If the Measurement Pause request is the last Measurement Request element in a repeated Radio Measurement Request frame, the STA shall delay processing the first Measurement Request element in the Radio Measurement Request frame for the next repeat. In each case the delay shall be no less than the Pause Time value specified in the Measurement Pause request.

NOTE—Measurement pause is always supported by a STA implementing radio measurements.

A measurement pause shall not be sent as the only Measurement Request element in a Radio Measurement Request frame. A measurement pause shall not be included as the last Measurement Request element in a Radio Measurement Request frame that has the Number of Repetitions field equal to 0.

A measurement pause cannot be processed in parallel to other measurements. If the Parallel bit is 1 in the Measurement Request element immediately prior to a measurement pause, an incapable response shall be returned even if dot11RMParallelMeasurementsActivated is true.

There is no measurement report associated with a Measurement Pause request.

11.10.9.8 Transmit Stream/Category Measurement report

The Transmit Stream/Category Measurement applies to TIDs for Traffic Streams associated with TSPECs and also to TIDs for Traffic Categories for QoS traffic without TSPECs.

If dot11RMTransmitStreamCategoryMeasurementActivated is true and has no resource constraint that prevents it from being able to make the requested measurement, a QoS STA receiving a Transmit Stream/Category Measurement request shall respond with a Radio Measurement Report frame containing one Measurement (Transmit Stream/Category Measurement) Report element. If the traffic stream (TS) that is corresponding to the Traffic Identifier is deleted, either by a DELTS frame or by disassociation, the STA shall cease sending Radio Measurement Reports.

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If dot11RMTransmitStreamCategoryMeasurementActivated is false, a STA shall reject the received Transmit Stream/Category Measurement request by returning a Transmit Stream/Category Measurement report with the Incapable bit in the Measurement Report Mode field set to 1.

The transmit stream/category measurement shall be made on traffic that is transmitted from the measuring QoS STA to the peer QoS STA and TID indicated in the request. The Peer STA Address may be the MAC address of the QoS STA from which the Measurement Request was sent, the MAC address of another QoS STA within the BSS, or the broadcast address. A broadcast address shall be used only with a TID corresponding to a TC. In the case of a broadcast address, measurement shall be made on all traffic for the specified TC. Depending on policy, a QoS AP may disallow transmit stream/category measurement requests for traffic to other QoS STAs in the BSS. In this case the QoS AP shall respond with a matching Radio Measurement Report frame with the Incapable subfield of the Measurement Report Mode field set to 1.

If, during the course of a Transmit Stream/Category Measurement, any counter that is included in the Transmit Stream/Category Measurement report increments to a value of 2^{32}–1, the Transmit Stream/Category Measurement shall terminate, and the Transmit Stream/Category Measurement report shall indicate the shortened, actual measurement duration.

If the measurement request included multiple transmit stream/category measurement requests for multiple TIDs, the corresponding measurement report shall include a transmit stream/category measurement report for each unique TID in the request that has been admitted. If the measurement request is for a TID that has not been admitted yet, a report is generated only after the TID becomes admitted.

The requesting and reporting STAs are QoS STAs. A non-QoS STA receiving a Transmit Stream/Category Measurement request shall reject the request by returning an indication of incapable.

A QoS STA may request that a measuring QoS STA send a transmit stream/category measurement report when the number of TID-specified MSDUs are discarded or delayed reaches a specified threshold. This is termed a triggered transmit stream/category measurement and shall be requested by setting the Enable and Report bits to 1 within a Measurement Request element containing the Transmit Stream/Category Measurement Type. The Measurement Request field shall contain a Transmit Stream/Category Measurement request with the trigger conditions specified in the Triggered Reporting subelement. One or more trigger conditions may be set with specified thresholds. See 9.4.2.20.11.

Depending on policy, a QoS AP might not permit the establishment of triggered transmit stream/category measurement. Such a QoS AP receiving a triggered transmit stream/category measurement request shall give an incapable indication. The number of simultaneous triggered transmit stream/category measurements supported at a QoS STA is outside the scope of the standard. A STA shall respond to further requests with a refused indication if the number of simultaneous triggered QoS measurements supported by the STA is reached.

If dot11RMTriggeredTransmitStreamCategoryMeasurementActivated is true, a QoS STA shall accept a triggered Transmit Stream/Category Measurement and shall reject it otherwise. A QoS STA accepting a triggered QoS measurement shall measure the requested TC or TS. If a trigger condition occurs, the measuring QoS STA shall send a Transmit Stream/Category Measurement report to the requesting QoS STA. The measuring QoS STA shall not send further triggered QoS reports until the Trigger Timeout period specified in the request has expired or new trigger conditions have been requested. Measurement of transmit stream/category metrics shall continue during the reporting timeout period. Reporting shall resume following the Trigger Timeout period, or immediately following the acceptance of new trigger conditions.

If a QoS STA receives a Transmit Stream/Category Measurement request for a TC, or TS that is already being measured using a triggered transmit stream/category measurement, the triggered traffic stream measurement shall be suspended for the duration of the requested traffic stream measurement. When triggered measurement resumes, the traffic stream metrics shall be reset.

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Traffic stream metrics reported in a triggered transmit stream/category measurement report shall be the values accumulated over the number of successfully and unsuccessfully transmitted MSDUs prior to the trigger event given in the Measurement Count field of the transmit stream/category measurement request that established the trigger condition. It is possible that a consecutive or delay trigger event occurs after acceptance of a triggered transmit stream/category measurement but before the number of MSDUs in Measurement Count has been transmitted. In this case the report shall be the values accumulated since measurement started. The measurement count value appears in the Transmitted MSDU Count field of a triggered transmit stream/category measurement report. Measurement duration shall not be used in triggered QoS measurement, and the Measurement Duration field in both the Measurement Request and any Measurement Report shall be set to 0.

The Measurement Start Time field of a triggered transmit stream/category measurement report shall contain the value of the QoS STA TSF timer at the time the trigger condition occurred to an accuracy of 1 TU.

Once accepted by a measuring QoS STA, a triggered QoS measurement continues to be active until

— The relevant TS is deleted,
— The measuring QoS STA or QoS STA that requested the measurement disassociates or successfully reassociates, or
— The measurement is terminated by the requesting QoS STA.

All triggered QoS measurements shall be terminated at a measuring QoS STA by receiving a triggered transmit stream/category measurement request with the Enable bit equal to 1 and the Report bit equal to 0. A triggered QoS measurement request with no trigger conditions specified in the Trigger Conditions field shall terminate a triggered QoS measurement for the TC or TS specified in the request. A QoS STA requesting a triggered QoS measurement may update the trigger conditions by sending a triggered transmit stream/category measurement request specifying the new trigger conditions.

11.10.9.9 Location Civic report

If dot11RMCivicMeasurementActivated is true and civic location information is not available, the STA shall reject a Location Civic request by returning a Radio Measurement Report frame including a Measurement Report element with the Refused bit set to 1. If dot11RMCivicMeasurementActivated is true and civic location information is available, the STA shall respond with a Radio Measurement Report frame including one Location Civic report.

A Location Civic request shall indicate a location request for the requesting STA, the reporting STA, or a third STA with the MAC address specified in the Target MAC Address field, by setting the Location Civic request Location Subject field to indicate a Local, a Remote, or a third-party request respectively. Local Location Civic request is used by requesting STA to obtain its own location by asking “Where am I?” Remote Location Civic request is used by requesting STA to obtain location of the reporting STA by asking “Where are you?” Third-party Location request is used by requesting STA to obtain location of a STA with the MAC address specified in the Target MAC Address field.

If dot11RMCivicMeasurementActivated is false, a STA that receives the received Location Civic request shall respond with a Location Civic report where the Incapable bit is set in the Measurement Report Mode field.

If dot11RM3rdPartyMeasurementActivated is false, a STA shall reject any LCI request that includes an LCI request with the Location Subject field equal to 2 by returning a Radio Measurement Report frame including an Radio Measurement Report element with the Incapable bit set to 1.

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It is optional for a STA to support a Location Civic request and a Location Civic report with the Location Subject field equal to 2. If dot11RM3rdPartyMeasurementActivated is true and a STA supports Location Civic request and Location Civic report, the following procedure shall be followed:

— When a non-AP STA requests the civic location of a STA with the MAC address specified in the Target MAC Address field, it shall also include its own MAC address in the Originator Requesting STA MAC address field. When an AP receives a Location Civic request with the Location Subject field value equal to 2, the AP shall generate a Location Civic request to the STA with the MAC address specified in the Target MAC Address field. If the AP does not have an association with the STA with the MAC address specified in the Target MAC Address field, the AP shall reject the received Location Civic request by returning a Location Civic report where the Incapable bit is set in the Measurement Report Mode field. The AP shall copy the Originator Requesting STA MAC address and Target MAC Address fields into the request from the received Location Civic request.

— When a STA receives a Location Civic request with the Location Subject field value equal to 2, the STA may generate a Location Civic report if the MAC address in the Target MAC Address field is its own MAC address; it shall not generate a Location Civic report otherwise. When a Location Civic report is generated, the reporting STA shall include its MAC address into the Target MAC Address field and the MAC address present in the Originator Requesting STA MAC address field of the corresponding Location Civic request into the Originator Requesting STA MAC address field. When an AP receives a Location Civic report with an Originator Requesting STA MAC address field present, the AP shall generate a Location Civic report to the associated STA with the MAC address specified in the Originator Requesting STA MAC address field. The AP shall copy the Originator Requesting STA MAC address and Target MAC Address fields into the Location Civic report being transmitted to the originating requesting STA.

When a STA receives a Location Civic request with the subject field equal to 2, but does not support third-party location, it shall respond with a Radio Measurement Report frame including a Radio Measurement Report element with the Incapable bit set to 1.

If dot11RMCivicMeasurementActivated is true and a STA has its own location configured in civic format, excluding an unknown civic location as defined in 9.4.2.21.13, the STA shall set dot11RMCivicConfigured to true.

If dot11RMCivicMeasurementActivated is true and a STA has its own location available in one or more location formats, as defined in Table 9-116, and includes Civic Location Type field value 0, indicating “IETF RFC 4776,” it shall set the Civic Location field to 1 in the Extended Capabilities element.

NOTE—The Location Civic field’s size limit constrains the amount of information that can be carried.

If the Location Civic report contains the Location Reference and Location Shape subelements, the receiving STA may use the information specified in those subelements in combination with the Civic Location field value for additional granularity on the position reported in the Civic Location field.

If the Location Civic report contains the Map Image subelement, the receiving STA’s SME can retrieve the floor plan specified by the Map URL field. The method to retrieve the floor plan specified by the Map URL field is out of scope of this document.

11.10.9.10 Location Identifier report

The Location Identifier report provides the ability for a STA to receive one or more:

— Indirect URI references and forward a subset of those references to an external agent for the purposes of that agent gathering the STA’s location value. The protocol used to query for a location report based on the Public Identifier URI/FQDN provided in the Location Identifier report is indicated by the URI/FQDN Descriptor field.

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— FQDNs, one per location server, that can be used to discover the location server and establish communications with it. The protocol used with the location server is indicated by the URI/FQDN Descriptor field.

If dot11RMIdentifierMeasurementActivated is true and location information is not available, the STA that receives a Location Identifier request shall respond with a Radio Measurement Report frame including a Measurement Report element with the Incapable bit set to 1. If dot11RMIdentifierMeasurementActivated is true and location information is available, the STA shall respond with a Radio Measurement Report frame including one Measurement Report element containing a Location Identifier report that carries one or more Public Identifier URI/FQDN subelements.

A Location Identifier request shall indicate a location request for the requesting STA, the reporting STA, or a third-party STA with the MAC address specified in the Target MAC Address field, by setting the Location Identifier request Location Subject field to indicate a Local, a Remote, or a Third-party request respectively. Local Location Identifier request is used by requesting STA to obtain its own location by asking "Where am I?" Remote Location Civic request is used by requesting STA to obtain location of the reporting STA by asking "Where are you?" Third-party Location request is used by requesting STA to obtain location of a STA with the MAC address specified in the Target MAC Address field.

If dot11RM3rdPartyMeasurementActivated is false, a STA that receives an LCI request that includes an LCI request with the Location Subject field equal to 2 shall respond with a Radio Measurement Report frame including an Radio Measurement Report element with the Incapable bit set to 1.

It is optional for a STA to support a Location Identifier request and a Location Identifier report with the Location Subject field equal to 2. If dot11RM3rdPartyMeasurementActivated is true and a STA supports Location Identifier request and Location Identifier report, the following procedure shall be followed:

— When a non-AP STA requests the location identifier of a STA with the MAC address specified in the Target MAC Address field, it shall also include its own MAC address in the Originator Requesting STA MAC address field. When an AP receives a Location Identifier request with the Location Subject field value equal to 2, the AP shall generate a Location Identifier request to the STA with the MAC address specified in the Target MAC Address field. If the AP does not have an association with the STA with the MAC address specified in the Target MAC Address field, the AP shall reject the received Location Identifier request by returning a Location Identifier report where the Incapable bit is set in the Measurement Report Mode field. The AP shall copy the Originator Requesting STA MAC address and Target MAC Address fields into the request from the received Location Identifier request.

— When a STA receives a Location Identifier request with the Location Subject field value equal to 2, the STA may generate a Location Identifier report if the MAC address in the Target MAC Address field is its own MAC address; it shall not generate a Location Identifier report otherwise. When a Location Identifier report is generated, the reporting STA shall include its MAC address into the Target MAC Address field and the MAC address present in the Originator Requesting STA MAC address field of the corresponding Location Identifier request into the Originator Requesting STA MAC address field. When an AP receives a Location Identifier report with an Originator Requesting STA MAC address field present, the AP shall generate a Location Identifier report to the associated STA with the MAC address specified in the Originator Requesting STA MAC address field. The AP shall copy the Originator Requesting STA MAC address and Target MAC Address fields into the Location Identifier report being transmitted to the originating requesting STA.

When a STA receives an Location Identifier request with the subject field equal to 2, but does not support third-party location, it shall respond with a Radio Measurement Report frame including a Radio Measurement Report element with the Incapable bit set to 1.

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If dot11RMIdentifierMeasurementActivated is false, a STA shall reject the received Location Identifier request by returning a Location Identifier report where the Incapable bit is set in the Measurement Report Mode field.

If dot11RMIdentifierMeasurementActivated is true and a STA has its own location available in one or more location formats, as defined in Table 9-116, and includes Civic Location Type field value 0, indicating "IETF RFC 4776" or geospatial format that can be referenced by a location identifier, it shall set the Identifier Location field to 1 in the Extended Capabilities element.

11.10.9.11 Fine Timing Measurement Range report

The Fine Timing Measurement Range report provides a means for a requesting STA to request a responding STA that advertises FTM Range Report Capability Enabled equal to true in the RM Enabled Capabilities element to measure and report the ranges between the responding STA and other nearby APs where the ranges are determined using the FTM procedure (see 11.21.6).

If dot11RMFineTimingMsmtRangeRepActivated is true, dot11FineTimingMsmtInitActivated shall be true also.

If dot11RMFineTimingMsmtRangeRepActivated is false, a STA shall reject any Fine Timing Measurement Range request by responding with a Radio Measurement Report frame that includes a Measurement Report element with the Incapable field set to 1.

If a responding STA with dot11RMFineTimingMsmtRangeRepActivated equal to true accepts a Fine Timing Measurement Range request, then:

— If the request includes a maximum age subelement and the STA has already determined FTM ranges to C APs listed in the Neighbor Report subelements in the Measurement Request field within the indicated Maximum Age, then the STA may use these ranges instead of initiating new FTM procedures with the C APs.Define C_{sub} as the subset of APs selected by the STA from the C eligible APs.

— Considering the remaining listed APs in the Neighbor Report subelements in the Measurement Request field, if Minimum AP Count exceeds C_{sub}, the responding STA shall wait a random delay up to the value of Randomization Interval field in the Measurement Request element (see 11.10.3) then initiate the FTM procedure with at least Minimum AP Count – C_{sub} remaining listed APs. The responding STA should initiate the FTM procedure with the remaining listed APs until either the responding STA has successfully measured the range between the responding STA with at least Minimum AP Count APs or has attempted the FTM procedure with all remaining listed APs. For each FTM procedure that is attempted with a remaining listed AP without success, the responding STA shall record an error entry.

  For procedures related to listed APs that operate on nonoperating channels, see 11.10.2.

  The responding STA shall transform the measurements obtained from each FTM procedure with an AP into a range and a maximum error between itself and the AP, while accounting for any clock offsets between the responding STA and the AP.

At the completion of all of the FTM procedures and transformations, the responding STA shall send the all computed range information between itself and other APs, and all error entries, to the requesting STA using a Measurement Report element with Measurement Type field set to Fine Timing Measurement Range in a Radio Measurement Report frame.

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A requesting STA may request a single set of range measurements by setting the Number of Repetitions field to 0 in the Radio Measurement Request frame, or request a regular sequence of range measurements by

— Setting the Number of Repetitions field greater than 0 in the Measurement Request frame, and
— Including a Measurement Request element with Measurement Type field equal to Fine Timing Measurement Range and a Measurement Request element with Measurement Type field equal to Measurement Pause (see 11.10.9.7).

11.10.10 Usage of the neighbor report

11.10.10.1 General

A neighbor report is sent by an AP and it contains information on neighboring APs that are members of ESSs requested in the neighbor report request. A neighbor report might not be exhaustive either by choice, or due to the fact that there might be neighbor APs not known to the AP. The neighbor report contents are derived from the NeighborListSet parameter of the MLME-NEIGHBORREPRESP.request primitive. The mechanism by which the contents of this table are determined is outside the scope of this standard, but it may include information from measurement reports received from the STAs within the BSS, information obtained via a management interface, or information from the DS.

NOTE—The purpose of the neighbor report is to enable the STA to optimize aspects of neighbor service set transition and ESS operation. A Neighbor Report element contains information on APs that the STA might use as candidates for a service set transition. Since the information in the neighbor report might be stale, it is advisory; information obtained by the report recipient through a scan or other sources might also be considered, possibly overriding information in the neighbor report. For example, where information contained within a neighbor report is contradicted by information in a Measurement Pilot, Beacon, or Probe Response frame, that response information needs to take precedence.

An AP in which dot11RMNeighborReportActivated is false shall not transmit a Fine Timing Measurement Range request. An AP in which dot11RMNeighborReportActivated is false should not transmit a Measurement Request with the Measurement Type field equal to LCI and the Location Subject field of the LCI request set to Location Subject Remote.

11.10.10.2 Requesting a neighbor report

A STA requesting a neighbor report from an AP shall send a Neighbor Report Request frame to its associated AP.

A STA can request LCI information of an AP and its neighboring APs, if the AP advertises the FTM responder capability (Extended Capabilities element with the Fine Timing Measurement Responder field set to 1), the geospatial location capability (Extended Capabilities element with the Geospatial Location field set to 1), and the neighbor report capability (RM Enabled Capabilities element with the Neighbor Report Capability Enabled field set to 1). A STA can request Civic Location information of an AP and its neighboring APs, if the AP advertises the FTM responder capability (Extended Capabilities element with the Fine Timing Measurement Responder field set to 1), the location civic capability (Extended Capabilities element with the Civic Location field set to 1), and the neighbor report capability (RM Enabled Capabilities element with the Neighbor Report Capability Enabled field set to 1).

To request the LCI of neighboring APs, the STA shall transmit a Neighbor Report Request frame that includes a Measurement Request element with the value of its Measurement Type field equal to LCI. To request the location civic of neighboring APs, the STA shall transmit a Neighbor Report Request frame that includes a Measurement Request element with the value of its Measurement Type field equal to Location Civic.

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11.10.10.3 Responding to a neighbor report request

If dot11RMNeighborReportActivated is true, an AP receiving a neighbor report request shall respond with a Neighbor Report Response frame containing zero or more Neighbor Report elements. If an SSID element is specified in the corresponding Neighbor Report Request frame, the Neighbor Report element(s) shall contain information only concerning neighbor APs that are members of the ESS identified by the SSID element contained within the neighbor report request. If the SSID element is omitted, the Neighbor Report element(s) shall contain information concerning neighbor APs that belong to the same ESS as the requesting STA. If the wildcard SSID element is specified in the corresponding Neighbor Request frame, the Neighbor Report element(s) shall contain information concerning all neighbor APs. If there are no neighbor APs available, the AP shall send a Neighbor Report Response frame with no Neighbor Report elements.

If dot11RMNeighborReportActivated is true and dot11FineTimingMsmtRespActivated is true, an AP receiving a neighbor report request shall respond with a Neighbor Report Response frame containing one or more Neighbor Report elements.

If dot11RMNeighborReportActivated is false in an AP receiving a neighbor report request, it shall ignore the request.

A serving AP shall include a TSF subelement in the Neighbor Report element if it is able to guarantee an accumulated error of 1.5 TU or better on the TSF Offset subfield. Otherwise, the AP shall not include a TSF subelement in the Neighbor Report element.

When the SSID element is omitted, the SSID element is specified by the wildcard SSID, or the SSID element is present and indicates the AP's own SSID and either of the following is true:

— An AP that has both dot11FineTimingMsmtRespActivated and dot11RMLCIConfigured equal to true receives a Measurement Request element with Measurement Type field equal to LCI

— An AP that has both dot11FineTimingMsmtRespActivated and dot11RMCivicConfigured equal to true receives a Measurement Request element with Measurement Type field equal to Location Civic

within a Neighbor Report Request frame, then the AP shall include a Neighbor Report element for the AP's own BSSID in the Neighbor Report Response frame (i.e., in this case the Neighbor Report Response frame contains one or more Neighbor Report elements). If dot11RMLCIConfigured is equal to true, the Neighbor Report element shall include a Measurement Report subelement with the Measurement Type field equal to LCI. If dot11RMCivicConfigured is equal to true, the Neighbor Report element shall include a Measurement Report sub element with the Measurement Type field equal to Location Civic.

When both of the following are true:

— The SSID element specified in the Neighbor Report Request does not include the AP's own SSID and an AP that has at least one of dot11FineTimingMsmtRespActivated and dot11RMLCIConfigured equal to false receives a Measurement Request element with the Measurement Type field equal to LCI within a Neighbor Report Request frame

— An AP that has at least one of dot11LciCivicInNeighborReport and dot11RMLCIConfigured equal to false receives a Neighbor Report Request frame

then the AP shall not include a Neighbor Report element containing a Measurement Report subelement with the Measurement Type field set to LCI describing the reporting AP in the Neighbor Report Response frame. In this case the Neighbor Report Response frame contains zero or more Neighbor Report elements.

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When both of the following are true:

— The SSID element specified in the Neighbor Report request does not include the AP's own SSID and an AP that has at least one of dot11FineTimingMsmtRespActivated and dot11RMCivicConfigured equal to false receives a Measurement Request element with the Measurement Type field equal to Location Civic within a Neighbor Report Request frame

— An AP that has at least one of dot11LciCivicInNeighborReport and dot11RMCivicConfigured equal to false receives a Neighbor Report Request frame

then the AP shall not include a Neighbor Report element containing a Measurement Report subelement with Measurement Type set to Location Civic describing the reporting AP in the Neighbor Report Response frame (i.e., in this case the Neighbor Report Response frame contains zero or more Neighbor Report elements). In this case the Neighbor Report Response frame contains zero or more Neighbor Report elements.

NOTE—The Neighbor Report Response frame includes a list of Neighbor Report elements one for each neighbor. The criteria for the selection of an AP as a neighbor AP is beyond the scope of this specification.

The Neighbor Report Response frame shall also include a Neighbor Report element for each neighbor AP.

When either of the following is true in a neighbor AP of the AP (reporting AP) that receives a Measurement Request element with the Measurement Type field equal to LCI within a Neighbor Report Request frame:

— The neighbor AP has both FTM responder capability (Extended Capabilities element with the Fine Timing Measurement Responder field set to 1) and LCI measurement capability (RM Enabled Capabilities element with the LCI Measurement Capability Enabled field set to 1)

— The reporting AP has dot11LciCivicInNeighborReport equal to true and the neighbor AP has LCI measurement capability (RM Enabled Capabilities element with the LCI Measurement Capability Enabled field set to 1)

then the reporting AP shall include a Neighbor Report element in the Neighbor Report Response frame. In addition if the neighbor AP has Geospatial Location capability (Extended Capabilities element with the Geospatial Location field set to 1), the Neighbor Report element shall include a Measurement Report subelement with Measurement Type equal to LCI. If the maximum horizontal or vertical location error of the neighbor AP relative to a reference AP is known to the AP and this relative error is smaller than the absolute error indicated in the LCI subelement, then the AP may include a Relative Location Error subfield in the Measurement Report field.

When either of the following is true in a neighbor AP of the AP (reporting AP) that receives a Measurement Request element with the Measurement Type equal to Location Civic within a Neighbor Report Request frame:

— The neighbor AP has both FTM responder capability (Extended Capabilities element with the Fine Timing Measurement Responder field set to 1) and civic location measurement capability (RM Enabled Capabilities element with Civic Location Measurement Capability Enabled set to 1)

— The reporting AP has dot11LciCivicInNeighborReport equal to true and the neighbor AP has civic location measurement capability (RM Enabled Capabilities element with Civic Location Measurement Capability Enabled set to 1)

then the reporting AP shall include a Neighbor Report element in the Neighbor Report Response frame. In addition if the neighbor AP has Civic Location (Extended Capabilities element with the Civic Location field set to 1), the Neighbor Report element shall include a Measurement Report subelement with the Measurement Type field equal to Location Civic.

Each Measurement Report subelement returned shall have the same Measurement Token value as in the Measurement Token field of the corresponding Measurement Request element, or if there is no corresponding Measurement Request then the Measurement Token value shall be set to 0.

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If an AP determines that the LCI and/or civic location of a neighboring AP changes, the AP may send an unsolicited Neighbor Report Response frame containing complete neighbor information including the updated neighboring AP location information. The Dialog Token field is set to 0 as defined in 9.6.6.7.

A STA that receives an LCI report that contains a Usage Rules/Policy subelement shall process the LCI information in compliance with the retransmission and retention permissions in the Usage-rules subelement.

The Wide Bandwidth Channel subelement shall not be included in the Neighbor Report element when either the HT Operation subelement or the VHT Operation subelement is included in the Neighbor Report element.

A VHT AP in which dot11FineTimingMsmtRespActivated is true that transmits a Neighbor Report element containing an HT Operation subelement shall include a VHT Operation subelement in the Neighbor Report element.

A non-DMG AP in which dot11FineTimingMsmtRespActivated is true that transmits a Neighbor Report element containing neither an HT Operation subelement nor a VHT Operation subelement shall include a Wide Bandwidth Channel subelement in the Neighbor Report element.

11.10.11 Link measurement

A STA may use a Link Measurement Request frame to request another STA to respond with a Link Measurement Report frame containing a TPC report element. If dot11RMLinkMeasurementActivated is true, a STA receiving a Link Measurement Request frame shall respond with a Link Measurement Report frame containing a TPC Report element indicating the power used to transmit the Link Measurement report. The Link Measurement report also contains antenna ID or DMG antenna ID and signal quality (RCPI and RSNI).

If dot11RMLinkMeasurementActivated is false in an AP or PCP receiving a Link Measurement Request, it shall ignore the request.

11.10.12 Measurement of the RPI histogram

To compute RPI densities for an RPI Histogram report (see 9.4.2.21.4), the STA shall measure the received power level on the specified channel, as detected at the antenna connector, as a function of time over the measurement duration. The tolerance of the received power measurements shall be ± 5 dB. Furthermore, the received signal power measurement should be a monotonic function of the actual power at the antenna connector. The time resolution of the received power measurements is in microseconds. The received power measurements are converted to a sequence of RPI values by quantizing the measurements according to Table 9-126. The RPI densities are then computed for each of the eight possible RPI values using

$$\text{RPI Density} = \left\lceil \frac{255 \times D_{RPI}}{1024 \times D_M} \right\rceil$$

where

D_{RPI} is the duration receiving at the specified RPI value (μs)
D_M is the measurement duration (TU)

The sum of the RPI densities is approximately 255, but could be up to 262 because of rounding effects.

11.10.13 Operation of the Max Transmit Power field

The Max Transmit Power field shall be less than or equal to the Max Regulatory Power value for the current channel.

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11.10.14 Multiple BSSID set

A multiple BSSID set is characterized as follows:

— All members of the set use a common operating class, channel, channel access functions, and antenna connector.

— The size of the set is 2^n, for a selected value of n, $1 \le n \le 8$.

— All BSSIDs within the multiple BSSID set are assigned in a way that they are not available as MAC addresses for STAs using a different operating class, channel or antenna connector.

NOTE—For example, if the APs within BSSs with BSSIDs 16, 17, and 27 share the same operating class, channel and antenna connector, and the range of MAC addresses from 16–31 are not assigned to other STAs using a different antenna connector, then the BSSIDs 16, 17, and 27 are members of a multiple BSSID set. The set is described by $n = 4$ ($2^n = 16$) with BSSIDs in the range 16–31. The set cannot be described by $n = 8$ for instance since at least one of the BSSIDs in the range 0–255 might be used as a BSSID by an AP that does not share the same operating class, channel, and antenna connector.

When the multiple BSSID set contains two or more members, the transmission of Measurement Pilot frames is constrained as described in 11.10.15.

A Multiple BSSID element, with or without optional subelements, indicates that all APs and PCPs within the indicated range of BSSIDs transmit using a common class, channel, and antenna connector.

A single Beacon frame may contain elements for the multiple BSSID set members; see 11.1.3.8.

11.10.15 Measurement Pilot frame generation and usage

11.10.15.1 General

The Measurement Pilot frame is a compact Action frame transmitted pseudo-periodically by an AP at a small interval relative to a Beacon Interval. The Measurement Pilot frame provides reduced information relative to a Beacon frame to allow for the required small interval. The purpose of the Measurement Pilot frame is to assist a STA with the following functions:

— Rapid discovery of the existence of a BSS via passive scanning

— Rapid collection of neighbor AP signal strength measurements via passive scanning

— Enable transmission of a Probe Request frame

A STA's dot11RMMeasurementPilotActivated determines the level of support for measurement pilot at the STA. Table 11-10 describes permitted values for dot11RMMeasurementPilotActivated and what they signify.

Table 11-10—Measurement pilot activated definition

Device function	dot11RM-MeasurementPilot Activated	Notes
AP and non-AP STA	0	If the STA is contained within an AP, it does not generate MPs and if the device is a non-AP STA, it ignores the MPs it receives
AP and non-AP STA	1	If the STA is contained within an AP, it can transmit MPs, and if the device is a non-AP STA, it can receive the MPs and can use the information contained in MPs.
Non-AP STA	2	The non-AP STA is making use of the MPs it receives or would receive if they were being transmitted.

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Table 11-10—Measurement pilot activated definition *(continued)*

Device function	dot11RM-MeasurementPilot Activated	Notes
Non-AP STA	3–7	Reserved
AP		The AP is transmitting MPs and using the information contained in them, and the AP is actively transmitting MPs with MP interval set to a value within the range as shown below. MP Interval with respect to Beacon Interval:
	2	> 3% and < 5% of Beacon Interval
	3	≥ 5% and < 10%
	4	≥ 10% and < 15%
	5	≥ 15% and < 20%
	6	≥ 20% and < 25%
	7	≥ 25% and < 50%

11.10.15.2 Measurement Pilot frame generation by an AP

The AP shall determine if it is a member of a multiple BSSID set with two or more members. If so, at most one AP of the multiple BSSID set shall have dot11RMMeasurementPilotActivated set to a value between 2 and 7. How this occurs is out of scope of this standard.

If dot11RMMeasurementPilotActivated is between 2 and 7, the following statements apply:

— If the AP is a member of a multiple BSSID set with two or more members, then the BSSIDs of all members of the multiple BSSID set shall be indicated in the Beacon and Probe Response frames by the Multiple BSSID subelement.

— The AP shall maintain a Measurement Pilot frame generation function, which transmits Measurement Pilot frames at a basic rate according to dot11RMMeasurementPilotPeriod.

— The AP defines a series of TMPTTs exactly dot11RMMeasurementPilotPeriod apart. A TMPTT arrives when the AP's local TSF timer (in μs) modulo the measurement pilot interval equals 0.

— At each TMPTT, the AP shall schedule a Measurement Pilot frame as the next frame for transmission ahead of other queued frames using the AC_VO EDCA parameters unless the TMPTT satisfies:

$$\text{TBTT} - \frac{T_{MPP}}{2} \leq \text{TMPTT} < \text{TBTT} + \frac{T_{MPP}}{2}$$

where T_{MPP} is dot11RMMeasurementPilotPeriod, for any TBTT of members of the multiple BSSID set, in which case the AP shall not generate the Measurement Pilot. This is illustrated in Figure 11-29. How the AP determines the TBTTs of members of the multiple BSSID set is out of scope of this standard.

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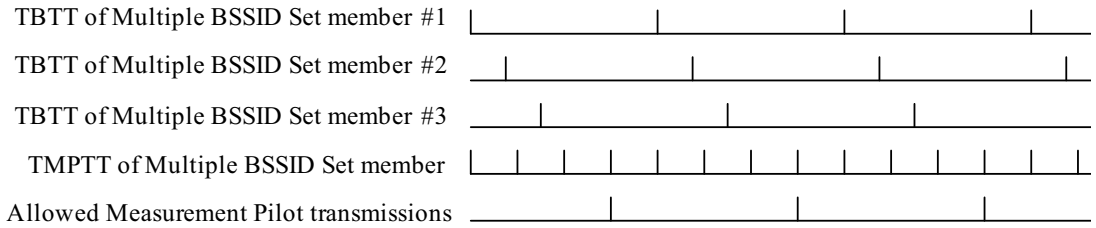

Figure 11-29—Example of Measurement Pilot frame scheduling

In case the medium is determined by the carrier-sense mechanism (see 10.3.2.1) to be unavailable at the TMPTT, the AP shall delay the actual transmission of a Measurement Pilot frame according to the basic medium access rules specified in Clause 10 for a maximum period of one dot11RMMeasurementPilotPeriod and drop the delayed Measurement Pilot frame at the next TMPTT. In this way, a continuously busy medium causes multiple successive Measurement Pilot frames to be delayed, then dropped. An AP shall transmit Measurement Pilot frames to the broadcast address. An AP shall not retransmit or buffer Measurement Pilot frames as part of the PSP mechanisms.

— If the AP is a member of a multiple BSSID set with two or more members, then the BSSIDs of all members of the multiple BSSID set shall be indicated in the Measurement Pilot frame using the Multiple BSSID subelement.

NOTE 1—APs are advised to enable Measurement Pilot frames judiciously due to the possibility of excessive medium time being consumed by Measurement Pilot frames from multiple overlapping APs. For instance dot11RMMeasurementPilotTransmissionInformationActivated might be set to false:

a) When enabling Measurement Pilot frames would cause:
   1) More than 10% of the medium time at the AP to be consumed by beacons and Measurement Pilot frames transmitted by any source, or
   2) More than 5% of the medium time at the AP to be consumed by Measurement Pilot frames transmitted by any source.
b) When STAs are not expected to be using Measurement Pilot frames. How this is determined is out of the scope of this standard, but may depend upon many STAs setting the Measurement Pilot Capability field in the RM Enabled Capabilities element to 0 or 1 upon association at any member of the multiple BSSID set recently or at similar times in the past.
c) When all members of the multiple BSSID set are within ESSs that contain one BSS only.
d) When the AP's operating regulatory domain is not subject to DFS regulations.
e) When the AP's operating regulatory domain is subject to DFS regulations but compliance with the regulations is impaired by Measurement Pilot frames.
f) When the number of channels valid for the AP's operating regulatory domain or frequency band is small.
g) When no members of the multiple BSSID set are located at ingress or egress points of an ESS, so are less useful for roaming between an IEEE 802.11 ESS and other networks.

NOTE 2—For efficient use of the medium, it is recommended that Measurement Pilot frames not be sent using a PHY specified in Clause 15 or Clause 16.

An AP that is not extended spectrum management capable shall not include a Wide Bandwidth Channel Switch subelement in a Measurement Pilot frame. If the Wide Bandwidth Channel Switch subelement is included in a Measurement Pilot frame, then the Operating Class shall include a 40 MHz channel spacing.

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11.10.15.3 Measurement pilot usage by a STA

Whenever testing a requested BSSID for equality against the BSSID field of a Measurement Pilot, the following statements apply:

— If the Measurement Pilot frame does not contain the Multiple BSSID element, then equality shall be true if the requested BSSID equals the BSSID field of the Measurement Pilot frame, and otherwise false.

— If the Measurement Pilot frame contains the Multiple BSSID element, and the requested BSSID is a non-wildcard BSSID, then equality shall be true if the requested BSSID equals any BSSID indicated by the Multiple BSSID element present in the Measurement Pilot, and otherwise false.

— If the Measurement Pilot frame contains the Multiple BSSID element, and the requested BSSID is the wildcard BSSID, then equality shall be true.

NOTE—STAs are advised that due to considerations such as those noted in the prior subclause, APs might not transmit Measurement Pilot frames at all times or in all bands.

11.10.16 Access delay measurement

Access delay is measured by the AP's or PCP's MAC layer being the average medium access delay for transmitted frames measured from the time the MPDU is ready for transmission (i.e., begins CSMA/CA access or SP access, as appropriate) until the actual frame transmission start time. Access delay measurement results are included in the BSS Average Delay element and in the BSS AC Access Delay element.

For the BSS Average Delay measurement, the AP or PCP shall measure and average the medium access delay for all transmit frames using the DCF or EDCAF over a continuous 30 s measurement window. For the infrastructure BSS AC Access Delay measurement, the QoS AP or PCP shall measure and average the medium access delay for all transmit frames of the indicated AC (see Figure 9-349) using EDCA mechanism over a continuous 30 s measurement window. The accuracy for the average medium access delay shall be ± 100 μs or better when averaged over at least 200 frames. Accuracy is not defined for measurements averaged over less than 200 frames.

11.10.17 BSS Available Admission Capacity

BSS Available Admission Capacity provides a means for an AP to advertise admission capacity available for explicit admission control in any UP or AC. This information may assist STAs in making service set transition decisions.

The transmitted BSS Available Admission Capacity value represents a proportion of time on the wireless medium scaled linearly in units of 32 μs/s from 0 (0% available time) to 31 250 (100% available time). If an AP transmits a BSS Load element, the values for any transmitted BSS Available Admission Capacity values shall be less than or equal to the Available Admission Capacity field value of the BSS Load value. If an AP transmits a BSS Available Admission Capacity element, the transmitted values should be current or recently calculated. The AP recalculates Available Admission Capacity values according to local policy. An Available Admission Capacity value of 0 transmitted in the BSS Available Admission Capacity element indicates that no admission capacity is available at the calculation time and that no explicit admissions can be granted by the AP for that UP or AC unless additional capacity becomes available. An AP that receives a TSPEC admission request for total medium time (in both directions, if applicable) that is less than or equal to the current available admission capacity for the requested UP or AC local policy may apply additional local policy before admitting the requested TSPEC.

NOTE 1—Available Admission Capacity values are dynamic in a BSS and the transmitted values cannot always reflect the actual values currently used by the AP for explicit admission control. Thus an AP should recalculate the Available Admission Capacity values regularly or after changes in the environment or the admitted capacity.

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NOTE 2—STAs are advised that requesting admission for any TSPEC at an UP or AC that requires more medium time than is reported as available for the requested UP or AC is possible yet unlikely to be successful.

11.10.18 AP Channel Report

The AP Channel Report element contains a list of channels in an operating class where a STA is likely to receive the Beacon or Probe Response frames sent by an AP, excluding the AP transmitting the AP Channel report. An AP Channel Report element only includes channels that are valid for the regulatory domain in which the AP transmitting the element is operating and consistent with the Country element in the frame in which it appears. One AP Channel Report element is included in the Beacon frame for each regulatory domain, which includes channels on which a STA is likely to receive the Beacon or Probe Response frames sent by an AP.

The contents of the AP Channel Report elements may be compiled from the list of unique operating/channel pairs found in the neighbor report. The contents of the AP channel report may be configured or obtained by other means beyond the scope of this standard.

11.10.19 Multicast diagnostic reporting

Multicast diagnostic reporting enables an AP to collect statistics on group addressed traffic at associated STAs. The method an AP uses to determine the multicast groups to which an associated STA is a member of is outside the scope of the standard and is typically performed by higher layer protocols. The Multicast Diagnostic request and Multicast Diagnostic report are defined in 9.4.2.20.13 and 9.4.2.21.12, respectively.

A STA with dot11MulticastDiagnosticsActivated equal to true shall support multicast diagnostics reporting and shall set to 1 the Multicast Diagnostics field of the Extended Capabilities elements that it transmits. When the Multicast Diagnostics field in the Extended Capabilities field is 1, the Incapable bit in the Measurement Report Mode field of a Multicast Diagnostic report shall not be set to 1.

Multicast diagnostic reporting may use the triggered autonomous reporting capability described in 11.10.8.

The Measurement Start Time field of a triggered diagnostic report shall contain the value of the STA TSF Timer at the time the trigger condition started to occur to an accuracy of ± 1 TU.

An AP may send a Multicast Diagnostic request consisting of one or more Multicast Diagnostic requests in a Radio Measurement Request frame to a non-AP STA that has indicated support of the multicast diagnostic capability or to a multicast group address if all associated non-AP STAs support the multicast diagnostic capability. If the STA accepts the request it shall count the number of received MSDUs with the specified group address and the STA shall record the maximum observed PHY data rate of the frames that contained these MSDUs during the requested Measurement Duration. These two values shall be returned in a Multicast Diagnostic report in a Radio Measurement Report frame, as defined in 9.4.2.21.12. A non-AP STA shall not transmit a Radio Measurement Request frame containing a Multicast Diagnostic request. A STA shall not respond to a Radio Measurement Request frame containing a Multicast Diagnostic request received from a STA other than the AP with which it is associated.

An AP may request that triggered multicast diagnostic reporting be enabled at associated non-AP STAs that have indicated support of the multicast diagnostic capability. To enable multicast diagnostic reporting, the AP shall send a Measurement Request element containing the Request Type field set to Multicast Diagnostics and with the Enable and Report bits set to 1 within a Radio Measurement Request frame. See 11.10.8. For triggered multicast diagnostic reporting, the Multicast MAC Address and trigger conditions for diagnostic reporting shall be specified in the request.

Multicast diagnostic reporting may be requested for broadcast traffic by setting the Multicast MAC Address field to the broadcast address.

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A non-AP STA accepting a request for triggered multicast diagnostic reporting shall send a Multicast Diagnostics report to the requesting STA if the specified trigger condition occurs. The measuring non-AP STA shall not send further triggered Multicast Diagnostics reports until the period specified in the Reactivation Delay field in the Multicast Diagnostic Request has expired, or the non-AP STA receives a revised trigger condition from a Multicast Diagnostic Request. To prevent generation of too many triggered reports, the Reactivation Delay field shall be set to a value greater or equal to A STA's MinTriggerTimeout.

Once accepted, Multicast Diagnostic reporting continues to be active for the specified Multicast MAC address until one of the following occurs:

— The STA receives a Measurement Request element containing a Multicast Diagnostic Request Type and with the Enable bit equal to 1 and the Report bits equal to 0 within a Radio Measurement Request frame.
— Receipt of a Measurement Request element containing a Multicast Diagnostic Request Type, with the Enable and Report bits equal to 1, but with no trigger conditions.
— The STA leaves the Multicast Group or disassociates.
— The STA sends a Measurement Report element with the Measurement Result bit set to 1.

The STA shall maintain an inactivity timer for every multicast diagnostic request accepted by the STA in which the Inactivity Timeout Request field is 1. When a timeout of the inactivity timer is detected, the STA shall send a multicast diagnostic report with the inactivity Timeout Trigger field in the Multicast Reporting Reason field set to 1. The inactivity timer at a recipient is reset when MSDUs corresponding to the monitored group address are received.

A STA that declines a request for triggered multicast diagnostic reporting sends a Measurement Report element (as described in 9.4.2.21) in a Radio Measurement Report frame (as described in 9.6.2.3) with the Measurement Report Mode field set appropriately to indicate the reason for a failed or rejected request.

11.10.20 CCA request and report

The response to a CCA request is a CCA report. A STA may support the generation of a CCA report. A STA may generate a CCA report in response to a CCA request.

11.10.21 RPI Histogram request and report

The response to an RPI Histogram request is an RPI histogram report. A STA may support the generation of an RPI histogram. A STA may generate an RPI histogram report in response to an RPI Histogram request.

11.11 DSE procedures

11.11.1 General

Regulations that apply to the U.S. 3650 MHz band require enabling STAs to implement a mechanism to enable mobile and portable STA operation. Similar regulations exist in other regulatory domains. This standard describes such a mechanism, referred to as *dependent STA enablement (DSE)*.

Regulations that apply to the U.S. 3650 MHz band require fixed STAs and enabling STAs to have their operating locations registered. Licensees with STAs suffering or causing harmful interference are expected to cooperate and resolve problems by mutually satisfactory arrangements. The DSE procedures provide the location of the enabling STA and unique identifiers to assist licensees in the resolution of interference issues. The DSE procedures might also satisfy needs in other frequency bands and be useful for other purposes.

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A STA shall use the DSE procedures defined in this subclause if dot11LCIDSERequired is true. dot11DSERequired and dot11ExtendedChannelSwitchActivated shall be true when regulatory authorities require DSE, with the following exceptions: dot11DSERequired shall be set to false to configure STAs to operate as registered STAs, and dot11ExtendedChannelSwitchActivated may be set to false when operating as a fixed STA. A summary of STA attributes and these MIB attributes are shown in Table 11-11.

Table 11-11—DSE STA attributes

Type of STA	Registered STA	dot11LCIDSERequired and dot11LCIDSEImplemented	dot11ExtendedChannelSwitchActivated	dot11DSERequired
Fixed STA	Yes	true	true or false	false
Enabling STA	Yes	true	true	false
Dependent STA	No	true	true	true

A fixed STA is a registered STA that broadcasts its registered location and is restricted from enabling other STAs (see 11.11.3). An enabling STA is a registered STA that broadcasts its registered location, and regulatory authorities permit it to enable operation of unregistered STAs (see 11.11.4). A dependent STA is an unregistered STA that operates under the control of an enabling STA (see 11.11.5). When management frame protection is negotiated, stations shall use Protected Dual of Public Action frames instead of individually addressed Public Action frames for DSE procedures.

The DSE procedures provide for the following:

— Registered STA operation
— Creation of a DSE service area for dependent STA operation
— Dependent STA operation with DSE

11.11.2 Enablement and deenablement

11.11.2.1 General

This subclause describes the procedures used for IEEE 802.11 enablement and deenablement. A STA keeps a state variable for each STA with which enablement communication is needed:

— Enablement state with a value of *unenabled* or
— Enablement state with a value of *enabled*

NOTE—Refer to 11.11.5 for description of dependent STA operation in either enablement state.

Enablement utilizes a two-frame transaction sequence. The first frame asserts identity and requests enablement. The second frame returns the enablement result. In the description in 11.11.2.2 and 11.11.2.3, the STA initiating the enablement is referred to as *enablement requester*, and the STA to which the initial frame in the exchange is addressed is referred to as *enablement responder*. The specific items in each of the frames described in the following subclauses are defined in 9.6.7.4 and 9.6.7.5. An enabling STA may decline to enable a requesting STA. If the result is "successful," the requesting STA shall be enabled.

Deenablement utilizes a one-frame transaction sequence. In the description in 11.11.2.4 and 11.11.2.5, the STA initiating the deenablement is referred to as *deenablement requester*, and the STA to which the frame is addressed is referred to as *deenablement responder*.

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11.11.2.2 Enablement requester STA

Upon receipt of an MLME-ENABLEMENT.request primitive, the enablement requester STA shall perform the following procedure:

a) Construct and transmit a DSE Enablement frame requesting enablement.
   1) Specific information items in the enablement frame are as follows.
      i) STA identity assertion (in RequesterSTAAddress)
      ii) Enabling STA identity assertion (in ResponderSTAAddress)
      iii) Reason result code = 2
      iv) Enablement identifier = 0
   2) Specific items in the enablement frame sent by the enablement responder STA are described in 11.11.2.3.

b) On receipt of a matching DSE Enablement frame (i.e., the Requester STA Address and Responder STA Address match the pending request) that acknowledges the DSE Enablement frame, issue an MLME-ENABLEMENT.confirm primitive to inform the SME of the result of the enablement.
   1) The primitive may contain information from an DSE Enablement frame received from the enabling STA (see 11.11.2.3), or it may be issued for another reason (see 9.6.7.4).
   2) The reason result code in the enablement confirmation frame indicates when the enablement is successful.
   3) If the enablement was successful, the enablement state variable for the enablement responder STA shall be set to Enabled.

c) If no matching DSE Enablement frame is received for the DSE Enablement frame within a period of EnablementTimeLimit TUs measured from the receipt of the MLME-ENABLEMENT.request primitive, issue an MLME-ENABLEMENT.confirm primitive with ResultCode set to TIMEOUT.

11.11.2.3 Enablement responder STA

Upon receipt of a Public Action DSE Enablement frame with a reason result code of 2, the enablement responder STA may enable the enablement requester STA using the following procedure:

a) Create and transmit a response frame with the enablement status as defined in 9.6.7.4 set in the Reason Result Code field and with a dependent enablement identifier chosen to be unique among all dependent enablement identifiers that have been assigned if enablement was successful. The enablement responder shall transmit the ResultCode parameter from the .confirm primitive mapped as specified in Table 9-367 of 9.6.7.4 to indicate the result of the enablement request.
   1) Specific information items in the enablement frame response are as follows:
      i) STA identity assertion (in RequesterSTAAddress)
      ii) Enabling STA identity assertion (in ResponderSTAAddress)
      iii) The result of the requested enablement as defined in 9.6.7.4
      iv) Enablement identifier

b) Issue an MLME-ENABLEMENT.indication primitive to inform the SME of the enablement.
   1) If the enablement is successful, the enablement state variable for the enablement requester STA shall be set to Enabled.

11.11.2.4 Deenablement requester STA

Upon receipt of an MLME-DEENABLEMENT.request primitive, the deenablement requester STA shall create and transmit a DSE Deenablement frame to the deenablement responder STA. Specific information items in the deenablement frame are as follows:

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a) Enabling STA identity assertion (in RequesterSTAAddress)
b) STA identity assertion (in ResponderSTAAddress)
c) Reason result code = 2

11.11.2.5 Deenablement responder STA

Upon receipt of a DSE Deenablement frame, the deenablement responder STA shall deenable with the deenablement requester STA by issuing an MLME-DEENABLEMENT.indication primitive to inform the SME of the deenablement. The enablement state variable for the deenablement requester STA shall be set to Unenabled.

11.11.3 Registered STA operation

A registered STA shall have dot11DSERequired equal to false. They shall transmit the DSE Registered Location element in every Beacon frame and shall set the Dependent STA bit in the DSE Registered Location element to 0. If the registered STA is located within a national policy area, such as a Fixed Satellite Service exclusion zone, or within an international agreement area near a national border, the RegLoc Agreement bit in the DSE Registered Location element shall be set to 1, signifying to other STAs that additional restrictions on STAs with directional antennas may apply; otherwise, it shall be set to 0.

The Latitude, Longitude, and Altitude fields of the DSE Registered Location element shall be reported at their best known resolutions, which might exceed the resolutions required by regulatory authorities. The Altitude Type field value shall be 3 (i.e., height above ground is in meters or, in other words, the altitude is in meters above adjacent terrain), unless another altitude type is required for operation in the regulatory domain. The Datum field value shall be 1 (World Geodetic System 1984), unless another datum is required for operation in the regulatory domain.

An enabling STA is a registered STA that broadcasts its registered location, and regulatory authorities permit it to enable operation of unregistered STAs (see 11.11.4). A dependent STA is an unregistered STA that operates under the control of an enabling STA (see 11.11.5).

A fixed STA is a registered STA that broadcasts its registered location and is restricted from enabling other STAs. A fixed STA shall have dot11LCIDSERequired set to true, and dot11ExtendedChannelSwitchActivated may be true or false. A fixed STA shall set dot11RegLocDSE to false and the RegLoc DSE bit in the DSE Registered Location element to 0, signifying that it is not creating a DSE service area. A fixed STA may operate in an infrastructure BSS or IBSS. A registered STA that is not an enabling STA may operate as an AP and relay Public Action frames (specifically, DSE Enablement, DSE Deenablement, DSE Measurement Request, DSE Measurement Report, DSE Power Constraint) from a dependent STA to its enabling STA. The specification of the algorithm by which Public Action frames are relayed is beyond the scope of this standard. Note that the enabling signal is not a Public Action frame and is not relayed (see 11.11.4).

11.11.4 Enabling STA operation with DSE

A registered STA may create and manage a DSE service area for dependent STA operation where regulatory requirements permit. A registered STA operating in this manner is referred to as an *enabling STA*. An enabling STA sets dot11RegLocDSE to true and signifies the creation of a DSE service area by setting the RegLoc DSE bit in the DSE Registered Location element to 1. Dependent STA transmission of any frames is conditional on receiving directly over the air and decoding a DSE Registered Location element with RegLoc DSE bit equal to 1, sent from an enabling STA. Before attempting enablement with any one enabling STA, a dependent STA may have detected several enabling STAs, may attempt enablement with one and fail, and then attempt enablement with another. An enabling STA shall assign dependent enablement identifiers in a way that makes them unique among STAs enabled by this enabling STA to help identify sources of interference.

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An enabling STA may issue a DSE measurement request to any of its dependent STAs in order to receive a DSE measurement report that may have reported DSE LCI fields received from nearby STAs. The licensed operator may be able to use these reports to identify interfering STAs or map overlapping coverage in a multiple BSS situation. Because reported DSE LCI fields may refer to any destination address, a single DSE report may contain elements received from STAs that are not yet associated with a BSS.

An enabling STA may issue an ECS announcement to any of its dependent STAs in order to have their radio operation changed in frequency, channel bandwidth, and other operational parameters. A dependent AP or DFS owner with dot11DSERequired true and receiving an ECS announcement from its enabling STA shall perform the extended channel switching procedure as specified in 11.9.

An enabling STA may issue a DSE power constraint announcement to any of its dependent STAs in order to have their transmit power reduced from the regulatory limit. A dependent AP or DFS owner with dot11DSERequired true and receiving a DSE power constraint announcement from its enabling STA shall perform the power constraint procedure as specified in 11.11.5.

11.11.5 Dependent STA operation with DSE

A dependent STA shall set dot11DSERequired to true.

A typical state machine implementation of dependent STA operation with DSE is provided in Figure 11-30.

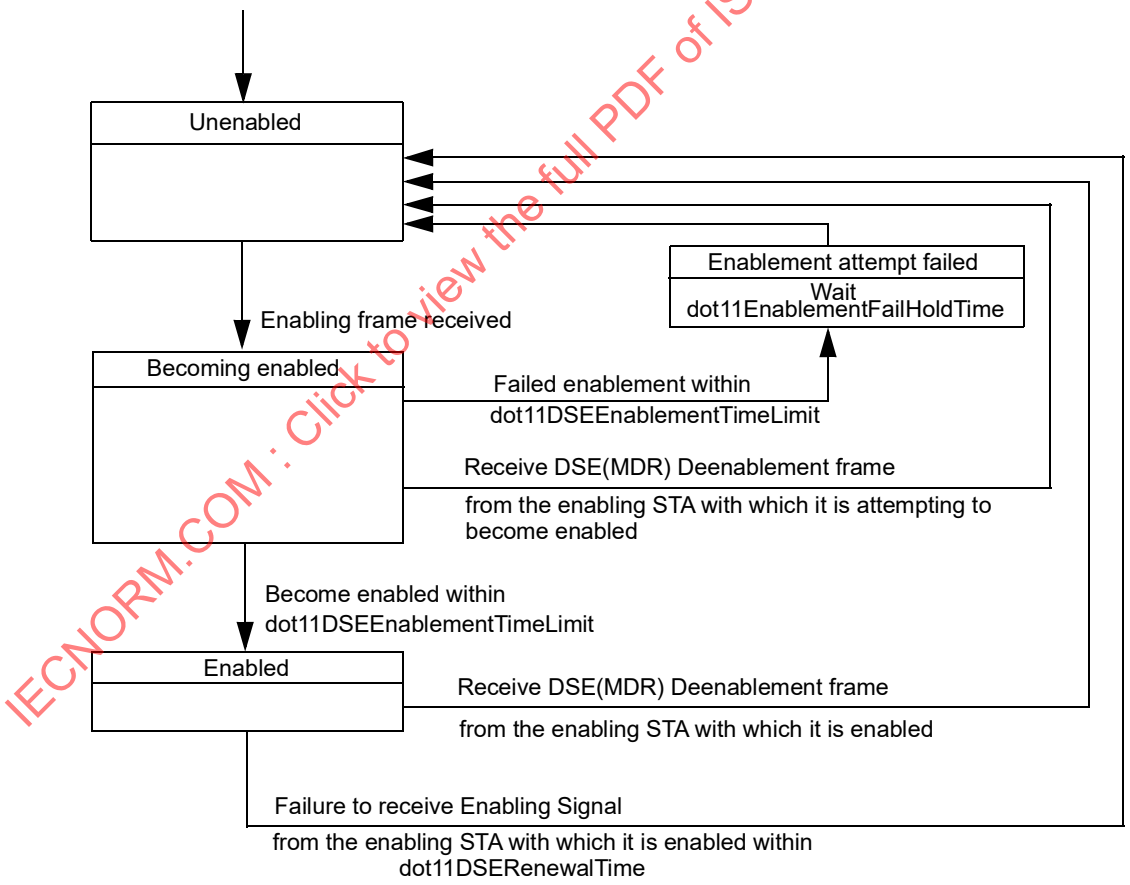

Figure 11-30—Dependent STA state machine

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For DSE, the following statements apply:

- A STA with dot11DSERequired true shall not transmit any frames unless it has received a Beacon frame from an enabling STA with the Spectrum Management bit equal to 1 in the Capability Information field and with the RegLocDSE bit equal to 1 in the DSE Registered Location element. A dependent STA that is not enabled shall not transmit, except to attain enablement with an enabling STA, unless such action is mandated to be allowed in the regulatory domain (e.g., emergency services).
- A dependent STA shall not attempt enablement with an enabling STA unless the enabling STA is transmitting Beacon frames with the RegLoc DSE bit equal to 1 in the DSE Registered Location element.
- A dependent STA creates a dependent DSE Registered Location element containing the enabling STA's DSE Registered Location element and having the RegLoc DSE bit set to 0 and the Dependent STA bit set to 1. Before enablement, the Dependent Enablement Identifier field shall be set to 0. Upon attaining enablement, the Dependent Enablement Identifier field shall be set to the dependent enablement identifier value received by the dependent STA from the enabling STA in the MLME-ENABLEMENT.response primitive.
- The dependent STA shall send a Public Action DSE Registered Location Announcement frame to the broadcast address whenever the sum of dot11TransmittedFragmentCount, dot11GroupTransmittedFrameCount, and dot11ReceivedFragmentCount, modulo dot11DSETransmitDivisor equals 0, possibly delayed by the completion of the sending of the frames of the current MSDU or MMPDU or by the completion of the current transmission opportunity (TXOP).
- A dependent STA that has not attained enablement shall not transmit beyond dot11DSEEnablementTimeLimit (in seconds), measured from the time of the first PHY-TXSTART.request primitive, while attempting to attain enablement. Then if it is not enabled, it shall not transmit for dot11DSEEnablementFailHoldTime (in seconds), before it again attempts to attain enablement.
- A dependent STA receiving a DSE Deenablement frame with the RequesterSTAAddress field matching the enabling STA with which it last attempted enablement and the ResponderSTAAddress field matching its own IEEE MAC address shall change its enablement state with the enabling STA to unenabled and set all fields of its DSE Registered Location Information field (see 9.4.2.51) to 0.
- A dependent STA shall return a DSE measurement report in response to a DSE measurement request if the request is received from the AP with which it is associated or the enabling STA with which it last attempted enablement and the ResponderSTAAddress field matches its own IEEE MAC address. The result may be the completed measurement or an indication that the STA is unable to complete the measurement request. A STA shall report it is too late to undertake a measurement request if it receives the request after the specified starting time for the measurement. The Measurement Report Mode field of a frame that is sent in response to a DSE Measurement Request frame shall not contain a value of 1 for the Incapable subfield and shall not contain a value of 1 for the Refused subfield of the Measurement Report Mode field of the DSE measurement report.
- A dependent STA receiving an ECS frame from the enabling STA with which it last attempted enablement or an ECS element from the AP with which it is associated shall perform the ECS procedure (see 11.9.3).
- A dependent STA receiving a DSE Power Constraint frame with the RequesterSTAAddress field matching the enabling STA with which it last attempted enablement and the ResponderSTAAddress field matching its own IEEE MAC address shall constrain its transmit power to be less than or equal to the maximum transmit power level specified for the current channel in the Country element minus the local power constraint specified in the DSE Power Constraint frame.
- An enabled dependent STA shall cease transmission within dot11DSERenewalTime (in seconds) if it has not received either a Beacon frame or a Probe Response frame from its enabling STA with the RegLoc DSE bit equal to 1 in the DSE Registered Location element. It shall then change its

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enablement state with the enabling STA to unenabled and set all fields of its DSE Registered Location Information field (see 9.4.2.51) to 0.

11.12 Group addressed management frame protection procedures

When management frame protection is negotiated, the MLME shall provide an encapsulation service for group addressed robust Management frames. All group addressed robust Management frames shall be submitted to this service for encapsulation and transmission.

For group addressed Management frames that are specified with Yes in the Group Addressed Privacy column of Table 9-51, the group addressed frame protection service shall take the following actions:

— The frames shall be encapsulated and protected with the MGTK using the group cipher negotiated during the AMPE exchange.

For all other group addressed Management frames, the group addressed frame protection service shall take the following actions:

— Management frame protection for multicast/broadcast shall be set using the MLME-SETPROTECTION.request primitive with the Protectlist including a Key Type value of IGTK. A non-AP STA shall also set the Protect Type value to Rx. In an IBSS, a STA shall set the ProtectType value to Rx_Tx. An AP shall set the Protect Type value to Tx.

— The IGTK shall be installed using the MLME-SETKEYS.request primitive with the value IGTK for the Key Type parameter of the SetKeyDescriptor.

— The frames shall be encapsulated and protected using BIP (see 12.5.4).

11.13 SA Query procedures

If dot11RSNAProtectedManagementFramesActivated is true, then the STA shall support the SA Query procedure.

To send an SA Query Request or SA Query Response frame to a peer STA, the SME shall issue an MLME-SA-QUERY.request or MLME-SA-QUERY.response primitive respectively. Reception of an SA Query Request or SA Query Response frame is signaled to the SME with an MLME-SA-QUERY.indication or MLME-SA-QUERY.confirm primitive respectively.

A STA that supports the SA Query procedure and receives an SA Query Request frame shall respond with an SA Query Response frame if none of the following are true:

— The STA is not currently associated to the STA that sent the SA Query Request frame.

— The STA has sent a (Re)Association Request frame within dot11AssociationResponseTimeOut but has not received a corresponding (Re)Association Response frame.

— dot11RSNAOperatingChannelValidationActivated is true and the sending STA had indicated OCVC capability in its association and either

  — OCI element is not present in the request or

  — Operating channel information indicated does not match the current channel information (see 12.2.9).

A STA that responds with an SA Query Response frame to a STA that indicated OCVC capability shall include OCI element in the response frame if dot11RSNAOperatingChannelValidationActivated is true.

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When a non-AP or non-PCP STA receives the SA Query Response frame from a STA that indicated OCVC capability, it shall ensure that OCI element is present in the response and the channel information in the OCI element matches current operating channel parameters (see 12.2.9). Otherwise, the receiving STA shall deem the response as invalid and discard it.

If a non-AP or non-PCP STA initiated an SA Query procedure following a channel switch and does not receive the SA Query Response frame from a STA that indicated OCVC capability within dot11AssociationSAQueryMaximumTimeout TUs from the beginning of the SA Query procedure, it shall deauthenticate from the BSS.

NOTE 1—A non-AP and non-PCP STA does not respond if it is trying to reassociate with the AP or PCP that sent the SA Query Request frame (since, except in the case of FT to the same AP, it no longer has the PTKSA) or to another AP or PCP (it could maintain the old association and PTKSA until the reassociation is completed). There is no such restriction for an AP or PCP.

If a non-AP and non-PCP STA that has an SA with its AP or PCP for an association that negotiated management frame protection receives an unprotected Deauthentication or Disassociation frame with reason code INVALID_CLASS2_FRAME or INVALID_CLASS3_FRAME from the AP or PCP, the non-AP and non-PCP STA may use this as an indication that there might be a mismatch in the association state between itself and the AP or PCP. In such a case, the non-AP and non-PCP STA's SME may initiate the SA Query procedure with the AP or PCP to verify the validity of the SA by issuing one MLME-SA-QUERY.request primitive every dot11AssociationSAQueryRetryTimeout TUs until a matching MLME-SA-QUERY.confirm primitive is received or dot11AssociationSAQueryMaximumTimeout TUs from the beginning of the SA Query procedure has passed. If the AP or PCP responds to the SA Query request with a valid SA Query response, the non-AP STA should continue to use the SA. If no valid SA Query response is received, the non-AP and non-PCP STA's SME may delete the SA and temporal keys held for communication with the STA by issuing an MLME-DELETEKEYS.request primitive and the non-AP and non-PCP STA may move into State 1 (or State 2, for a DMG STA) with the AP.

NOTE 2—The mechanism by which the MAC, MLME and SME coordinate the actions needed to effect these operations is outside the scope of this standard.

When an S1G STA in a power save mode wakes up with an interval longer than dot11AssociationSAQueryMaximumTimeout, an existing SA can be destroyed. So, to maintain its valid SA status, the S1G STA shall wake to listen to SA Query Request frame with the interval specified by dot11AssociationSAQueryMaximumTimeout. When dot11RSNAProtectedManagementFramesActivated is true, an S1G AP shall provide the Timeout Interval (Association Comeback time, which is set to dot11AssociationSAQueryMaximumTimeout) in an Association Response frame and Reassociation Response frame with a status code 0 to the S1G STA.

11.14 HT BSS Operation

An HT STA that is starting or joining a BSS shall be able to receive and transmit at each of the MCS values listed in the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive.

A STA that transmits a frame that contains both an HT Operation element and a DSSS Parameter Set element shall set the Primary Channel field in the HT Operation element to the same value as the Current Channel field in the DSSS Parameter Set element.

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11.15 20/40 MHz BSS operation

11.15.1 Rules for operation in 20/40 MHz BSS

The rules described in 11.15.1 to 11.15.12 are applicable to STAs that are either a STA 5G or a STA 2G4.

A 40-MHz-capable STA (40MC STA) shall support 20/40 BSS coexistence management.

NOTE—A 40MC HT STA that transmits a frame containing an Extended Capabilities element sets the 20/40 BSS Coexistence Management Support field of this element to 1.

An HT STA 2G4 that is an IBSS STA and that transmits a frame containing an HT Operation element or Secondary Channel Offset element shall set the Secondary Channel Offset field of this element to SCN.

11.15.2 Basic 20/40 MHz BSS functionality

An HT AP declares its channel width capability (20 MHz only or 20/40 MHz) in the Supported Channel Width Set subfield of the HT Capabilities element.

An HT AP shall set the STA Channel Width field to 1 in frames in which it has set the Secondary Channel Offset field to SCA or SCB. An HT AP shall set the STA Channel Width field to 0 in frames in which it has set the Secondary Channel Offset field to SCN.

A non-AP HT STA declares its channel width capability (non-40MC HT STA or 40MC HT STA) in the Supported Channel Width Set subfield in the HT Capabilities element.

NOTE 1—A 20/40 MHz BSS might include any mixture of 40MC HT STAs, non-40MC HT STAs, and non-HT STAs. Protection requirements for mixed networks are defined in 10.27.

NOTE 2—A non-AP HT STA can switch between 40MC HT STA and non-40MC HT STA operation by disassociation followed by association.

An HT STA shall not indicate support for 40 MHz unless it supports reception and transmission of 40 MHz PPDUs using all MCSs within the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive and all MCSs that are mandatory for the attached PHY.

An HT STA shall not transmit a 20 MHz PPDU containing one or more Data frames using the secondary channel of a 20/40 MHz BSSs. The Notify Channel Width frame may be used by a STA to notify another STA that the STA wishes to receive frames in the indicated channel width.

An HT STA that is an IBSS STA adopts the Secondary Channel Offset field in received frames according to the rules in 11.1.5 and shall not transmit either of the following:

— A value in the Secondary Channel Offset field that differs from the most recently adopted value
— An operating class in the Extended Channel Switch Announcement frame or element with a different behavior than the currently adopted PrimaryChannelLowerBehavior or PrimaryChannelUpperBehavior

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11.15.3 Channel scanning and selection methods for 20/40 MHz operation

11.15.3.1 General

An HT STA shall set the following to true: dot11OperatingClassesImplemented, dot11OperatingClassesRequired, and dot11ExtendedChannelSwitchActivated.

An AP operating a 20/40 MHz BSS, on detecting an OBSS whose primary channel is the AP's secondary channel, switches to 20 MHz BSS operation and may subsequently move to a different channel or pair of channels. A DFS owner (DO) operating a 20/40 MHz IBSS, on detecting an OBSS whose primary channel is the DO's secondary channel, may choose to move to a different pair of channels.

NOTE—The setting up of a 40 MHz off-channel TDLS direct link is specified in 11.20.6.3.

11.15.3.2 Scanning requirements for a 20/40 MHz BSS

Before an AP or DO starts a 20/40 MHz BSS, it shall perform a minimum of dot11BSSWidthChannelTransitionDelayFactor OBSS scans (see 11.15.5) to search for existing BSSs.

If the AP or DO starts a 20/40 MHz BSS in the 5 GHz band and the BSS occupies the same two channels as any existing 20/40 MHz BSSs, then the AP or DO shall select a primary channel of the new BSS that is identical to the primary channel of the existing 20/40 MHz BSSs and a secondary channel of the new 20/40 MHz BSS that is identical to the secondary channel of the existing 20/40 MHz BSSs, unless the AP discovers that on these two channels are existing 20/40 MHz BSSs with different primary and secondary channels.

If an AP or DO starts a 20/40 MHz BSS in the 5 GHz band, the selected secondary channel should correspond to a channel on which no beacons are detected during the dot11BSSWidthChannelTransition-DelayFactor OBSS scan time performed by the AP or DO, unless there are beacons detected on both the selected primary and secondary channels.

NOTE 1—The 20/40 MHz channel sets and their corresponding behavior limits (i.e., choice of primary and secondary channels) permissible in each operating class are defined in Annex E and Annex D, respectively.

An HT AP or a DO that is also an HT STA should not start a 20 MHz BSS in the 5 GHz band on a channel that is the secondary channel of a 20/40 MHz BSS.

The AP or DO may continue to periodically scan after the BSS has been started. Information obtained during such scans is used as described within this subclause and within 11.15.2.

After starting a 20 MHz BSS, a 40MC HT AP 2G4 shall perform a minimum of dot11BSSWidthChannelTransitionDelayFactor OBSS scans, either by itself or through its associated STAs before making a transition from a 20 MHz BSS to a 20/40 MHz BSS. When the AP performs the scanning and the secondary channel for the 20/40 MHz BSS has been selected, then the scan shall be performed over the set of channels that are allowed operating channels within the current operational regulatory domain and whose center frequency falls within the *affected frequency range* given by Equation (11-1). When the AP performs the scanning without an intended secondary channel for the 20/40 MHz BSS or when the AP's associated STA(s) perform the scanning, then the scan shall be performed on all channels in the frequency band.

NOTE 2—A 40MC HT AP can change from operating a 20 MHz BSS to a 20/40 MHz BSS while maintaining associations by making a change to the transmitted Secondary Channel Offset field.

$$\textit{affected frequency range} = [\frac{f_P + f_S}{2} - 25\ \text{MHz}, \frac{f_P + f_S}{2} + 25\ \text{MHz}] \quad (11\text{-}1)$$

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where

f_P is the center frequency of channel P

f_S is the center frequency of channel S

A 40MC HT AP 2G4 shall maintain a MAC variable *20/40 Operation Permitted* that can have either the value true or false. The initial value of *20/40 Operation Permitted* shall be false. The value of *20/40 Operation Permitted* is recomputed according to Equation (11-2) whenever a BSS channel width trigger event is detected or whenever a period of time has elapsed with no BSS channel width triggers being detected and no overlap being reported, as defined in 11.15.12.

$$\begin{aligned} \textit{20/40 Operation Permitted} = {} & (P == OP_i \text{ for all values of } i) \text{ AND} \\ & (P == OT_i \text{ for all values of } i) \text{ AND} \\ & (S == OS_i \text{ for all values of } i) \end{aligned} \tag{11-2}$$

where

P is the operating or intended primary channel of the 20/40 MHz BSS

S is the operating or intended secondary channel of the 20/40 MHz BSS

OP_i is member i of the set of channels that are members of the channel set C and that are the primary operating channel of at least one 20/40 MHz BSS that was detected within the AP's BSA during the previous dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds

OS_i is member i of the set of channels that are members of the channel set C and that are the secondary operating channel of at least one 20/40 MHz BSS that was detected within the AP's BSA during the previous dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds

OT_i is member i of the set that comprises all channels that are members of the channel set C that were listed at least once in the Channel List fields of 20/40 BSS Intolerant Channel Report elements received during the previous dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds and all channels that are members of the channel set C and that are the primary operating channel of at least one 20 MHz BSS that was detected within the AP's BSA during the previous dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds

C is the set of all channels that are allowed operating channels within the current operational regulatory domain and whose center frequency falls within the *affected frequency range* given by Equation (11-1)

If either side of "==" above is the empty set or has a null value, then the expression is defined to have a Boolean value of true.

A 40MC HT AP 2G4 shall not start a 20/40 MHz BSS in the 2.4 GHz band if the MAC variable *20/40 Operation Permitted* is false [see Equation (11-2)].

A 40MC HT AP 2G4 may transmit a frame containing a Secondary Channel Offset field set to a value of SCA or SCB only if *20/40 Operation Permitted* is true.

In addition to information obtained by the 40MC HT AP 2G4 through its own scanning, a 40MC HT AP 2G4 shall use 20/40 BSS Intolerant Channel Report element information from received 20/40 BSS Coexistence Management frames with an Address 1 field that matches the 40MC HT AP 2G4 using either individual or group addressing, but with no qualification of the Address 3 value, when determining if *20/40 Operation Permitted* is true or false. The information from the Channel List fields of received 20/40 BSS Intolerant Channel Report elements is used in generating the *OT* set for Equation (11-2).

After initial establishment of the 20/40 MHz BSS, if the value of *20/40 Operation Permitted* becomes false, the 40MC HT AP 2G4 reverts to 20 MHz BSS operation (see 11.15.12). The 40MC HT AP 2G4 might subsequently move the BSS to a pair of channels where the value of *20/40 Operation Permitted* evaluates to true.

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11.15.3.3 Channel management at the AP and in an IBSS

While operating a 20/40 MHz BSS, a DO or an AP may move its BSS, and an AP may switch the BSS to 20 MHz operation either alone or in combination with a channel move. These channel moving or BSS width switching operations might occur if, for example, another BSS starts to operate in either or both of the primary or secondary channels, or if radar is detected in either or both of the primary or secondary channels, or for other reasons that are beyond the scope of this standard. Specifically, the AP or DO may move its BSS to a different pair of channels, and the AP may separately, or in combination with the channel switch, change from a 20/40 MHz BSS to a 20 MHz BSS using either the primary channel of the previous channel pair or any other available 20 MHz channel. While operating a 20 MHz BSS, a DO or an AP may move its BSS, and an AP may switch the BSS to a 20/40 MHz BSS, either alone or in combination with a channel move.

When switching a 20/40 MHz BSS to an operating channel width of 20 MHz, the AP may recalculate the TS bandwidth budget and may delete one or more active TSs by invoking the MLME-DELTS.request primitive with a ReasonCode value of SERVICE_CHANGE_PRECLUDES_TS.

An AP switches between 20/40 MHz BSS and 20 MHz BSS as follows:

— By changing the Secondary Channel Offset field of the HT Operation element in the Beacon frame, and/or
— By changing the Secondary Channel Offset field of the Secondary Channel Offset element, and/or
— Through the New Operating Class field of transmitted Extended Channel Switch Announcement elements.

In order to maintain existing associations and/or minimize disruption to communications with other STAs while making a channel width change or while performing a channel pair relocation, an AP may inform HT STAs within its BSS that it is making the change by including an Extended Channel Switch Announcement element in Beacon, Probe Response, and Extended Channel Switch Announcement frame transmissions until the intended channel switch time. A DO may inform HT STAs within its BSS that it is performing a channel pair relocation by including an Extended Channel Switch Announcement element in Beacon, Probe Response, and Extended Channel Switch Announcement frame transmissions until the intended channel switch time. The New Channel Number field of the Extended Channel Switch Announcement element represents the new channel (when the BSS after relocation/width change will be a 20 MHz BSS) or the primary channel of the new pair of channels (when the BSS after relocation/width change will be a 20/40 MHz BSS). When changing to a new pair of channels, the New Operating Class field specifies the position of the secondary channel relative to the new primary channel, i.e., either above or below.

When transmitting HT Operation elements, Channel Switch Announcement elements, and/or Extended Channel Switch Announcement elements, the AP moving the BSS or changing its channel width selects a combination of operating parameters from any single row of any one of the tables in Annex E that is appropriate for the current operating domain of the AP. Similarly, when transmitting HT Operation elements, Channel Switch Announcement elements, and/or Extended Channel Switch Announcement elements, the DO moving the BSS selects a combination of operating parameters from any single row of any one of the tables in Annex E that is appropriate for the current operating domain of the DO. The AP or DO selects one channel number from the “Channel set” column of the selected row. The AP or DO includes the selected information in subsequently transmitted frames that contain any combination of the following four elements:

— HT Operation element
— Channel Switch Announcement element
— Extended Channel Switch Announcement element
— Secondary Channel Offset element

The AP or DO shall set the Secondary Channel Offset field of transmitted HT Operation elements and transmitted Secondary Channel Offset elements to SCA if the Behavior limits set column of the selected row

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contains the value PrimaryChannelLowerBehavior. The AP or DO shall set the Secondary Channel Offset field of transmitted HT Operation elements and transmitted Secondary Channel Offset elements to SCB if the Behavior limits set column of the selected row contains the value PrimaryChannelUpperBehavior. The AP or DO shall set the Secondary Channel Offset field of transmitted HT Operation elements and transmitted Secondary Channel Offset elements to SCN if the Behavior limits set column of the selected row contains neither the value PrimaryChannelLowerBehavior nor the value PrimaryChannelUpperBehavior.

The AP or DO shall set the New Channel Number field of transmitted Channel Switch Announcement elements and Extended Channel Switch Announcement elements to the value of the selected channel from the selected row.

The AP or DO shall set the New Operating Class field of transmitted Extended Channel Switch Announcement elements to the value of the "Operating class" column of the selected row.

Movement of a 20/40 MHz BSS from one channel pair to a different channel pair and changing between 20 MHz and 20/40 MHz operation should be scheduled so that all STAs in the BSS, including STAs in power save mode, have the opportunity to receive at least one Extended Channel Switch Announcement element or Channel Switch Announcement element before the switch.

When the Extended Channel Switch Announcement element and Extended Channel Switch Announcement frame are transmitted in bands where dot11SpectrumManagementRequired is true, the Channel Switch Announcement element and Channel Switch Announcement frame may also be transmitted. A STA that announces a channel switch using both the Extended Channel Switch Announcement element and the Channel Switch Announcement element shall set the New Channel Number field of both elements to the same value. An HT STA that receives a channel switch announcement through both the Extended Channel Switch Announcement element and the Channel Switch Announcement element ignores the received Channel Switch Announcement element; this is called a *superseded* Channel Switch Announcement element.

For 20 MHz operation when the new operating class signifies 40 MHz channel spacing, the 20 MHz channel is the primary channel of the 40 MHz channel.

11.15.4 40 MHz PPDU transmission restrictions

11.15.4.1 Fields used to determine 40 MHz PPDU transmission restrictions

Several fields from various frames are used to convey information between STAs regarding the support for 40 MHz PPDU transmission and reception and regarding any current prohibition against the transmission and reception of 40 MHz PPDUs.

The rules defined in 11.15.4.2, 11.15.4.3, and 11.15.4.4 describe the behavior that accompanies those fields.

The fields that are used to determine the status of the transmission and reception of 40 MHz PPDUs are as follows:

- The Supported Channel Width Set subfield of the HT Capabilities element
- The Secondary Channel Offset field of the HT Operation element
- The STA Channel Width field of the HT Operation element
- The Channel Width field of the Notify Channel Width frame
- The Extended Channel Switch Announcement element

The Supported Channel Width Set subfield is used to indicate whether the transmitting STA is capable of transmitting and receiving 40 MHz PPDUs.

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NOTE—The Supported Channel Width Set subfield transmitted by an AP is constant for the lifetime of its BSS as it is a parameter of the MLME-START.request primitive.

In addition to the restrictions on transmission of 40 MHz mask PPDUs found in 11.15.4.1 to 11.15.4.4, if a STA operating in the 2.4 GHz industrial, scientific, and medical (ISM) band has no means of determining the presence of non-IEEE-802.11 communication devices operating in the area, then the STA shall not transmit any 40 MHz mask PPDUs.

In addition to the restrictions on transmission of 40 MHz mask PPDUs found in 11.15.4.1 to 11.15.4.4, if a STA operating in the 2.4 GHz ISM band has a means of determining the presence of non-IEEE-802.11 communication devices operating in the area and determines either that no non-IEEE-802.11 communication device is operating in the area or that non-IEEE-802.11 communication devices are operating in the area but the STA implements a coexistence mechanism for these non-IEEE-802.11 communication devices, then the STA may transmit 40 MHz mask PPDUs; otherwise, the STA shall not transmit any 40 MHz mask PPDUs.

11.15.4.2 Infrastructure non-AP STA restrictions

A STA that is associated with an AP shall not transmit a value in the Supported Channel Width Set subfield that differs from a previously transmitted value during its current association.

The Secondary Channel Offset field is used to indicate whether the BSS is occupying a 40 MHz wide pair of channels and, when a secondary channel exists, whether it is above or below the primary channel in frequency. The Extended Channel Switch Announcement frame and the Extended Channel Switch Announcement element can each be used to indicate a transition from 20/40 MHz BSS operation to 20 MHz BSS operation and vice versa and to indicate whether a secondary channel, when it exists, is above or below the primary channel in frequency.

A 40MC HT STA shall maintain a MAC variable *40MHzOperatingClass* as described here. The initial value of *40MHzOperatingClass* shall be false. The value of *40MHzOperatingClass* is recomputed according to the rules in this subclause at every TBTT and following the reception of a frame transmitted by the AP associated with the STA when that frame contains either of the following fields:

— Current Operating Class field
— New Operating Class field

The MAC variable *40MHzOperatingClass* becomes true upon reception of a frame transmitted by the associated AP if the frame contained a Current Operating Class field with a value that corresponds to an operating class that corresponds to a channel spacing value of 40 MHz, as specified in Annex E.

The MAC variable *40MHzOperatingClass* becomes false upon reception of a frame transmitted by the associated AP if the frame contained a Current Operating Class field with a value that corresponds to an operating class that does not correspond to a channel spacing value of 40 MHz.

The MAC variable *40MHzOperatingClass* becomes true at the n^{th} TBTT following reception of a frame transmitted by the associated AP that contains an Extended Channel Switch Announcement element with a value of *n* in the Channel Switch Count field and a value in the New Operating Class field that corresponds to an operating class that corresponds to a channel spacing value of 40 MHz provided that the frame is the most recently received frame meeting the above conditions.

The MAC variable *40MHzOperatingClass* becomes false at the n^{th} TBTT following reception of a frame transmitted by the associated AP that contains an Extended Channel Switch Announcement element with a value of *n* in the Channel Switch Count field and a value in the New Operating Class field that corresponds to an operating class that does not correspond to a channel spacing value of 40 MHz provided that the frame is the most recently received frame meeting the above conditions.

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A STA can choose to dynamically constrain its operating channel width to 20 MHz while being a member of a 20/40 MHz BSS. Transitions to and from this constrained state are indicated using the transmission of a frame that carries the Channel Width field. A Channel Width field value of 0 indicates that the transmitting STA is not currently able to receive 40 MHz PPDUs, beginning at the end of the transmission of the frame that contained the Channel Width field.

A STA shall not transmit a frame containing a STA Channel Width field or a Channel Width field set to 1 if the value of its Supported Channel Width Set subfield is 0.

A STA that is associated with an infrastructure BSS (STA1) shall not transmit a 40 MHz PPDU containing one or more frames addressed to another STA (STA2) unless the following three conditions are true:

— The Supported Channel Width Set subfield of the HT Capabilities element of both STAs is equal to 1.
— The Secondary Channel Offset field of the most recently received HT Operation element sent by the AP of the BSS has a value of SCA or SCB.
— The MAC variable *40MHzOperatingClass* is true.

If the above three conditions are met, STA1 should not transmit a 40 MHz PPDU containing one or more frames addressed to STA2 unless the following two conditions are true:

— Either STA1 has not received a Notify Channel Width frame that was transmitted by STA2, or the Channel Width field of the most recently received Notify Channel Width frame at STA1 that was transmitted by STA2 is nonzero.
— If STA2 is an AP, the STA Channel Width field of the most recently received HT Operation element that was transmitted by STA2 is equal to 1.

11.15.4.3 AP restrictions

An AP shall not transmit a 40 MHz PPDU containing one or more frames addressed to another STA unless the following three conditions are true:

— The Supported Channel Width Set subfield of the HT Capabilities element of the AP and all associated STAs are not equal to 0.
— The Secondary Channel Offset field of the AP's most recently transmitted HT Operation element has a value of SCA or SCB.
— The MAC variable *40MHzOperatingClass* is true.

If the above three conditions are met, the AP should not transmit a 40 MHz PPDU containing frames addressed to another STA unless either the AP has not received a Notify Channel Width frame that was transmitted by the STA or the Channel Width field of the most recently received Notify Channel Width frame at the AP that was transmitted by the STA is nonzero.

An AP shall not transmit a 40 MHz PPDU containing one or more frames with a group address in the Address 1 field unless the following three conditions are true:

— The Supported Channel Width Set subfield of the HT Capabilities element of the AP is equal to 1.
— The Secondary Channel Offset field of the AP's most recently transmitted HT Operation element has a value of SCA or SCB.
— The MAC variable *40MHzOperatingClass* is true.

If the above three conditions are met, the AP should not transmit a 40 MHz PPDU containing one or more frames with a group address in the Address 1 field unless either the AP has not received a Notify Channel Width frame from any STA in the BSS or the Channel Width field of the most recently received Notify Channel Width frame from each STA that transmitted a Notify Channel Width frame is nonzero.

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11.15.4.4 Restrictions on non-AP STAs that are not infrastructure BSS members

An HT STA 2G4 that is not a member of an infrastructure BSS shall not transmit a 40 MHz mask PPDU.

An HT STA 5G that is not associated with an infrastructure BSS (STA1) shall not transmit a 40 MHz PPDU containing frames addressed to another STA (STA2) unless the following three conditions are true:

— The Supported Channel Width Set subfield of the HT Capabilities element of both STAs is equal to 1.

— The Secondary Channel Offset field of the most recently received HT Operation element sent by STA2 has a value of SCA or SCB.

— The Secondary Channel Offset field of the most recently transmitted HT Operation element sent by STA1 has a value of SCA or SCB.

If the above three conditions are met, STA1 should not transmit a 40 MHz PPDU containing one or more frames addressed to STA2 unless STA1 has not received a STA Channel Width field that was transmitted by STA2 or the most recently received STA Channel Width field at STA1 that was transmitted by STA2 is nonzero.

An HT STA 5G that is not associated with an infrastructure BSS (STA1) shall not transmit a 40 MHz PPDU containing one or more frames with a group address in the Address 1 field unless the following two conditions are true:

— The Supported Channel Width Set subfield of the HT Capabilities element transmitted by STA1 is equal to 1.

— The Secondary Channel Offset field of the HT Operation element most recently transmitted by STA1 has a value of SCA or SCB.

If the above two conditions are met, STA1 should not transmit a 40 MHz PPDU containing one or more frames with a group address in the Address 1 field unless the most recently received STA Channel Width field for each other known member of the BSS of which STA1 is a member is equal to 1.

11.15.5 Scanning requirements for 40MC HT STA 2G4

An OBSS scan operation is a passive or active scan of a set of channels that are potentially affected by 20/40 MHz BSS operation, i.e., the 20 MHz channels that wholly or partly overlap the 40 MHz signal. Each channel in the set may be scanned more than once during a single OBSS scan operation. OBSS scans are performed by STAs that are 40MC HT STA 2G4. STAs that are 40MC HT STA 5G are not required to perform OBSS scan operations.

NOTE 1—STAs that perform OBSS scans report discovered BSSs and received 20/40 BSS coexistence information to their associated AP (see 11.15.12).

During an individual scan within an OBSS scan operation, the minimum per-channel scan duration is dot11OBSSScanPassiveDwell TU (when scanning passively) or dot11OBSSScanActiveDwell TU (when scanning actively). During an OBSS scan operation, each channel in the set is scanned at least once per dot11BSSWidthTriggerScanInterval seconds, and the minimum total scan time (i.e., the sum of the scan durations) per channel within a single OBSS scan operation is dot11OBSSScanPassiveTotalPerChannel TU for a passive scan and dot11OBSSScanActiveTotalPerChannel TU for an active scan.

NOTE 2—The values provided in the previous paragraph indicate the minimum requirements. For some combinations of parameter values, it is necessary to exceed the minimum values of some parameters in order to meet the minimum value constraints of all parameters.

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When an AP transmits an Overlapping BSS Scan Parameters element, the value of each of the fields of the element shall be set to the MIB attribute from the transmitting AP's MIB according to the mapping between the frame fields and MIB attributes as defined in 9.4.2.58.

Upon receipt of a frame containing an Overlapping BSS Scan Parameters element from the AP with which a 40MC HT STA 2G4 is associated, the MLME of the receiving 40MC HT STA 2G4 shall update each of the values of the MIB attributes used during OBSS scanning operations according to the mapping between the frame fields and MIB attributes as defined in 9.4.2.58.

A 40MC HT AP 2G4 may transmit frames containing an Overlapping BSS Scan Parameters element to any or all associated STAs in order to provide OBSS scan parameter values that are different from the default values.

A 40MC HT STA 2G4 that is associated with a 40MC HT AP 2G4 shall perform at least one OBSS scan every dot11BSSWidthTriggerScanInterval seconds, unless the 40MC HT STA 2G4 satisfies the conditions described in 11.15.6.

11.15.6 Exemption from OBSS scanning

A 40MC HT STA 2G4 shall maintain a MAC variable *ActivityFraction*. The value of *ActivityFraction* is defined by Equation (11-3).

$$ActivityFraction = \frac{T_{ACTIVE}}{T_{MEASURE\text{-}ACTIVE}} \tag{11-3}$$

where

T_{ACTIVE} is the total duration of transmitted MSDUs and received individually addressed MSDUs during the previous $T_{MEASURE\text{-}ACTIVE}$ seconds

$T_{MEASURE\text{-}ACTIVE}$ is dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds

A 40MC HT STA 2G4 may transmit to its associated AP a 20/40 BSS Coexistence Management frame with the Scanning Exemption Request field in the 20/40 BSS Coexistence element set to 1.

If the last 20/40 BSS Coexistence Management frame received by a 40MC HT STA 2G4 in an individually addressed frame from its associated AP has the Scanning Exemption Grant field equal to 1, the STA is exempted from scanning whenever the value of its MAC variable *ActivityFraction* is less than dot11OBSSScanActivityThreshold/10 000.

A 40MC HT AP 2G4 shall not transmit a 20/40 BSS Coexistence Management frame with the Scanning Exemption Grant field set to 1 addressed to a 40MC HT STA if the following condition is true:

— The 40MC HT STA has transmitted one or more channel report elements and is the only STA in the BSS that has indicated one or more channels on which a STA has found conditions that disallow the use of a 20/40 MHz BSS.

If there is more than one 40MC HT STA in the BSS that has indicated conditions that disallow the use of 20/40 MHz BSS on a specific channel, then the following apply:

— If all of the 40MC HT STAs that have indicated unavailability of a channel have also requested to be exempt from scanning, the AP shall disallow at least one of the 40MC HT STA to be exempt from scanning.

— If, from the group of 40MC HT STAs that have indicated unavailability of a channel, there is at least one 40MC HT STA that has not requested to be exempt from scanning, the AP may allow all of the STAs that have requested to be exempt from scanning to be exempted from scanning.

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11.15.7 Communicating 20/40 BSS coexistence information

In addition to the 20/40 BSS Coexistence Management frame, a STA can include the 20/40 BSS Coexistence element in transmitted Beacon, Probe Request, Probe Response, (Re)Association Request, and (Re)Association Response frames.

11.15.8 Support of DSSS/CCK in 40 MHz

Transmission and reception of PPDUs using DSSS/CCK by 40MC HT STAs is managed using the DSSS/CCK Mode in 40 MHz subfield of the HT Capability Information field in the HT Capabilities element (see 9.4.2.55.2).

An HT STA declares its capability to use DSSS/CCK rates while it has a 40 MHz operating channel width through the DSSS/CCK Mode in 40 MHz subfield of its (Re)Association Request frames.

If the DSSS/CCK Mode in 40 MHz subfield is equal to 1 in Beacon and Probe Response frames, an associated HT STA in a 20/40 MHz BSS may generate DSSS/CCK transmissions. If the subfield is equal to 0, then the following apply:

— An associated HT STA shall not generate DSSS/CCK transmissions.
— The AP shall not include an ERP element in its Beacon and Probe Response frames.
— The AP shall not include DSSS/CCK rates in the Supported Rates and BSS Membership Selectors element or Extended Supported Rates and BSS Membership Selectors element.
— The AP shall refuse association requests from a STA that includes only DSSS/CCK rates in its Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element.
— The DSSS/CCK Mode in 40 MHz subfield transmitted by a (re)associating STA is ignored.

A STA not operating in the 2.4 GHz band shall set the DSSS/CCK Mode in 40 MHz subfield to 0.

11.15.9 STA CCA sensing in a 20/40 MHz BSS

This subclause defines CCA sensing rules for an HT STA that is not a VHT STA. For rules related to a VHT STA, see 10.3.2.7, 10.23.2.7, and 10.23.3.

A STA may transmit a 20 MHz mask PPDU in the primary channel following the rules in 10.23.2.

A STA transmitting a 40 MHz mask PPDU that begins a TXOP using EDCA as described in 10.23.2.4 or that is using a PIFS as permitted in 10.3.2.3.4 shall sense CCA on both the 20 MHz primary channel and the 20 MHz secondary channel before the 40 MHz mask PPDU transmission starts.

Unless explicitly stated otherwise, a STA may treat a PHY-CCA.indication(BUSY) primitive as a PHY-CCA.indication(IDLE) primitive in the following cases:

— If the channel-list parameter is present and equal to {secondary} and the STA is transmitting a 20 MHz mask PPDU on the primary channel, or
— If the channel-list parameter is present and equal to {primary} and the STA is transmitting a 20 MHz mask PPDU on the secondary channel.

NOTE 1—Transmission of PPDUs on the secondary channel is also subject to constraints in 11.15.2.

At the specific slot boundaries (see Figure 10-25) determined by the STA based on the 20 MHz primary channel CCA, when the transmission begins a TXOP using EDCA (as described in 10.23.2.4), the STA may transmit a pending 40 MHz mask PPDU only if the secondary channel has also been idle during the times the

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primary channel CCA is performed (defined in 10.23.2.4) during an interval of a PIFS for the 5 GHz band and DIFS for the 2.4 GHz band immediately preceding the expiration of the backoff counter. If a STA was unable to transmit a 40 MHz mask PPDU because the secondary channel was occupied during this interval, it may take one of the following steps:

a) Transmit a 20 MHz mask PPDU on the primary channel.

b) Restart the channel access attempt. In this case, the STA shall invoke the backoff procedure as specified in 10.23.2 as though the medium is busy as indicated by either physical or virtual CS and the backoff counter has a value of 0.

NOTE 2—As a result of this rule, the STA selects a new random number using the current value of CW[AC], and the retry counts are not updated.

When a TXOP is obtained for a 40 MHz PPDU, the STA may transmit 40 MHz PPDUs and/or 20 MHz PPDUs during the TXOP. When the TXOP is obtained by the exchange of 20 MHz PPDUs only in the primary channel, the STA shall not transmit 40 MHz PPDUs during the TXOP.

11.15.10 NAV assertion in 20/40 MHz BSS

An HT STA shall update its NAV using the Duration/ID field value in any frame received in a 20 MHz PPDU in the primary channel or received in a 40 MHz PPDU and that does not have an RA matching the STA's MAC address.

NOTE—A STA need not set its NAV in response to 20 MHz frames received on the secondary channel or any other channel that is not the primary channel, even if it is capable of receiving those frames.

11.15.11 Signaling 40 MHz intolerance

An HT STA 2G4 shall set the Forty MHz Intolerant field to 1 in transmitted HT Capabilities elements if dot11FortyMHzIntolerant is true; otherwise, the field shall be set to 0.

A STA 2G4 shall set the Forty MHz Intolerant field to 1 in transmitted 20/40 BSS Coexistence fields if dot11FortyMHzIntolerant is true; otherwise, the field shall be set to 0. A STA 2G4 that is not an HT STA 2G4 shall include a 20/40 BSS Coexistence element in Management frames in which the element may be present if dot11FortyMHzIntolerant is present and dot11FortyMHzIntolerant is true.

A STA 5G shall set the Forty MHz Intolerant field to 0 in transmitted HT Capabilities elements and 20/40 BSS Coexistence fields.

11.15.12 Switching between 40 MHz and 20 MHz

A VHT STA is not required to perform any of the behavior described in this subclause associated with Information Request and 20 MHz BSS Width Request.

The following events are defined to be BSS channel width trigger events (TEs):

— **TE-A**: On any of the channels of the channel set defined in Clause 18, reception of a Beacon frame that does not contain an HT Capabilities element.

— **TE-B**: On any of the channels of the channel set defined in Clause 18, reception of a 20/40 BSS Coexistence Management, Beacon, Probe Request, or Probe Response frame that contains a value of 1 in a Forty MHz Intolerant field and that has the Address 1 field equal to the receiving STA's address or to a group address value, with no further addressing qualifications.

— **TE-C**: Reception of a 20/40 BSS Coexistence Management frame with the 20 MHz BSS Width Request field equal to 1 and with an Address 1 field that matches the receiving STA using either

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individual or group addressing and with a TA field that corresponds to the MAC address of a STA with which the receiver is associated.

— **TE-D**: Reception of a 20/40 BSS Coexistence Management frame containing at least one 20/40 BSS Intolerant Channel Report element with a nonzero length and with an Address 1 field equal to the receiving STA's address or to a group address value, but with no qualification of the Address 3 field.

A 40MC HT AP 2G4 shall reevaluate the value of the MAC variable *20/40 Operation Permitted* (see 11.15.3.2) when either of the following events occurs:

— A BSS channel width trigger event TE-A is detected.

— A BSS channel width trigger event TE-D is detected.

A 40MC HT AP 2G4 may reevaluate the value of the MAC variable *20/40 Operation Permitted* (see 11.15.3.2) when either of the following situations occurs:

— No BSS channel width trigger events TE-A are detected for a period of time equal to dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds.

— No BSS channel width trigger events TE-D are detected for a period of time equal to dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds.

A 40MC HT AP 2G4 that detects either BSS channel width trigger event TE-B or TE-C or that determines that the value of the MAC variable *20/40 Operation Permitted* has changed from true to false shall set the Secondary Channel Offset field to SCN in transmitted HT Operation elements beginning at the next DTIM or next TBTT if no DTIMs are transmitted to indicate that no secondary channel is present (i.e., that the BSS operating width is 20 MHz).

A 40MC HT AP 2G4 shall not set the Secondary Channel Offset field to a value of SCA or SCB in transmitted HT Operation elements unless the following two conditions have been met:

— A period of dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds have elapsed during which no BSS channel width trigger events TE-B or TE-C are detected.

— The value of the MAC variable *20/40 Operation Permitted* (see 11.15.3.2) is true.

To request an update of the status of the 20 MHz BSS Width Request field, a 40MC HT AP 2G4 can transmit a 20/40 BSS Coexistence Management frame with a value of 1 in the Information Request field as described in 11.16.

A 40MC HT STA 2G4 that is associated with a 40MC HT AP 2G4 shall maintain a record of detected BSS channel width trigger events as follows:

— For each detected BSS channel width trigger event TE-A:
  — If a DSSS Parameter Set field is present in the received Beacon frame, the channel of the BSS channel width trigger event is set to the value of the Current Channel field of the DSSS Parameter Set field; otherwise, the channel of the BSS channel width trigger event is the channel on which the detecting STA received the Beacon frame.
  — If a Supported Operating Classes element is present in the received Beacon frame, the operating class of the BSS channel width trigger event is set to the value of the Current Operating Class field of the Supported Operating Classes element of the received Beacon frame; otherwise, the operating class of the BSS channel width trigger event is "unknown."
— For each detected BSS channel width trigger event TE-A of a unique combination of operating class and channel, the 40MC HT STA 2G4 shall maintain a record containing two MAC variables:
  — The operating class of the BSS channel width trigger event
  — The channel of the BSS channel width trigger event

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NOTE—If a BSS channel width trigger event TE-A is detected for an operating class and channel combination for which no record exists, the STA creates such a record.

If a BSS channel width trigger event TE-A is detected for an operating class and channel combination for which a record already exists, the information in that record shall be updated with the information determined from the new trigger event.

For all BSS channel width trigger events TE-B, the 40MC HT STA 2G4 shall maintain a single record containing an indication of whether one or more trigger events TE-B have been detected.

At the completion of an OBSS scan operation (i.e., at the end of the period of time equal to dot11BSSWidthTriggerScanInterval) or when it receives a 20/40 BSS Coexistence Management frame from its associated AP that contains a value of 1 in the Information Request field, a 40MC HT STA 2G4 that is associated with a 40MC HT AP 2G4 shall create a 20/40 BSS Coexistence Management frame by including a value of 0 for all fields of a 20/40 BSS Coexistence Management frame and then transferring information from the BSS channel width trigger event TE-A and TE-B records to the frame according to the following four steps:

— For each unique operating class that is stored in the set of BSS channel width trigger event TE-A records, the STA shall create a 20/40 BSS Intolerant Channel Report element for inclusion in the frame and include all of the unique channels associated with the operating class in the channel list of that element.
— The STA sets the Forty MHz Intolerant field of the 20/40 BSS Coexistence element per the rules listed in 11.15.11.
— The STA shall set to 1 the 20 MHz BSS Width Request field of the 20/40 BSS Coexistence element for inclusion in the frame if a record for BSS channel width trigger event TE-B exists and indicates that at least one trigger event TE-B has been detected.
— The STA may set to 1 the Information Request field.

Upon completion of these four steps, the 40MC HT STA 2G4 shall delete all records for trigger events TE-A and TE-B. Subsequently detected trigger events cause the creation of new records as necessary to be used in subsequently generated 20/40 BSS Coexistence Management frames. Following the record deletion, the 40MC HT STA 2G4 shall transmit to its associated 40MC HT AP 2G4 the 20/40 BSS Coexistence Management frame if any of the following conditions is true:

— At least one 20/40 BSS Intolerant Channel Report element with the Length field not equal to 0 is included.
— The Forty MHz Intolerant field is equal to 1.
— The 20 MHz BSS Width Request field is equal to 1.
— The Information Request field is equal to 1.
— The frame was created in response to an Information Request field that was equal to 1.

11.16 20/40 BSS Coexistence Management frame usage

A STA that supports the 20/40 BSS Coexistence Management frame type shall set the 20/40 BSS Coexistence Management Support field to 1 in transmitted Extended Capabilities elements.

A STA that supports the 20/40 BSS Coexistence Management frame type shall include an Extended Capabilities element in transmitted Beacon, (Re)Association Request, (Re)Association Response, Probe Request, and Probe Response frames.

A STA shall not transmit to another STA a 20/40 BSS Coexistence Management frame with an individual address in the Address 1 field if the Extended Capabilities element from the recipient STA contained a value

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of 0 in the 20/40 BSS Coexistence Management Support field. A STA that transmits a 20/40 BSS Coexistence Management frame may set the Address 1 field to a group address.

NOTE—A 20/40 BSS Coexistence Management frame is a Class 1 frame and, therefore, can be sent to a STA that supports reception of such frames and that is not a member of the same BSS as the transmitting STA. In such a case, the BSSID field of the frame is set to the wildcard BSSID value, regardless of whether the Address 1 field contains an individual or group address value.

A STA may transmit a 20/40 BSS Coexistence Management frame that contains a value of 1 for the Request Information field to another STA that supports the transmission of and reception of the 20/40 BSS Coexistence Management frame, except when the frame is a response to a 20/40 BSS Coexistence Management frame that contains a value of 1 for the Request Information field.

A non-VHT STA that receives a 20/40 BSS Coexistence element with the Information Request field equal to 1, an Address 1 field that matches the receiving STA using an individual address, and a nonwildcard BSSID field that matches the STA's BSS shall immediately queue for transmission a 20/40 BSS Coexistence Management frame with the transmitting STA as the recipient.

11.17 Public Action frame addressing

A STA that is a member of a BSS and that transmits an individually addressed Public Action frame to a STA that is not a member of the same BSS shall set the BSSID field of the frame as follows:

— If the recipient STA is known to be a member of another BSS (including being an AP) and that BSS's BSSID is known, the BSSID field shall be set to the BSS's BSSID or the wildcard BSSID value.
— Otherwise, the BSSID field of the frame shall be set to the wildcard BSSID value.

A STA that is a member of a BSS and that transmits a group addressed Public Action frame shall set the BSSID field of the frame to the BSS's BSSID or the wildcard BSSID value.

A STA that is a member of a BSS and that transmits an individually addressed Public Action frame to a STA that is a member of the same BSS shall set the BSSID field of the frame to the BSS's BSSID.

A STA that is not a member of a BSS and that transmits a Public Action frame shall set the BSSID field of the frame as follows:

— If the frame is individually addressed, the recipient STA is known to be a member of a BSS (including being an AP), and that BSS's BSSID is known, the BSSID field shall be set to the BSS's BSSID or the wildcard BSSID value.
— Otherwise, the BSSID field of the frame shall be set to the wildcard BSSID value.

11.18 STAs communicating Data frames outside the context of a BSS

When dot11OCBActivated is true in a STA:

a) Synchronization, authentication, association, and frame classes as defined in 11.1 and 11.3 are not used. Data confidentiality as defined in Clause 12 is not used. The STA may send Action frames and, if the STA maintains a TSF Timer, Timing Advertisement frames.
b) The STA may send Control frames, except those of subtype PS-Poll and CF-End.
c) The STA may send Data frames of subtype Data, Null, QoS Data, and QoS Null.
d) The STA shall set the BSSID field in all Management and Data frames to the wildcard BSSID value.

A STA with dot11OCBActivated equal to true shall not join or start a BSS.

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Whenever MAC sublayer and PHY parameters are changed in a STA in which dot11OCBActivated is true, MAC sublayer and PHY operation shall resume with the appropriate MIB attributes in less than 2 TU.

11.19 Timing advertisement

11.19.1 Introduction

A STA may advertise a time standard by transmitting a Timing Advertisement element in one of the following frames: Timing Advertisement, Probe Response, Beacon, DMG Beacon or Announce. As defined in 9.4.2.60 the Time Advertisement element contains two estimates. The Time Value field contains an estimate of the difference between a time standard and the timestamp included in the same frame. The Time Error field contains an estimate of the standard deviation of the error in the estimate in the Time Value field. The time standard might be derived from an external time source. A STA with an external time source might implement an estimator in a variety of ways, which are beyond the scope of this standard.

11.19.2 Timing advertisement frame procedures

The SME provides the Time Advertisement element to the MLME when it requests the MLME to send a Timing Advertisement frame. When a Timing Advertisement frame is received by a STA, its MLME reports the Timestamp, Local Time, Time Advertisement element, and estimates of propagation delay to the SME. For a STA that maintains a TSF Timer and receives a Timing Advertisement frame, Local Time is the value of the STA's TSF timer at the start of reception of the first octet of the Timestamp field of the frame. Otherwise, the Local Time is unspecified. The receiving STA's SME might use the Timestamp, Local Time, and Time Advertisement element to align its estimate of the time standard to the transmitting STA's estimate of the corresponding time standard.

11.19.3 UTC TSF Offset procedures

When dot11UTCTSFOffsetActivated is true, the Time Advertisement and Time Zone elements shall be included in all Probe Response frames, and the Time Advertisement element shall be included in the Beacon frame every dot11TimeAdvertisementDTIMInterval DTIMs. When dot11UTCTSFOffsetActivated is false, the Time Advertisement and Time Zone elements shall not be included in Beacon and Probe Response frames.

The AP should periodically synchronize to a UTC reference clock (ITU-R Recommendation TF.460-6 (2002) [B53]) so that the UTC TSF offset can account for drift. The AP shall increment the Time Update Counter field value in the Time Advertisement element each time the synchronization occurs. The method the AP uses to synchronize with a UTC reference clock is out of scope of the standard.

11.20 Tunneled direct-link setup

11.20.1 General

Tunneled direct-link setup (TDLS) is characterized by encapsulating setup frames in Data frames, which allows them to be transmitted through an AP transparently. Therefore, the AP does not need to be direct- link capable, nor does it have to support the same set of capabilities that are used on the direct link between the two TDLS peer STAs. TDLS also includes power saving, in the form of TDLS peer PSM (scheduled) and TPU (unscheduled). STAs that set up a TDLS direct link remain associated with their BSS, but have the option of transmitting frames directly to the other TDLS peer STA.

Transmitting a TDLS frame through the AP means that the frame's RA is set to the BSSID. Transmitting a frame over the direct path means that the frame's RA is set to the MAC address of the TDLS peer STA.

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To set up and maintain a direct link, both TDLS peer STAs shall be associated with the same infrastructure BSS.

A DMG STA shall not use the TDLS protocol.

A TDLS peer STA may be involved in direct links with multiple TDLS peer STAs at the same time.

The primary channel on which the AP operates is referred to as the base channel and a TDLS STA that operates on this channel is referred to as on the base channel. If the direct link is switched to a channel that is not the base channel, then this channel is referred to as the off-channel, and a TDLS STA that operates on this channel is referred to as off-channel.

Features that are not supported by the BSS but that are supported by both TDLS peer STAs may be used on a TDLS direct link between those STAs. An example is the use of an HT-MCS on a TDLS direct link between HT STAs when these STAs are associated with a non-HT BSS. Features that are supported by the BSS shall follow the BSS rules when they are used on a TDLS direct link on the base channel. The channel width of a TDLS direct link on the base channel shall not exceed the channel width of the BSS of which the TDLS peer STAs are members, except when the TDLS Wider Bandwidth subfield in the Extended Capabilities element of the TDLS Setup Request frame or the TDLS Setup Response frame is 1 for both TDLS peer STAs.

A VHT STA with a TDLS link that is not an off-channel direct link shall use as its primary channel the primary channel or the only channel of its BSS. The channel width of a VHT TDLS link shall not be wider than the maximum channel width supported by either the TDLS initiator STA or the TDLS responder STA.

A 160 MHz bandwidth is defined to be identical to an 80+80 MHz bandwidth (i.e., one bandwidth is not wider than the other).

A STA shall not participate in a TDLS direct link with the same primary 80 MHz channel as the infrastructure BSS or another TDLS direct link of the STA but with a different secondary 80 MHz channel.

When admission control is required for an AC on the base channel, then the TDLS peer STA that intends to use this AC for direct-link transmissions on the base channel is responsible for setting up a TS with Direction of Direct Link with the AP, as defined in 10.23.4.2.

An S1G STA with a TDLS link that is not an off-channel direct link shall use as its primary channel the channel indicated by the Primary Channel Number field in the S1G Operation element. The channel width of an S1G TDLS link shall not be wider than the maximum channel width supported by either the TDLS initiator STA or the TDLS responder STA.

A non-AP STA may act as TDLS initiator STA or TDLS responder STA when dot11TunneledDirectLinkSetupImplemented is true.

TDLS frames shall use the formatting as specified in 11.20.2 when they are transmitted through the AP and when they are transmitted over the TDLS direct link. A STA shall not transmit a TDLS Action field in a frame with the Type field of the frame set to Management. A received TDLS Action field in a frame with the Type field equal to Management shall be discarded. Note that the TDLS Discovery Response frame is not a TDLS frame but a Public Action frame.

TDLS shall not be used in an IBSS.

TDLS shall not be used in an MBSS.

Security is available on the TDLS direct link only when both TDLS peer STAs have an RSNA with the BSS.

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TDLS shall not be used when the TDLS Prohibited subfield included in the Extended Capabilities element of the Association Response frame or Reassociation Response frame that led to the current association is equal to 1.

The HT Operation element shall be present in a TDLS Setup Confirm frame when both STAs are HT capable.

The VHT Operation element shall be present in a TDLS Setup Confirm frame when both STAs are VHT capable and the TDLS direct link is not established in the 2.4 GHz band. When the TDLS Setup Confirm frame includes a VHT Operation element, the Basic VHT-MCS And NSS Set field is reserved.

The S1G Operation element shall be present in a TDLS Setup Confirm frame for S1G STA.

11.20.2 TDLS payload

TDLS uses Ethertype 89-0d frames, as defined in Annex H. The TDLS payload contains a TDLS Action field as is specified in 9.6.12. The UP shall be AC_VI, unless otherwise specified.

11.20.3 TDLS Discovery

To discover TDLS STAs in the same BSS, a TDLS initiator STA may send a TDLS Discovery Request frame to an individual DA, through the AP. The TDLS responder STA Address field contained in the Link Identifier element of the TDLS Discovery Request frame shall be set to the Destination Address of the TDLS Discovery Request frame. A TDLS STA that receives a TDLS Discovery Request frame with a matching BSSID in the Link Identifier element shall send a TDLS Discovery Response frame to the requesting STA, via the direct path. The TDLS responder STA Address field contained in the Link Identifier element of the TDLS Discovery Response frame shall be set to the MAC address of the STA sending the TDLS Discovery Response frame. A TDLS Discovery Request frame shall not be sent within dot11TDLSDiscoveryRequestWindow DTIM intervals after transmitting TDLS Discovery Request frame.

A TDLS STA may send an individually addressed TDLS Discovery Response frame via the direct path without prior reception of a TDLS Discovery Request frame. A TDLS STA that receives such an unsolicited TDLS Discovery Response frame may respond with an individually addressed TDLS Discovery Response frame.

A TDLS Discovery Request frame shall not be sent to a group address. A TDLS Discovery Response frame shall not be sent to a group address.

A TDLS STA may also send a TDLS Setup Request frame to a STA in the same BSS to discover whether the peer STA is a TDLS STA. A TDLS Setup Response frame transmitted in response to TDLS Setup Request frame indicates that the peer STA sending the TDLS Setup Response frame is a TDLS STA.

An alternative mechanism to discover TDLS STAs in the same BSS, is provided by the TDLS Capability ANQP-element, as described in 11.22.3.3.10. This mechanism allows the ANQP request/response frames to use the direct path between the peer STAs.

11.20.4 TDLS direct-link establishment

To establish a TDLS direct link, the TDLS initiator STA shall send a TDLS Setup Request frame to the intended TDLS responder STA.

TDLS Setup Request frames, TDLS Setup Response frames, and TDLS Setup Confirm frames shall be transmitted through the AP and shall not be transmitted to a group address.

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Upon receipt of a TDLS Setup Request frame, the following options exist at the TDLS responder STA:

a) The TDLS responder STA accepts the TDLS Setup Request frame, in which case the TDLS responder STA shall respond with a TDLS Setup Response frame with status code SUCCESS.

b) The TDLS responder STA declines the TDLS Setup Request frame, in which case the TDLS responder STA shall respond with a TDLS Setup Response frame with status code REQUEST_DECLINED. A TDLS setup request shall be declined when the BSSID in the received Link Identifier does not match the BSSID of the BSS of which the TDLS responder STA is a member.

c) The TDLS Setup Request frame is received after sending a TDLS Setup Request frame and before receiving the corresponding TDLS Setup Response frame, and the source address of the received TDLS Setup Request frame is higher than its own MAC address, in which case the TDLS responder STA shall discard the frame and the TDLS responder STA shall send no TDLS Setup Response frame.

d) The TDLS Setup Request frame is received after sending a TDLS Setup Request frame and before receiving the corresponding TDLS Setup Response frame, and the source address of the received TDLS Setup Request frame is lower than its own MAC address. In this case, the TDLS responder STA shall terminate the TDLS setup it initiated. The TDLS responder STA shall send a response according to item a) or item b) above in this case.

e) If a TDLS Setup Request frame is received from a TDLS responder STA with which a currently active TDLS session exists, then the receiving STA shall tear down the existing TDLS direct link as if a TDLS Teardown frame was received, and respond with a TDLS Setup Response frame.

If no TDLS Setup Response frame is received within dot11TDLSResponseTimeout, or if a TDLS Setup Response frame is received with a status code not equal to SUCCESS, the TDLS initiator STA shall terminate the setup procedure and discard the TDLS Setup Response frame. Otherwise, the TDLS initiator STA shall send a TDLS Setup Confirm frame to the TDLS responder STA to confirm the receipt of the TDLS Setup Response frame.

When the BSS does not support EDCA, EDCA may be used on the direct link (on the base channel and on the off-channel), with the default EDCA Parameter Set, per 10.2.3.2.

If security is required on the TDLS direct link (see 12.7.8.1), then the TPK handshake messages are included in the TDLS Setup frames, as follows:

— TPK handshake message 1 shall be included in the TDLS Setup Request frame.
— TPK handshake message 2 shall be included in the TDLS Setup Response frame.
— TPK handshake message 3 shall be included in the TDLS Setup Confirm frame.

When the TDLS setup handshake has been completed, the TDLS initiator STA and the TDLS responder STA are TDLS peer STAs. A TDLS peer STA shall accept Data frames received from the respective TDLS peer STA directly and Data frames destined for the respective TDLS peer STA may be transmitted over the direct link.

Subsequent to the successful completion of the TPK handshake, all frames transmitted and received on the TDLS direct link shall be protected using the TPKSA, per the procedures defined in Clause 12.

To avoid possible reordering of MSDUs, a TDLS initiator STA shall cease transmitting MSDUs to the TDLS responder STA through the AP after sending a TDLS Setup Request frame, and a TDLS responder STA shall cease transmitting MSDUs to the TDLS initiator STA through the AP after sending a TDLS Setup Response frame indicating status code SUCCESS.

The TDLS Setup Request frame and the TDLS Setup Response frame shall be transmitted using the lowest AC that was used for transmitting MSDUs to the respective TDLS peer STA during the previous

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dot11TDLSACDeterminationInterval seconds, or at AC_BK. When no MSDUs were transmitted during the previous dot11TDLSACDeterminationInterval seconds, then the TDLS Setup Request frame and the TDLS Setup Response frame may be sent at any AC, subject to applicable Admission Control rules.

If no TDLS Setup Response frame is received within dot11TDLSResponseTimeout, or if a TDLS Setup Response frame is received with status code other than SUCCESS, the TDLS initiator STA may resume transmitting MSDUs to the TDLS responder STA through the AP.

If a TDLS Setup Confirm frame is transmitted with a status code other than SUCCESS, the TDLS initiator STA may resume transmitting MSDUs to the TDLS responder STA through the AP.

If a TDLS Setup Confirm frame is received with a status code other than SUCCESS, the TDLS responder STA may resume transmitting MSDUs to the TDLS initiator STA through the AP.

A TDLS peer STA shall not transmit MSDUs over the direct link before transmitting or receiving a TDLS Setup Confirm frame with status code SUCCESS.

11.20.5 TDLS direct-link teardown

To tear down a direct link, a TDLS peer STA shall send a TDLS Teardown frame to the respective TDLS peer STA. A TDLS peer STA shall disable the direct link and delete the related security parameters after successfully transmitting TDLS Teardown frame. If security is required on the TDLS direct link (see 12.7.8.1), then the FTE shall be included in the TDLS Teardown frame.

The TDLS Teardown frame shall be sent over the direct path and the reason code shall be set to TDLS_UNSPECIFIED_REASON except when the TDLS peer STA is unreachable via the TDLS direct link, in which case, the TDLS Teardown frame shall be sent through the AP and the reason code shall be set to TDLS_PEER_UNREACHABLE. If the direct link is on an off-channel when this condition occurs, then the TDLS peer STA may switch back to the base channel without initiating a channel switch frame exchange, before transmitting the TDLS Teardown frame.

If present, the contents of the FTE in the TDLS Teardown frame shall be the same as that included in the TPK handshake message 3 with the exception of the MIC field. The MIC shall be calculated on the concatenation, in the following order, of:

— Link Identifier element
— Reason Code
— Dialog token that was used in the MIC calculation for TPK handshake message 3
— Transaction Sequence number (1 octet) which shall be set to the value 4
— FTE, with the MIC field of the FTE set to 0

The MIC shall be calculated using the TPK-KCK and the AES-128-CMAC algorithm. The output of the AES-128-CMAC shall be 128 bits.

If the TPK handshake was successful for this TDLS session, then a receiving STA shall validate the MIC in the TDLS Teardown frame prior to processing the TDLS Teardown frame; a TDLS Teardown frame in which the MIC validation fails is called an *invalid* TDLS Teardown frame. A TDLS peer STA that receives a TDLS Teardown frame that is not an invalid TDLS Teardown frame shall disable the direct link and delete the related security parameters.

When a TDLS direct link gets torn down, any related TSs shall be deleted by the TDLS peer STAs.

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A TDLS Teardown frame with Reason Code LEAVING_NETWORK_DEAUTH shall be transmitted to all TDLS peer STAs (via the AP or via the direct path) prior to reassociation with a different AP, deauthentication, disassociation, or association. After receiving a Deauthentication frame or a Disassociation frame from the AP, a Deauthentication frame with Reason Code LEAVING_NETWORK_DEAUTH shall be transmitted via the direct path to all TDLS peer STAs that are in the awake state, if management frame protection has not been negotiated on the TDLS direct link.

11.20.6 TDLS channel switching

11.20.6.1 General

A STA that supports TDLS channel switching has dot11TDLSChannelSwitchingActivated equal to true and shall set dot11MultiDomainCapabilityActivated and dot11ExtendedChannelSwitchActivated to true. When TDLS channel switching is enabled, the STA may set TDLS Channel Switching subfield to 1. The STA shall include a Supported Channels element and a Supported Operating Classes element in all TDLS Setup Request and TDLS Setup Response frames that have a TDLS Channel Switching subfield equal to 1. The STA shall include only channels in the Supported Channels element for which it can adhere to the local power constraint. A channel switch shall not be initiated by a STA when the TDLS peer STA did not set the TDLS Channel Switching capability field to 1 in the transmitted TDLS Setup Request frame or the TDLS Setup Response frame that caused the TDLS direct link to be set up.

TDLS Channel Switch Request frames and TDLS Channel Switch Response frames shall be transmitted over the TDLS direct link.

TDLS channel switching is different from (I)BSS channel switching as defined in 11.8.8.

The target channel is the destination channel of an intended channel switch. The target channel is specified by the STA that initiates a channel switch, from the set of operating classes supported by both TDLS peer STAs. The target channel and operating class are specified in the TDLS Channel Switch Request frame. The Country and Coverage Class settings on the target channel are the same as in the BSS of which both TDLS peer STAs are currently members. Both STAs are entitled to request a channel switch. The events occurring for a channel switch are illustrated in Figure 11-31.

In Figure 11-31, the TDLS peer STAs (STA1 and STA2) are operating on an initial channel. After contending for the medium, STA1 transmits a TDLS Channel Switch Request frame to STA2, via the direct link, indicating a requested switch to a target channel. STA2 transmits an Ack frame (denoted ACK1 in Figure 11-31) after SIFS, and processes the TDLS Channel Switch Request frame. After contending for the medium, STA2 transmits a TDLS Channel Switch Response frame to STA1, possibly also after entering power save mode with the AP. STA1 responds with an Ack frame (denoted ACK2 in Figure 11-31) after SIFS. If the TDLS Channel Switch Response frame indicated with status code REQUEST_DECLINED, then both STAs continue to operate on the current channel. If the TDLS Channel Switch Response frame indicated with status code SUCCESS, then both STAs shall be listening on the target channel not later than SwitchTime after the end of the last symbol of ACK2, as measured on the WM. After switching channels, each TDLS peer STA shall perform a clear channel assessment (CCA) on the target channel, until a frame is detected by which it can set its NAV, or until a period of time equal to at least dot11TDLSNavSync has transpired (this combined event is indicated as “ProbeTime” in Figure 11-31). The first transmission on the target channel shall be preceded by a random backoff, which shall start at the end of the ProbeTime. The first transmission on the new channel shall not start before the end of SwitchTime. The initiator of the channel switch shall transmit a Data frame on the target channel, unless the SwitchTimeout has expired or the responder to the channel switch transmitted a Data frame on the target channel.

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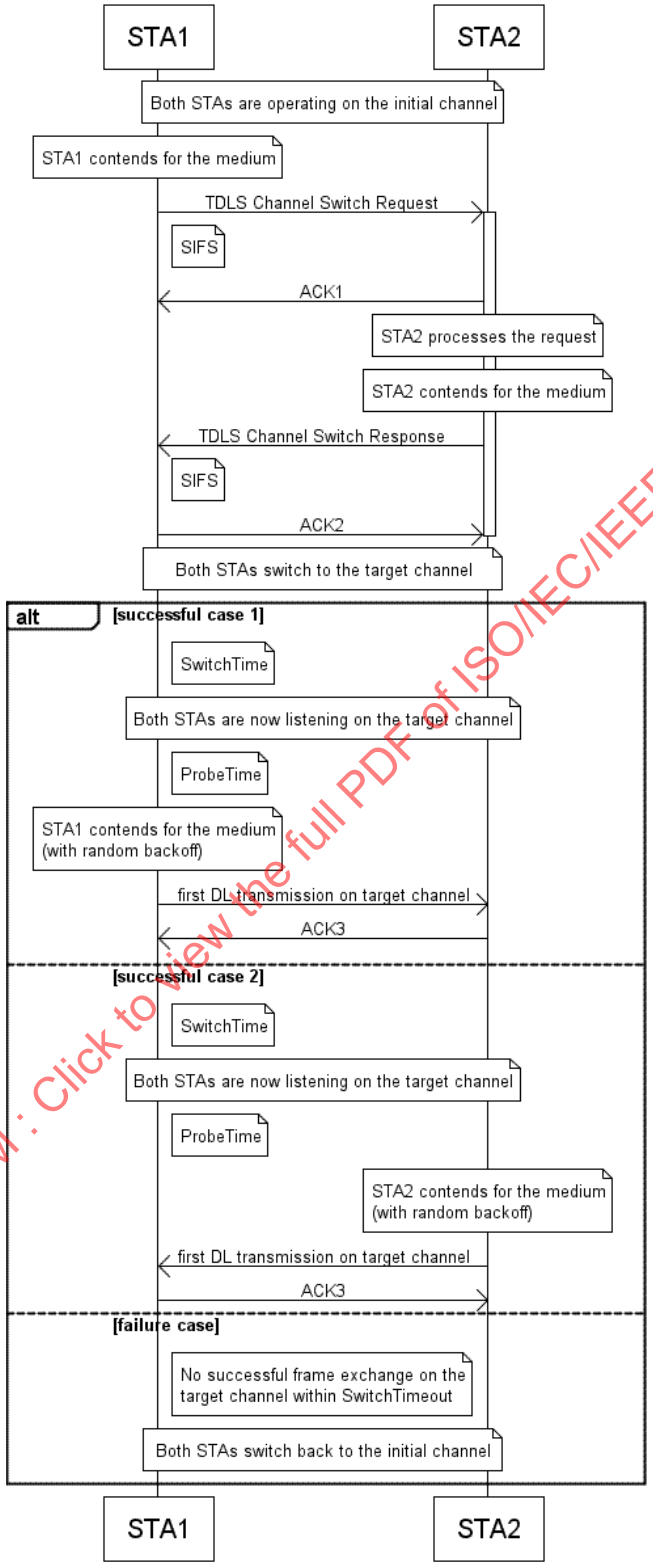

Figure 11-31—Events occurring for a TDLS direct-link channel switch

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If no successful frame exchange has occurred on an off-channel within SwitchTimeout after the end of the last symbol of ACK2, as measured on the WM, a STA shall go back to the base channel, where they shall be listening not later than SwitchTime after the end of the SwitchTimeout. After changing channels (either from the base channel to the off-channel or from the off-channel to the base channel), a TDLS peer STA shall perform CCA until a frame is detected by which it can set its NAV, or until a period of time equal to the ProbeTime has transpired.

Both the TDLS Channel Switch Request frame and the TDLS Channel Switch Response frame shall contain a Channel Switch Timing element. The SwitchTime and SwitchTimeout values in the TDLS Channel Switch Timing element included in the TDLS Channel Switch Request frame shall specify the values required at the STA sending the TDLS Channel Switch Request frame. The SwitchTime and SwitchTimeout values specified in the TDLS Channel Switch Timing element included in the TDLS Channel Switch Response frame shall meet the requirements at the STA sending the TDLS Channel Switch Response frame and shall be equal to or larger than the values specified in the TDLS Channel Switch Request frame. The timing parameters specified in the Channel Switch Timing element included in the TDLS Channel Switch Response frame shall be used for the TDLS channel switching procedure. This procedure causes the larger of the two switch times to become the value that is transmitted in the TDLS Channel Switch Response frame.

The TDLS peer STA shall be in PS mode with the AP and shall not be involved in an active Service Period with the AP before sending a TDLS Channel Switch Request frame or a TDLS Channel Switch Response frame with Status Code set to SUCCESS. The TDLS peer STA that receives a TDLS Channel Switch Request frame may enter PS mode with the AP prior to sending the TDLS Channel Switch Response frame.

Because there is at least a backoff between the TDLS Channel Switch Request frame and the TDLS Channel Switch Response frame, there is a (small) probability that two STAs issue a TDLS Channel Switch Request frame at more or less the same time. To reduce the probability for this event to occur, a TDLS peer STA should not transmit a TDLS Channel Switch Request frame when a TDLS Channel Switch Request frame is received and no TDLS Channel Switch Response has been transmitted in response. If a TDLS Channel Switch Request frame is received from the TDLS peer STA to which a pending TDLS Channel Switch Request frame was previously sent before receiving TDLS Channel Switch Response, the TDLS initiator STA shall not reply to the TDLS Channel Switch Request frame and the TDLS responder STA shall reply to the TDLS Channel Switch Request frame.

If a TDLS Channel Switch Response frame does not imply a channel switch because the STAs already are on the requested channel, then the SwitchTime and ProbeTime may be skipped and both TDLS peer STAs continue to operate on the requested channel. To cross means that a TDLS Channel Switch Request frame is received from a peer STA after transmitting a TDLS Channel Switch Request frame to the TDLS peer STA, instead of the expected TDLS Channel Switch Response frame.

When a TDLS peer STA does not receive an acknowledgment to a TDLS Channel Switch Response frame, it may retransmit the frame but the number of retransmissions shall be lesser of the maximum retry limit and dot11TDLSPeerSTAMissingAckRetryLimit.

A channel switch from an off-channel to the base channel may be accomplished by sending a TDLS Channel Switch Response frame indicating the base channel as the target channel, without prior TDLS Channel Switch Request frame. The Channel Switch Timing element shall be the same as contained in the Channel Switch Response frame that caused the switch to the off-channel.

TDLS Channel Switching shall not be used when the TDLS Channel Switching Prohibited subfield included in the Extended Capabilities element of the Association Response frame or Reassociation Response frame that led to the current association is equal to 1.

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11.20.6.2 General behavior on the off-channel

If dot11SpectrumManagementRequired is true, a TDLS peer STA shall not transmit a TDLS Channel Switch request specifying an off-channel where radar detection is required, unless the STA has tested that channel for the presence of radar, according to regulatory requirements. If a TDLS peer STA that is operating in such a channel detects radar, the TDLS peer STA shall discontinue transmissions according to regulatory requirements, and it shall send a TDLS Channel Switch Request frame indicating a switch to the base channel. The channel switch avoids an interruption on the direct link.

The TDLS peer STA initiating the switch to the channel where radar detection is required by regulation shall be the DFS owner.

The secondary channel of an existing 40 MHz network shall not be selected as an off-channel.

On an off-channel, the TDLS peer STAs remain associated with their BSS, so the BSSID remains the same.

It is recommended that in general TDLS STAs propose target channels that have no detectable medium occupancy. If no such channel is available, then it is recommended that the TDLS STA propose a target channel where beacons are detected but with little or no additional medium occupancy. It is further recommended that TDLS STAs do not propose a target channel where the presence of beacons indicate that ACM subfields are set, unless little or no additional medium occupancy is detected.

11.20.6.3 Setting up a 40 MHz direct link

11.20.6.3.1 General

A 40 MHz off-channel direct link may be started if both TDLS peer STAs indicated 40 MHz support in the Supported Channel Width Set field of the HT Capabilities element (which is included in the TDLS Setup Request frame and the TDLS Setup Response frame).

Switching to a 40 MHz off-channel direct link is achieved by including the following information in the TDLS Channel Switch Request frame:

— Operating Class field indicating 40 MHz channel spacing
— Secondary Channel Offset field indicating SCA or SCB

A 40 MHz off-channel direct link shall not be established in the 2.4 GHz band.

The TDLS peer STA initiating the switch to the 40 MHz off-channel shall be the DO.

11.20.6.3.2 Basic 40 MHz functionality

TDLS peer STAs may transmit 40 MHz PPDUs on a 40 MHz direct link. A TDLS peer STA shall not transmit a 20 MHz PPDU in the secondary channel of its 40 MHz direct link.

11.20.6.3.3 Channel selection for a 40 MHz direct link

If a TDLS peer STA chooses to start a 40 MHz direct link that occupies the same two channels as an existing 40 MHz network (i.e., a 20/40 MHz BSSs or a 40 MHz direct link), then it shall select primary and secondary channels of the new direct link that are identical to the primary and secondary channels of the existing 40 MHz network, unless the TDLS peer STA discovers that on these two channels there are existing 40 MHz networks with different primary and secondary channels.

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If a TDLS peer STA chooses to start a 40 MHz direct link, the selected secondary channel should correspond to a channel on which no beacons are detected.

11.20.6.3.4 Switching from a 40 MHz to a 20 MHz direct link

Switching from a 40 MHz off-channel direct link to a 20 MHz off-channel direct link is established through a TDLS channel switch. When on a 40 MHz off-channel direct link, a requested switch to a 20 MHz direct link shall always be accepted.

11.20.6.3.5 CCA sensing and NAV assertion in a 40 MHz direct link

When active on a 40 MHz direct link, a TDLS peer STA shall follow the CCA rules as defined in 11.15.9 and the NAV rules as defined in 11.15.10.

11.20.6.4 TDLS channel switching and power saving

A TDLS direct link shall not be switched to an off-channel during a TPU service period. While on an off-channel, a TDLS peer STA shall not enter TPU power save mode.

A TDLS direct link may be switched to an off-channel when TDLS peer PSM is active on the link. The wakeup windows occur on the off-channel in the same way they would have occurred had the STAs remained on the base channel. Suspension of the wakeup windows implies a switch back to the base channel.

11.20.6.5 Setting up a wide bandwidth off-channel direct link

11.20.6.5.1 General

A wideband TDLS off-channel TDLS direct link is a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz off-channel TDLS direct link for VHT STAs or a 2 MHz, 4 MHz, 8 MHz, or 16 MHz off-channel TDLS direct link for S1G STAs.

A wideband off-channel TDLS direct link may be started if both TDLS peer STAs indicated wideband support in the VHT Capabilities element or S1G Capabilities element included in the TDLS Setup Request frame or the TDLS Setup Response frame.

Switching to a wideband off-channel direct link is achieved by including any of the following information in the TDLS Channel Switch Request frame:

— An Operating Class element indicating 40 MHz Channel spacing and a Secondary Channel Offset element indicating SCA or SCB
— A Wide Bandwidth Channel Switch element indicating 80 MHz, 160 MHz, or 80+80 MHz channel width for VHT STAs
— A Wide Bandwidth Channel Switch element indicating 4 MHz, 8 MHz, or 16 MHz channel width for S1G STAs

For VHT STAs, the operating class in TDLS Channel Switch Request frame shall have a value representing 5 GHz for the channel starting frequency.

A TDLS peer STA that is extended spectrum management capable and that announces new TPC parameters that come into effect at the same time as the switch to an off-channel direct link, shall include at least one Transmit Power Envelope element in the transmitted the TDLS Channel Switch Request frame. The recipient TDLS peer STA that is extended spectrum management capable and that has dot11SpectrumManagementRequired or dot11RadioMeasurementActivated equal to true shall use the parameters in these received element(s) in the recipient STA's TPC calculations for the off-channel direct link.

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When announcing new operating classes or both a new operating class table index and new operating classes that come into effect at the same time as the switch to the direct link and that express new regulatory requirements, the TDLS peer VHT or S1G STA initiating the switch shall include a Country element in a transmitted TDLS Channel Switch Request frame. The Country element shall contain all of the Operating Classes for the off-channel direct link in Operating Triplet fields and zero Subband Triplet fields. The Country element shall include one Operating Triplet field that contains the same Operating Class as the Operating Class field in the same frame. The country indicated by the Country string in the TDLS Channel Switch Request frame shall be equal to the country indicated by the Country string of the BSS. The recipient TDLS peer VHT or S1G STA that has dot11MultiDomainCapabilityActivated, dot11SpectrumManagementRequired, or dot11RadioMeasurementActivated equal to true shall use the parameters in the received Country element in the TDLS Channel Switch Request frame in order to maintain regulatory compliance.

The TDLS peer STA initiating the switch to the wideband off-channel shall be the DO on that channel.

11.20.6.5.2 Basic wideband functionality

TDLS peer STAs may transmit up to 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz PPDUs on a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz direct link, respectively. A TDLS peer STA shall not transmit a 20 MHz PPDU in the nonprimary channel of its 80 MHz, 160 MHz, or 80+80 MHz direct link.

A TDLS peer STA shall not transmit a 40 MHz PPDU that does not use the primary 40 MHz channel of its 80 Hz, 160 MHz, or 80+80 MHz direct link. A TDLS peer STA shall not transmit an 80 MHz PPDU that does not use the primary 80 MHz channel of its 160 MHz or 80+80 MHz direct link.

TDLS peer S1G STAs may transmit up to 4 MHz, 8 MHz, or 16 MHz PPDUs on a 4 MHz, 8 MHz, or 16 MHz off-channel TDLS direct link, respectively. An S1G STA determines the channelization based on the Wide Bandwidth Channel Switch element of the TDLS Channel Switch Request frame.

A TDLS peer S1G STA shall not transmit a 1 MHz PPDU in the nonprimary 1 MHz channel of its 4 MHz, 8 MHz or 16 MHz off-channel TDLS direct link. A TDLS peer S1G STA shall not transmit a 2 MHz PPDU in the nonprimary 2 MHz channel of its 4 MHz, 8 MHz, or 16 MHz off-channel TDLS direct link. A TDLS peer S1G STA shall not transmit a 4 MHz PPDU that does not use the primary 4 MHz channel of its 8 MHz or 16 MHz off-channel TDLS direct link. A TDLS peer S1G STA shall not transmit an 8 MHz PPDU that does not use the primary 8 MHz channel of its 16 MHz off-channel TDLS direct link.

11.20.6.5.3 Channel selection for a wideband off-channel direct link

If a non-S1G TDLS peer STA chooses to start a wideband direct link, the TDLS peer STA shall follow the primary channel selection rules defined in 11.38.2 and 11.21.15 and the secondary 80 MHz channel rule defined in 11.20.1.

If an S1G TDLS peer STA chooses to start a wideband direct link, the TDLS peer STA shall follow the primary channel selection rules defined in 10.46.4 and 11.21.15.

11.20.6.5.4 Switching from a wideband to a 20 MHz, 1 MHz, or 2 MHz direct link

Switching from a wideband off-channel direct link to a 20 MHz, 1 MHz, or 2 MHz off-channel direct link is established through a TDLS channel switch. A non-S1G STA operating on a wideband off-channel direct link shall accept a requested switch to a 20 MHz direct link. An S1G STA operating on a wideband off-channel direct link shall accept a requested switch to 1 MHz or 2 MHz direct link.

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11.20.6.5.5 CCA sensing and NAV assertion in a 20 MHz, 40 MHz, 80 MHz, 160 MHz, 80+80 MHz, 1 MHz, 2 MHz, 4 MHz, 8 MHz, or 16 MHz direct link

TDLS peer VHT STAs shall follow the CCA rules defined in 10.3.2.7, 10.23.2.8, and 10.23.3 and the NAV rules defined in 11.38.5.

TDLS peer S1G STAs shall follow the CCA rules defined in 10.3.2.7 and 10.23.2.8 and the NAV rules defined in 10.46.6.

11.21 Wireless network management procedures

11.21.1 Wireless network management dependencies

When dot11WirelessManagementImplemented is true, the STA is a WNM STA and dot11ExtendedChannelSwitchActivated and dot11RadioMeasurementActivated shall be true. This subclause describes WNM procedures for requesting and reporting WNM capabilities between STAs that support WNM procedures.

When dot11WirelessManagementImplemented is true, and one or more of bit 7 to bit 27 in the Extended Capabilities element have the value 1, the Extended Capabilities element shall be included in Beacon frames, Association Request and Response frames, Reassociation Request and Response frames, and Probe Request and Response frames. When dot11WirelessManagementImplemented is true, for each bit 7 to bit 27 in the received Extended Capabilities element that is 0, a STA shall not request the corresponding feature from the sending STA. A WNM STA receiving a request for a WNM feature from another STA shall reject the request if the receiving WNM STA has not advertised support for the corresponding WNM feature.

11.21.2 Event request and report procedures

11.21.2.1 Event request and event report

The Event Request and Event Report frames enable network real-time diagnostics. A STA with dot11EventsActivated equal to true shall support event requests and reports and shall set to 1 the Event field of the Extended Capabilities elements that it transmits. If dot11EventsActivated is true, a STA shall log all Transition, RSNA, peer-to-peer, and WNM log events, including the corresponding TSF, UTC Offset and Event Time Error.

The STA log of events shall not be cleared as a result of BSS transitions. However, if the STA moves to a different ESS or IBSS, the STA shall delete all event log entries.

A STA that supports event reporting may send an Event Request or Event Report frame to a STA within the same infrastructure BSS or the same IBSS whose last received Extended Capabilities element contained a value of 1 for the Event bit in the Extended Capabilities field; it shall not send an Event Request or Event Report frame otherwise. If the STA receives an Event Request frame without error and it supports event reporting, it shall respond with an Event Report frame that includes a Dialog Token field that matches the one in the Event Request frame.

The permitted source and destination STAs for an Event Request frame are shown in Table 11-9.

An AP may include zero or more Event Request elements in an Event Request frame. Each Event Request element contains an Event Token that associates this Event Request with any subsequent Event Report elements. When sending Event Report elements, a STA shall use the same Event Token that was included in the original request.

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Only a single Event Request frame from a STA is outstanding at a given STA at any time. If a STA that supports event reporting receives a subsequent Event Request frame with a different dialog token before completing the Event Report for the previous request from the requesting STA, the receiving STA may respond to the most recent request frame; it shall not respond to a request frame that is not the most recent one.

Upon a BSS transition, the STA shall cancel any event requests in the latest Event Request frame.

The Event Request elements can contain conditions that specify events to be reported and conditions that establish event reporting when a STA experiences problems or failures. A STA sends an Event Request frame containing one or more Event Request elements, each of which contains zero or more subelements. Subelements are defined for each event type. A STA shall include in the corresponding Event Report element only those events that meet the specified event conditions within the ESS or IBSS of which the transmitting STA is a member.

In each Event Report element, a STA shall include a Status field that indicates the result of the event request/report transaction. If the STA is able to return one or more Event Report elements, then the STA shall return a value of "Successful" in the Event Report element. If the STA has no logged events of the requested type, the STA shall return a value of Successful in the Event Report element without an event included in the Event Report field. If the STA is unable to process the request at that time, the STA shall return a value of "Request failed" in the Event Report element. If a STA refuses an event request, the STA shall return a value of "Request refused" in the Event Report element. The reasons for refusing an event request are outside the scope of this standard but may include reduced quality of service, unacceptable power consumption, measurement scheduling conflicts, or other significant factors. If the STA is incapable of generating an Event Report of the type specified in the Event Request frame, the STA shall return a value of "Request incapable" indicating that the requester should not request again.

If the Event Report elements do not fit into a single MMPDU, the reporting STA shall send the remaining elements in additional Event Report frames until all Event Report elements have been returned to the requesting STA. In any subsequent Event Report frame and for all remaining Event Report elements a reporting STA shall include the same values of the Dialog Token and Event Token fields, respectively, that was sent in the corresponding Event Request frame. When multiple MMPDUs are required, the non-AP STA shall include complete Event Report elements and shall not fragment an element across multiple MMPDUs.

A STA shall transmit both the Event Request frame and the Event Report frame only with a destination address that is an individual address. In an infrastructure BSS, only an AP shall transmit an Event Request frame to a non-AP STA. An AP that supports event reporting shall discard received Event Request frames.

When a STA transmits an Event Request frame to another STA it shall indicate the types of events requested by setting the Event Type field and shall indicate the maximum number of logged events to report by using the Event Response Limit field in each included Event Request element. If the number of available logged events of the requested type exceeds the Event Response Limit, the STA shall report an Event Response Limit number of the most recent events. If there are no available logged events of the type specified in the Event Request frame, the STA shall send the Event Report frame without any Event Report element. The reporting STA shall send all available Event Report elements for the requested event type when the Event Request field is not present in the Event Request element.

A STA may include a Destination URI element in the Event Request frame. The AP includes the URI in the Destination URI element that the reporting non-AP STA may use to send Event Reports, upon the loss or interruption of connectivity to the BSS.

On receipt of an Event Request frame with an Destination URI element, the reporting non-AP STA SME may send the Event Report to the AP using the Destination URI with another network interface (if available). The non-AP STA SME shall not send the Event Report to the URI contained in the Destination URI element except after detecting loss of BSS connection.

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The non-AP STA shall determine loss of connection to the AP that issued the Event Request frame when it has not detected any Beacon frames from the AP for a period no less than the ESS Detection Interval.

If the BSS connection is reestablished to the AP that transmitted the Event Request frame, the non-AP STA shall transmit the corresponding Event Report frame to the AP without using the Destination URI.

When the non-AP STA uses the Destination URI mechanism, it shall transport the Frame Body field of the Event Report frame using the URI given in the Destination URI Element. An example use of the Destination URI is given in Annex Q.

11.21.2.2 Transition event request and report

The Transition Event report provides information on the previous transition events for a given non-AP STA. The Transition Event request and report are only permitted in the infrastructure BSS.

Each STA supporting the Transition Event shall log up to the last five Transition events occurring since the STA associated to the ESS. A STA may log more than five of the most recent Transition events.

Upon receipt of an Event Request frame containing an Event Request element including a Transition Event request, the non-AP STA shall respond with an Event Report frame that includes available Event Report elements within the ESS of which the transmitting STA is a member for the Transition event type.

Transition Event Request subelements are used to specify conditions for reporting of transition events. If any Transition Event Request subelements are present in the Event Request frame, the reporting non-AP STA shall include in the Event Report frame only those available Transition Event Report elements that meet the transition event reporting condition(s) specified in the Event Request frame. If no transition event subelements are present in the Event Request field, the reporting STA shall include all available Transition Event Report elements.

A Frequent Transition subelement in an Event Request frame defines conditions for frequent transition. Frequent transition occurs when the number of BSS transitions exceeds the frequent transition count threshold within the indicated time interval as defined in the Frequent Transition subelement in 9.4.2.66.2. A STA that receives a Frequent Transition subelement shall, at each BSS transition, apply the conditions for frequent transition to the log of transition events. If the logged transition events meet the conditions for frequent transition, the STA shall send an Event Report frame including a Transition Event Report element with Event Report Status set to Detected Frequent Transition and include in that Event Report element the last logged transition event.

For transition logging and reporting purposes, the transition time is defined as the time difference between the starting time and the ending time of a transition between APs, even if the transition results in remaining on the same AP.

The starting time is one of the following items:

- The start of a search for an AP, when the transition reason is 4 (first association to WLAN).
- The latest time that a frame could have been transmitted or received on the source BSS.
- The start of a search for an AP, after determination that a transition has failed.

The ending time is one of the following items:

- The earliest time that a Data frame can be transmitted or received on the target BSS, after completion of RSN, IEEE 802.1X, or other authentication and key management transmissions, when such are required by the target BSS.
- The time that a determination is made that the transition has failed.

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11.21.2.3 RSNA event request and report

The RSNA Event Report provides authentication events for a given non-AP STA. The RSNA Event Request and Report are only permitted in an infrastructure BSS.

Each STA supporting the RSNA Event shall log up to the last five RSNA events occurring since the STA associated to the ESS. A STA may log more than five of the most recent RSNA events.

Upon receipt of an Event Request frame containing an Event Request element including an RSNA Event request, the non-AP STA shall respond with an Event Report frame that includes available Event Report elements within the ESS of which the transmitting STA is a member for the RSNA event type.

If an RSNA Event Request subelement is present in the Event Request field, the reporting non-AP STA shall include available Event Report elements that meet the specified condition for the RSNA event type. If no RSNA Event Request subelement is present in the Event Request field, the reporting STA shall include all available RSNA Event Report elements.

11.21.2.4 Peer-to-peer link event request and report

The peer-to-peer link event report provides peer-to-peer connectivity events for a given non-AP STA. A peer-to-peer event occurs when a peer-to-peer link is initiated or terminated.

Each STA supporting the peer-to-peer link event shall log up to the last five peer-to-peer link events occurring since the STA associated to the ESS or IBSS. A STA may log more than five of the most recent peer-to-peer link events. When a link is initiated, a STA shall log and record the TSF time of the peer-to-peer link event without a connection time. When a peer-to-peer link is terminated, a STA shall log the peer-to-peer link event including the connection time for the terminated link and shall delete from the log any initiation event for the same peer-to-peer link.

Upon receipt of an Event Request frame containing an Event Request element including a peer-to-peer link event request, the non-AP STA shall respond with an Event Report frame that includes available Event Report elements within the ESS or IBSS of which the transmitting STA is a member for the Peer-to-peer event type. When a STA includes a Peer-to-Peer Link Event Report element for a link initiation, the STA shall include a connection time for the event report element which indicates the time difference from the event timestamp to the current time.

If a Peer-to-Peer Link Event Request subelement is present in the Event Request field, the reporting non-AP STA shall include available Event Report elements that meet the specified condition for the Peer-to-peer event type. If no Peer-to-Peer Link Event Request subelements are present in the Event Request field, the reporting STA shall include all available Peer-to-Peer Link Event Report elements.

11.21.2.5 WNM log event request and report

The WNM log event report is intended to capture PHY and MAC layer events related to the operation of those layers in vendor-specific, human-readable (ASCII text) form. The WNM log is a general reporting mechanism that can apply to configuration or monitoring behavior for PHY and MAC. The WNM log is particularly useful for logging success or failure events across areas such as driver status, IEEE 802.11 or IEEE 802.1X authentication, authorization, status changes while associated or unassociated.

For example:

<0>Oct 03 17:47:00 00:01:02:03:04:05 Adapter DLL Service initialized
<1>Oct 03 17:48:40 00:01:02:03:04:05 Authentication started
<1>Oct 03 17:48:46 00:01:02:03:04:05 IEEE 802.1X Authentication Failed, credential failure
<1>Oct 03 17:49:00 00:01:02:03:04:05 Authentication success

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A non-AP STA that supports event reporting may be queried at any time for its current set of WNM log messages. The WNM log messages returned by the non-AP STA may provide insight into the trouble being experienced by non-AP STA.

Upon receipt of an Event Request frame containing an Event Request element including a WNM log event request, the non-AP STA shall respond with an Event Report frame that includes WNM Log Event Report elements.

11.21.2.6 Vendor Specific event request and report

The procedures for use of the Vendor Specific Event Request and Report are vendor specific and are not part of this standard.

11.21.3 Diagnostic request and report procedures

11.21.3.1 Diagnostic request and diagnostic report

The Diagnostic Request and Diagnostic Report protocol provides a tool to diagnose and debug complex network issues. A STA with dot11DiagnosticsActivated equal to true shall support diagnostic reporting and shall set to 1 the Diagnostics field of the Extended Capabilities elements that it transmits.

A STA that supports diagnostics reporting shall send a Diagnostics Request or Diagnostics Report frame to a STA within the same infrastructure BSS or the same IBSS whose last received Extended Capabilities element contained a value of 1 for the Diagnostics bit in the Extended Capabilities field; it shall not send a Diagnostics Request or Diagnostics Report frame otherwise.

The Diagnostic Request frame contains a unique Dialog Token. A value of 0 for the Dialog Token field is a reserved and shall not be used. The source and destination of a Diagnostic Request frame shall both be members of the same BSS. The permitted source and destination STAs for a Diagnostic Request frame are shown in Table 11-9. A STA may include one or more Diagnostic Request elements in a Diagnostic Request frame. Each Diagnostic Request element contains a unique Diagnostic Token that identifies the element within the Diagnostic Request frame.

If a STA that supports diagnostic reporting receives a Diagnostic Request frame without error, the STA shall respond with a Diagnostic Report frame that includes a Dialog Token field that matches the one in the Diagnostic Request frame. Each Diagnostic Report element that corresponds to the Diagnostic Request element shall contain the same Diagnostic Token that was included in the original request.

Only a single Diagnostic Request frame from a STA is outstanding at a given STA at any time. If a STA receives a subsequent Diagnostic Request frame with a different dialog token before completing the Diagnostic Report for the previous request from the requesting STA, the STA shall respond to the most recent Diagnostic Request frame; the STA shall not respond to a Diagnostic Request frame that is not the most recent one.

All outstanding diagnostic requests, as indicated by received MLME-DIAGREQUEST.indication primitives, are canceled upon a BSS transition, except when the BSS transition occurs as a result of responding to or initiating a diagnostic request. All outstanding diagnostic requests, as indicated by received MLME-DIAGREQUEST.indication primitives, are canceled after the time indicated in the Diagnostic Timeout field, in the Diagnostic Request frame. When a STA that supports diagnostic reporting receives a Diagnostic Request frame with a Diagnostic Request Type of Cancel Diagnostic Request, the STA cancels all outstanding diagnostic requests, and discards all pending diagnostic reports, as indicated by received MLME-DIAGREQUEST.indication primitives.

All Diagnostic Report elements shall include a Status field that indicates the overall result of the transaction. If the STA is able to complete the diagnostic request made in the Diagnostic Request element, then a value of

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"Successful" shall be returned. If the STA is unable to process the request at that time a value of "Fail" shall be returned. If the STA is incapable of generating a report of the type specified, it shall return a value of "Incapable." If the STA cannot support the request for any other reason, the value of Refused shall be returned.

A STA shall transmit both the Diagnostic Request frame and the Diagnostic Report frame with a destination address that is an individual address.

A STA may include a Destination URI element in the Event Request frame. The AP includes the URI in the Destination URI element that the reporting non-AP STA may use to send Diagnostic Reports, upon the loss or interruption of connectivity to the BSS.

On receipt of an Diagnostic Request frame with an Destination URI element, the reporting non-AP STA SME may send the Diagnostic Report to the AP using the Destination URI with another network interface (if available).

The non-AP STA shall determine loss of connection to the AP that issued the Diagnostic Request frame when it has not detected any Beacon frames from the AP for a period no less than the ESS Detection Interval.

If the BSS connection is reestablished to the AP that transmitted the Diagnostic Request frame, the non-AP STA shall transmit the corresponding Diagnostic Report frame to the AP without using the Destination URI.

When the non-AP STA uses the Destination URI mechanism, it shall transport the payload of the Diagnostic Report frame using the URI given in the Destination URI Element. An example use of the Destination URI is given in Annex Q.

If a non-AP STA that receives an Destination URI subelement in an Diagnostic Request fails to detect any Beacon frames, belonging to the AP that issued the request for a Diagnostic report, for the period specified by the ESS detection interval, it may use the URI specified in the Destination URI subelement to transport the Diagnostic Report to the AP.

If the Diagnostic Report elements do not fit into a single MMPDU, the reporting STA shall send the remaining elements in additional frames until all Diagnostic Report elements have been returned to the requesting STA. A STA shall include the same values of the Dialog Token and Diagnostic Token fields that were transmitted in the corresponding Diagnostic Request frame in each subsequent Diagnostic Report frame and Diagnostic Report elements. When multiple MMPDUs are required, the STA shall include complete Diagnostic Report elements and shall not fragment an element across multiple MMPDUs.

A STA that supports diagnostic reporting may cancel a previously sent Diagnostic Request frame for which it has not yet received a Diagnostic Report frame by sending a Diagnostic Request frame with the Diagnostic Request Type field value of 0, indicating "Canceled," to the STA to which it previously sent the Diagnostic Request frame. A STA that supports diagnostic reporting shall inform a STA from which it has previously received a Diagnostic Request frame that the request has been locally canceled by sending a Diagnostic Report frame with the Diagnostic Status field set to a value of 4, indicating "Canceled," to the requesting STA. In a Diagnostic Request frame with the Diagnostic Request Type field value of 0, and a Diagnostic Report frame with the Diagnostic Status field set to a value of 4, no Diagnostic subelements are included in the Diagnostic Request or Response element.

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11.21.3.2 Configuration Profile report

The Configuration Profile report enables an AP to discover the current profile in use for an associated STA, and additional profiles for the ESS of which the STA is a member. A non-AP STA that supports diagnostic reporting and receives a Configuration Profile report request type shall respond with a Diagnostic Report frame that includes all available Diagnostic elements allowed for the type.

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STAs that support multiple configuration profiles for an ESS may include multiple Diagnostic Report elements in a single Diagnostic Report frame (or multiple frames if required). Each Diagnostic Report element shall contain a Profile ID element that uniquely identifies the configuration profile(s) for the ESS of which the STA is a member that are available on the device.

11.21.3.3 Manufacturer information STA report

The Manufacturer Information STA Report enables an AP to discover static manufacturer specific data about an associated STA. A non-AP STA that supports diagnostic reporting and receives a Manufacturer Information STA Report request type shall respond with a Diagnostic Report frame that includes all available Diagnostic elements allowed for the type.

When more than one Antenna Type/Antenna Gain pair is enabled, multiple Antenna Type subelements shall be included in the Manufacturer Information STA Report Diagnostic Report element.

When more than one Collocated Radio Type, or Device Type is supported, multiple Collocated Radio Type subelements, or Device Type subelements shall be included in the Manufacturer Information STA Report Diagnostic Report element. If the existence or the type of collocated radio is unknown, no Collocated Radio Type subelements shall be included.

11.21.3.4 Association diagnostic

The purpose of the association diagnostic is to determine that a STA is able to associate with a designated BSS. This test directs an association to be completed with a specific AP.

To initiate the test, an AP that supports diagnostic reporting shall send a Diagnostic Request frame containing a Diagnostic Request Type field set to 3 (i.e., Association Diagnostic) to a STA that supports diagnostic reporting. The AP shall not send an association diagnostic request with a designated BSS that is not part of the ESS and the STA receiving an association diagnostic request shall reject requests to perform diagnostics on a BSS that is not part of the ESS. All parameters required to complete the association are included in the Diagnostic Request element.

Upon receipt of the Diagnostic Request frame containing a Diagnostic Request element specifying an association request, the STA determines whether to accept the request. If the STA declines the request, it shall send a Diagnostic Report frame with the Status field of a Diagnostic Report element set to Refused. If the STA accepts the request, it shall cause an authentication to occur to the AP indicated in the Diagnostic Request element and the STA's SME shall issue an MLME-DIAGREPORT.request primitive, indicating the results of the diagnostic.

One means to cause an authentication to occur is for the STA's SME to issue an MLME-DEAUTHENTICATE.request primitive to deauthenticate from the current AP, and an MLME-AUTHENTICATE.request primitive to authenticate to the AP indicated in the Diagnostic Request element. If successful, the STA shall issue an MLME-(RE)ASSOCIATE.request primitive to associate with the AP indicated in the Diagnostic Request element. If successful, the STA's SME shall then issue an MLME-DEAUTHENTICATE.request primitive to deauthenticate from the AP indicated in the Diagnostic Request element, reassociate with the AP from which it received the Diagnostic Request, and issue an MLME-DIAGREPORT.request primitive, indicating the results of the diagnostic.

11.21.3.5 IEEE 802.1X authentication diagnostic

The purpose of the IEEE 802.1X authentication diagnostic is to determine that the STA is able to complete an IEEE 802.1X authentication with a designated BSS. This test directs an association and IEEE 802.1X authentication to be completed with a specific AP. If a STA that supports diagnostic reporting also supports RSN, the STA shall support the IEEE 802.1X authentication diagnostic.

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To initiate the test, an AP that supports diagnostic reporting shall send a Diagnostic Request frame containing a Diagnostic Request Type field set to 4 (i.e., IEEE 802.1X Authentication Diagnostic) to a STA that supports diagnostic reporting. A STA that supports diagnostic reporting in an IBSS or an AP that supports diagnostic reporting shall not send an IEEE 802.1X authentication diagnostic request with a designated BSS that is not part of the ESS, or IBSS and a STA that supports diagnostic reporting which receives a diagnostic request shall reject requests to perform diagnostics on other networks. The AP, EAP method and credential type values included in the AP Descriptor, EAP Method and Credential Type subelements in the Diagnostic Request element shall be used to complete the association and IEEE 802.1X authentication.

Upon receipt of the Diagnostic Request frame containing a Diagnostic Request element specifying an IEEE 802.1X Authentication Diagnostic request, the STA determines whether to accept the request. If the STA declines the request, it shall send a Diagnostic Report frame with the Status field of a Diagnostic Report element set to Refused. If the STA accepts the request, it shall cause an IEEE 802.1X authentication to occur to the AP indicated in the Diagnostic Request element and the STA's SME shall issue an MLME-DIAGREPORT.request primitive indicating the results of the diagnostic.

One means to cause an authentication to occur is for the STA's SME to issue an MLME-DEAUTHENTICATE.request primitive to deauthenticate from the current AP, and an MLME-AUTHENTICATE.request primitive to authenticate to the AP indicated in the Diagnostic Request element. If successful, the STA shall issue an MLME-(RE)ASSOCIATE.request primitive to the AP indicated in the Diagnostic Request element. If (re)association succeeds, the STA shall try to complete IEEE 802.1X authentication using parameters specified in the Diagnostic Request element. The STA shall then issue an MLME-DEAUTHENTICATE.request primitive to deauthenticate from the AP indicated in the Diagnostic Request element, reassociate with the AP from which it received a diagnostic request, and issue an MLME-DIAGREPORT.request primitive, indicating the results of the diagnostic.

11.21.4 Location track procedures

11.21.4.1 Location track configuration procedures

A STA with dot11LocationTrackingActivated equal to true shall support location tracking and shall set to 1 the Location field of the Extended Capabilities elements that it transmits.

In an infrastructure BSS, a non-AP STA shall not transmit Location Configuration Request frames.

A STA that supports location may configure another STA to transmit Location Track Notification frames for the purpose of tracking the receiving STA's location by sending Location Indication Channels, Location Indication Interval and Location Indication Broadcast Data Rate subelements in a Location Parameters element in a Location Configuration Request frame. The minimum Normal and In-Motion Report Interval in a Location Configuration Request frame is 500 ms.

A STA may transmit the Location Configuration Request frame as a broadcast or individually addressed frame. A STA that supports location and receives a broadcast Location Configuration Request frame shall send a Location Configuration Response frame if the STA does not accept the parameters included in the Location Configuration request; the STA shall not send a Location Configuration Response frame if it accepts the parameters included in the Location Configuration request.

A STA that supports location and receives an individually addressed Location Configuration Request frame shall respond with a Location Configuration Response frame. Upon reception of a new Location Configuration Request frame, the STA shall override any information from a previously received Location Configuration Request frame with the new frame. If all Location Parameter subelements included in the Location Configuration Request frame are successfully configured on the receiving STA, then the STA shall include in the Location Configuration Response frame a single Location Status subelement indicating success. Upon successful configuration, the receiving STA shall start transmitting the Location Track Notification frames

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based on the Location Configuration Request frame parameters, as described in 11.21.4.2. If one or more Location Parameter subelements are unsuccessfully configured, then the STA shall include in the Location Configuration Response frame a Location Status subelement for each failed subelement indicating the subelement ID, the status value and the corresponding Location Parameter subelement as described in the paragraphs that follow.

The Location Status subelement has four possible status values: Success, Fail, Refused and Incapable. When the requesting STA receives a Location Configuration Response frame with Location Status indicating anything other than Success, the requesting STA shall assume the original request was not processed and no configuration took effect on the receiving STA and the requesting STA should take appropriate action based on the status value returned.

For Location Status Fail:

— If the receiving STA has been configured successfully prior to the current Location Configuration Request and continues to transmit Location Track Notification frames based on those parameters, the STA shall respond with its current Location Parameters subelements values.
— If the STA has no previously configured value, the STA shall respond with its minimum Location Parameters subelements that it is capable of supporting.
— The configuring STA may either retry the original request or send an alternate request.

For Location Status Incapable:

— The STA responding to the configuration request may include the minimum Location Parameters subelements that it is capable of supporting.
— The configuring STA shall not send another configuration request matching the previous configuration request while the reporting STA is a member of the same BSS.
— The configuring STA may send an alternate request.

For Location Status Refuse:

— The STA responding to the configuration request may include the minimum Location Parameters subelements that it is capable of supporting.
— The configuring STA may send an alternate request.

The location configuration methods, from highest to lowest precedence, are as follows: 1) an individually addressed Location Configuration Request frame, 2) broadcast Location Configuration Request frame. When a STA receives a new Location Configuration frame at the same or higher precedence than the previous it shall cancel the previous configuration and begin using the newest configuration.

The Location Indication Broadcast Data Rate subelement included in Location Configuration Request frames indicates the target data rate at which the STA shall transmit Location Track Notification frames. The Location Indication Broadcast Data Rate included in the Location Configuration Request frame should be a data rate defined in the basic data rate set.

The Indication Multicast Address field configured in the Location Indication Parameters subelement shall be a multicast locally administered IEEE MAC address as defined in IEEE Std 802 that is shared across all APs in the same ESS. The STA shall transmit Location Track Notification frames to the Indication Multicast Address with the BSSID field set to the wildcard BSSID. An AP shall discard Location Track Notification frames that are not addressed to the Indication Multicast Address field configured for the ESS.

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A non-AP STA shall terminate the transmission of Location Track Notification frames for any of the following reasons:

— The non-AP STA receives a Location Configuration Request frame from the STA to which it is currently associated that includes a Location Parameters element with a Location Indication Parameters subelement specifying an interval of 0.

— The non-AP STA fails to detect any Beacon frames, belonging to the same ESS that originally configured the non-AP STA, for the period specified by the essDetectionInterval value included in the Location Parameters element transmitted in the Location Configuration Request frame.

— dot11LocationTrackingActivated is false.

— The non-AP STA is disassociated for any reason from the ESS that configured it, including power off, or is configured by a different ESS.

— In an IBSS when the STA detects that it is no longer connected to the other STA that formed the IBSS.

NOTE—All Public Action frames, including the Location Track Notification frames, are Class 1 frames and the treatment of Public Action frames upon reception by STAs is defined in 11.3.

11.21.4.2 Location track notification procedures

Implementation of location track notification is optional for a WNM STA. A STA that implements location track notification has dot11LocationTrackingImplemented equal to true. When dot11LocationTrackingImplemented is true, dot11WirelessManagementImplemented shall be true. A STA in which dot11LocationTrackingActivated is true is defined as a STA that supports location track notification. When location track notification is supported, a STA configured by another STA as described in the previous subclause shall transmit Location Track Notification frames as shown in Figure 11-32.

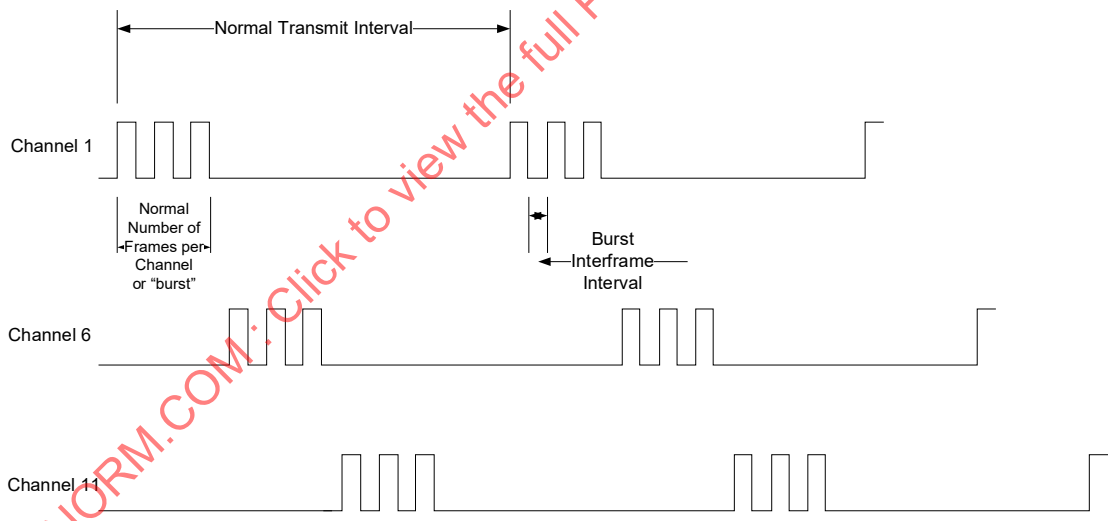

Figure 11-32—STA transmission on three channels, three frames per channel with Normal Report Interval

Implementation of Motion Detection or the Time of Departure reporting is optional for a WNM STA. A STA that implements motion detection shall set dot11MotionDetectionImplemented to true. When dot11MotionDetectionImplemented is true, dot11WirelessManagementImplemented shall be true. A STA with dot11MotionDetectionActivated equal to true shall support motion detection. A STA that implements the time of departure capability shall set its dot11TODImplmented to true. When dot11TODImplemented is true, dot11WirelessManagementImplemented shall be true. A STA with dot11TODActivated equal to true shall support time of departure for location tracking.

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The STA transmits Location Track Notification frames based on the following parameters and procedures described in 11.21.4.1:

a) Location Indication Channels. This subelement indicates the channels on which the STA shall transmit Location Track Notification frames.

b) Indication Multicast Address

1) A non-IBSS STA shall transmit the Location Track Notification frames to the Indication Multicast Address field in the Location Indication Parameters subelement configured by the Location Configuration Request frame.

2) An AP shall discard any Location Track Notification frame received from a STA that does not match the Indication Multicast Address field value for the AP's ESS.

3) An IBSS STA shall transmit the Location Track Notification frames to the destination address of the STA that configured the STA using Location Configuration Request frames.

c) Location Indication Interval

1) When the STA is stationary or dot11MotionDetectionActivated is false, the STA shall transmit a sequence of groups of Location Track Notification frames on each channel. Each group of frames shall contain Normal Number of Frames Per Channel field frames. The first frame in each group of Location Track Notification frames shall be separated from the first frame in the previous group of Location Track Notification frames by a minimum duration indicated by the value of the Normal Report Interval field times the value of the Normal Report Interval Units field.

2) When the STA is in motion and dot11MotionDetectionActivated is true, the STA shall transmit a sequence of groups of Location Track Notification frames on each channel. Each group of frames shall contain In-Motion Number of Frames Per Channel field frames. The first frame in each group of Location Track Notification frames shall be separated from the first frame in the previous group of Location Track Notification frames by a minimum duration indicated by the value of the In-Motion Report Interval field times the value of the In-Motion Report Interval Units field.

3) If a STA is configured to transmit on multiple channels, the STA shall transmit the frames on a single channel before continuing onto the next channel in the configured list of channels.

4) All Location Track Notification frames transmitted on a single channel shall be transmitted with a minimum gap specified by the Burst Interframe Interval field.

5) A STA can never be stationary and in-motion at the same time, and therefore only the Normal Interval field or the In-Motion Interval field apply at any given moment.

d) Tracking Duration

1) The STA shall transmit Location Track Notification frames until the Tracking Duration duration is reached.

2) The duration starts as soon as the STA sends a Configuration Location Response frame with a Location Status value of Success.

3) If the Tracking Duration is a nonzero value the STA shall transmit Location Track Notification frames, based on the Normal and In-Motion Report Interval field values, until the duration ends or is configured to terminate transmission as described in 11.21.4.1.

4) If the Tracking Duration is 0 the STA shall continuously transmit Location Track Notification frames as defined by Normal and In-Motion Report Interval field values until configured to terminate transmission as described 11.21.4.1.

e) ESS Detection

1) The ESS Detection Interval field is specified in the Location Indication Parameters subelement configured by the Location Configuration Request frame. The ESS Detection Interval defines how often the STA should check for beacons transmitted by one or more APs belonging to the same ESS that configured the STA.

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2) If no beacons from the ESS are received during this interval, the STA shall terminate transmission of Location Track Notification frames.

f) Location Indication Options

1) The RM Enabled Capabilities element contained in (Re)Association Request frames indicates the STA's ability to perform radio measurements as described in 9.4.2.44. The Location Indication Options subelement Options Used field Beacon Measurement Mode Used bit shall be set to 0 by the AP when the RM Enabled Capabilities element bits (defined in Table 9-179), Beacon Passive Measurement Capability Enabled, Beacon Active Measurement Capability Enabled and Beacon Table Measurement Capability Enabled are all set to 0. If any of RM Enabled Capabilities element bits Beacon Passive Measurement capability enabled, Beacon Active Measurement Capability Enabled or Beacon Table Measurement Capability Enabled are equal to 1 then the Location Indication Options subelement Options Used field Beacon Measurement Mode Used bit may be set to 1.

2) If the Location Indication Options subelement is included and the Options Used field with the Beacon Measurement Mode Used bit equal to 1 in the most recently received Location Configuration Request frame, the STA shall include in the Location Track Notification frames, the result of the most recent successful beacon measurement that was performed using the requested Beacon Measurement Mode contained in the Location Indications Options subelement.

3) If the STA has never performed a successful beacon measurement using the requested Beacon Measurement Mode prior to transmission of the Location Track Notification frame, the STA shall perform the beacon measurement using the requested Beacon Measurement Mode and include the results of that measurement in Location Track Notification frames.

4) After a successful Location Configuration Request frame that included the Location Indication Options subelement and Options Used field with Beacon Measurement Mode Used bit equal to 1, a STA should continue to perform beacon measurement as defined by the Beacon Measurement Mode periodically. How often and under what circumstances the STA performs this measurement is out of scope of this standard.

5) Whenever a STA includes the beacon measurement in the Location Track Notification frames, the STA shall set the Measurement Token field in the Measurement Report element to the same value as the Dialog Token field in the Location Configuration Request frame that initiated the transmission of the location track notification frames by the STA.

6) If the Location Indication Options subelement is not included in the most recently received Location Configuration Request frame or the Location Indication Options subelement is included with the Options Used field with Beacon Measurement Mode Used bit equal to 0, the STA shall not include any beacon measurements in the Location Track Notification frame

g) Location Indication Broadcast Data Rate. The STA shall transmit Location Track Notification frames at the data rate specified in this subelement.

h) Time of Departure

1) If dot11TODActivated is true, the STA shall transmit this subelement in the Location Track Notification frame.

2) In all location tracking frames transmitted by a STA following a successful configuration, the Time of Departure subelement TOD Clock Rate field shall be set to the same value.

3) If the STA has multiple antennas, it shall transmit using an approximation to an omnidirectional pattern.

NOTE—The values of the fields in the Time of Departure subelement are measured by the PHY in real time, then passed without real-time requirements to the MAC via the TXSTATUS parameter list in the PHY-TXSTART.confirm primitive.

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The diagram in Figure 11-32 shows an example of Location Track Notification frame transmission, for a STA configured to transmit on three channels, with three frames per channel. In this example, a Normal Transmit Interval and Normal number of frames per channel are shown. When a STA is capable of motion detection and is in motion, the In-Motion Report Interval and In-Motion number of frames per channel would apply.

11.21.5 Timing measurement procedure

Implementation of timing measurement is optional for a WNM STA. A STA in which dot11TimingMsmtActivated is true is defined as a STA that supports timing measurement.

A STA in which dot11TimingMsmtActivated is true shall set the Timing Measurement field of the Extended Capabilities element to 1.

A STA in which dot11TimingMsmtActivated is false shall set the Timing Measurement field of the Extended Capabilities element to 0.

A STA that supports the timing measurement procedure may transmit a Timing Measurement Request frame to a peer STA to request it to initiate or to stop an ongoing timing measurement procedure, depending on the Trigger field in the request frame. See Figure 11-33.

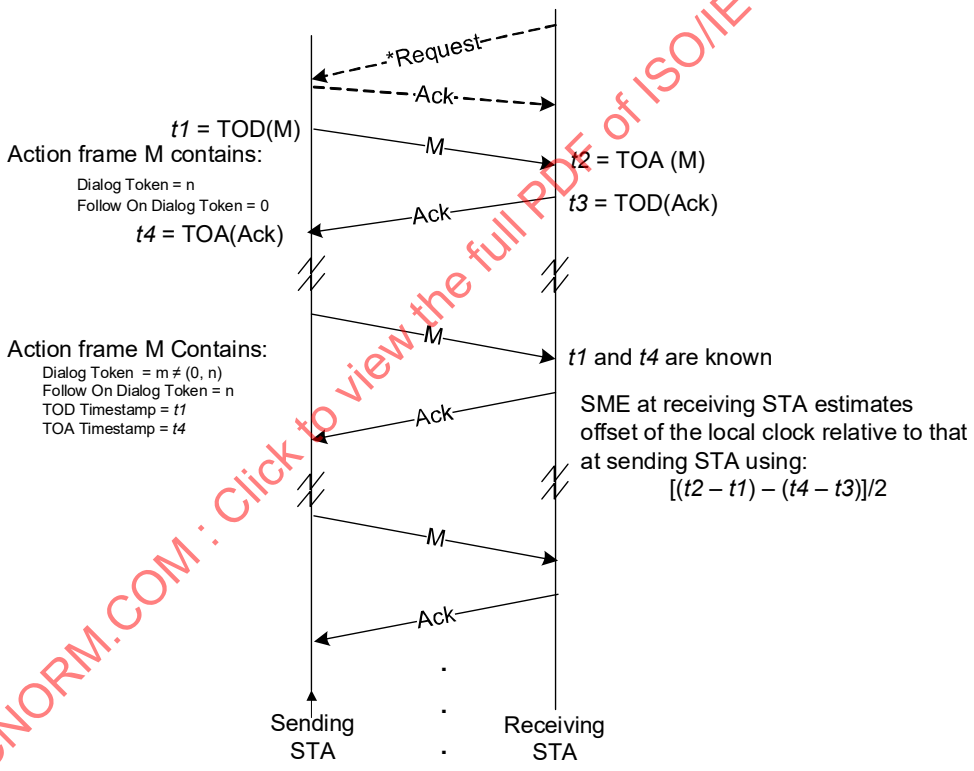

Figure 11-33—Timing measurement procedure

A STA that supports the timing measurement procedure may transmit Timing Measurement frames addressed to a peer STA that also supports the timing measurement procedure. One higher-layer protocol for synchronizing a local clock time between STAs using this feature is specified in IEEE Std 802.1AS.

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For non-DMG STAs, both the Timing Measurement frame and the corresponding Ack frame shall be transmitted using a single transmit chain.

A sending STA transmits Timing Measurement frames in overlapping pairs. The first Timing Measurement frame of a pair contains a nonzero value in the Dialog Token field. The follow up Timing Measurement frame contains a Follow Up Dialog Token field set the value of the Dialog Token field in the first frame of the pair. With the first Timing Measurement frame, both STAs capture timestamps. The sending STA captures the time at which the Timing Measurement frame is transmitted (t1). The receiving STA captures the time at which the Timing Measurement frame arrives (t2) and the time at which the Ack frame response is transmitted (t3). The sending STA captures the time at which the Ack frame arrives (t4). See Figure 6-16 in 6.3.55. In the follow up Timing Measurement frame, the sending STA transfers the timestamp values it captured (t1 and t4) to the receiving STA.

NOTE 1—A Timing Measurement frame can contain nonzero values in both the Dialog Token and Follow Up Dialog Token fields, meaning that the Action frame contains follow up information from a previous measurement, and new Timestamp values are captured to be sent in a future follow up Timing Measurement frame.

The offset of the clock at the receiving STA with respect to the clock at the sending STA is calculated using Equation (11-4) (assuming a symmetric wireless channel). See Figure 6-16 in 6.3.55.

$$\textit{Clock offset at receiving STA relative to sending STA} = [(t2 - t1) - (t4 - t3)]/2 \quad (11\text{-}4)$$

NOTE 2—An example of state machines and other computations for synchronizing a local clock time between IEEE 802.11 STAs using the values of t1, t2, t3, and t4 provided by the Timing Measurement feature is found in Clause 12 of IEEE Std 802.1AS-2020.

The acknowledgment procedure for Timing Measurement frames is the same as that for other Management frames (see 10.3.2.11). If the Ack frame for a transmitted Timing Measurement frame is not received, the sending STA may retransmit the frame. The sending STA shall capture a new set of timestamps for the retransmitted frame and its Ack frame.

On receiving a Timing Measurement frame with a Dialog Token for which timestamps have previously been captured, the receiving STA shall discard previously captured timestamps and capture a new set of timestamps.

11.21.6 Fine timing measurement (FTM) procedure

11.21.6.1 Overview

The FTM procedure allows a STA to determine its distance from another STA. In order for a STA to obtain its location, the STA may perform this procedure with multiple STAs whose locations are known.

An FTM session is an instance of an FTM procedure between an initiating STA and a responding STA along with the associated scheduling and operational parameters of that instance (see 9.4.2.167). An FTM session is composed of a negotiation, measurement exchange and termination. A STA might have multiple concurrent FTM sessions. Concurrent FTM sessions might occur with responding STAs that are members of different BSSs and possibly different ESSs, or possibly outside of a BSS, each session using its own scheduling, channel and operational parameters.

A responding STA might be required to establish overlapping FTM sessions with a large number of initiating STAs (e.g., an AP providing measurements to STAs at a mall or a store). On the other hand, an initiating STA might have multiple ongoing FTM sessions on the same or different channels with different responding STAs, while being associated with an AP for the exchange of data or signaling.

To support the constraints of both the initiating and responding STAs, during the negotiation phase the initiating STA initially requests a preferred periodic time window allocation. The responding STA

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subsequently responds by accepting or overriding the allocation request based on its resource availability and capability.

Since some of the initiating STA's activities may be nondeterministic and might have higher precedence than the FTM session (e.g., data transfer interaction with an associated AP), a conflict might prevent the initiating STA from being available at the beginning of the burst instance determined by the responding STA.

Figure 11-34 shows an example of such scheduling conflicts.

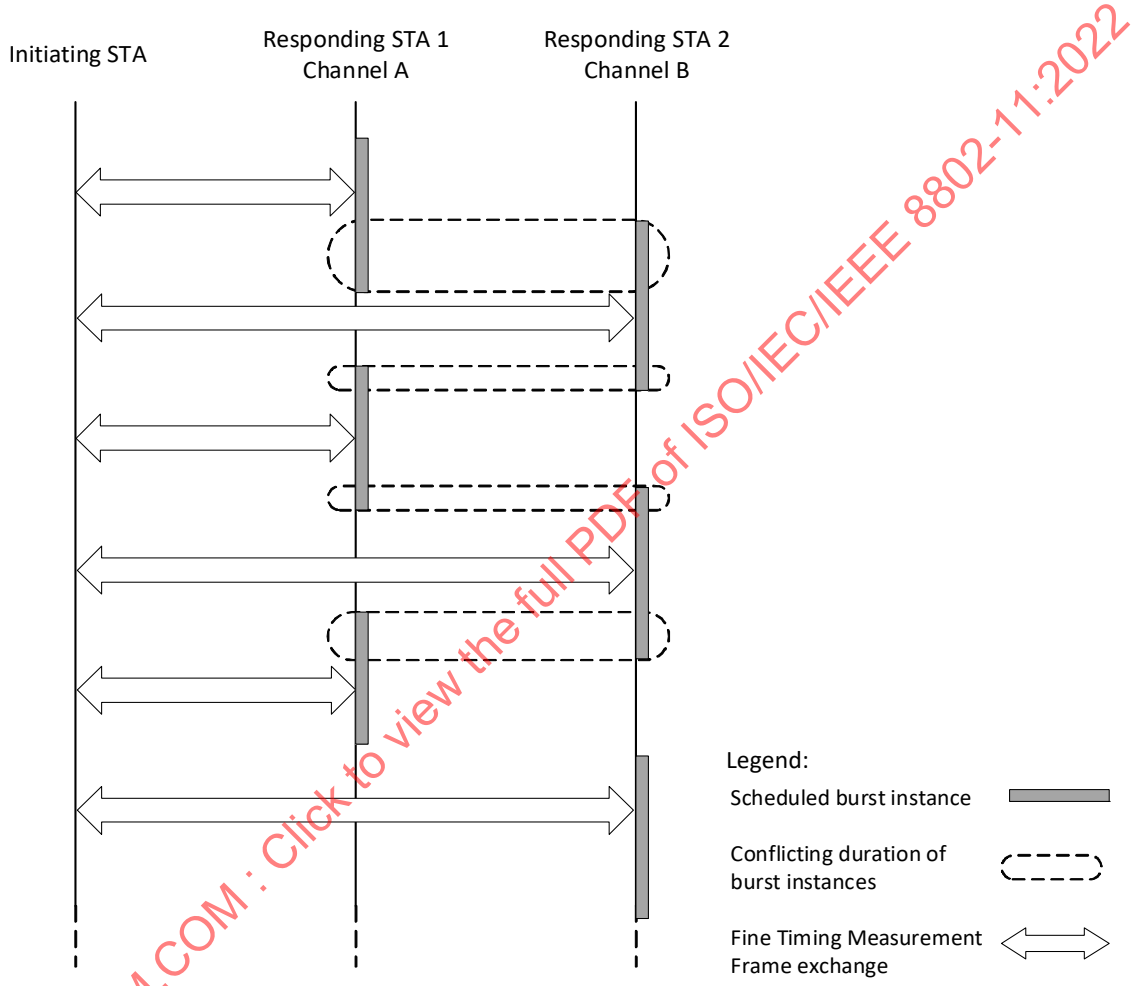

Figure 11-34—Concurrent FTM sessions

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The initiating STA in Figure 11-34 establishes sessions with responding STA 1 and responding STA 2 on different channels. The sessions' burst instance periodicity might be different as well as the STAs' clock offsets and thus, over time, some temporal conflicts may occur. To overcome this, during each burst instance the initiating STA indicates its availability by transmitting a Fine Timing Measurement Request frame (see 11.21.6.4). During each burst instance, the responding STA transmits one or more Fine Timing Measurement frames as negotiated.

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11.21.6.2 FTM capabilities

Implementation of FTM is optional for a WNM STA. A STA in which dot11FineTimingMsmtRespActivated is true is defined as a STA that supports FTM as a responder. A STA in which dot11FineTimingMsmtInitActivated is true is defined as a STA that supports FTM as an initiator.

When dot11FineTimingMsmtRespActivated is true, dot11WirelessManagementImplemented shall be true. When dot11FineTimingMsmtInitActivated is true, dot11WirelessManagementImplemented shall be true.

A STA in which dot11FineTimingMsmtRespActivated is true shall set the Fine Timing Measurement Responder field of the Extended Capabilities element to 1.

A STA in which dot11FineTimingMsmtInitActivated is true shall set the Fine Timing Measurement Initiator field of the Extended Capabilities element to 1.

A STA in which dot11FineTimingMsmtRespActivated is false shall set the Fine Timing Measurement Responder field of the Extended Capabilities element to 0.

A STA in which dot11FineTimingMsmtInitActivated is false shall set the Fine Timing Measurement Initiator field of the Extended Capabilities element to 0.

11.21.6.3 Fine timing measurement procedure negotiation

In order to initiate an FTM procedure, a STA that supports the FTM procedure as an initiator (referred to as an *initiating STA*) shall transmit a Fine Timing Measurement Request frame. This frame is called the *initial* Fine Timing Measurement Request frame. After transmission of this frame, the initiating STA shall be ready to receive a Fine Timing Measurement frame.

A STA that supports the FTM procedure as a responder (referred to as a *responding STA*) shall not transmit Fine Timing Measurement frames addressed to a peer STA unless the responding STA has received an initial Fine Timing Measurement Request frame from the peer STA.

The initial Fine Timing Measurement Request frame shall have

— The Trigger field set to 1, and
— A set of scheduling parameters in a Fine Timing Measurement Parameters element that describe the initiating STA's availability for measurement exchange.

The first Fine Timing Measurement frame in the FTM session is called the *initial* Fine Timing Measurement frame. The responding STA should transmit an initial Fine Timing Measurement frame within 10 ms in response to the initial Fine Timing Measurement Request frame. This initial Fine Timing Measurement frame shall include the Fine Timing Measurement Parameters element. The Status Indication subfield indicates the outcome of the request.

NOTE 1—In an initial Fine Timing Measurement frame, the responding STA might indicate that the request for an FTM session is successful, even if the initial Fine Timing Measurement frame includes at least one of the following:
a) A Measurement Report element that indicates an unknown LCI or
b) A Measurement Report element that indicates an unknown civic location.

In the case of requests for 160 MHz bandwidth, the initiating STA shall indicate in the Format And Bandwidth subfield whether it uses a single or two separate RF LOs. In the cases when the responding STA indicates use of 160 MHz bandwidth, the responding STA shall indicate in the Format And Bandwidth subfield whether it uses a single or two separate RF LOs.

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The initiating STA shall indicate, in the Format and Bandwidth subfield, a format and bandwidth that it supports.

If the request was successful:

- The responding STA shall indicate, in the Format and Bandwidth subfield, a format and bandwidth that it supports. The responding STA should indicate the same format and bandwidth in the Format and Bandwidth subfield as that requested by the initiating STA, if the responding STA supports this. The responding STA shall not indicate a bandwidth wider than requested. The responding STA shall not indicate a VHT format if DMG, HT-mixed or non-HT format was requested. The responding STA shall not indicate an HT format if DMG or non-HT format was requested. The responding STA shall not indicate a DMG format if VHT, HT-mixed or non-HT format was requested.
- An initiating STA performing an FTM procedure with a responding STA that is an AP shall support non-ASAP operation.
- A responding STA that is an AP shall support and select non-ASAP operation when so requested by an initiating STA.
- An initiating STA performing an FTM procedure with a responding STA that is not an AP shall support ASAP operation.
- A responding STA that is not an AP shall support and select ASAP operation when so requested by an initiating STA.
- If the responding STA is ASAP capable, the responding STA's selection of ASAP should be the same as that requested by the initiating STA.
- The responding STA's selection of the Min Delta FTM subfield value shall be greater than or equal to the value requested by the initiating STA.
- The responding STA's selection of the Number of Bursts Exponent subfield value shall be 0 if the initiating STA requested it to be 0.
- The responding STA's selection of the Burst Duration subfield value should be less than or equal to the one requested by the initiating STA if the requested FTMs Per Burst subfield value is set to a value indicating no preference, subject to the recommendations below and the responding STA's policy on the maximum and minimum Burst Duration subfield values.
  - If the Number of Bursts Exponent subfield is set to 0 and the ASAP subfield is set to 1, the Burst Duration subfield value should be set to indicate the value BD_1, defined as follows:

    $$BD_1 = ((N_{FTMPB} \times (K + 1)) - 1) \times T_{MDFTM} + T_{FTM} + \text{aSIFSTime} + T_{Ack}$$

    where

    N_{FTMPB} is the value of the FTMs Per Burst subfield

    K is the maximum number of Fine Timing Measurement frame retransmissions the responding STA might attempt

    T_{MDFTM} is the duration indicated by the Min Delta FTM subfield of the Fine Timing Measurement Parameters field of the initial Fine Timing Measurement frame (FTM_1)

    T_{FTM} is the duration of the initial Fine Timing Measurement frame if the FTMs Per Burst subfield of the Fine Timing Measurement Parameters field of FTM_1 is set to 1, and the duration of the non initial Fine Timing Measurement frame otherwise

    T_{Ack} is the duration of the Ack frame expected as a response
  - Otherwise, the Burst Duration subfield value should be set to indicate a value greater than or equal to the following value:

    $$BD_1 + T_{FTMR} + \text{aSIFSTime} + T_{Ack} + T_{ACCESS_FTM}$$

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where

T_{FTMR} is the duration of a Fine Timing Measurement Request frame without a Measurement Request element and without a Fine Timing Measurement Parameters element

T_{ACCESS_FTM} is the estimated medium access time for the first Fine Timing Measurement frame in a burst

— The responding STA's selection of the FTMs Per Burst subfield should be the same as the one requested by the initiating STA if the requested the Burst Duration subfield indicates no preference (see Table 9-279), subject to the responding STA's policy on the maximum value of the FTMs Per Burst subfield.

— The responding STA's selection of Burst Period shall be greater than or equal the responding STA's selection of Burst Duration.

NOTE 2—Except as indicated in this subclause, the subfields in the Fine Timing Measurement Parameters field of the Fine Timing Measurement Parameters element in the initial Fine Timing Measurement frame have no constraints.

When the responding STA cannot support the initiator's Min Delta FTM or Number of Bursts Exponent constraints, the responding STA shall set the Status Indication subfield to Request incapable and the FTM session ends. When the responding STA is unable to fulfill the request by the initiating STA, the responding STA shall set the Status Indication subfield to Request failed and the FTM session ends.

11.21.6.4 Measurement exchange

The time windows during which TOD measurement for the transmission of the Fine Timing Measurement frame and the TOA measurement on the receipt of the acknowledgment corresponding to the transmitted Fine Timing Measurement frame are performed are known as burst instances. Fine Timing Measurement frames over which TOD and TOA measurements are performed shall not be sent outside burst instances. The timing of the burst instances is defined by the following parameters:

— Partial TSF Timer: The partial TSF timer, as defined in 9.4.2.167, at the beginning of the first burst instance.

— Burst Duration: The duration of each burst instance starting at the boundary of a burst period.

— Burst Period: The interval from the beginning of one burst instance to the beginning of the following burst instance.

The initiating STA shall transmit a Fine Timing Measurement Request frame without a Measurement Request element, without a Fine Timing Measurement Parameters element and with the Trigger field set to 1 as soon as it is available on channel during a burst instance. This indicates to the responding STA its availability for the remainder of the burst instance. In response, the responding STA shall transmit an Ack frame and should transmit FTMs Per Burst Fine Timing Measurement frames before the end of the burst instance. In addition, the initiating STA shall be ready to receive a Fine Timing Measurement frame. The first Fine Timing Measurement frame and its retransmissions in the burst instance from the responding STA shall include an FTM Synchronization Information element in the FTM Synchronization Information field. The TSF Sync Info field in the FTM Synchronization Information element contained in the Fine Timing Measurement frame might be used by the initiating STA to synchronize its TSF with the responding STA's in order to determine the start of subsequent burst instances. Subsequent Fine Timing Measurement frames within the burst instance shall not include a Fine Timing Measurement Parameters element and shall not include an FTM Synchronization Information field (for additional constraints on the Fine Timing Measurement frame see 11.21.6.7). Consecutive Fine Timing Measurement frames to a given peer STA shall be spaced at least Min Delta FTM apart. Within a burst instance the initiating STA shall perform FTM on each Fine Timing Measurement frame addressed to it, except the last Fine Timing Measurement frame. The initiating STA may perform FTM on the last Fine Timing Measurement frame in a burst instance.

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NOTE 1—If the initiating STA successfully transmits a non-initial Fine Timing Measurement Request frame late in a burst instance, fewer than FTMs per burst might be successfully transmitted by the responding STA in the burst instance. If a Fine Timing Measurement frame, except for the initial Fine Timing Measurement frame in the ASAP=0 case, is sent outside a burst instance, it might not be acknowledged.

The first burst instance shall start at the value indicated by the Partial TSF Timer subfield in the initial Fine Timing Measurement frame, regardless of the ASAP field's value. When ASAP is set to 1 by the responding STA, the Partial TSF Timer subfield value shall be set to a value less than 10 ms from the reception of the most recent initial Fine Timing Measurement Request frame.

The scheduling parameters of an FTM session are illustrated in Figure 11-35.

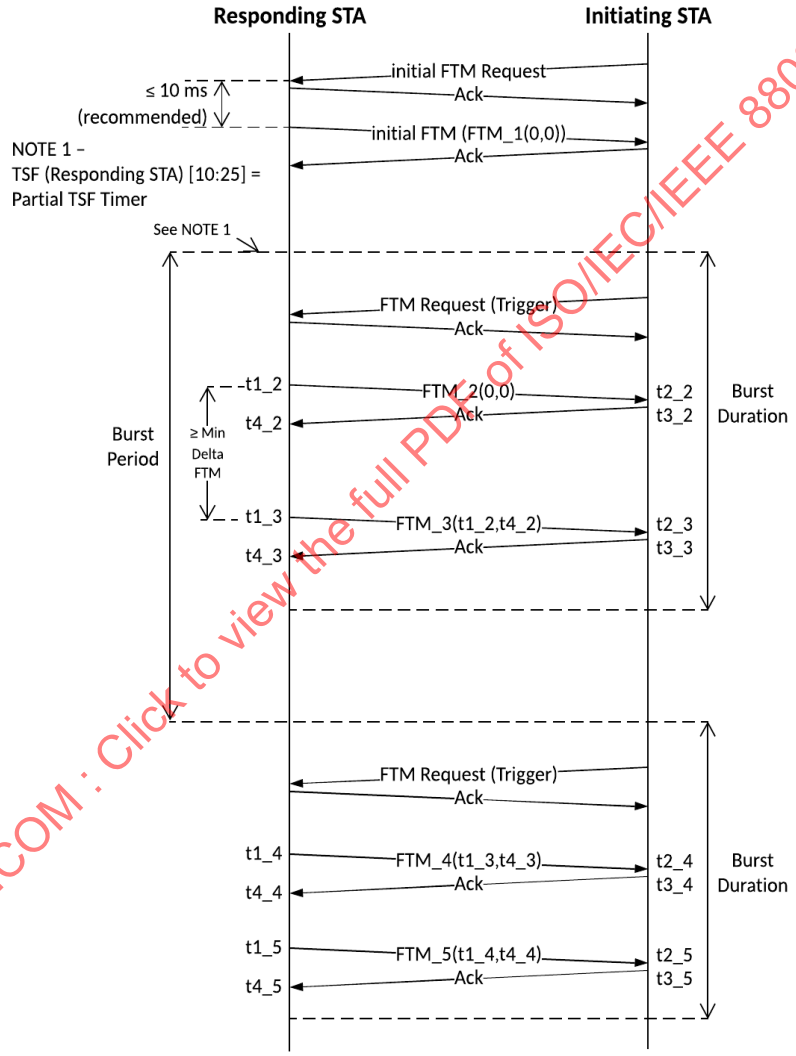

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Figure 11-35—Example negotiation and measurement exchange sequence, ASAP=0, and FTMs Per Burst = 2

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The initiating STA can request the responding STA to start the burst instances "as soon as possible" by setting the ASAP subfield to 1. The scheduling in this case is illustrated in Figure 11-36.

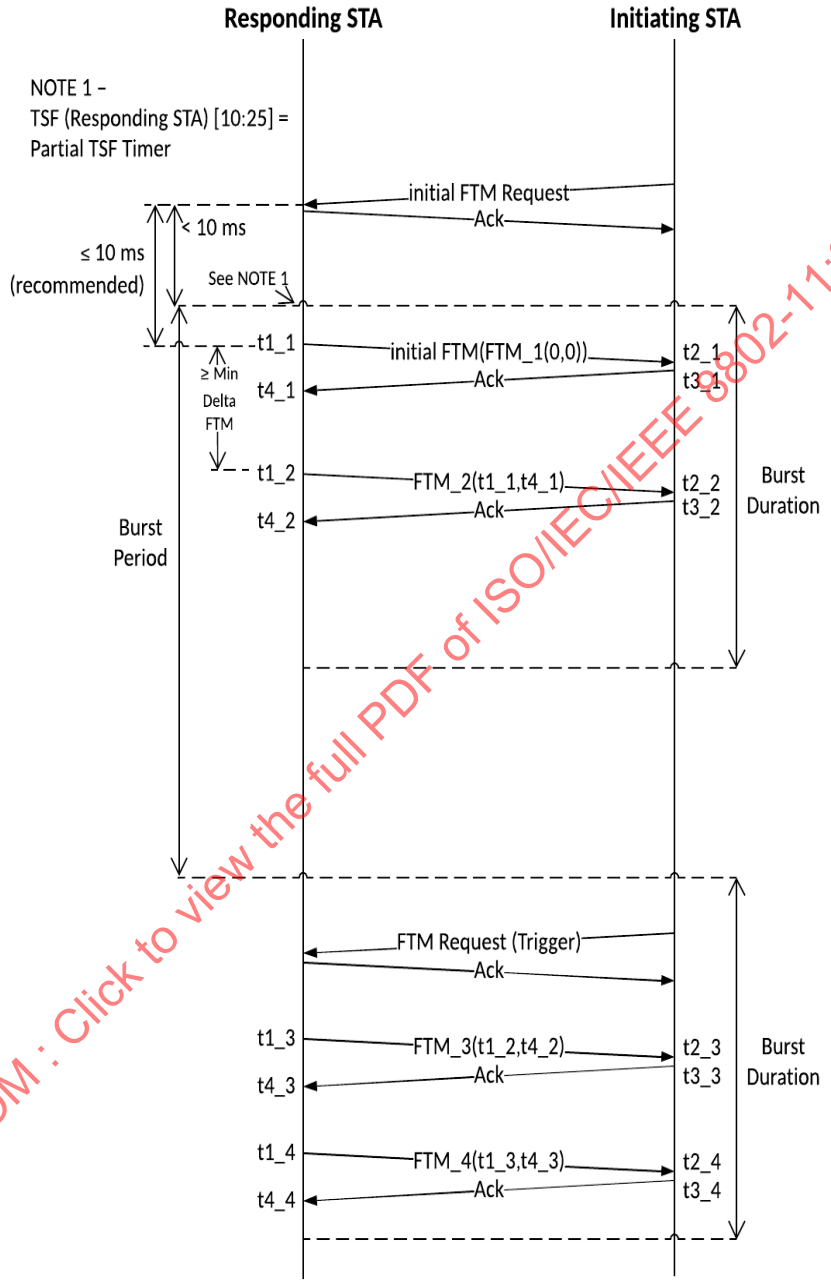

Figure 11-36—Example negotiation and measurement exchange sequence, ASAP=1, and FTMs Per Burst = 2

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The initiating STA may also request a single burst of FTMs to be taken as soon as possible, in which case it sets the Number of Bursts Exponent subfield to 0 and the ASAP subfield to 1. This is illustrated in Figure 11-37.

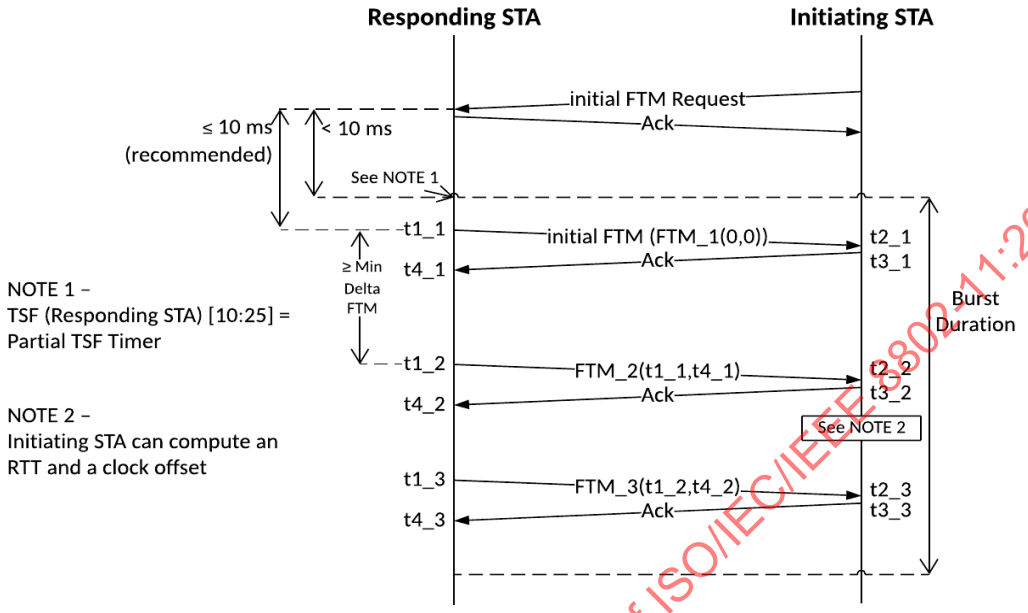

Figure 11-37—Example negotiation and measurement exchange sequence for a single burst instance, ASAP=1, and FTMs Per Burst = 3

For non-DMG STAs, both the Fine Timing Measurement frame and the corresponding Ack frame shall be transmitted using a single transmit chain.

The responding STA shall not transmit Fine Timing Measurement frames using Clause 15 or Clause 16 formats, MCS 32 format, or HT-greenfield format.

The responding STA should transmit Fine Timing Measurement frames with the format and bandwidth it indicated in the initial Fine Timing Measurement frame.

For the Fine Timing Measurement frames transmitted during the FTM session:

— The responding STA shall not use a bandwidth wider than it indicated in the initial Fine Timing Measurement frame.

— The responding STA shall not use a VHT format if it indicated HT-mixed or non-HT format in the initial Fine Timing Measurement frame.

— The responding STA shall not use an HT format if it indicated non-HT format in the initial Fine Timing Measurement frame.

The ASAP Capable subfield shall be set to 1 in the initial Fine Timing Measurement frame if a responding STA is ASAP-capable; otherwise it shall be set to 0.

A responding STA transmits Fine Timing Measurement frames in overlapping pairs of consecutive frames. For example, in Figure 11-36, FTM_1 and FTM_2, FTM_2 and FTM_3, and FTM_3 and FTM_4 are overlapping pairs of consecutive frames. The first Fine Timing Measurement frame of a pair of consecutive Fine Timing Measurement frames contains a nonzero value in the Dialog Token field. The follow up Fine Timing Measurement frame contains a Follow Up Dialog Token field set to the value of the Dialog Token field in the

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first frame of the consecutive pair. Dialog Token field values of consecutive Fine Timing Measurement frames shall be consecutive, except when the value wraps around to 1 or in the last Fine Timing Measurement frame in an FTM session. With the first Fine Timing Measurement frame, both STAs capture timestamps. The responding STA captures the time at which the Fine Timing Measurement frame is transmitted (*t1*). The initiating STA captures the time at which the Fine Timing Measurement frame arrives (*t2*) and the time at which the Ack response is transmitted (*t3*). The responding STA captures the time at which the Ack frame arrives (*t4*). See Figure 6-17. In the follow up Fine Timing Measurement frame, in the same or the subsequent burst, the responding STA transfers the timestamp values it captured (*t1* and *t4*) to the initiating STA. In this follow up Fine Timing Measurement frame, the timestamp values (*t1* and *t4*) shall be the measurement according to the responding STA's clock (i.e., without applying any frequency offset correction to the time bases).

NOTE 2—A Fine Timing Measurement frame can contain nonzero values in both the Dialog Token and Follow Up Dialog Token fields, meaning that the Action frame contains follow up information from a previous measurement, and new Timestamp values are captured to be sent in a future follow up Fine Timing Measurement frame.

When the ASAP subfield is set to 0 by a responding STA, the Follow Up Dialog Token, TOD, TOA, TOD Error, and TOA Error fields in the Fine Timing Measurement frame following the initial Fine Timing Measurement frame shall be reserved.

When the ASAP subfield is set to 1 by a responding STA, the timestamps for the initial Fine Timing Measurement frame shall be captured and sent in the following Fine Timing Measurement frame. In the Fine Timing Measurement frame following the initial Fine Timing Measurement frame, the TOD and TOA fields shall be set to the timestamps associated with the initial Fine Timing Measurement frame.

The round trip time (RTT) is defined by Equation (11-5).

$$RTT = [(t4' - t1') - (t3 - t2)] \quad (11\text{-}5)$$

where *t1*' and *t4*' are the time at which the Fine Timing Measurement frame was transmitted and the time at which the Ack was received, respectively, as determined by the initiating STA.

At the initiating STA, the mechanism by which *t1*' and *t4*' are derived from the TOD and TOA fields is implementation dependent.

The FTM procedure can also be used to synchronize a local clock between STAs. One higher-layer protocol for synchronizing a local clock time between STAs is specified in IEEE Std 802.1AS.

The SME at the initiating STA may estimate the offset of the local clock relative to that at the responding STA using clock offset as defined by Equation (11-6).

$$clock\ offset = [(t2 - t1') - (t4' - t3)]/2 \quad (11\text{-}6)$$

NOTE 3—The initiating STA might track this clock offset over time to derive an estimate of the difference between the initiating STA's time base and the responding STA's time base, and thereby improve the accuracy of its derivation of *t1*' and *t4*' from the TOD and TOA fields.

If the Ack frame for a transmitted Fine Timing Measurement frame is not received, the responding STA shall not retry the frame. In order to send the frame again, the responding STA shall send a Fine Timing Measurement frame with the same Action frame body as the Fine Timing Measurement frame for which the Ack was not received, except for updating the Dialog Token if it was nonzero. The Sequence Number in the MAC header is also updated. This is called an *FTM retransmission*.

A responding STA that transmits a Fine Timing Measurement frame with the ASAP subfield set to 0 shall set the Partial TSF Timer subfield to an offset value D_{TSF} from the partial value of the responding STA's TSF

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timer at the time of the transmission of the Ack to the last Fine Timing Measurement Request frame from the initiating STA, subject to

$$D_{TSF} \geq K_1 \times T_{MDFTM} + T_{FTM_1} + \text{aSIFSTime} + T_{Ack} + T_{ACCESS_FTM1}$$

where

K_1	is the maximum number of initial Fine Timing Measurement frame (FTM_1) retransmissions the responding STA might attempt
T_{MDFTM}	is the value of the Min Delta FTM subfield of the Fine Timing Measurement Parameters field of FTM_1
T_{FTM_1}	is the duration of the FTM_1
T_{Ack}	is the duration of the Ack frame expected as a response
T_{ACCESS_FTM1}	is the estimated medium access time for FTM_1

NOTE 4—This Partial TSF Timer subfield ought to result in the Fine Timing Measurement Request frame not being transmitted before a successful transmission of FTM_1.

When neither an Ack to the initial Fine Timing Measurement frame nor a Fine Timing Measurement Request frame has been received by the responding STA, the responding STA shall not terminate the FTM session before the time indicated by the Partial TSF timer plus the Burst Duration.

The responding STA shall set the Follow Up Dialog Token field to 0 in the initial Fine Timing Measurement frame and its FTM retransmissions.

The responding STA shall set the Dialog Token field to 0 in the last Fine Timing Measurement frame and its FTM retransmissions.

11.21.6.5 Fine timing measurement parameter modification

During an FTM session, an initiating STA may terminate the current session and request a new session with modified session parameters by transmitting a Fine Timing Measurement Request frame with Trigger field set to 1 and including a new Fine Timing Measurement Parameters element. The existing FTM session is terminated upon reception of such a Fine Timing Measurement Request frame. This Fine Timing Measurement Request frame is an initial Fine Timing Measurement Request frame for the new FTM session, which follows the behavior described in 11.21.6.3.

11.21.6.6 Fine timing measurement termination

An FTM session terminates after the last burst instance, as indicated in the Number of Bursts Exponent, Burst Duration, FTMs Per Burst and Burst Period fields in the initial Fine Timing Measurement frame.

An FTM session may be terminated before then through one of the following:

— At any time during the FTM session when the responding STA is permitted to transmit a Fine Timing Measurement frame (see 11.21.6.4), the responding STA sends a Fine Timing Measurement frame with the Dialog Token field set to 0.

— At any time during the FTM session when the initiating STA is permitted to transmit a Fine Timing Measurement Request frame (see 11.21.6.4), the initiating STA sends a Fine Timing Measurement Request frame with the Trigger field set to 0. This frame shall not include the following:

  — A Measurement Request element

  — A Fine Timing Measurement Parameters element

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— At any time during the FTM session when the initiating STA is permitted to transmit a Fine Timing Measurement Request frame (see 11.21.6.4), the initiating STA terminates the current session and requests a new session with modified Fine Timing Measurement parameters (see 11.21.6.5).
— After the number of burst instances indicated in the Number of Bursts Exponent field in the initial Fine Timing Measurement frame has been reached.

11.21.6.7 LCI and Location Civic retrieval using FTM procedure

Within the FTM procedure, a STA, to request the LCI of a responding STA that transmits an Extended Capabilities element with the Fine Timing Measurement Responder field set to 1, shall include a Measurement Request element with Measurement Type field equal to LCI within the Fine Timing Measurement Request frame.

Within the FTM procedure, a STA, to request the Location Civic of a responding STA that transmits an Extended Capabilities element with the Fine Timing Measurement Responder field set to 1, shall include a Measurement Request element with Measurement Type field equal to Location Civic within the Fine Timing Measurement Request frame.

A Measurement Request element with Measurement Type field equal to LCI shall not be included in a Fine Timing Measurement Request frame unless the Fine Timing Measurement Request frame also includes a Fine Timing Measurement Parameters element. A Measurement Request element with Measurement Type field equal to Location Civic shall not be included in a Fine Timing Measurement Request frame unless the Fine Timing Measurement Request frame also includes a Fine Timing Measurement Parameters element.

When a responding STA that has both dot11FineTimingMsmtRespActivated and dot11RMLCIConfigured equal to true receives a Measurement Request element with Measurement Type field equal to LCI within an initial Fine Timing Measurement Request frame, the responding STA shall include a Measurement Report element with Measurement Type field equal to LCI in the initial Fine Timing Measurement frame. If the maximum horizontal or vertical location error of the responding STA relative to a reference STA is known and this relative error is smaller than the absolute error indicated in the LCI subelement, then the responding STA may include a Relative Location Error subfield in the Measurement Report field. The responding STA shall not include a Measurement Report element with Measurement Type field equal to LCI in the Fine Timing Measurement frame in the current FTM session unless the responding STA's LCI has changed since the last time it was reported to the initiating STA.

When a responding STA that has at least one of dot11FineTimingMsmtRespActivated and dot11RMLCIConfigured equal to false receives a Measurement Request element with Measurement Type field equal to LCI within a Fine Timing Measurement Request frame, the responding STA shall include a Measurement Report element with the Incapable field set to 1 in the initial Fine Timing Measurement frame.

When a responding STA that has both dot11FineTimingMsmtRespActivated and dot11RMCivicConfigured equal to true receives a Measurement Request element with Measurement Type field equal to Location Civic within an initial Fine Timing Measurement Request frame, the responding STA shall include a Measurement Report element with Measurement Type field equal to Location Civic in the initial Fine Timing Measurement frame. The responding STA shall not include a Measurement Report element with Measurement Type field equal to Location Civic in the Fine Timing Measurement frame in the current FTM session unless the responding STA's civic location has changed since the last time it was reported to the initiating STA.

When a responding STA that has at least one of dot11FineTimingMsmtRespActivated and dot11RMCivicConfigured equal to false receives a Measurement Request element with Measurement Type equal to Location Civic within a Fine Timing Measurement Request frame, the responding STA shall include a Measurement Report element with the Incapable field set to 1 in the initial Fine Timing Measurement frame.

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Each Measurement Report element returned shall have the same Measurement Token value as in the Measurement Token field of the corresponding Measurement Request element. The Fine Timing Measurement frame containing the Measurement Report element(s) should be returned without undue delay to the STA.

A STA that receives an LCI report that contains a Usage Rules/Policy subelement shall process the LCI information in compliance with the retransmission and retention permissions in the Usage Rules/Policy subelement.

11.21.7 BSS transition management for network load balancing

11.21.7.1 BSS transition capability

The BSS transition capability enables improved throughput, effective data rate and/or QoS for the aggregate of STAs in a network by shifting (via transition) individual STA traffic loads to more appropriate points of association within the ESS. In addition, the BSS transition capability provides accounting/session control information to a non-AP STA, which might be used to provide an alert to the non-AP STA's user that the STA's session is almost over and the STA will be disassociated from the ESS.

The BSS Transition Management Query, BSS Transition Management Request, BSS Transition Management Response frames provide a means and a protocol to exchange the information needed to enable an AP to inform associated STAs that the BSS will be terminated and to enable a network to manage BSS loads by influencing STA transition decisions. A STA may provide neighbor report information to its associated AP for BSSs that it considers to be transition targets. This information enables the AP to request that the STA transition to a BSS that the STA also prefers.

Implementation of BSS transition management is optional for a WNM STA. When dot11BSSTransitionActivated is true, dot11WirelessManagementImplemented shall be true. A STA with dot11BSSTransitionActivated equal to true shall support BSS transition management and shall set to 1 the BSS Transition field of the Extended Capabilities elements that it transmits.

The provisions in this clause for BSS transition management and network load balancing do not apply in an IBSS.

11.21.7.2 BSS transition management query

A non-AP STA supporting BSS transition management may request a BSS Transition Candidate list by sending a BSS Transition Management Query frame to its associated AP if the associated AP indicates that it supports the BSS Transition capability in the Extended Capabilities element. A non-AP STA should include the BSS Transition Candidate List Entries field in the BSS Transition Management Query frame to indicate the non-AP STA's transition preferences. If the non-AP STA transmits a BSS Transition Query frame only to provide transition preferences to the AP, then the BSS Transition Query Reason field of the BSS Transition Management Query frame shall be set to a value of 19, indicating "Preferred BSS Transition Candidate List Included."

The BSS Transition Candidate List Entries field of a BSS Transition Management Query frame contains zero or more Neighbor Report elements describing the non-AP STA's preferences for target BSS candidates. The Preference field value of a Neighbor Report element used in a BSS Transition Management Query frame shall be between 1 and 255. The value of 0 is reserved. The values between 1 and 255 provide the indication of order, with 255 indicating the most preferred BSS within the given candidate list, decreasing numbers representing decreasing preference relative only to entries with lower values of the Preference field, and equal numbers representing equal preference.

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11.21.7.3 BSS transition management request

An AP that supports BSS transition management shall respond to a BSS Transition Management Query frame with a BSS Transition Management Request frame. The AP may send an unsolicited BSS Transition Management Request frame to a non-AP STA at any time if the non-AP STA indicates in the Extended Capabilities element that it support BSS transition management; otherwise the AP shall not send an unsolicited BSS Transition Management Request frame to the STA. The AP may transmit a group addressed BSS Transition Management Request frame to associated non-AP STAs if all associated non-AP STAs support the BSS transition management; otherwise the AP shall not transmit a group addressed BSS Transition Management Request frame. When the BSS Transition Management Request frame is transmitted as a group addressed frame, a receiving non-AP STA shall not respond with a BSS Transition Management Response frame. A non-AP STA that supports BSS transition management shall respond to an individually addressed BSS Transition Management Request frame with a BSS Transition Management Response frame.

The AP shall include the BSS Transition Candidate List Entries field in the BSS Transition Management Request frame if the AP has information in response to the BSS Transition Management Query frame. The BSS Transition Candidate List Entries field contains zero or more Neighbor Report elements describing the preferences for target BSS candidates. A Preference field value of 0 indicates that the BSS listed is an excluded BSS. The STA should refrain from associating to an AP corresponding to an excluded BSS. The Preference field values are used to establish the relative order of entries within the given list at the given time, and for the given AP.

The values between 1 and 255 provide the indication of order, with 255 indicating the most preferred BSS within the given candidate list, decreasing numbers representing decreasing preference relative only to entries with lower values of the Preference field, and equal numbers representing equal preference. The Preference field value is valid only before the validity interval has expired. The AP may include zero or more subelements in the BSS Transition Candidate List Entries field.

Upon reception of a BSS Transition Management Query frame or BSS Transition Response frame from a non-AP STA that contains a nonempty BSS Transition Candidate List Entries field, the AP should include at least one BSS candidate from that list with a nonzero Preference field value in the BSS Transition Candidate List Entries field of any subsequent BSS Transition Management Request frame with the Preferred Candidate List Included field set to 1 transmitted to the non-AP STA. The AP shall evaluate the BSSs indicated in the BSS Transition Candidate List Entries field in the latest BSS Transition Management Query frame or BSS Transition Management Response frame received from the non-AP STA as BSS transition candidate(s) for the non-AP STA. The means by which the AP evaluates and determines BSS transition candidates is outside the scope of this standard.

A STA that receives a BSS Transition Management Request frame with the Preferred Candidate List Included subfield of the Request Mode field equal to 0 may ignore the BSS Transition Candidate List Entries field of the frame.

A non-AP STA that receives the Abridged bit with a value of 1 shall treat any BSSID in the ESS of which it is a member that does not appear in the BSS Transition Candidate List as if it were present in the BSS Transition Candidate List with a Preference value of 0.

The AP may include one BSS Termination Duration subelement for each BSS in the BSS Transition Candidate List Entry field, including the BSS Termination Duration value and a BSS Termination TSF value. The BSS Termination Duration value may be different for each BSS.

When the AP transmits a BSS Transition Management Request frame with the Disassociation Imminent field set to 1 to a non-AP STA, the Disassociation Timer field in the BSS Transition Management Request frame shall be set to 0 or set to the number of TBTTs that will occur prior to the AP disassociating the non-AP STA. The AP shall start a timer for the non-AP STA with the initial timer value set to the Disassociation Timer field

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value. The AP shall decrement the timer by one after transmitting each Beacon frame until the timer has value of 0. In subsequent BSS Transition Management Request frames that the AP transmits to the non-AP STA, the Disassociation Timer field shall be set to the value of the timer.

If the most recent BSS Transition Management Request frame that an AP has transmitted to a non-AP STA has the Disassociation Imminent field set to 1, then the AP shall not transmit a Disassociation frame to the non-AP STA unless the timer for the non-AP STA has value of 0.

An AP's SME may have accounting session control information, such as a notice of session expiration. The means by which the AP's SME obtains accounting session control information is out of scope of this standard. Accounting session control information might include a duration after which the non-AP STA will be disassociated from the ESS and an optional session information URL at which information may be obtained to extend the accounting session. When an AP's SME has accounting session control information, it shall issue an MLME-BTM.request primitive to the AP's MLME and shall encode the time to session expiration in the Disassociation Timer parameter and shall encode the URL, if available, in the SessionInformationURL parameter. A non-AP STA's SME that receives an MLME-BTM.indication primitive shall forward the MLME-BTM.indication parameters to the appropriate entity within the device (e.g., web browser) to inform the end user; the means and protocol by which the SME accomplishes this is outside the scope of this standard.

A STA's SME receiving an MLME-BTM.indication primitive containing the BSS Transition Candidate List Entries field should use this list of candidates, with individual transition preference values, to make BSS transition decisions. Upon receiving an MLME-BTM.indication primitive, the STA's SME shall disregard any previous MLME-BTM.indication primitive received from the same AP. The STA shall not use the corresponding BSS Transition Candidate List Entries field information after the indicated validity interval. The STA may send a BSS Transition Management Query frame at any time to obtain an updated BSS Transition Candidate List Entries field or to indicate the STA's BSS transition candidates.

A STA's SME receiving an MLME-BTM.indication primitive containing a nonzero value of the Disassociation Timer field should attempt to find a suitable AP with which to reassociate before the indicated disassociation time.

11.21.7.4 BSS transition management response

When the STA's SME receives an MLME-BTM.indication primitive, it may issue an MLME-BTM.response primitive.

The STA's SME may include the result of its BSS transition decision in the Target BSSID field and BTM Status Code field in the MLME-BTM.response primitive. A BTM Status Code field set to a value of 0 (i.e., Accept) indicates the STA will transition from the current BSS. If a STA's SME receives an MLME-BTM.indication primitive indicating a BSS transition management request that it is unable to comply with, it may issue an MLME-BTM.response primitive with a status code indicating rejection.

When a non-AP STA's SME receives an MLME-BTM.indication primitive with the BSS Termination Included field in the Request Mode field equal to 1 it may issue an MLME-BTM.response primitive with the BTM Status Code field set to one of the following values:

- 0 – Accept. Accept the BSS Termination request.
- 4 – Reject, BSS Termination Undesired. Request for deferral of BSS Termination, interval not specified.
- 5 – Reject, BSS Termination Delay. Request for deferral of BSS Termination interval specified in the BSS Termination Delay field in the BSS Transition Management Response frame.

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The AP's SME may terminate or delay BSS Termination based on policies that are out of the scope of this standard. The MLME-RESET.request primitive is invoked to terminate the BSS. The AP shall disassociate all STAs immediately prior to termination of the BSS.

When a non-AP STA's SME receives an MLME-BTM.indication primitive with both the Disassociation Imminent and Preferred Candidate List Included fields equal to 0, the non-AP STA's SME shall issue an MLME-BTM.response primitive with the BTM Status Code field set to one of the following values:

— 0 – Accept.
— 2 – Reject, Insufficient Beacon or Probe Response frames received from all candidates.
— 3 – Reject, Insufficient available capacity from all candidates.
— 6 – Reject, STA BSS Transition Candidate List provided.
— 7 – Reject, No suitable BSS transition candidates.
— 8 – Reject, Leaving ESS.

When an AP's SME receives an MLME-BTM.confirm primitive with the BTM Status Code field equal to a value of 2, indicating "Reject, Insufficient Beacon or Probe Response frames received from all candidates," the AP's SME should generate an MLME-BTM.request primitive with both the Disassociation Imminent and Preferred Candidate List Included fields set to 0 after providing sufficient time for the non-AP STA to perform its scanning procedures.

If the BTM Status Code field is a value of 6, indicating "Reject, STA BSS Transition Candidate List provided," the non-AP STA shall include a nonempty BSS Transition Candidate List Entries field in the BSS Transition Management Response frame to indicate the non-AP STA's transition preferences. The BTM Status Code field is a value of 8, indicating "Reject, Leaving ESS" if the non-AP STA intends to disassociate from the ESS.

The BSS Transition Candidate List Entries field of a BSS Transition Management Response frame contains zero or more Neighbor Report elements describing the non-AP STA's preferences for target BSS candidates. The Preference field value of a Neighbor Report element used in a BSS Transition Management Response frame shall be between 1 and 255. The value of 0 is reserved. The values between 1 and 255 provide the indication of order, with 255 indicating the most preferred BSS within the given candidate list, decreasing numbers representing decreasing preference relative only to entries with lower values of the Preference field, and equal numbers representing equal preference. The non-AP STA should not list any BSS that is not considered as a target BSS candidate.

When a non-AP STA receives a BSS Transition Management Request frame that has both the Disassociation Imminent and Preferred Candidate List Included fields equal to 1 and a nonempty BSS Transition Candidate List Entries field, if the non-AP STA transmits a BSS Transition Management Response frame to the AP with the BTM Status Code field set to 0 (Accept), then the non-AP STA shall either disassociate from the AP or attempt to (re)associate with an AP corresponding to one of the nonexcluded BSSs in the BSS Transition Candidate List Entries field of the received BSS Transition Management Request frame.

Prior to transitioning to an excluded BSS listed in the BSS Transition Candidate List Entries field of a received BSS Transition Management Request frame, the non-AP STA shall transmit a BSS Transition Management Response frame to the AP indicating the reject reason.

11.21.8 FMS multicast rate processing

An AP that supports FMS indicates its ability to deliver group addressed frames at alternate delivery intervals by its advertisement of the FMS capability. A STA that supports FMS includes the FMS Request element in FMS Request frames to indicate a request to use the FMS service, including use of a higher multicast rate. The AP selects the TXVECTOR parameters to use with the STA and indicates the rate that these parameters produce and the multicast address in the FMS Response element in the FMS Response frame.

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The AP selects TXVECTOR parameters that will be used for transmission to the currently associated STAs requesting FMS service from the AP for the same FMS stream identified by FMSID (the "existing STAs"), and to the requesting STA subject to the following constraints:

- The rate shall not be higher than the lowest rate value provided by the existing STAs and the requesting STA
- The selection of the following TXVECTOR parameters shall be compatible with capabilities declared by the existing STAs and the requesting STA:
  - FORMAT
  - NON_HT_MODULATION
  - PREAMBLE_TYPE
  - MCS
  - CH_BANDWIDTH
  - STBC
  - FEC_CODING
  - GI_TYPE

The STA's SME may request membership in a multicast group or changes in multicast data rate by issuing an MLME-FMS.request primitive. Upon receipt of an FMS Request frame at the AP's SME as indicated by reception of the MLME-FMS.indication primitive the AP's SME shall issue an MLME-FMS.response primitive, indicating the FMS Request element, including the multicast address. The AP may send an FMS Response frame to the STA to change the STA's multicast rate. When the AP sends an FMS Response frame to the STA with an Element Status field, indicating "Multicast rate changes not allowed," the STA shall not send further FMS Request frames to request a change in the multicast rate while the STA is associated to the AP.

11.21.9 Collocated interference reporting

Collocated interference might cause degradation of IEEE 802.11 STA performance either periodically or continuously. Collocated interference reporting allows a requesting STA to receive information concerning the collocated interference being experienced by another STA that is operating on the same channel as the requesting STA. Such interference might be due to an interaction between radios where a reporting STA is collocated with another radio device. Collocated interference information might be used by the requesting STA to manage communication to the reporting STA such that the effect of the interference might be limited.

Implementation of Collocated interference reporting is optional for a WNM STA. A STA that implements Collocated Interference reporting has dot11CoLocIntfReportingImplemented equal to true. When dot11CoLocIntfReportingImplemented is true, dot11WirelessManagementImplemented shall be true. A STA with dot11CoLocIntfReportingActivated equal to true shall support collocated interference reporting and shall set to 1 the Collocated Interference Reporting field of the Extended Capabilities elements that it transmits.

A requesting STA may request that collocated interference reporting is enabled at another STA that has indicated support for the interference reporting capability. To enable collocated interference reporting, the STA shall send a Collocated Interference Request frame with Automatic Response Enabled bit set to the value representing the requested reporting type; see 9.6.13.13. A STA accepting a request for collocated interference reporting shall send the first report when it has knowledge of collocated interference.

Subsequently, a STA accepting a request with the Automatic Response Enabled subfield equal to 1 shall send a collocated interference report when the temporal characteristics of the interference or the level of the interference caused by collocated interferer significantly change to provide updated information, subject to meeting the Report Timeout requirement. A STA accepting a request with the Automatic Response Enabled subfield equal to 2 or 3 shall send the collocated interference reports periodically using the period included in the Report Period field in the Collocated Interference Reporting element in the report frames. In addition to

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sending reports periodically, a STA accepting a request with the Automatic Response Enabled field equal to 3 shall send a collocated interference report when the temporal characteristics of the interference or the level of the interference caused by collocated interferer significantly change, subject to meeting the Report Timeout requirement.

The criteria a reporting STA uses for determining significant changes are internal to the reporting STA and outside the scope of this standard. When the reporting STA sends a collocated interference report, it shall restart the Report Period timer for periodic reporting. For either periodic reporting or reporting due to the changes in collocated interference, the reporting STA shall not generate collocated interference reports more frequently than indicated by the Report Timeout field in Interference Request field in the Collocated Interference Request frame.

The requesting STA may disable reporting by sending a Collocated Interference Request frame with the Automatic Response Enabled subfield set to 0. The collocated interference reporting shall be terminated on receipt of a Collocated Interference Request frame with the Automatic Response Enabled subfield equal to 0. All outstanding collocated interference requests are canceled upon a BSS transition and/or channel switch. A new collocated interference request included in the new collocated Interference Request frame supersedes any previously received requests sent by the same STA.

A STA that supports collocated interference reporting may send a Collocated Interference Request frame to another STA that supports collocated interference reporting immediately after they are associated, so that the reporting STA can send a collocated interference report as soon as it has knowledge of collocated interference. The Dialog Token field is the nonzero value received in the corresponding Collocated Interference Request frame which was used to enable reporting.

The reporting STA shall use the Interference Index field in the Collocated Interference Report frame to indicate different types of interference. The reporting STA shall select a unique interference index value for each collocated interference source. For example if the reporting STA has knowledge of collocated interference originating from two interference sources the reporting STA shall report both type of interference using separate Collocated Interference Report elements having separate Interference Index field. Both Collocated Interference Report elements can be sent in the same Collocated Interference Report frame and both can have the same report period. A report with the Interference Index field in the Collocated Interference Report element equal to 0 indicates that no collocated interference is present.

The characteristics of the interference are known a priori without requiring interference detection, measurement, and characterization by the IEEE 802.11 STA. The methods used by a reporting STA to know the periodicity, level of interference, accuracy of the reported interference level, interference center frequency and interference bandwidth are outside the scope of this standard.

11.21.10 QoS Traffic capability procedure

Implementation of the QoS Traffic capability is optional for a WNM STA. A STA that implements QoS Traffic capability has dot11QoSTrafficCapabilityImplemented equal to true. When dot11QoSTrafficCapabilityImplemented is true, dot11WirelessManagementImplemented shall be true. A STA with dot11QoSTrafficCapabilityActivated equal to true shall support QoS traffic capability and shall set to 1 the QoS Traffic Capability field of the Extended Capabilities elements that it transmits.

If dot11QoSTrafficCapabilityActivated is true, a QoS AP may use the QoS Traffic Capability field values received from a non-AP QoS STA as one of the factors when determining association, reassociation, and the BSS transition of the STA. A non-AP STA in which dot11QoSTrafficCapabilityActivated is true may send an Association Request, a Reassociation Request or QoS Traffic Capability Update frame to an AP whose last received Extended Capabilities element contained a value of 1 for the QoS Traffic Capability bit in the Extended Capabilities field.

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If dot11QoSTrafficCapabilityActivated is true, a non-AP QoS shall construct the QoS Traffic Capability Flags as specified in 9.4.2.77 and 9.6.13.23. QoS Traffic Capability Flags are constructed at the SME of the non-AP QoS STA, from application requirements supplied to the SME. The QoS Traffic Capability Flags are constructed from two application requirements: whether generation of traffic is required for applications and whether a specific UP is required for the generated traffic. If such requirements are supplied to the SME, the SME shall set the flag corresponding to the specific UP to 1.

NOTE—The requirements might be known before the traffic is actually generated. For example, a phone application might configured to generate UP 6 traffic upon the initiation of a voice session.

Unless application requirements for a specific UP are supplied to the SME, the SME shall set the flag corresponding to the UP to 0.

If dot11QoSTrafficCapabilityActivated is true, a non-AP QoS STA shall include the QoS Traffic Capability element in an Association Request frame or in a Reassociation Request frame when it is sending such a frame to associate or reassociate with an AP. If there is any change in QoS Traffic Capability Flags while associated with an AP, the non-AP STA shall send a QoS Traffic Capability Update frame (see 9.6.13.23) including the updated QoS Traffic Capability Flags to the AP.

11.21.11 AC Station Count

Implementation of AC Station Count is optional for a WNM STA. A STA that implements AC Station Count has dot11ACStationCountImplemented equal to true. When dot11ACStationCountImplemented is true, dot11WirelessManagementImplemented and dot11QoSTrafficCapabilityImplemented shall be true. When dot11ACStationCountActivated is true, the STA shall set the AC Station Count field to 1 in the Extended Capabilities element to indicate that the STA supports the AC station count capability. When dot11ACStationCountActivated is false, the STA shall set the AC Station Count field in the Extended Capabilities element to 0 to indicate that the STA does not support this capability.

If dot11ACStationCountActivated is true, a QoS AP shall construct the QoS Traffic Capability Bitmask and AC STA Count list as specified in 9.4.2.77. The AP shall construct the STA Count List value based on the UP-to-AC mappings as defined in Table 10-1, the QoS Traffic Capability Bitmask/Flags of the non-AP STAs that are currently associated with it, and additional information. If dot11ACStationCountActivated is true, a QoS AP shall include the QoS Traffic Capability element in a Probe Response frame and in a Beacon frame.

If dot11ACStationCountActivated is true, a non-AP QoS STA may use the STA Count field values as one of the factors when determining association, reassociation, and the BSS transition. If dot11ACStationCountActivated is false, a non-AP QoS STA shall not use the STA Count field values as one of the factors when determining association, reassociation, and the BSS transition.

11.21.12 TFS procedures

11.21.12.1 TFS capability

Implementation of the TFS capability is optional for a WNM STA. A STA that implements TFS shall set dot11TFSImplemented to true. If dot11TFSImplemented value is true, then dot11WirelessManagementImplemented shall be true. A STA with dot11TFSActivated equal to true shall support TFS and shall set to 1 the TFS field in the Extended Capabilities elements that it transmits.

A STA in which dot11TFSActivated is true may send a TFS Request, TFS Response, TFS Notify frame, or TFS Notify Response frame to a STA within the same infrastructure BSS whose last received Extended Capabilities element contained a value of 1 for the TFS bit in the Extended Capabilities field. The traffic filtering service is not supported in an IBSS.

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A traffic filtering agreement is established using a TFS Request frame transmitted from a non-AP STA to an AP and a TFS Response frame transmitted from the AP to the non-AP STA. At most one traffic filtering agreement can exist at any one time between a STA and its associated AP.

A traffic filtering agreement comprises one or more traffic filter sets, with a logical OR operation on the match conditions of each traffic filter set.

A traffic filter set contains one or more traffic filters, with a logical AND operation on the match conditions of each traffic filter, and also includes a traffic filter set action. The traffic filter set action defines the actions taken at the AP when a frame match occurs. A frame match occurs when a frame matches to the filtering parameters for a TFS traffic filter set.

NOTE—The frame match can occur when the matched frames are either individually addressed or group addressed.

A TFS Request frame contains one or more TFS Request elements. Each traffic filter set is conveyed by one TFS Request element, within a TFS Request frame.

One TFS Request element contains one or more TFS Request subelements. A TFS Request subelement might be a TFS subelement, in which case it contains the filtering parameters for one traffic filter.

A TFS subelement contains one or more TCLAS elements and an optional TCLAS Processing element that defines the relationship among multiple TCLAS elements within the TFS subelement. The TCLAS Processing element shall be present if more than one TCLAS element is included in the TFS subelement.

A TFS Response frame contains the status of the traffic filters requested in the corresponding TFS Request frame.

An AP may propose alternative filtering parameters by returning a TFS subelement in the corresponding TFS Response subelement. (See 11.21.12.2 and 11.21.12.3). When an AP proposes alternative filtering parameters it shall ensure that the TFS subelements related to the traffic filter set specified by a single TFS Request element all fit within a single TFS Response element.

When an AP transmits a TFS Response frame to a STA in which the Status for all traffic filter requests is “Accept”, it shall enable TFS for the STA. The previously established filter parameters, if any, remain in effect when the AP transmits a TFS Response frame with any other Status.

When a traffic filter for group addressed frames is enabled at the AP, the group addressed frames are still delivered, without regard to the frames matching the traffic filter, since other associated STAs may also receive these frames. Because a STA using TFS can be in power save mode for an extended period of time, group addressed frames that match the traffic filter might be delivered before the STA is aware that the traffic filter has been matched. It is likely (but not guaranteed) that the STA does not receive those group addressed frames matching the traffic filter at the scheduled group addressed delivery time. To detect when this might have happened, the STA can request a notification frame be sent when requesting the establishment of the traffic filter. If negotiated with the AP, a frame match is indicated to the non-AP STA via a notification frame.

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11.21.12.2 TFS non-AP STA operation

To use the TFS, the non-AP STA’s SME that supports TFS shall issue an MLME-TFS.request primitive to send a TFS Request frame. The MLME-TFS.request primitive shall include a valid TFSRequest parameter as defined in the TFS Request elements.

The receipt of an MLME-TSF.confirm primitive with a valid TFSResponse parameter indicates to the STA’s SME that the AP has processed the corresponding TFS request. The content of the TFSResponse parameter

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provides the status of each of the TFS Request elements processed by the AP. A TFSResponse parameter optionally contains modified filtering parameters for the corresponding TFS request.

A TFS Response frame in which the Status for all traffic filter requests is "Accept" indicates to the non-AP STA that the filtering operation at the AP has started. Otherwise, the STA might use the information in the TFS Response frame to form a new TFS request.

In order to request the AP to delete a traffic filter set (identified by a unique TFS ID) when a frame matches to the traffic filter set, a non-AP STA shall set the Delete After Match subfield of the TFS Action Code field of the TFS Request element in the TFS Request frame to 1.

In order to request a TFS Notify frame to be sent by the AP upon a frame match, a non-AP STA shall set the Notify subfield of the TFS Action Code field of the TFS Request element in the TFS Request frame to 1.

After receiving a TFS Notify frame, in order to request the AP to resume generation of the TFS Notify frame upon a future frame match, a non-AP STA shall transmit to the AP a TFS Notify Response frame containing one or more TFS IDs.

The non-AP STA may indicate that it is no longer using a particular TFS Request element by transmitting a TFS Request frame without that TFS Request element. The AP shall send a TFS Response frame with the corresponding Status field value set to Accept, upon receipt of the TFS Request frame.

The non-AP STA may choose to terminate use of the TFS service by sending a TFS Request frame with no TFS Request elements in the request thereby canceling all traffic filters at the AP.

11.21.12.3 TFS AP operation

When an AP's SME receives an MLME-TFS.indication primitive with a valid TFSRequest parameter, it shall issue an MLME-TFS.response primitive with a TFSResponse parameter indicating the status of the associated request.

An AP establishes a traffic filtering agreement and starts the filtering operation defined by that traffic filtering agreement when it receives an MLME-TFS.response primitive in which the Status for all traffic filter requests is "Accept".

When the AP establishes a traffic filtering agreement for a requesting STA, the AP shall add to the traffic filtering agreement a traffic filter set that matches individually addressed EAPOL-Key frames addressed to the requesting STA, with bits 0 and 1 of the TFS Action Code field set to 0, without any status indication for this traffic filter set in the TFS Response frame.

When an AP's SME receives an MLME-TFS.indication primitive with a valid TFSRequest parameter having a requested TCLAS-based classifier which it is unable to provide, the SME shall issue an MLME-TFS.response primitive indicating the status of the corresponding request and may include a TFSResponse parameter having a suggested alternative TCLAS-based classifier.

When a traffic filtering agreement is established for a STA, the AP shall discard all individually addressed frames destined for the STA until a frame is found that matches one or more traffic filter sets within the traffic filtering agreement. When a frame is found that matches one or more of the traffic filter sets within the traffic filtering agreement (a matching frame), the AP shall perform the following actions:

— If the traffic filter set action specifies both Delete After Match and Notify, then the AP shall generate a single individually addressed TFS Notify frame for the frames matching to the traffic filter set identified by the corresponding TFS ID. Subsequently, the AP shall delete the traffic filtering agreement.

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— If the traffic filter set action specifies Notify but not Delete After Match, then the AP shall generate a single individually address TFS Notify frame for all frames matching to the traffic filter set identified by the corresponding TFS ID. All traffic filter sets established at the AP for the non-AP STA remain to be effective upon a match. If the AP receives a TFS Notify Response frame from the corresponding non-AP STA, the AP resumes generation of a single individually addressed TFS Notify frame for the next frame matching to the traffic filter sets identified by the TFS IDs included in the TFS Notify Response frame. Otherwise, the AP shall not send additional TFS Notify frames upon frame matches.

NOTE—Due to the operation of group addressed frame delivery, a group addressed frame that matches a traffic filter might result in the STA receiving indication of the group addressed frame either before or after the group addressed frame is transmitted by the AP, if the TFS Notify frame is queued in the STA's power save queue. This might result in the STA receiving the group addressed frame in some cases and not receiving it in other cases.

Upon receiving an MLME-TFS.indication primitive, the AP's SME shall disregard any previous MLME-TFS.indication primitive received from the same STA.

The AP shall terminate any TFS operation for a STA when no traffic filters remain for a STA or if the AP's SME receives an MLME-TFS.indication primitive with a null TFSRequest.

11.21.13 BSS max idle period management

If dot11BssMaxIdlePeriod is nonzero, an AP shall include the BSS Max Idle Period element in the (Re)Association Response frame. Otherwise, an AP shall not include the BSS Max Idle Period element in the (Re)Association Response frame. A non-S1G STA may send protected or unprotected keepalive frames, as indicated in the Idle Options field.

Extended BSSMaxIdlePeriod values are those that had a nonzero unified scaling factor (Table 9-48) value signaled by an S1G STA. An S1G non-AP STA may include the BSS Max Idle Period element in transmitted (Re)Association Request frames to indicate a preferred BSSMaxIdlePeriod value.The S1G AP chooses a value for BSSMaxIdlePeriod based on the S1G STA's preferred BSSMaxIdlePeriod (if any) and the type of the S1G STA. The S1G AP indicates its chosen value to the S1G STA in the (Re)Association Response frame.

If dot11WirelessManagementImplemented is true, dot11BSSMaxIdlePeriod is nonzero and dot11BSSMaxIdlePeriodIndicationByNonAPSTA is true, then a non-S1G non-AP STA shall include a BSS Max Idle Period element in the (Re)Association Request frame. If the BSS Max Idle Period element is present in the (Re)Association Request frame received by a non-S1G AP that has dot11BSSMaxIdlePeriodIndicationByNonAPSTA equal to true, then the non-S1G AP may choose the non-AP STA's preferred maximum idle period. The non-S1G AP indicates its chosen value to the non-S1G STA in the (Re)Association Response frame.

The value chosen by the AP is the value that the AP will use in making disassociate decisions based on the timeout value equal to BSSMaxIdlePeriod for the non-AP STA that is the recipient of the (Re)Association Response frame. An AP may provide different values for BSSMaxIdlePeriod to different STAs.

A STA may send at least one protected or unprotected keepalive frame per BSSMaxIdlePeriod, as indicated in the Idle Options field. When a STA transmits an unprotected keepalive frame, it shall use a frame that has 48-bit TA and RA fields.

The Max Idle Period field of the BSS Max Idle Period element indicates the time period during which a STA can refrain from transmitting frames to its associated AP without being disassociated. A non-AP STA is considered inactive if the AP has not received a Data frame, PS-Poll frame, or Management frame (protected or unprotected as specified in this paragraph) of a frame exchange sequence initiated by the STA for a time period greater than or equal to the time specified by the Max Idle Period field. If the Idle Options field requires

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protected keepalive frames, then the AP may disassociate the STA if no protected frames are received from the STA for a duration of BSSMaxIdlePeriod. If the Idle Options field allows unprotected or protected keepalive frames, then the AP may disassociate the STA if no protected or unprotected frames with 48-bit TA and RA fields are received from the STA for a duration of BSSMaxIdlePeriod.

NOTE—The AP can disassociate or deauthenticate the STA at any time for other reasons even if the STA satisfies the keep-alive frame transmission requirements.

11.21.14 Proxy ARP service

Implementation of the proxy ARP service is optional for a WNM STA. A STA that implements the proxy ARP service has dot11ProxyARPImplemented equal to true. When dot11ProxyARPImplemented is true, dot11WirelessManagementImplemented shall be true. When dot11ProxyARPActivated is true, the Proxy ARP Service bit in the Extended Capabilities field shall be set to 1 to indicate that the AP supports the proxy ARP service. When dot11ProxyARPActivated is false, the Proxy ARP Service bit shall be set to 0 to indicate that the AP does not support the proxy ARP service.

When the AP sets the Proxy ARP field to 1 in the Extended Capabilities element, the AP shall maintain a Hardware Address to Internet Address mapping for each associated station, and shall update the mapping when the Internet Address of the associated station changes. When the IPv4 address being resolved in the ARP request (IETF RFC 826) is used by a non-AP STA currently associated to the BSS, the proxy ARP service shall respond on behalf of the STA to an ARP request or an ARP probe (IETF RFC 5227).

When an AP receives an ARP request from one associated STA or from the DS with a target IP address that corresponds to a second associated STA, the AP shall insert the second STA MAC address as the Sender's MAC Address in the ARP response packet.

When an IPv6 address is being resolved, the Proxy ARP service shall respond with a Neighbor Advertisement message (Section 4.4, IETF RFC 4861) on behalf of an associated STA to an Internet Control Message Protocol version 6 (ICMPv6) Neighbor Solicitation message (Section 4.3, IETF RFC 4861). When MAC address mappings change, the AP may send unsolicited Neighbor Advertisement Messages on behalf of a STA.

NOTE—The Neighbor Solicitation message is used for both address discovery and duplicate address detection (IETF RFC 4862).

11.21.15 Channel usage procedures

Channel Usage information is a set of channels provided by an AP to non-AP STAs for operation of a noninfrastructure network or an off-channel TDLS direct link. The Channel Usage information provided by the AP to the non-AP STA is to advise the STA on how to coexist with the infrastructure network.

Implementation of Channel Usage is optional for a WNM STA. A STA that implements Channel Usage has dot11ChannelUsageImplemented equal to true. When dot11ChannelUsageImplemented is true, dot11WirelessManagementImplemented shall be true, or the STA shall be capable of acting as an S-AP within a CCSS. A STA with dot11ChannelUsageActivated equal to true shall support channel usage and shall set to 1 the Channel Usage field of the Extended Capabilities elements that it transmits.

A non-AP STA that supports Channel Usage and is not associated to an AP prior to using a noninfrastructure network or an off channel TDLS direct link may transmit a Probe Request frame including both Supported Operating Classes and Channel Usage elements. A non-AP STA supporting Channel Usage may send a Channel Usage Request frame at any time after association to the AP that supports the use of Channel Usage to request the Channel Usage information for supported operating classes.

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Upon receipt of a Channel Usage element in the Probe Request frame, the AP supporting Channel Usage shall send a Probe Response frame including one or more Channel Usage elements. Upon receiving a Channel Usage Request frame, the AP supporting Channel Usage shall send a Channel Usage Response frame including one or more Channel Usage elements. Channel Usage elements shall include channels that are valid for the regulatory domain in which the AP transmitting the element is operating and consistent with the Country element in the Beacon or Probe Response frame; the Channel Usage elements shall not include any other channels. When the Channel Usage element in a received Probe Request or Channel Usage Request frame includes one or more Operating Class/Channel Pair fields, the Operating Class/Channel Pair field(s) indicate(s) the requested non-AP STA operating class/channels for the usage mode indicated in the frame.

The AP may send an unsolicited group addressed or individually addressed Channel Usage Response frame to the STAs that have requested Channel Usage information if the corresponding Channel Usage information needs to be updated. The Country element shall be included in the unsolicited and/or group addressed Channel Usage Response frame. The AP may include the Power Constraint information and EDCA Parameter in the Channel Usage Response frame. The values of the fields in the Power Constraint and EDCA Parameter Set elements included in the Channel Usage Response frame shall be the same values of the fields in the Power Constraint and EDCA Parameter Set elements that are transmitted by the AP.

Upon receipt of a Channel Usage element in the Probe Response or Channel Usage Response frame, the receiving STA may use the following:

— The channel usage information as part of channel selection processing to start a noninfrastructure network or an off-channel TDLS direct link
— The Power Constraint element, if present, as part of determining its maximum transmit power for transmissions for the noninfrastructure network or an off-channel TDLS direct link
— The EDCA Parameter Set element, if present, as part of determining its EDCA parameters for transmissions for the noninfrastructure network or an off-channel TDLS direct link
— The QMF Policy element, if present and dot11QMFActivated is true, as part of determining its classification of Management frames for transmissions for the noninfrastructure network or an off-channel TDLS direct link

If either a recommended operating class, or a recommended channel, or both are not supported or understood by the recipient, or if the operating country of the sender is unknown, the recipient shall discard the corresponding channel usage recommendation. A STA that has not requested Channel Usage information shall discard an unsolicited group addressed Channel Usage Response frame.

11.21.16 Group addressed transmission service

11.21.16.1 General

The group addressed transmission service provides delivery of group addressed frames and comprises the two services, DMS and GCR. DMG STAs do not use GCR.

11.21.16.2 DMS procedures

In this subclause, the following terms are used:

— *DMS provider*: An AP, PCP, or DMG STA associated with a PCP that provides DMS.
— *DMS recipient*: A non-AP STA that uses DMS.

In an infrastructure BSS, directed multicast service (DMS) is a service that may be provided by an AP to associated STAs that support DMS, where the AP transmits group addressed MSDUs as individually addressed A-MSDUs.

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In a PBSS, DMS is a service that may be provided by any STA to other STAs in the same PBSS that support DMS, where the STA transmits group addressed MSDUs as individually addressed A-MSDUs. If the PCP of the PBSS has the PCP Forwarding field within the PCP's DMG Capabilities element set to 0, a non-PCP STA in the PBSS shall not use the PCP as a DMS provider in the PBSS.

Implementation of DMS is optional for a WNM STA and mandatory for a robust AV streaming STA (as defined in 11.25.1). A STA that implements DMS has dot11DMSImplemented equal to true. When dot11DMSImplemented is true,

— At least one of dot11WirelessManagementImplemented and dot11RobustAVStreamingImplemented shall be true.
— dot11HighThroughputOptionImplemented shall be true for a non-DMG STA that is not a DMG or an S1G STA.

A STA with dot11DMSActivated equal to true shall support the directed multicast service and shall set to 1 the DMS field of the Extended Capabilities element that it transmits.

A DMS recipient may request use of DMS of one or more flows by sending a DMS Request frame or Reassociation Request frame that includes a DMS Request element containing one or more DMS Descriptors with the Request Type field set to "Add" per flow. Each DMS Descriptor field in the DMS Request element identifies group addressed frames that shall be transmitted to the requesting DMS recipient as individually addressed frames in addition to the group address frame transmission. In the TCLAS element, the Classifier Type subfield shall be set to the value 0, 1, or 4, and the Destination Address or Destination IP Address subfield shall be set to the multicast address of the flow that the STA requests to receive as individually addressed frames. In the TSPEC element, the STA may define the characteristics and QoS expectations of the corresponding traffic flow.

Upon receipt of a DMS Request frame or Reassociation Request frame from a DMS recipient, a DMS provider shall respond with a corresponding DMS Response frame or Reassociation Response frame. The response frame shall contain a matching (i.e., as the same DMSID) DMS Status field for each received DMS Descriptor field preserving the order present in the request frame.

NOTE 1—There is no requirement that the number of DMS Request elements and the number of DMS Response elements match. There is no requirement that the number of DMS Descriptor fields within any DMS Request element matches the number of DMS Status fields within any DMS Response element.

If a DMS provider accepts a DMS request identified by a DMS Descriptor, the Response Type field of the corresponding DMS Status field in the DMS Response element shall be set to "Accept" and a nonzero DMSID shall be assigned. If a DMS provider denies a DMS request identified by a DMS Descriptor, the Response Type field of the corresponding DMS Status field in the DMS Response element shall be set to "Denied" and the DMSID shall be set to 0. If the Response Type field is set to "Accept" or "Denied," then the TCLAS Elements, TCLAS Processing Element, TSPEC Element and Optional Subelements fields of a DMS Status field in a DMS Response element shall be copied from the respective TCLAS Elements, TCLAS Processing Element, TSPEC Element and Optional Subelements fields of the corresponding DMS request. When one or more STAs send a DMS request to a DMS provider, containing a DMS descriptor with a set of TCLAS element and TCLAS Processing elements that are identical irrespective of ordering to another received DMS request that is not yet terminated, the DMS provider shall assign the same DMSID as was assigned to the previous DMS request.

If a DMS provider denies the DMS Request, it may suggest an alternative TCLAS-based classifier by including one or more TCLAS elements and an optional TCLAS Processing element. The DMS provider may include fewer TCLAS elements in the DMS Response element than were present in the request; when the DMS provider's response includes a single TCLAS element, it shall not include a TCLAS Processing element. If the DMS provider changes a TCLAS element's Classifier Type field in the DMS Response element but is unable to suggest a value for the Classifier Mask field, it shall set that field to 0. If the DMS provider changes a

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TCLAS element's Classifier Type field or Classifier Mask field in the DMS Response element but is unable to suggest values for one or more Classifier Parameter subfields, it shall set those subfields to 0.

A DMS recipient receiving a DMS Response frame containing a modified TCLAS element having a Classifier Mask field equal to 0 or having one or more Classifier Parameter subfields equal to 0 shall interpret the values of 0 to mean that no suggested value has been provided by the DMS provider.

If the requested DMS is accepted by the DMS provider, the DMS provider shall send subsequent group addressed MSDUs that match the frame classifier specified in the DMS Descriptors to the DMS recipient as A-MSDU subframes within an individually addressed A-MSDU frame (see 9.3.2.2 and 10.11). The A-MSDU shall be formatted as specified in 9.3.2.2 which includes the A-MSDU subframe headers' DA set to the multicast address for the corresponding MSDUs. The DMS provider shall continue to transmit the matching frames as group addressed frames (see 10.3.6, and 11.2.3.14) if at least one associated STA has not requested DMS for these frames.

A DMS recipient may request modification of the traffic characteristics or attributes of one or more accepted DMS traffic flows by sending a DMS Request frame or Reassociation Request frame that includes a DMS Request element that contains one or more DMS Descriptors each with the Request Type field set to "Change" and the DMSID field set to the DMSID of the accepted DMS traffic flows to be modified. The values of at least one of the TSPEC Element and Optional Subelement fields shall be different from those of the accepted DMS traffic flow.

If a DMS provider accepts a DMS change request identified by a DMS Descriptor, the Response Type field of the corresponding DMS Status field in the DMS Response element shall be set to "Accept" and the DMSID field shall be set to the DMSID carried in the DMS Descriptor. If a DMS provider denies a DMS change request identified by a DMS Descriptor, the Response Type field of the corresponding DMS Status field in the DMS Response element shall be set to "Denied" and the DMSID field shall be set to the DMSID carried in the DMS Descriptor. If a DMS provider denies a DMS change request identified by a DMS Descriptor, the existing DMS traffic flow of the corresponding DMSID shall remain unchanged.

A DMS recipient may request removal of one or more accepted DMS traffic flows by sending a DMS Request frame or Reassociation Request frame that includes a DMS Request element containing one or more DMS Descriptors each with the Request Type field set to "Remove" and the DMSID field set to the DMSID of the accepted DMS traffic flow to be removed. The DMS Length field shall be set to 1. The TCLAS Elements, TCLAS Processing Element TSPEC Element and Optional Subelements fields shall not be included.

A DMS provider shall terminate one or more accepted DMS traffic flows upon receipt of a DMS Request frame or Reassociation Request frame that includes a DMS Request element containing one or more DMS Descriptors each with the Request Type field equal to "Remove" and the DMSID field set to the DMSID of an accepted DMS traffic flow. The DMS provider shall respond to the termination request by sending a DMS Response frame containing one or more DMS Status fields each including the corresponding DMSID and a value of "Terminate" in the Response Type field. The DMS Length field shall be set to 3. The TCLAS Elements, TCLAS Processing Element, TSPEC Element and Optional Subelement fields shall not be included.

A DMS provider may send an unsolicited DMS Response frame at any time to terminate an accepted DMS traffic flow by including the DMSID and a value of "Terminate" in the Response Type field in the DMS Status field in a DMS Response element. A DMS provider may reject a new DMS traffic flow or terminate a granted DMS traffic flow at any time based on network condition, for example the number of associated STAs and channel load.

A DMS recipient shall keep a list of group addresses for which it has requested DMS and that have been accepted by a DMS provider and shall discard group addressed frames that match a group address in this list until the DMS has been terminated. When the DMS is terminated, and if the sequence number value is provided in the Last Sequence Control field in the DMS Response frame, using the value of the Last Sequence

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Control field, the DMS recipient shall discard the group addressed frames that are the duplicates of the individually addressed frames.

NOTE 2—When the Last Sequence Control field in the DMS Response frame is not supported at a DMS provider (i.e., the sequence number value is not provided in the field), and a group addressed MSDU that has sent using both individually addressed and group addressed frame transmission, termination of the DMS stream by the DMS provider might result in a DMS recipient receiving undetectable duplicate MSDUs that are not filtered out by the MAC.

If the length of the DMS Descriptors exceeds 255 octets, then multiple DMS Request elements shall be included, each containing only those DMS Descriptors that are completely contained within 255 octets. If the length of the DMS status fields exceeds 255 octets, then multiple DMS Response elements shall be included, each containing only those DMS Status fields that are completely contained within the first 255 octets.

If a DMS recipient supports both DMS and FMS, it shall not request both services for the same group addressed frames simultaneously, but may request them for different group addressed frames simultaneously.

If a DMS provider supports both DMS and TFS, it shall first apply TFS to the frame and then apply DMS.

11.21.16.3 GCR procedures

11.21.16.3.1 Overview

Groupcast with retries (GCR) is a flexible service to improve the delivery of group addressed frames while optimizing for a range of criteria. GCR service may be provided by the AP to associated STAs in an infrastructure BSS or by a mesh STA to its peer mesh STAs in a mesh BSS. GCR uses the setup, modification, and termination procedures defined 11.21.16.2. The differences between GCR procedures and DMS procedures are as follows:

a) A GCR agreement applies to a single group address and, if a TCLAS Processing element is present, it has the Processing subfield value set to 0, whereas a DMS flow is not restricted to a single group address.
b) DMS offers group-to-individually addressed conversion only, whereas GCR includes several retransmission policies and delivery methods.

A non-DMG STA with dot11RobustAVStreamingImplemented true shall implement the GCR procedures defined in 11.21.16.3.2 to 11.21.16.3.6. When dot11RobustAVStreamingImplemented is true, dot11DMSImplemented and dot11HighThroughputOptionImplemented shall be true. A STA that implements advanced GCR supports GCR block ack (11.21.16.3.7) and GCR-SP (11.21.16.3.8) and has dot11AdvancedGCRImplemented equal to true. When dot11AdvancedGCRImplemented is true, dot11RobustAVStreamingImplemented shall be true. In a mesh BSS, a STA that implements GCR has dot11MeshGCRImplemented equal to true. When dot11MeshGCRImplemented is true, dot11HighThroughputOptionImplemented shall be true.

DMS allows the transmission of group addressed MSDUs as individually addressed A-MSDUs and is particularly suited to small numbers of group members. It provides a high level of reliability but has low scalability as the efficiency decreases and delay increases proportionally to the number of group members.

GCR employs the DMS Request and DMS Response elements with the addition of GCR Request and Response subelements, respectively, for administering the announcement, setup, modification, and teardown of GCR services between an AP and non-AP STAs or between peer mesh STAs. The DMS procedures and state machine of 11.21.16.2 shall apply to GCR with the extensions and constraints specific to GCR described below in 11.21.16.3.3 to 11.21.16.3.8.

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Along with the No-Ack/No-Retry or non-GCR (defined in 10.3.6) and the DMS (defined in 11.21.16.2) retransmission mechanisms, GCR defines two additional retransmission policies for group addressed frames:

— GCR unsolicited retry
— GCR block ack

When using the GCR unsolicited retry retransmission policy for a group address, the STA providing GCR service retransmits an MSDU one or more times (subject to applicable retry or lifetime limits) to increase the probability of correct reception at STAs that are listening to this group address. The decision to retransmit these MSDUs is implementation dependent. GCR unsolicited retry is particularly suited to use with large numbers of group members as it has moderate delay, efficiency, and reliability, but high scalability.

The GCR block ack retransmission policy extends the block acknowledgment mechanism to group addressed frames. The STA providing the GCR service initiates block ack agreements with each STA receiving GCR frames that supports GCR block ack for a particular group address. Once this block ack agreement is in place, the STA providing GCR service regularly sends BlockAckReq frames to the STAs receiving the frames to ascertain the reception status of MSDUs related to this group address, as described in 10.25.8. This allows the STA providing GCR service to discover MSDUs that have not been received and to schedule their retransmission. GCR block ack is particularly suited to use with moderate numbers of group members as it has moderate delay, high efficiency, and moderate scalability and reliability.

The GCR service has two delivery methods for group addressed frames:

— Non-GCR-SP
— GCR-SP (see 11.21.16.3.8)

The non-GCR-SP delivery method may be provided using one or more of the following:

— FMS (see 11.2.3.14)
— Transmit frames in a GCR stream after the DTIM Beacon frame if any STA in the GCR group is in PS mode
— Transmit frames at any time if all STAs in the GCR group are in active mode in an infrastructure BSS
— In accordance with 14.14 in a mesh BSS

GCR-SP transmits GCR group addressed frames at intervals, where the interval between transmissions might be smaller than the beacon interval. Compared to non-GCR-SP, GCR-SP might provide lower delay and jitter.

GLK-GCR is a variant of GCR where the setup is implicit and is accomplished using a (Re)Association Request and Response frame exchange between the peers and termination is implicit and is accomplished when the corresponding general link is torn down. Modification is explicit and is accomplished using a GLK Groupcast Mode Change Notification frame.

GLK-GCR defines two retransmission policies for group addressed frames:

— GLK-GCR unsolicited retry
— GLK-GCR block ack

When a GLK STA implements the GLK-GCR procedures defined in 11.21.16.4.2 or 11.21.16.4.3, it shall set dot11GLKGCRImplemented to true; otherwise dot11GLKGCRImplemented shall be set to false. When dot11GLKGCRImplemented is true the GLK-GCR bit field shall be set to 1 in the Extended Capabilities element, to indicate support for GLK-GCR, otherwise the field shall be set to 0.

See 10.25.8 for the mechanisms by which GCR block ack operates.

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11.21.16.3.2 GCR group membership procedures

The GCR group membership procedures do not apply to GLK-GCR. GLK-GCR uses SYNRAs.

The procedures described in 11.21.16.3.3 to 11.21.16.3.8 depend upon the AP or mesh STA knowing the membership of the multicast groups of STAs that support GCR.

One method for an AP to discover the multicast groups that its associated STAs are receiving or for a mesh STA to discover the multicast groups that its peer mesh STAs are receiving is to use the Group Membership Request frame (as defined in 9.6.18.4) to request the contents of the dot11GroupAddressesTable of its associated STAs or peer mesh STAs.

Other methods of group membership detection are also possible, using information that is outside the scope of this standard. For example, group membership detection could be achieved by inspecting the protocol messages of IETF RFC 3376 [B37].

An AP may transmit a Group Membership Request frame as an individually addressed frame to an associated STA that has indicated that it supports robust AV streaming (as indicated by the Robust AV Streaming bit equal to 1 in the Extended Capabilities element) to request the associated STA's dot11GroupAddressesTable. An AP shall not send a Group Membership Request frame to an associated STA that has the Robust AV Streaming bit equal to 0 in its Extended Capabilities element.

A STA for which dot11GCRActivated or dot11MeshGCRActivated is true shall reply to a Group Membership Request frame by sending a Group Membership Response frame with the Dialog Token field set to the value from the Group Membership Request frame, the Address Count field set to the number of entries in the dot11GroupAddressesTable, and the Group Address List field set to the group MAC addresses in the dot11GroupAddressesTable. A STA for which dot11GCRActivated or dot11MeshGCRActivated is true shall set dot11GCRGroupMembershipAnnouncementActivated to true upon reception of a Group Membership Request frame.

A STA for which dot11GCRGroupMembershipAnnouncementActivated and at least one of dot11MeshGCRActivated and dot11GCRActivated are true shall send an unsolicited Group Membership Response frame with the Dialog Token field set to 0, the Address Count field set to the number of entries in the dot11GroupAddressesTable, and the Group Address List field set to the group MAC addresses in the dot11GroupAddressesTable, every time the contents of the dot11GroupAddressesTable is modified.

If an unsolicited Group Membership Response frame is sent by an associated STA, the frame shall be transmitted as an individually addressed frame to the AP with which it is associated. If an unsolicited Group Membership Response frame is sent by a mesh station in a mesh BSS, the frame shall be transmitted as a broadcast frame.

11.21.16.3.3 GCR setup procedures

The following setup procedures apply only if the underlying link is a non-general link.

An AP with dot11GCRActivated true may transmit to an associated non-AP STA an unsolicited individually addressed DMS Response frame that contains one DMS Status field with a GCR Response subelement per group address, if it detects that the associated non-AP STA meets all of the following conditions:

— Robust AV Streaming was equal to 1 in the Extended Capabilities element in the most recently received (Re)Association Request frame from the non-AP STA.
— The non-AP STA is receiving one or more group addresses for which there is an active GCR service.
— The non-AP STA does not have a GCR agreement for one or more of these group addresses.

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A mesh STA with dot11MeshGCRActivated true may transmit to a peer mesh STA an unsolicited individually addressed DMS Response frame that contains one DMS Status field with a GCR Response subelement per group address, if it detects that the peer mesh STA meets all of the following conditions:

— Mesh GCR was equal to 1 in the Extended Capabilities element in the most recently received mesh beacon from the peer mesh STA.

— The peer mesh STA is receiving one or more group addresses for which there is an active GCR service.

— The peer mesh STA does not have a GCR agreement for one or more of these group addresses.

Each DMS Status field includes a TCLAS element to identify the GCR group address, the DMSID corresponding to this GCR traffic flow, and other associated parameters. The Status subfield of this DMS Status field shall be set to "GCR Advertise." A STA that receives this DMS Response frame from its AP may initiate a GCR agreement for one or more of the group addresses contained in the frame.

A STA requests use of the GCR service for a group address by sending a DMS Descriptor (as described in 11.21.16.2) with the following modifications:

— The DMS Descriptor shall contain one TCLAS element with the frame classifier type equal to 0 (Ethernet parameters), one TSPEC element, and one GCR Request subelement.

— In addition, the DMS Descriptor may contain other TCLAS elements.

— When there are multiple TCLAS elements, a TCLAS Processing element shall be present, and the Processing subfield in the TCLAS Processing element shall be set to 0. Otherwise, no TCLAS Processing elements shall be present in the DMS Descriptor.

— The TSID subfield within the TS Info field of the TSPEC element shall be reserved. Since the AP might choose a delivery method of GCR-SP, the non-AP STA should set the Minimum Service Interval, Maximum Service Interval, and Service Start Time fields in the TSPEC element to indicate the STA's preferred wakeup schedule. In a mesh BSS, the Delivery Method field shall not be set to "GCR-SP."

— The GCR Request subelement specifies the retransmission policy and delivery method requested by the non-AP STA for the group addressed stream.

A STA shall not request transmission of a group address via the GCR service while it has an active DMS for this group address. A STA shall not request transmission of a group address via DMS while it has an active GCR service for this group address.

An AP or mesh STA accepts a GCR request by sending a DMS Response frame with a DMS Response element that contains a DMS Status field with the Response Type field set to "Accept" (as described in 11.21.16.2) with the following modifications:

— The DMS Status field shall include a GCR Response subelement indicating the retransmission policy, delivery method, and GCR concealment address for the group addressed stream. The Retransmission Policy field shall not be set to "No Preference." The Delivery Method field shall not be set to "No Preference." The GCR Concealment Address field of the GCR Response subelement shall be set to dot11GCRConcealmentAddress. In a mesh BSS, the Delivery Method field shall not be set to "GCR-SP."

— If the GCR group addressed stream is subject to the GCR-SP delivery method, then the AP shall also include a Schedule element in the DMS Status field indicating the wakeup schedule for the group addressed stream.

— If a TSPEC element is included, the TSID subfield shall be set to 0.

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For each GCR Request subelement, the AP or mesh STA may

- Adopt the requested retransmission policy and delivery method, or
- Maintain its existing retransmission policy and delivery method, or
- Select an alternate retransmission policy and delivery method, or
- Deny GCR service for the group addressed stream.

In an infrastructure BSS, the retransmission policy shall not be GCR block ack for a GCR group address while the AP has a GCR agreement for the group address with a non-AP STA that had the Advanced GCR field equal to 0 in the Extended Capabilities element in the (Re)Association Request frame most recently received by the AP.

In a mesh BSS, the retransmission policy shall not be GCR block ack for a GCR group address while the mesh STA has a GCR agreement for the group address with a peer mesh STA that had the Mesh GCR field equal to 0 in the Extended Capabilities element.

An AP or mesh STA denies a GCR request by sending a DMS Response frame with a DMS Response element that contains a DMS Status field with

- The Response Type field set to "Denied" (as described in 11.21.16.2), and
- An empty GCR Response subelement.

If an AP or mesh STA denies a GCR request, it may suggest an alternative TCLAS-based classifier by including one or more TCLAS elements and an optional TCLAS Processing element (as described in 9.4.2.32). One TCLAS element shall be included in the DMS Descriptor with the frame classifier type equal to 0 (Ethernet parameters). Other TCLAS elements may be included in the DMS Descriptor, but, if present, a TCLAS Processing element with the Processing subfield equal to 0 shall also be included.

If a STA requesting GCR service determines that one or more GCR Response subelements are unacceptable, then the STA shall discard any received ADDBA Request frames for the unacceptable GCR streams and shall send a new DMS Request frame containing a DMS Request element with one DMS Descriptor for each unacceptable GCR stream. The DMSID fields shall be set to the DMSIDs of the unacceptable streams, and the Request Type field shall be set to "Remove."

In an infrastructure BSS, if the non-AP STA accepts the response to its GCR request, the non-AP STA shall set dot11GCRConcealmentAddress to the value contained in the GCR Concealment Address field of the GCR Response subelement.

In a mesh BSS, if a STA requesting GCR service accepts the response to its GCR request, it shall add to dot11GroupAddressesTable the value contained in the GCR Concealment Address field of the GCR Response subelement.

In a mesh BSS, a GCR agreement instance is identified by a GCR agreement instance identifier. The mesh GCR agreement instance consists of the DMSID, localMAC, peerMAC, and concealment address.

For each group addressed stream requested by the non-AP STA and accepted by the AP, the AP shall immediately initiate a block ack negotiation if both of the following conditions are true:

- The AP advertised an Advanced GCR field equal to 1 in its Extended Capabilities element.
- The non-AP STA advertised an Advanced GCR field equal to 1 in the Extended Capabilities element in the (Re)Association Request frame most recently received by the AP.

For each group addressed stream requested by a mesh STA's peer (STA1), the mesh STA (STA2) receiving the request shall immediately initiate a block ack negotiation if STA2 transmitted a Mesh GCR field equal to 1 in

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the Extended Capabilities element in its mesh Beacon frame and STA2 received a mesh Beacon frame from STA1 in which the Mesh GCR field in the Extended Capabilities element is equal to 1.

If all of the above conditions are true, the AP or mesh STA shall immediately initiate a block ack negotiation by sending an ADDBA Request frame to the STA that originated the GCR request. The Block Ack Policy subfield in the Block Ack Parameter Set field within the ADDBA Request frame shall not be set to 0. The TID subfield in the Block Ack Parameter Set field within the ADDBA Request frame shall be set to 0. The A-MSDU Supported subfield within the ADDBA Request frame shall be set to 1 (A-MSDU permitted). The Starting Sequence Number field within the ADDBA Request frame shall be greater than (modulo 4096) the last sequence number of the last group address frame transmitted before the ADDBA Request frame. A STA shall maintain this block ack agreement for the duration of its GCR agreement, irrespective of whether GCR block ack is the current retransmission policy. While the retransmission policy of the GCR group addressed stream is DMS, the STA receiving GCR frames shall suspend its block ack processing for the group addressed stream.

NOTE—Having a block ack agreement with all members of a GCR group address allows the AP or mesh STA to change the GCR retransmission policy dynamically.

For each GCR agreement, there shall be only one retransmission policy and delivery method active at any time. A GCR agreement between a non-AP STA and an AP or between peer mesh STAs shall begin when the STA providing GCR service successfully transmits an individually addressed DMS Response frame with a DMS Response element containing a DMS Status field that has the Status field set to “Accept” (as described in 11.21.16.2) with the DMS Status field including a GCR Response subelement.

11.21.16.3.4 GCR operation

The GCR operation do not apply to GLK-GCR. See 11.21.16.4.2 for GLK-GCR frame exchange procedures.

In an infrastructure BSS, a GCR block ack agreement exists between a non-AP STA and an AP for a group addressed stream from when the non-AP STA successfully transmits an ADDBA Response frame until one of the following situations occurs:

— The AP or non-AP STA successfully transmits a DELBA frame to the other party.
— The GCR agreement no longer exists.

In a mesh BSS, a GCR block ack agreement exists between a mesh STA and its peer mesh STA for a group addressed stream from the time when the mesh STA successfully transmits an ADDBA Response frame to the peer mesh STA until one of the following situations occurs:

— The mesh STA or the peer mesh STA successfully transmits a DELBA frame to the other party.
— This GCR block ack agreement expires (see 10.25.4).
— The GCR agreement is terminated.

An AP or a mesh STA may transmit a group addressed stream via the No-Ack/No-Retry (non-GCR; see 10.3.6) service and GCR service simultaneously. Each frame shall be transmitted via the No-Ack/No-Retry retransmission policy before it is transmitted via the GCR service, except when using the GCR-SP delivery method. The AP may transmit each frame via the No-Ack/No-Retry retransmission policy before or after it transmits the frame via the GCR service when using the GCR-SP delivery method. A STA providing GCR service may switch between the DMS, GCR block ack, or GCR unsolicited retry retransmission policies, but only one delivery mode may be active at any given time for each GCR group address.

An AP or mesh STA shall transmit a frame belonging to a group address via the GCR service if any associated STA or peer mesh STA has a GCR agreement for the group address and, otherwise, does not transmit the frame via the GCR service.

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In an infrastructure BSS, an AP shall transmit a frame belonging to a group address via the No-Ack/No-Retry service if one or more of the following situations occur:

— The group address is the broadcast address.
— The group address is not the broadcast address, and at least one associated STA has the Robust AV Streaming bit equal to 0 in the Extended Capabilities element of the STA's most recent (Re)Association Request frame and has been determined by the AP to be a member of the group address (how this determination is made is out of the scope of this standard).
— The group address is not the broadcast address, at least one non-AP STA has a block ack agreement for the group address, and the frame precedes the start of the block ack agreement (the sequence number of the frame is less than the starting sequence number of the block ack agreement, as described in 10.25.2).

In a mesh BSS, a mesh STA providing GCR service shall transmit a frame belonging to a group address via the No-Ack/No-Retry service if one or more of the following situations occur:

— The group address is the broadcast address.
— The group address is not the broadcast address, and at least one peer mesh STA has the Mesh GCR bit equal to 0 in the Extended Capabilities element of the STA's most recent mesh Beacon frame and has been determined to be a member of the group address (how this determination is made is out of the scope of this standard).
— The group address is not the broadcast address, at least one peer mesh STA has a block ack agreement for the group address, and the frame precedes the start of the block ack agreement (the sequence number of the frame is less than the starting sequence number of the block ack agreement, as described in 10.25.2).

When the AP updates the retransmission policy, the AP shall set the Last Sequence Control field in the GCR Response subelement to the sequence number of the MPDU corresponding to the GCR traffic flow that is being updated that was delivered prior to the change in retransmission policy.

To avoid undetected retries being passed up at a receiver's MAC SAP, duplicate detection and removal for group addressed frames is required in STAs with dot11RobustAVStreamingImplemented true or dot11MeshGCRImplemented true (see 10.3.2.14).

GCR frames shall be QoS Data frames (with QoS subfield of the Subtype subfield set to 1).

If the block ack agreement is successfully established for the group addressed stream and the delivery method for the group addressed stream is GCR-SP, then the non-AP STA is awake for subsequent SPs (see 11.21.16.3.8).

A STA may request a change of GCR service for a group addressed stream by sending a DMS Descriptor with the DMSID identifying the group address and the Request Type field set to "Change" (as described in 11.21.16.2) with the following modifications:

— The DMS Descriptor shall contain zero TCLAS elements, zero TCLAS Processing elements, one TSPEC element, and one GCR Request subelement.
— The TSPEC element and GCR Request subelement of this DMS Descriptor shall together contain at least one field that is different from the original TSPEC element and GCR Request subelement identified by the DMSID.

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An AP or mesh STA may update the retransmission policy, delivery method, and schedule for any reason, such as the size of the group changes, the capabilities of the members of the group change, GCR Request subelements for the group are received, or multicast diagnostics are needed. The AP or mesh STA advertises the current settings upon a change and periodically by either of the following methods:

— Transmitting an unsolicited DMS Response frame with the current settings addressed to the GCR concealment address. This DMS Response frame shall be scheduled for delivery at the appropriate DTIM interval or SP in which all STAs within the group are awake to receive the frame. One TCLAS element shall be included with the frame classifier type equal to 0 (Ethernet parameters). Other TCLAS elements may be present, but if present, a TCLAS Processing element with the Processing subfield equal to 0 shall also be included. One TSPEC element and one GCR subelement shall be included per DMS Descriptor in the DMS Response element of the DMS Response frame to identify each GCR stream. The DMSID that identifies the GCR stream shall be included in the DMS Descriptor. Each Status field in the DMS Status fields included in the frame shall be set to "GCR Advertise."

— Transmitting unsolicited DMS Response frames with the current settings individually addressed to each GCR group member. Each GCR stream is identified by the DMSID in a DMS Status field in the DMS Response element of the DMS Response frame. These DMS Status fields shall not include a TCLAS element, TSPEC element, or GCR subelement. Each Status field in the DMS Status fields included in the frame shall be set to "GCR Advertise."

A STA receiving GCR frames shall recover from missing group addressed DMS Response frames containing GCR Response subelements that advertise a changed retransmission policy or delivery method according to Table 11-12 or Table 11-13, respectively.

Table 11-12—STA recovery procedures for a changed retransmission policy

Current retransmission policy state at STA receiving GCR frames	Actual retransmission policy being used by the AP or mesh STA providing GCR service	Recovery procedure
GCR unsolicited retry or GCR block ack	No-Ack/No-Retry	A STA receiving GCR frames shall cancel the GCR service for the group address by sending a DMS Response frame that contains a DMS Descriptor with the Request Type field set to "Remove" when no frames for the group address are received via the GCR service after a period of dot11GCRPolicyChangeTimeout.
DMS	GCR unsolicited retry or GCR block ack	A STA receiving GCR frames shall update its current retransmission policy of the GCR stream to GCR unsolicited retry upon receiving an A-MSDU for the DMS group address concealed via the GCR concealment address.
GCR unsolicited retry or GCR block ack	DMS	A STA receiving GCR frames shall update its current retransmission policy of the GCR stream to DMS upon receiving an A-MSDU with the RA field equal to the non-AP STA's individual address and the DA field of the A-MSDU subframe equal to the GCR group address.

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Table 11-12—STA recovery procedures for a changed retransmission policy *(continued)*

Current retransmission policy state at STA receiving GCR frames	Actual retransmission policy being used by the AP or mesh STA providing GCR service	Recovery procedure
GCR unsolicited retry	GCR block ack	A STA receiving GCR frames shall update its current retransmission policy of the GCR stream to GCR block ack upon receiving a BlockAckReq frame with a GCR Group Address subfield equal to the GCR group address.
GCR block ack	GCR unsolicited retry	A STA receiving GCR frames shall update its current retransmission policy of the GCR stream to GCR unsolicited retry if MSDUs for the GCR group address concealed via the GCR concealment address are being received yet no BlockAckReq frames for the GCR group address are received after a period of dot11GCRPolicyChangeTimeout.

Table 11-13—Non-AP STA recovery procedures for a changed delivery method

Current delivery method state at non-AP STA	Actual delivery method being used by the AP	Recovery procedure
Non-GCR-SP	GCR-SP	A non-AP STA shall update the current delivery method state of the GCR stream to GCR-SP if a) No frames with the More Data subfield in the Frame Control field equal to 1 for the GCR stream are received for a period of dot11GCRPolicyChangeTimeout, and b) At least one frame for the GCR stream with the More Data subfield in the Frame Control field equal to 0 is received. Note that upon detecting condition a), the STA should enter the awake state in order to assist with detecting condition b).
GCR-SP	Non-GCR-SP	A non-AP STA shall update the current delivery method of the GCR stream to Non-GCR-SP if no frames with the More Data subfield in the Frame Control field equal to 0 for the GCR stream are received for a period of dot11GCRPolicyChangeTimeout and at least one frame for the GCR stream with the More Data subfield in the Frame Control field equal to 1 is received.

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A GCR agreement between a non-AP STA and an AP or between peer mesh STAs shall end (as described in 11.21.16.2) when one of the following situations occurs:

— In an infrastructure BSS, the AP deauthenticates or disassociates the non-AP STA, or

— In a mesh BSS, the mesh STA providing GCR service tears down the peer link to the mesh STA receiving GCR frames, or

— The non-AP STA or mesh STA receiving GCR frames successfully transmits a DMS Request frame to the AP or mesh STA providing GCR service containing a DMS Request element that has a DMS Descriptor with the DMSID identifying the group addressed stream and the Request Type field set to “Remove,” or

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— The AP or a mesh STA providing GCR service successfully transmits an individually addressed DMS Response frame with a DMS Response element containing a DMS Status field with the DMSID identifying the group addressed stream that has the Response Type field set to "Terminate."

A GCR agreement between a non-AP STA and an AP or between peer mesh STAs shall end (as described in 11.21.16.2) with the following modifications:

— The DMS Status field shall include a GCR Response subelement.
— The DMS Response frame may be transmitted by an AP to the GCR concealment address or as an individually addressed frame to each STA that has an active GCR agreement for this GCR group address. The DMS Response frame shall be transmitted by a non-AP STA or mesh STA as an individually addressed frame to the STA that it has an active GCR agreement for this GCR group address.

A cancellation of a GCR agreement shall also cause the block ack agreement to be canceled for the GCR stream.

11.21.16.3.5 Concealment of GCR transmissions

The concealment of GCR transmissions does not apply to GLK-GCR.

Concealment prevents group addressed frames transmitted via the GCR unsolicited retry or GCR block ack retransmission policies from being passed up through the MAC SAPs of GCR-incapable STAs.

GCR group addressed MSDUs shall be sent in an A-MSDU when

— Retransmitted via the GCR unsolicited retry or GCR block ack retransmission policies, or
— Transmitted via the GCR-SP delivery method.

The MPDU containing this A-MSDU shall have the Address 1 field set to dot11GCRConcealmentAddress and the Retry subfield of the Frame Control field set to 1. The DA field in the A-MSDU subframe shall contain the GCR group address that is being concealed (i.e., the same value as the DA field for non-GCR group addressed delivery). One A-MSDU subframe shall be contained within one A-MSDU frame. GCR group addressed MSDUs retransmitted via the GCR unsolicited retry or GCR block ack retransmission policies shall set the Sequence Control field of the MPDU containing this A-MSDU to the same value as the Sequence Control field of the frame that contained the corresponding MSDU that was transmitted with the Retry subfield equal to 0. The first transmission attempt of a GCR group addressed MSDU transmitted via the GCR-SP delivery method shall set the Sequence Control field of the MPDU containing this A-MSDU according to the procedures defined in 10.3.2.14.

A STA with dot11RobustAVStreamingImplemented true or dot11MeshGCRImplemented true shall not use its GCR concealment address for any purpose other than the transmission of GCR streams.

A STA with dot11RobustAVStreamingImplemented true or dot11MeshGCRImplemented true and with a GCR agreement shall add the GCR concealment address from the GCR Response subelement to the STA's dot11GroupAddressesTable.

An AP with dot11RobustAVStreamingImplemented true shall not send an MSDU to the DS that has the DA field set to the GCR concealment address.

The Individual/Group Address bit (bit 0) of dot11GCRConcealmentAddress shall be set to 1.

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11.21.16.3.6 GCR unsolicited retry

The GCR unsolicited retry procedures do not apply to GLK-GCR. See 11.21.16.4.3 for GLK-GCR unsolicited retry.

A STA supports the GCR unsolicited retry retransmission policy if dot11RobustAVStreamingImplemented or dot11MeshGCRImplemented is true; otherwise, the STA does not support the GCR service with retransmission policy equal to GCR unsolicited retry.

An AP or a mesh STA adopting the GCR unsolicited retry retransmission policy for a GCR group address chooses a lifetime limit for the group address. The AP or a mesh STA may vary the lifetime limit for the group address at any time and may use different lifetime limits for different GCR group addresses. An AP adopting the GCR unsolicited retry retransmission policy for a GCR group address shall transmit each MSDU according to 11.21.16.3.5, subject to the lifetime and retry limits. Transmission uses the backoff procedure described in 10.23.2.12.2.

If a block ack agreement has successfully been established for a group addressed stream that is delivered using the GCR unsolicited retry retransmission policy, the STA shall follow the duplicate detection procedures defined in 10.3.2.14.

If a block ack agreement has successfully been established for all STAs receiving a GCR group address, for a group delivered using the GCR unsolicited retry retransmission policy, the AP may retransmit any of the last *m* A-MSDUs that have the DA field in the A-MSDU subfield set to the GCR group address, where *m* is GCR buffer size (as defined in 11.21.16.3.7), subject to the lifetime limits.

If there is a STA with an active GCR agreement for a group address that does not have an active block ack agreement, the AP shall not retransmit a preceding A-MSDU for that group address. A preceding A-MSDU is defined as an A-MSDU with a sequence number value that precedes, using the modulo 2^{12} rules defined in 10.25.1, the sequence number value of the last transmitted A-MSDU for the GCR group address.

11.21.16.3.7 GCR block ack

The GCR block ack procedures do not apply to GLK-GCR. See 11.24.16.4.4 for GLK-GCR block ack.

A STA supports the GCR block ack retransmission policy if dot11AdvancedGCRImplemented is true or dot11MeshGCRImplemented is true; otherwise, the STA does not support the GCR service with retransmission policy equal to GCR Block Ack.

The AP shall maintain a set of the most recently received values of the Buffer Size subfield from the Block Ack Parameter Set field in the ADDBA Response frame received from each member of a specific group address. The minimum of that set of values is defined to be the *GCR buffer size* for that group address (see 10.25.8).

11.21.16.3.8 GCR-SP

The GCR-SP delivery method does not apply to GLK-GCR.

The GCR-SP delivery method transmits GCR group addressed frames at intervals that might be smaller than the beacon interval.

A STA supports the GCR-SP delivery method if dot11AdvancedGCRImplemented is true; otherwise, the STA does not support the GCR service with the delivery method equal to GCR-SP.

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NOTE—Group addressed traffic transmitted at the end of a DTIM beacon might be an impediment to providing QoS for uplink transmissions and in OBSSs. Therefore, APs in an overlapped environment are advised to make use of GCR-SP for group addressed traffic that consumes appreciable medium time.

Group addressed MSDUs shall not be transmitted via the GCR-SP delivery method policy if a non-GCR-SP delivery method is active for that group address.

All MSDUs transmitted via the GCR-SP delivery method shall be concealed using the procedures described in 11.21.16.3.5. A STA receiving group addressed MSDUs transmitted via the GCR-SP delivery method shall discard all nonconcealed MSDUs for this group address.

An AP advertises that a group addressed stream is subject to GCR-SP within a GCR Response subelement. The subelement indicates the start of each SP. See 11.2.3.5. When the Service Interval field in the Schedule element of the DMS Response frame is greater than 0, at every scheduled SP, the AP schedules for transmission buffered GCR-SP group addressed frames assigned to that particular group address.

An AP shall not establish both a GCR-SP and an FMS agreement for a group addressed stream with a single non-AP STA.

An AP may use the GCR-SP delivery method for an accepted GCR service when all of the non-AP STAs that requested the GCR service for the group address have the Robust AV Streaming bit in the Extended Capabilities element equal to 1 and the Advanced GCR bit in the Extended Capabilities element equal to 1. Otherwise, the AP shall not use the GCR-SP delivery method for the accepted GCR service.

When the Service Interval field in the Schedule element of the DMS Response frame is 0, the AP may transmit group addressed frames that are subject to this GCR agreement at any time without regard to the power state of non-AP STAs in the group. This delivery method is called *GCR-A*, where all members of the group need to stay in the awake state to receive these group addressed frames.

11.21.16.4 GLK-GCR

11.21.16.4.1 Overview

GLK-GCR functions as GCR does except as described in the subclauses below. The RA field in the MAC header corresponding to the Data frames transmitted under the GLK-GCR agreement shall contain a SYNRA.

11.21.16.4.2 GLK-GCR operation

A GLK AP that supports GLK-GCR and has set up GLK-GCR for groupcast transmissions shall transmit group addressed frames only via the GLK-GCR mechanism. The GLK AP shall not transmit groupcast frames via the No-Ack/No-Retry (non-GCR; see 10.3.6) service as long as GLK-GCR is active. Data frames using the GLK-GCR mechanism use the non-GCR-SP delivery mode. A GLK AP providing GLK-GCR service may switch between GCR block ack, or GCR unsolicited retry retransmission policies only after indicating such a switch using the GLK Groupcast Mode Change Notification frame.

When the GLK AP updates the GLK-GCR retransmission policy, the GLK AP shall set the Last Sequence Control field in the GLK-GCR Parameter Set element to the sequence number of the MPDU corresponding to the GCR traffic flow that is being updated that was delivered prior to the change in retransmission policy.

To avoid undetected retries being passed up at a receiver's MAC SAP, GLK non-AP STAs that support GLK-GCR should detect duplicates of received group addressed frames and discard them (see 10.3.2.14).

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A GLK AP may update the retransmission policy for any reason, such as a change in the size of the group or the capabilities of the members of the group The GLK AP advertises the current settings using a GLK Groupcast Mode Change Notification frame.

11.21.16.4.3 GLK-GCR unsolicited retry

A STA supports the GLK-GCR unsolicited retry retransmission policy if dot11GLKGCRImplemented is true; otherwise, the STA does not support the GLK-GCR unsolicited retry retransmission policy.

A GLK AP adopting the GLK-GCR unsolicited retry retransmission policy uses the backoff procedure described in 10.23.2.12.2.

If a block ack agreement has successfully been established for a group addressed stream that is delivered using the GLK-GCR unsolicited retry retransmission policy, the GLK STA shall follow the duplicate detection procedures defined in 10.3.2.14 and 10.25.3.

11.21.16.4.4 GLK-GCR block ack

A STA supports the GLK-GCR block ack retransmission policy if dot11GLKGCRImplemented is true; otherwise, the STA does not support the GLK-GCR block ack retransmission policy.

The Buffer Size subfield in the GLK-GCR Parameters field in the GLK-GCR Parameter Set element sent in the (Re)Association Response frame by the GLK AP is the GCR buffer size (see 10.25.8).

11.21.17 WNM notification

Implementation of the WNM notification capability is optional for a WNM STA. A STA that implements the WNM notification capability has dot11WNMNotificationImplemented equal to true. When dot11WNMNotificationImplemented is true, dot11WirelessManagementImplemented shall be true. A STA in which dot11WNMNotificationActivated is true is defined as a STA that supports WNM notification. The STA shall set to 1 the WNM Notification field of the Extended Capabilities elements that it transmits.

A STA that supports WNM notification reporting may send a WNM Notification Request or Response frame to a STA within the same infrastructure BSS or the same IBSS whose most recently received Extended Capabilities element contained a value of 1 for the WNM Notification field in the Extended Capabilities field; it shall not send a WNM Notification Request or Response frame otherwise.

A STA shall transmit both the WNM Notification Request frame and the WNM Notification Response frame with a destination address that is an individual address.

The WNM notification capability enables a STA to indicate management information to a peer STA:

a) Information about its firmware
b) Beacon protection failure

Use of the information provided is outside the scope of this standard. A non-AP STA that supports WNM notification and receives a WNM Notification Request frame with the Type field indicating firmware upgrade notification shall respond with a WNM Notification Response frame with the Response Status field set to 0.

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11.22 WLAN interworking with external networks procedures

11.22.1 General

This subclause describes the actions and the procedures that provide interworking capabilities between IEEE 802.11 infrastructure and external networks.

11.22.2 Interworking capabilities and information

STAs indicate their support for interworking service by setting dot11InterworkingServiceActivated to true. When dot11InterworkingServiceActivated is true, STAs include the Interworking element in Beacon and Probe Response frames, and non-AP STAs include the Interworking element in Probe Request frames.

When dot11InterworkingServiceActivated and dot11ExtendedChannelSwitchActivated are both true in an infrastructure BSS, the AP may provide its operating channel and operating class to an Interworked SSPN using the values from dot11OperatingClassesTable.

In an infrastructure BSS, the Interworking element contains signaling for Homogeneous ESSs. The HESSID is a 6-octet MAC address that identifies the homogeneous ESS. The HESSID value shall be identical to one of the BSSIDs in the homogeneous ESS. Thus, it is a globally unique identifier that, in conjunction with the SSID, may be used to provide network identification for an SSPN.

NOTE—This standard assumes that the HESSID field in the Interworking element is administered consistently across all BSSs in a homogeneous ESS.

The Interworking element also provides an access network type in Beacon and Probe Response frames to assist the non-AP STA with network discovery and selection.

11.22.3 Interworking procedures: generic advertisement service (GAS)

11.22.3.1 Introduction

This subclause describes the actions and procedures that are used to invoke GAS. GAS may be used to enable network selection or service discovery for STAs when dot11InterworkingServiceActivated is true. GAS provides transport mechanisms for advertisement services while STAs are in the unassociated state as well as the associated state. This is accomplished via the use of Public Action frames, which are Class-1 frames. GAS information shall be transmitted using Public Action frames. When management frame protection is negotiated, stations shall use individually addressed Protected Dual of Public Action frames instead of Public Action frames.

A GAS frame exchange may take place between two STAs; one STA transmits a GAS Query Request and the other STA transmits the GAS Query Response as described in 11.22.3.2. The advertisement protocol transported by the GAS is one of the query protocols in Table 9-237.

A STA may transmit group addressed GAS Query Request. Multiple STAs that receive a group addressed GAS Query Request may send an individually addressed or group addressed GAS Query Response.

A STA that receives multiple, similar GAS Query Requests from multiple STAs that require the same GAS Query Response may aggregate the response and transmit a group addressed GAS Query Response.

A STA that receives a group addressed GAS Query Response may process the GAS Response information without transmitting a GAS Query Request frame.

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GAS shall be supported by a STA when dot11InterworkingServiceActivated is true. ANQP shall be supported by a STA when dot11InterworkingServiceActivated is true. Other advertisement protocols shall be supported when the corresponding dot11GASAdvertisementID is present.

A STA shall not transmit a GAS Query Request for any advertisement protocol unless that advertisement protocol ID is included in the Advertisement Protocol element in a Beacon or Probe Response frame. The Advertisement Protocol element specifies the advertisement protocols that a STA may use to communicate with Advertisement Servers, which may be collocated with a STA or in an external network. The advertisement protocol identifies the query language used by the advertisement server. The GAS protocol, which is used to transport Queries and Query Responses, is transparent to the advertisement protocol.

11.22.3.2 GAS Protocol

11.22.3.2.1 General

The presence of the Interworking element in Beacon or Probe Response frames indicates support for the GAS protocol. The additional presence of the GAS Extension element with the Group-addressed GAS subfield in the GAS Extension element set to true in a GAS Initial Request frame or group addressed GAS frames indicates support for the use of group addressed GAS frames. The presence of the Advertisement Protocol element in Beacon or Probe Response frames indicates the advertisement protocol IDs supported in the BSS or IBSS. A STA transmits a GAS Query Request in either a GAS Initial Request frame or a Group Addressed GAS Request frame, and the responding STA provides the GAS Query Response or information on how to receive the GAS Query Response in a GAS Initial Response frame or Group Addressed GAS Response frame. The GAS Query Response shall be delivered in a single GAS Initial Response frame, in a Group Addressed GAS Response frame, or in one or more GAS Comeback Response frames; the GAS Query Response shall not be split between a GAS Initial Response frame and one or more GAS Comeback Response frames or between a Group Addressed GAS Response frame and one or more GAS Comeback Response frames. The GAS message sequence diagrams are shown in Figure 11-38, Figure 11-39, Figure 11-40, and Figure 11-41.

If a GAS Initial Request frame or a Group Addressed GAS Request frame contains a Maximum Channel Time field in the GAS Extension Element and if the conditions for replying as described in 11.22.3.2.3 and 11.22.3.2.4 are met, the responding STA shall queue for transmission a GAS Initial Response frame or a Group Addressed GAS Response frame within the indicated Maximum Channel Time.

Figure 11-38 describes the GAS frame exchange sequence when dot11GASPauseForServerResponse is true and the result of the GAS Query Request fits within one MMPDU.

Figure 11-39 describes the GAS frame exchange sequence when dot11GASPauseForServerResponse is true and the result of the GAS Query Request is too large to fit in one MMPDU and GAS fragmentation is used for delivery. The number of GAS Comeback Request and GAS Comeback Response frames depends on the number of GAS fragments required for delivery of the result of the GAS Query Request.

Figure 11-40 describes the GAS frame exchange sequence when dot11GASPauseForServerResponse is false. The number of GAS Comeback Request and GAS Comeback Response frames depends on the number of GAS fragments required for delivery of the GAS Query Response.

Figure 11-41 describes the GAS frame exchange sequence when a STA sends a Group Addressed GAS Request frame to a group of STAs. The receiving STA may or may not respond to the GAS Query Request. If the receiving STA responds, it may respond with either a GAS Initial Response frame or a Group Addressed GAS Response frame.

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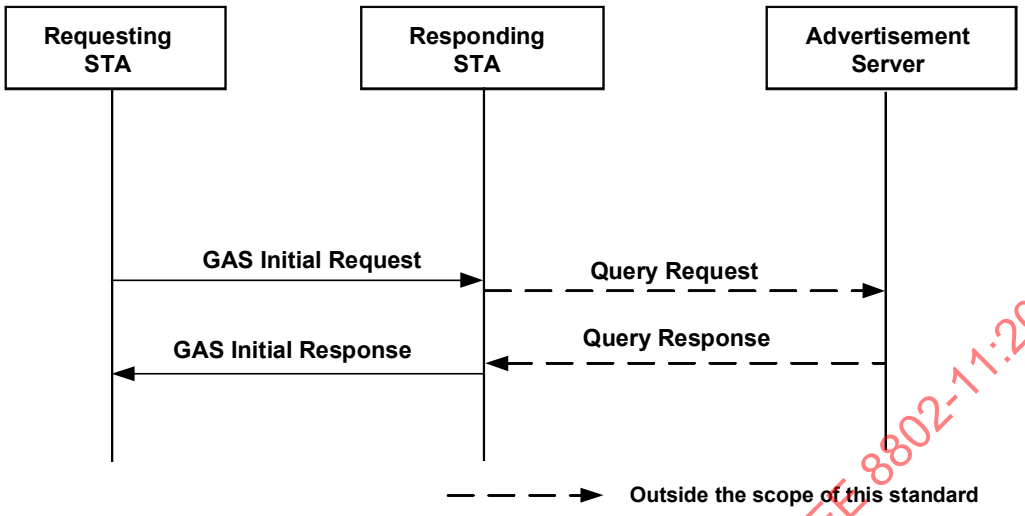

Figure 11-38—GAS frame sequence with dot11GASPauseForServerResponse equal to true

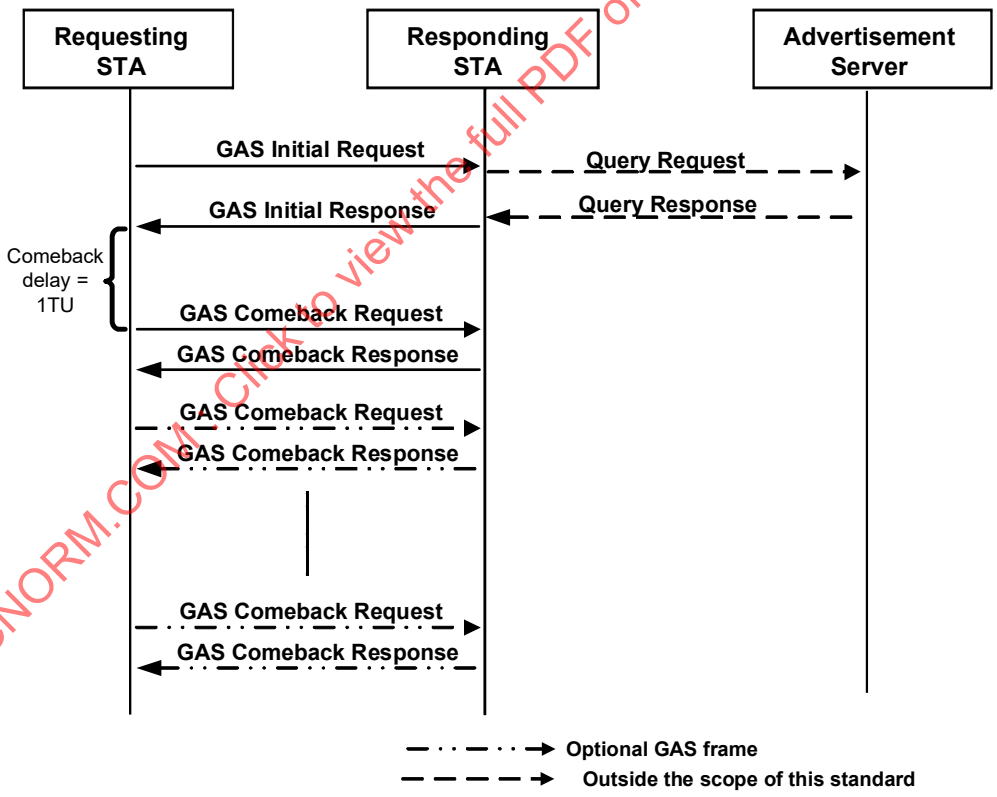

Figure 11-39—GAS frame sequence with GAS fragmentation and dot11GASPauseForServerResponse equal to true

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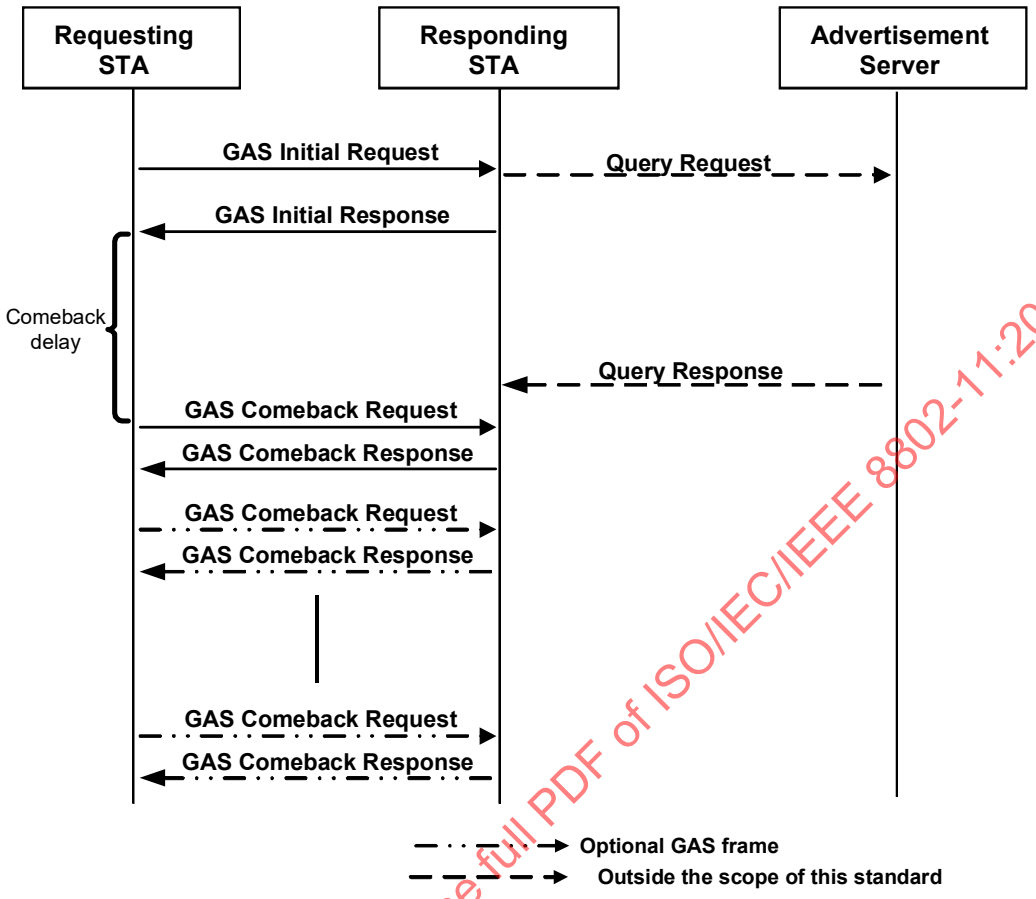

Figure 11-40—GAS frame sequence with GAS fragmentation and dot11GASPauseForServerResponse equal to false

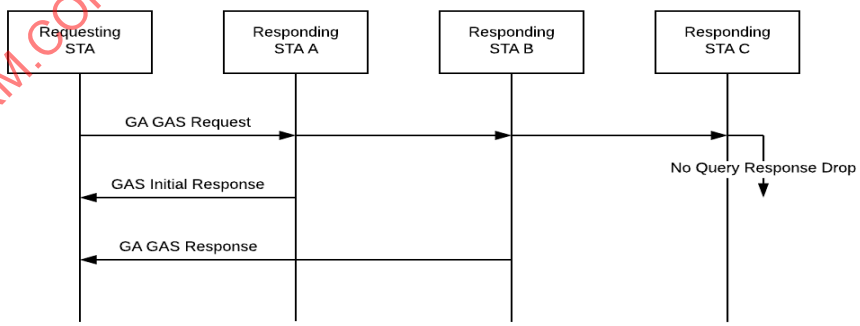

Figure 11-41—Group addressed GAS Query Request exchange sequence

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Figure 11-42 describes a GAS frame exchange sequence when multiple STAs send a GAS Initial Request frame that would result in the same GAS Query Response. The receiving STA responds with a Group Addressed GAS Response frame.

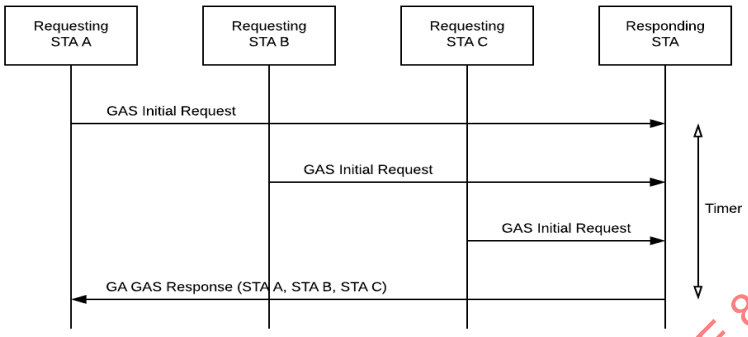

Figure 11-42—Group addressed GAS Query Response exchange sequence

Figure 11-43 describes the GAS frame exchange sequence when a STA issues a GAS Initial Request frame and, during the course of receiving a fragmented GAS Comeback Response frame, requests a specific fragment for retransmission from the transmitting STA.

Figure 11-44 describes a GAS frame exchange sequence using CAG Version when a requesting STA requests information that the requesting STA has a cached version of a previous query response and the associated Common Advertisement Group (CAG) Version. The requesting STA provides its cached CAG Version in a GAS Initial Request frame along with the query request. When the responding STA determines that the CAG Version cached by the requesting STA matches a valid CAG Version that the responding STA receives from a relevant Advertisement Server as indicated by the CAG Information Type, which is provided by the requesting STA in the same CAG Tuple field that contains the cached CAG Version, then the responding STA provides a GAS response indicating that the information cached by the requesting STA is still valid. When the responding STA determines that the CAG Version cached by the requesting STA does not match any valid CAG Version that the responding STA receives from a relevant Advertisement Server as indicated by the CAG Information Type, which is provided by the requesting STA in the same CAG Tuple field that contains the cached CAG Version, then the responding STA posts the query request to the relevant Advertisement Server as specified in 11.22.3.2.3, receives a query response from the Advertisement Server, and transmits the query response to the requesting STA as specified in 11.22.3.2.4.

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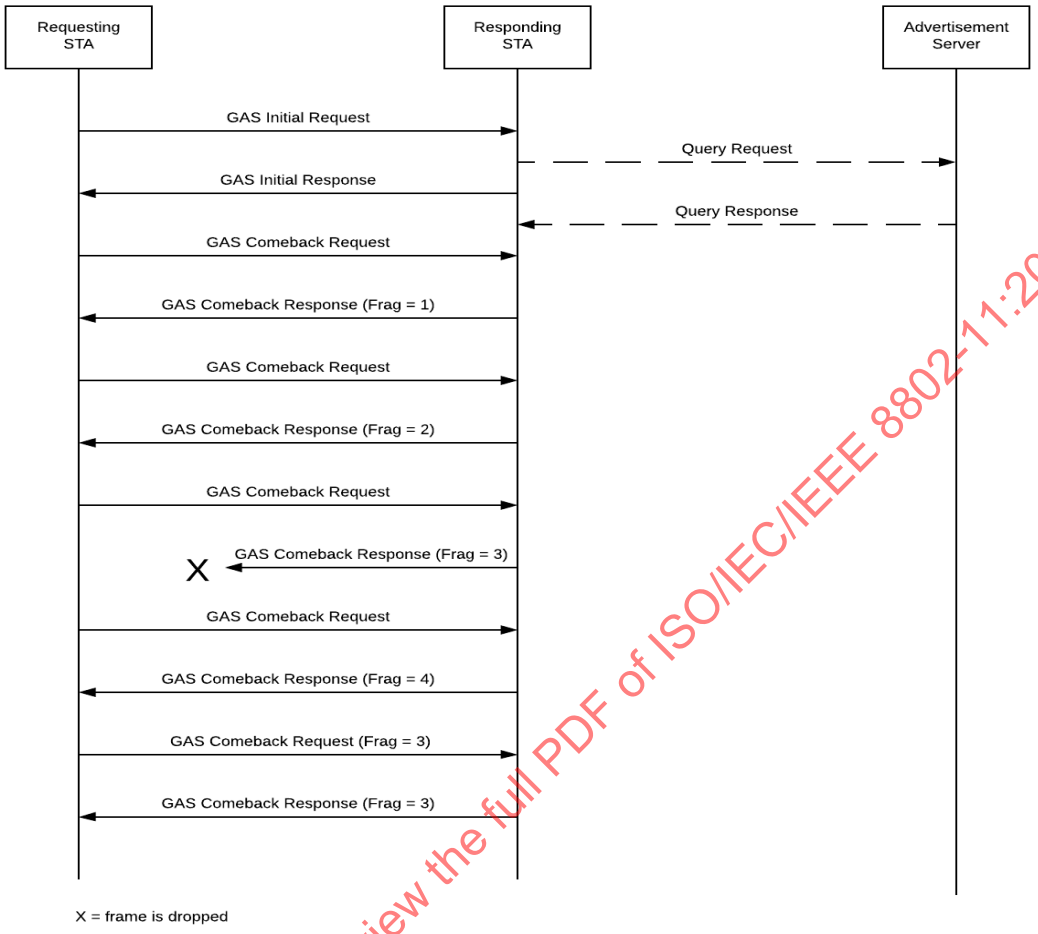

Figure 11-43—Group addressed GAS Query Request for a specific fragment exchange sequence

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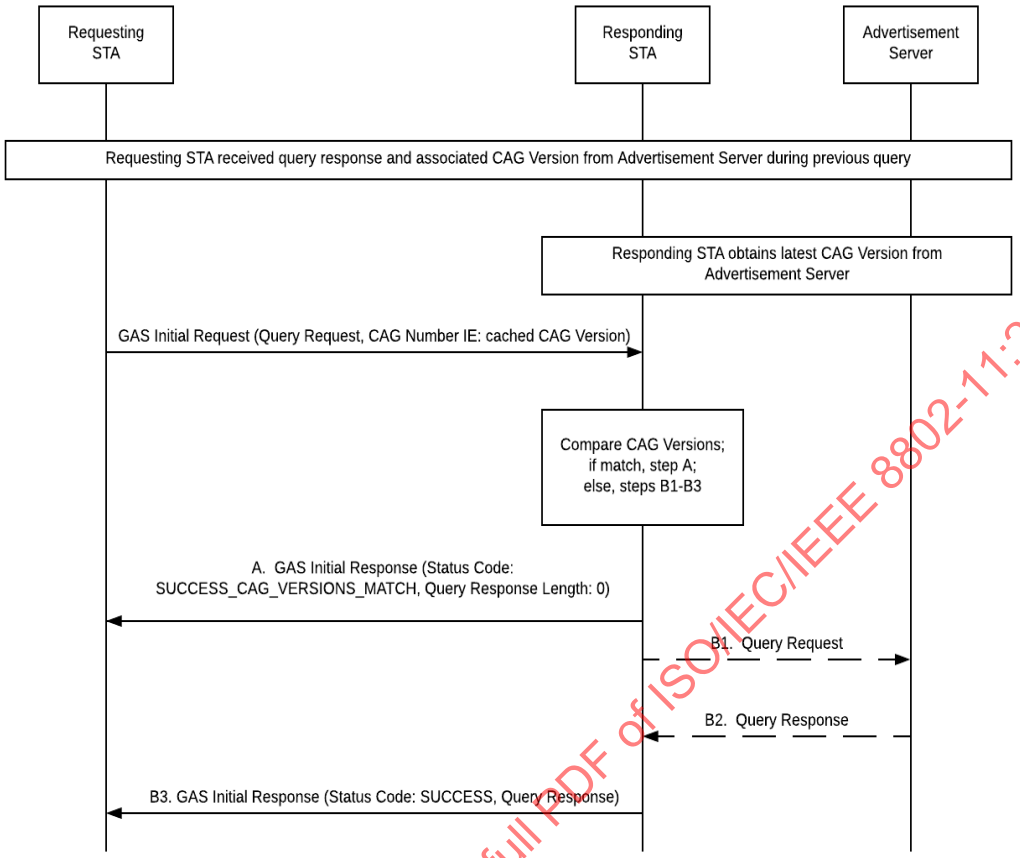

Figure 11-44—GAS frame exchange sequence using CAG Version

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11.22.3.2.2 STA procedures to transmit a GAS Query Request

Upon receipt of an MLME-GAS.request primitive, the requesting STA shall engage in the following procedure to transmit a query:

a) If GAMode in the primitive is null or set to false, the requesting STA sends a GAS Query Request by transmitting a GAS Initial Request frame containing a Dialog Token, an Advertisement Protocol element containing an Advertisement Protocol ID field and GAS Query Request in the Query Request field. If the GAS Initial Request frame requests information relating to a frequency band different from the frequency band in which the frame is transmitted, the STA shall include a Multi-band element in the GAS Initial Request frame with the Band ID, Operating Class, and Channel Number fields set to indicate to which frequency band the GAS Initial Request frame applies, with other fields in the Multi-band element being reserved. If the frame requests information relating to the frequency band in which the frame is transmitted, a Multi-band element shall not be included in the frame. If the GAS Initial Request frame requests information that the requesting STA has a cached version of a previous query response and the associated CAG Version, the requesting STA may include the cached CAG Version and the associated CAG Information Type in a CAG Number element in the GAS Initial Request frame. If GAMode in the primitive is set to true, the requesting STA transmits a Group Addressed GAS Request frame including a GAS Extensions element with the Maximum Channel Time field set to the value of the dot11GASResponseTimeout divided by 10, rounded to the nearest integer, and limited to a value of 255.

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b) Upon transmission of the GAS Initial Request frame or Group Addressed GAS Request frame, the STA shall set a timer, referred to as the *dot11GASResponseTimer*, equal to dot11GASResponseTimeout or the QueryFailureTimeout parameter provided in the MLME-GAS.request primitive. If both values are present, the timer shall be set to the lesser of the two values.

c) If the requesting STA is not in the associated state, it shall remain in active mode until the receipt of a GAS Initial Response frame or Group Addressed GAS Response frame with the same value of the Dialog Token field as in the GAS Initial Request frame or until the expiration of the timer, whichever occurs first. If the requesting STA is in the associated state, it may go into power save state until the GAS Initial Response frame or Group Addressed GAS Response frame is available for receipt or the timer expiration, whichever occurs first.

d) If the dot11GASResponseTimer expires before a GAS Initial Response frame or Group Addressed GAS Response frame is received, the GAS Query Request was not successful and the MLME shall issue an MLME-GAS.confirm primitive with ResultCode equal to GAS_QUERY_TIMEOUT and shall set the Query Response Length field to 0.

11.22.3.2.3 STA procedures to post a GAS Query Request to an Advertisement Server

Upon receipt of a GAS Initial Request or a Group Addressed GAS Request frame, an MLME-GAS.indication primitive shall be issued to the STA's SME. Upon receipt of an MLME-GAS.indication primitive indicating the receipt of a GAS Initial Request frame, the STA shall transmit a GAS Initial Response or Group Addressed GAS Response frame to the requesting STA according to the following procedures. Upon receipt of an MLME-GAS.indication primitive indicating the receipt of a Group Addressed GAS Request frame, the STA may transmit a GAS Initial Response frame to the requesting STA or transmit a Group Addressed GAS Response frame according to the following procedures. If the requesting STA is in the associated state and in the power save mode, the responding STA shall buffer the MMPDU for transmission according to the procedures in 11.2.3; otherwise the STA shall queue the MMPDU for transmission as follows:

a) If the Advertisement Protocol ID field in the Advertisement Protocol element does not equal the value contained in any dot11GASAdvertisementID, then the STA shall not post the query to an Advertisement Server. The STA shall transmit an individually addressed GAS Initial Response frame to the requesting STA containing a dialog token whose value is identical to the dialog token in the GAS Initial Request frame, a Status Code equal to GAS_ADVERTISEMENT_PROTOCOL_NOT_SUPPORTED (see Table 9-50), an Advertisement Protocol element containing the Advertisement Protocol ID field used in the GAS Initial Request frame and a Comeback Delay and Query Response Length both set to 0.

b) If the query request corresponds to an advertisement protocol whose server is currently unreachable, the responding STA shall transmit an individually addressed GAS Initial Response frame to the requesting STA containing a dialog token whose value is identical to the dialog token in the GAS Initial Request frame, a Status Code equal to SERVER_UNREACHABLE, an Advertisement Protocol element containing an Advertisement Protocol ID field equal to the advertisement protocol ID contained in the GAS Initial Request frame and a Comeback Delay and Query Response Length both set to 0. The method used by the AP to determine the server is unreachable is out of scope of this standard. A STA receiving a status code indicating SERVER_UNREACHABLE should wait at least 1 minute before transmitting any further queries using the same advertisement protocol ID to the responding STA.

c) If the GAS Initial Request frame includes a CAG Number element and all the CAG Versions in the CAG Number element match a valid CAG Version that the STA receives from the associated Advertisement Server, which is identified by the CAG Information Type subfield within the same CAG Tuple field as the CAG Version subfield, then the STA may transmit an individually addressed GAS Initial Response frame to the requesting STA containing a dialog token whose value is identical to the dialog token in the GAS Initial Request frame, a Status Code equal to

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SUCCESS_CAG_VERSIONS_MATCH, an Advertisement Protocol element containing the Advertisement Protocol ID field used in the GAS Initial Request frame, and a GAS Comeback Delay and Query Response Length both set to 0, without posting the query to an Advertisement Server. This completes the GAS Query Request and GAS Query Response exchange.

d) If the Advertisement Protocol ID field in the Advertisement Protocol element equals the value contained in any dot11GASAdvertisementID, then the STA shall initialize a timer, referred to as the *PostReplyTimer*, to the value of the Maximum Channel Time field times 10, if received in the GAS Initial Request or Group Addressed GAS Request frame, or otherwise, to the value in dot11GASResponseTimeout. The STA posts the query to the advertisement server identified by the advertisement protocol ID. If the GAMode associated with the Query Request is true, the STA includes the GAMode parameter, the GAS extension information, the MAC Address, and the Dialog token when it posts the query to the Advertisement Server for processing. The methods and protocols the STA uses to post the query are outside the scope of this standard.

   1) If the GAMode associated with the Query Request is true and the Advertisement Server has no response to the Query Request, the Advertisement Server may drop the request.

   2) If the Advertisement Server receives multiple GAS Query Requests resulting in the same response, the Advertisement Server may aggregate these responses into a single GAS Query Response. The Advertisement Server responds to the STA including the aggregated responses as described in 11.22.3.2.5.

e) If dot11GASPauseForServerResponse is false, the responding STA shall transmit an individually addressed GAS Initial Response frame to the requesting STA containing a dialog token whose value is identical to the dialog token in the GAS Initial Request frame, a Status Code set to SUCCESS, an Advertisement Protocol element containing the Advertisement Protocol ID field used in the GAS Initial Request frame, a GAS Comeback Delay set to the value in dot11GASComebackDelay for this advertisement protocol and a Query Response Length set to 0.

f) If dot11GASPauseForServerResponse is true, the GAS Query Response is delivered as defined in 11.22.3.2.4.

11.22.3.2.4 STA procedures for transmitting the GAS Query Response

After receiving a query response from the Advertisement Server, the responding STA shall buffer the query response for a minimum of dot11GASResponseBufferingTime after the expiration of the GAS Comeback Delay or until the query response is delivered. If the responding STA does not receive a GAS Comeback Request frame whose source MAC address and dialog token match the source MAC address and value of the Dialog Token field respectively of the corresponding GAS Initial Response frame within this time, it may drop the query response. If the query response received from the Advertisement Server is larger than dot11GASQueryResponseLengthLimit for the matching dot11GASAdvertisementID or is larger than the value of the Query Response Length Limit field received from the requesting STA, the responding STA shall discard the response and instead return a status code of GAS_QUERY_RESPONSE_TOO_ LARGE in the GAS Comeback Response frame. This behavior helps to prevent abuses of the medium that may be caused by overly general queries, which evoke a very large query response.

The GAS protocol supports Query Responses whose length is greater than the IEEE 802.11 maximum MMPDU size by the STA's use of the GAS Query Response Fragment ID field in the GAS Comeback Response frame; the Query Response Fragment ID shall be set to 0 for the initial fragment and incremented by 1 for each subsequent fragment in a multi-fragment query response. If the Query Response is a multi-fragment response (i.e., contains more than 1 fragment), the STA shall transmit all fragments that belong to the same Query Response until all fragments are exhausted. The STA shall set the More GAS Fragments field of the GAS Query Response Fragment ID to 0 when the transmitted fragment is the final fragment.

If the GAS Initial Request frame that initiated the GAS transaction contains a Multi-band element, but the GAS Initial Response frame transmitted as a response does not contain a copy of the same Multi-band element, the

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Status Code in the GAS Initial Response frame shall be set to REQUEST_DECLINED. Otherwise, the requesting and responding STAs shall include a copy of the same Multi-band element in all subsequent GAS Initial Response, GAS Comeback Request, and GAS Comeback Response frames transmitted as part of the GAS transaction. Inclusion of the Multi-band element indicates to which frequency band the GAS transaction applies. If the GAS Initial Request frame that initiated the GAS transaction does not contain a Multi-band element, then none of the subsequent GAS Initial Response, GAS Comeback Request, and GAS Comeback Response frames transmitted as part of the GAS transaction shall include a Multi-band element.

The following procedures shall be used by the responding STA to deliver the query response to the requesting STA:

a) If dot11GASPauseForServerResponse is true:

   1) If the query response is received from the Advertisement Server before the PostReplyTimer expires, and if the query response's length is less than or equal to the maximum MMPDU size and the query response is not an aggregated response, the STA shall transmit an individually addressed GAS Initial Response frame to the requesting STA containing a dialog token whose value is identical to the dialog token in the GAS Initial Request frame, a Status Code set to SUCCESS, an Advertisement Protocol element containing the Advertisement Protocol ID field used in the GAS Initial Request frame or the Group Addressed Request frame, a GAS Comeback Delay set to 0, the Query Response and a Query Response Length set to the query response length. This completes the GAS request and response exchange.

   2) If the query response is received from the Advertisement Server before the PostReplyTimer expires, and if the query response's length is less than or equal to the maximum MMPDU size and the query response is an aggregated response, the STA shall transmit a Group Addressed GAS Response frame containing a dialog token set to 0, a Status Code set to SUCCESS, an Advertisement Protocol element containing the Advertisement Protocol ID field used in the GAS Initial Request frame or the Group Addressed Request frame, a GAS Comeback Delay set to 0, the Query Response and a Query Response Length set to the query response length, and a GAS Extension element containing a list of MAC Address/Dialog Token pairs in the Response Map Duples subfield of the GAS Extension element, identifying the requesting STAs and their Query Requests to which the Group Addressed GAS Response frame responds. This completes the GAS request/response exchange.

   3) If the PostReplyTimer expires before the query response is received from the Advertisement Server for responding to a GAS Initial Request frame, then the responding STA shall transmit an individually addressed GAS Initial Response frame to the requesting STA containing a dialog token whose value is identical to the dialog token in the GAS Initial Request frame, a Status Code set to GAS_QUERY_TIMEOUT (see Table 9-50), an Advertisement Protocol element containing the Advertisement Protocol ID field used in the GAS Initial Request frame, a GAS Comeback Delay set to 0 and a Query Response Length set to 0. If the query response is subsequently received from the Advertisement Server, it shall be dropped by the responding STA.

   4) If the PostReplyTimer expires before the query response is received from the Advertisement Server for responding to a Group Addressed GAS Request frame, then the responding STA shall not transmit an individually addressed GAS Initial Response frame or a Group Addressed GAS Response frame to the requesting STA.

      NOTE—If there is no response to the Query Request, the Advertisement Server may drop the request.

   5) If the Query Response received from the Advertisement Server is larger than dot11GASQueryResponseLengthLimit or requires more than 128 fragments for transmission to the requesting STA, it shall be dropped by the responding STA. Then the responding STA shall transmit an individually addressed GAS Initial Response frame to the requesting STA containing a dialog token whose value is identical to the dialog token in the GAS Initial Request frame, a Status Code set to GAS_QUERY_RESPONSE_TOO_ LARGE (see Table 9-50), an Advertisement Protocol element containing the Advertisement Protocol ID

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field used in the GAS Initial Request frame, a GAS Comeback Delay set to 0 and a Query Response Length set to 0.

6) If the query response's length is larger than the maximum MMPDU size, the responding STA shall transmit an individually addressed GAS Initial Response frame to the requesting STA containing a dialog token whose value is identical to the dialog token in the GAS Initial Request frame, a Status Code set to SUCCESS, an Advertisement Protocol element containing the Advertisement Protocol ID field used in the GAS Initial Request frame, a GAS Comeback Delay set to 1 TU, and a Query Response Length set to 0; this indicates the query response will be transmitted using GAS Comeback Request and Response frames that support GAS fragmentation as follows. If the responding STA is capable of retransmitting a Query Response fragment upon request, the responding STA shall include, in the GAS Initial Response frame, a GAS Extension element with the Fragment Retransmission subfield of the GAS Flags field set to 1.

b) If dot11GASPauseForServerResponse is false:

1) If the PostReplyTimer expires before the GAS Query Response is received from the Advertisement Server then the responding STA shall buffer for transmission a GAS Comeback Response frame with a status code equal to GAS_QUERY_TIMEOUT (see Table 9-50). If the query response is subsequently received from the Advertisement Server, it shall be dropped by the STA.

2) If the Query Response received from the Advertisement Server is larger than dot11GASQueryResponseLengthLimit, it shall be dropped by the responding STA. Then the STA shall buffer for transmission a GAS Comeback Response frame with status code set to GAS_QUERY_RESPONSE_TOO_ LARGE.

c) If the Query Response is received before the expiration of the PostReplyTimer and its length is less than dot11GASQueryResponseLengthLimit, then the Query Response shall be buffered in one or more GAS Comeback Response frames with status code set to SUCCESS. The responding STA transmits one GAS Comeback Response frame in response to each GAS Comeback Request frame. If the Query Response received from the Advertisement Server is less than or equal to the maximum MMPDU size, then the GAS Query Response Fragment ID shall be set to 0 and the More GAS Fragments field in the GAS Query Response Fragment ID shall be set to 0. If the Query Response received from the Advertisement Server is greater than the maximum MMPDU size, then the GAS Query Response Fragment ID shall be set to 0 if this is the first fragment of the Query Response transmitted; otherwise it shall be incremented by 1; the More GAS Fragments field in the GAS Query Response Fragment ID shall be set to 1 if there are more fragments of the Query Response to be transmitted; otherwise it shall be set to 0 (i.e., this fragment is the last fragment of the Query Response). If a responding STA receives a GAS Comeback Request that includes the GAS Extension element with the Fragment ID field set to a valid Fragment ID the responding STA shall respond with a GAS Comeback Response frame that includes the fragment corresponding to the received Fragment ID.

d) If a responding STA receives a GAS Comeback Request frame whose source MAC address and dialog token match the destination MAC address and value of the Dialog Token field respectively of an outstanding GAS Initial Response frame and the query response has not been received from the Advertisement Server and the PostReplyTimer has not expired, the responding STA shall transmit a GAS Comeback Response frame with status code equal to GAS_RESPONSE_NOT_RECEIVED_FROM _SERVER (see Table 9-50) and GAS Comeback Delay set to the value in dot11GASComebackDelay for this advertisement protocol to indicate when the requesting STA should come back to obtain its Query Response.

e) If a responding STA receives a GAS Comeback Request frame whose source MAC address and Dialog Token do not match the destination MAC address and value of the Dialog Token field respectively of an outstanding GAS Initial Response frame, the STA should transmit a GAS Comeback Response frame with a status code equal to NO_OUTSTANDING_GAS_REQUEST.

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A requesting STA shall transmit a GAS Comeback Request frame including the Dialog Token (drawn from the corresponding GAS Initial Response frame) immediately after the expiration of the GAS Comeback Delay. In response, the responding STA provides the Query Response in one or more GAS Comeback Response frames with the corresponding Dialog Token.

If the requesting STA supports GAS extension, and the requesting STA is unable to receive a GAS Query Response fragment, then the following procedures apply:

a) If the Fragment Retransmission subfield in the GAS Extension element in the corresponding GAS Initial Response frame is equal to 1, the requesting STA may transmit a GAS Comeback Request frame, including the GAS Extension element with the Fragment ID subfield of the GAS Flags field set to the fragment ID of the Query Response to be retransmitted. Upon receiving the GAS Comeback Request, the responding STA shall transmit a GAS Comeback Response frame that includes the Query Response fragment corresponding to the value received in the Fragment ID field and with the GAS Query Response Fragment ID subfield in GAS Query Response Fragment field set to the value received in the Fragment ID field. If the Query Response fragment is not available, the responding SA shall respond with a GAS Comeback Response frame with a status code set to GAS_FRAGMENT_NOT_AVAILABLE.

b) If the corresponding GAS Initial Response frame does not contain a GAS Extension element or the the Fragment Retransmission subfield in the GAS Extension element is equal to 0, the requesting STA shall not request the retransmission of a GAS Query Response fragment using a GAS Comeback Request frame.

If a requesting STA receives a GAS Comeback Response frame with status equal to QUERY_RESPONSE_OUTSTANDING, the requesting STA shall wait for the GAS Comeback Delay from that frame and upon expiration of the GAS Comeback Delay, transmit another GAS Comeback Request frame. If the requesting STA's dot11GASResponseTimer (set in 11.22.3.2.2 step b) expires prior to receiving a GAS Comeback Response frame whose source MAC address and dialog token match those in the corresponding GAS Initial Response frame, the STA shall issue an MLME-GAS.confirm primitive with ResultCode equal to GAS_QUERY_TIMEOUT and shall set the Query Response Length to 0.

If a requesting STA receives a GAS Comeback Response frame with status equal to SUCCESS and the More GAS Fragments field in the GAS Query Response Fragment ID equal to 1, it shall transmit another GAS Comeback Request frame in order to retrieve the next GAS fragment of a multi-fragment query response.

If a requesting STA receives a GAS Comeback Response frame with status equal to SUCCESS and the More GAS Fragments field in the GAS Query Response Fragment ID equal to 0, the requesting STA's MLME shall determine that all fragments have been received by confirming that all fragment IDs from 0 to the value in the GAS Query Response Fragment ID when the More GAS Fragments field was equal to 0 have been received. Upon receipt of the first GAS Comeback Response frame and every GAS Comeback Response frame thereafter, the dot11GASResponseTimer shall be reset. If all of the query response fragments were received before the expiration of the dot11GASResponseTimer, then the MLME shall issue an MLME-GAS.confirm primitive with result code set to SUCCESS along with the query response. If not all of the query response fragments were received before the expiration of the dot11GASResponseTimer, then the MLME shall issue an MLME-GAS.confirm primitive with ResultCode equal to GAS_QUERY_TIMEOUT and shall set the Query Response Length to 0.

After a requesting STA receives the first GAS fragment of a multi-fragment query response, it shall continue retrieving the query response until all GAS fragments are received or until a transmission failure is detected; the requesting STA shall not commence the retrieval of another GAS Query Response from the same STA until all GAS fragments are received or until a transmission failure is detected on the first GAS Query Response.

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If a requesting STA receives a GAS Comeback Response with status equal to GAS_QUERY_TIMEOUT or GAS_QUERY_RESPONSE_TOO_ LARGE then the MLME shall issue an MLME-GAS.confirm primitive with result code so indicating and shall set the Query Response Length to 0.

If a requesting STA receives a GAS Comeback Response with status equal to NO_OUTSTANDING_GAS_REQUEST, then the MLME shall issue an MLME-GAS.confirm primitive with result code set to NO_OUTSTANDING_GAS_REQUEST and shall set the Query Response Length to 0.

11.22.3.2.5 Group addressed GAS procedures

Upon receipt of an MLME-GAS.request primitive with the GAMode parameter set to 1 (true), the requesting STA shall follow procedures defined in 11.22.3.2.2 to transmit a Group Addressed GAS Request frame instead of a GAS Initial Request frame.

Upon receipt of an aggregated Query Response from the Advertisement Server, the responding STA may transmit the aggregated Query responses using Group Addressed GAS Response frame to the receiving STAs. The length of the Group Addressed GAS Response frame shall not exceed the IEEE 802.11 maximum MMPDU size. The STA shall include a list of MAC Address/Dialog Token pairs in the Response Map Duples subfield of the GAS Extension element included in the Group Addressed GAS Response frame.

11.22.3.2.6 GAS procedures interaction with multiple BSSID set

Non-AP STAs in the unassociated state may use GAS procedures to query Advertisement Servers for information. As described in 11.22.3.2, APs indicate their support for a particular GAS advertisement protocol by including an Advertisement protocol element with that Advertisement protocol ID in Beacon and Probe Response frames as described in 9.3.3.2 and 9.3.3.10 respectively. Non-AP STAs receiving Beacon or Probe Response frames from different APs may choose to engage in GAS frame exchange sequences with one or more of these APs. In some deployment scenarios, these APs may be operating as a multiple BSSID set (as defined in 11.10.14) and may relay the GAS queries to the same Advertisement Server. Depending on the configuration of the IEEE 802.11 access network, the external network and the Advertisement Server, a query response from the Advertisement Server might or might not be dependent on the BSSID used in the GAS frame exchange sequence and thus the STA from which the query was relayed. If the GAS Query Response is dependent on the BSSID, a requesting STA may choose to post queries using GAS procedures to more than one STA and expect possibly different Query Responses. If the Query Response is not dependent on the BSSID, then a requesting STA may choose to post queries using GAS procedures to only one STA in the multiple BSSID set (i.e., posting the same query to another member of the multiple BSSID set would yield the same response).

When a Multiple BSSID (as defined in 11.10.14) set contains two or more members and dot11InterworkingServiceActivated is true and dot11GASAdvertisementID is present and a query to the Advertisement Server corresponding to dot11GASAdvertisementID is not dependent on the BSSID value used in the GAS frame exchange sequence to post the query, then the PAME-BI bit in the Advertisement Protocol tuple of the Advertisement Protocol element corresponding to dot11GASAdvertisementID shall be set to 1; otherwise this bit shall be set to 0.

11.22.3.3 ANQP procedures

11.22.3.3.1 General

A STA may use ANQP to retrieve information as defined in Table 9-331 from a peer STA.

A non-AP STA shall not transmit an ANQP request to an AP for any ANQP-element unless the ANQP Advertisement Protocol ID field is included in the Advertisement Protocol element in a Beacon or Probe Response frame from that AP.

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The ANQP request consists of one or more ANQP elements drawn from Table 9-331 having an element type of Q in Table 11-14 and shall be ordered by nondecreasing Info ID. A Query List ANQP-element included in an ANQP request is formed as described in 11.22.3.2.2. The ANQP request is transported in the Query Request field of GAS Request frames as described in 11.22.3.2.4.

The ANQP response should consist of ANQP elements having Info IDs present in the Query List ANQP-element response (if present) plus zero or more responses to other query elements; these ANQP elements shall be chosen from among those listed in Table 9-331 having an element type of S in Table 11-14 and shall be ordered by nondecreasing Info ID. The ANQP response is transported in the Query Response field of GAS Response frames, as described in 11.22.3.2.4.

Table 11-14—ANQP usage

ANQP-element name	ANQP-element (subclause)	ANQP-element type	BSS		IBSS
			AP	Non-AP and non-PCP STA	STA
Query List	9.4.5.2	Q	T, R	T, R	T, R
Capability List	9.4.5.3	S	T, R	T, R	T, R
Venue Name	9.4.5.4	S	T	R	—
Emergency Call Number	9.4.5.5	S	T	R	—
Network Authentication Type	9.4.5.6	S	T	R	—
Roaming Consortium	9.4.5.7	S	T	R	—
Vendor Specific	9.4.5.8	Q, S	T, R	T, R	T, R
IP Address Type Availability	9.4.5.9	S	T, R	T, R	T, R
NAI Realm	9.4.5.10	S	T	R	T, R
3GPP Cellular Network	9.4.5.11	S	T	R	—
AP Geospatial Location	9.4.5.12	S	T	R	T, R
AP Civic Location	9.4.5.13	S	T	R	T, R
AP Location Public Identifier URI/FQDN	9.4.5.14	S	T	R	T, R
Domain Name	9.4.5.15	S	T	R	—
Emergency Alert Identifier URI	9.4.5.16	S	T	R	T, R
TDLS Capability	9.4.5.18	Q, S	T,R	T,R	T, R
Emergency NAI	9.4.5.17	S	T	R	—
Neighbor Report	9.4.5.19	S	T	R	—
Venue URL	9.4.5.20	S	T	R	—
Advice of Charge	9.4.5.21	S	T	R	—
Local Content	9.4.5.22	S	T	R	—
Network Authentication Type with Timestamp	9.4.5.23	S	T	R	—

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Table 11-14—ANQP usage *(continued)*

ANQP-element name	ANQP-element (subclause)	ANQP-element type	BSS		IBSS
			AP	Non-AP and non-PCP STA	STA
Query AP List	9.4.5.24	Q	R	T	—
AP List Response	9.4.5.25	S	T	R	—
Common Advertisement Group	9.4.5.26	S	T	R	—
Service Information Request	9.4.5.27	Q	R, G	T, G	—
Service Information Response	9.4.5.28	S	T, G	R, G	—
Local MAC Address Policy	9.4.5.29	S	T	R	—

Symbols
Q element is an ANQP request
S element is an ANQP response
T ANQP-element may be transmitted by MAC entity
R ANQP-element may be received by MAC entity
G Group addressed ANQP request/response may be transmitted and received by a MAC entity
— ANQP-element is neither transmitted nor received by MAC entity

A STA receiving a CAG ANQP-element in an ANQP response should cache the ANQP-element contents, for later use. The STA caches the ANQP CAG Version and ANQP responses corresponding to each Info ID from the received CAG ANQP-element together with the values of BSSID, or HESSID and the corresponding SSID of the responding AP's BSS. The STA obtains the required ANQP responses either as an ANQP response to a previous ANQP request, or by transmitting an ANQP request for the ANQP response .

The AP obtains the current value of a CAG Version from the associated advertisement server. How the AP obtains the value of the CAG Version from the associated advertisement server is out of the scope of this standard.

When dot11InterworkingServiceActivated is true, an AP may provide one or more current version numbers of the CAG (CAG Version) associated with the AP, where each version number is associated with a specific advertisement protocol by including the CAG Number element in the Beacon or Probe Response frame.

In order to reduce the network discovery delay at an AP, the BSSID, HESSID, or the corresponding SSID of that AP's BSS are used as a key index in the STA's cache to determine if an ANQP CAG Version received from an AP matches previously cached information.

A STA that makes use of the CAG Version is subject to the following:

— The STA may obtain the CAG Version from the CAG Number element received in Beacon or Probe Response frames.
— The STA searches its cached information using the BSSID, HESSID, or SSID of the AP's BSS as an index to obtain the correct cached ANQP CAG Version entry.
— If the cached ANQP CAG Version does not match the CAG version received in Beacon or Probe Response frames, the STA should transmit an ANQP request for any of the ANQP-elements contained within the CAG. If the CAG Versions do match, the STA should use the cached ANQP elements corresponding to the CAG Version for network discovery.

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The mapping of the ANQP CAG Version to the ANQP elements by an advertisement server is outside the scope of this standard.

ANQP usage for infrastructure BSSs and IBSSs shall be in accordance with Table 11-14. ANQP usage defines the entities permitted to transmit and receive particular ANQP-elements.

A STA having dot11InterworkingServiceActivated equal to true shall be capable of using the Query List ANQP-element to request the Capability List ANQP-element; support for all other ANQP-elements is optional.

A STA that encounters an unknown or reserved ANQP Info ID value in a GAS frame (see 9-364) received without error shall ignore that ANQP Info ID and shall parse any remaining ANQP Info IDs.

A STA that encounters an unknown vendor-specific OI field or subfield in a GAS frame (see 9-364) received without error shall ignore that field or subfield respectively, and shall parse any remaining fields or subfields for additional information with recognizable field or subfield values.

11.22.3.3.2 Query list procedure

The Query List ANQP-element is used by a requesting STA to perform an ANQP request using the procedures defined in 11.22.3.3.1. The requesting STA may include Info IDs in the Query List ANQP-element that have the sole ANQP-element type of S as shown in Table 11-14; the STA shall not include other Info IDs.

A responding STA that encounters an unknown or reserved ANQP Info ID value in an Query List ANQP-element received without error shall ignore that ANQP Info ID and shall parse any remaining ANQP Info IDs.

11.22.3.3.3 Roaming Consortium procedure

The Roaming Consortium ANQP-element, which contains a set of OIs, can be retrieved from an AP by a non-AP STA using the query list procedure defined in 11.22.3.3.2. The list of OIs included in the Roaming Consortium ANQP-element shall be those OIs in the dot11RoamingConsortiumTable. An AP may include an OI in the dot11RoamingConsortiumTable if in conjunction with an AS, it is capable of successfully authenticating a non-AP STA having valid security credentials for the SSPN identified by that OI; the AP shall not include an OI otherwise. Methods used by the AP to authenticate the non-AP STA include, but are not limited to, RSNA algorithms and Open System authentication.

Each OI identifies an SSP or group of SSPs (i.e., a roaming consortium). An SSP or group of SSPs can register for and obtain an OI using the procedures described in IEEE SA FAQs—IEEE Registration Authority [B15].

A non-AP STA might have a locally stored binding between an OI and a set of security credentials with which it can authenticate to the network identified by the OI, that is, the SSPN. The method by which this binding is obtained is outside the scope of this standard. A non-AP STA can select from that list of credentials when authenticating to the BSS.

11.22.3.3.4 AP procedure for advertising EAP Method associated with an NAI Realm

When dot11RSNAActivated is true, NAI realms along with their supported authentication methods may be advertised using the NAI Realm ANQP-element (see 9.4.5.10). Each realm may optionally be associated with a set of EAP methods. Each EAP method may optionally be associated with a set of Authentication Parameters. The NAI realm ANQP-element provides a hint on the methods a STA might use to establish an association in an RSN IEEE 802.1X environment. If the non-AP STA recognizes the NAI realm, it may attempt authentication even if it believes the EAP methods are incorrect.

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When dot11RSNAActivated is false and the Network Authentication Type (see 9.4.5.6) contains a Network Authentication Type Unit having a Network Authentication Type Indicator field equal to http/https redirection or DNS redirection, NAI realms without supported authentication methods may be advertised using the NAI Realm ANQP-element (see 9.4.5.10).

A non-AP STA having dot11InterworkingServiceActivated equal to true may process the NAI Realm ANQP-element. The selection of the NAI realm the non-AP STA uses for authentication is outside the scope of this standard. A non-AP STA requests the NAI Realm ANQP-element using Query List procedures defined in 11.22.3.3.2.

A non-AP STA having dot11InterworkingServiceActivated equal to true may process the EAP Method list as follows:

— The EAP Method list provided by the AP shall be in priority order (the most preferred EAP Method is listed first).
— The credential types help the STA to determine what credentials to use for authentication.
— The STA should confirm the GAS advertisement after an RSNA is established by performing a GAS Query Request for the NAI Realm ANQP-element using Protected Dual of Public Action frames.

NOTE—The advertisements should be confirmed after the RSNA is established to avoid downgrade attacks.

The policy that determines whether a non-AP STA should attempt authentication and/or association with any particular IEEE 802.11 Access Network is outside the scope of this standard.

11.22.3.3.5 3GPP Cellular Network procedure

A STA may retrieve 3GPP Cellular Network information using the Query List procedure in 11.22.3.3.2. Realms referenced in the 3GPP Cellular Network ANQP-element should not be included in the NAI Realm ANQP-element (see 9.4.5.10).

11.22.3.3.6 AP Geospatial Location procedure

A STA may retrieve an AP's geospatial location using the Query List procedure in 11.22.3.3.2. A STA in the associated state should retrieve Geospatial location information from the AP using the procedures in 11.10.9.6.

11.22.3.3.7 AP Civic Location procedure

A STA may retrieve an AP's civic location using the Query List procedure in 11.22.3.3.2. A STA in the associated state should retrieve civic location information from the AP using the procedures in 11.10.9.9.

11.22.3.3.8 AP Location Public Identifier URI/FQDN procedures

A STA when dot11InterworkingServiceActivated is true may retrieve an AP's Location Public Identifier URI or a location server's FQDN using ANQP procedures in 11.22.3.3. A STA in the associated state should retrieve Location Public Identifier URI/FQDN information from the AP using the procedures in 11.10.9.10.

Due to security concerns, there are some URI schemes that should be cautiously processed when received by a STA. For example, URIs using the scheme names "data:" and "http:" may direct applications (e.g., a browser) on the STA to Internet pages that contain active scripts. Therefore, URIs received via this ANQP procedure should not be processed in a general manner, as these scripts may be inadvertently activated. Instead of listing all of the types of URIs that might be misused or potentially have harmful effects, Section 3.3 IANA registers acceptable URI schemes.

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11.22.3.3.9 Emergency NAI procedure

A STA that does not have valid credentials to authenticate to a network may use the information in the Emergency NAI ANQP-element as its EAP identity.

The Emergency NAI ANQP-element can be retrieved from the AP using the Query List procedure in 11.22.3.3.2.

The STA uses the emergency NAI procedure to indicate its intention to access the network without peer authentication by using the emergency NAI information as its identity in the authentication process, as described in IETF RFC 5216.

11.22.3.3.10 TDLS Capability procedure

A STA may use the TDLS Capability ANQP-element (see 9.4.5.18) to discover TDLS capabilities of another TDLS STA using the Query List procedure in 11.22.3.3.2.

An example of TDLS capability discovery using ANQP is given in Figure 11-45.

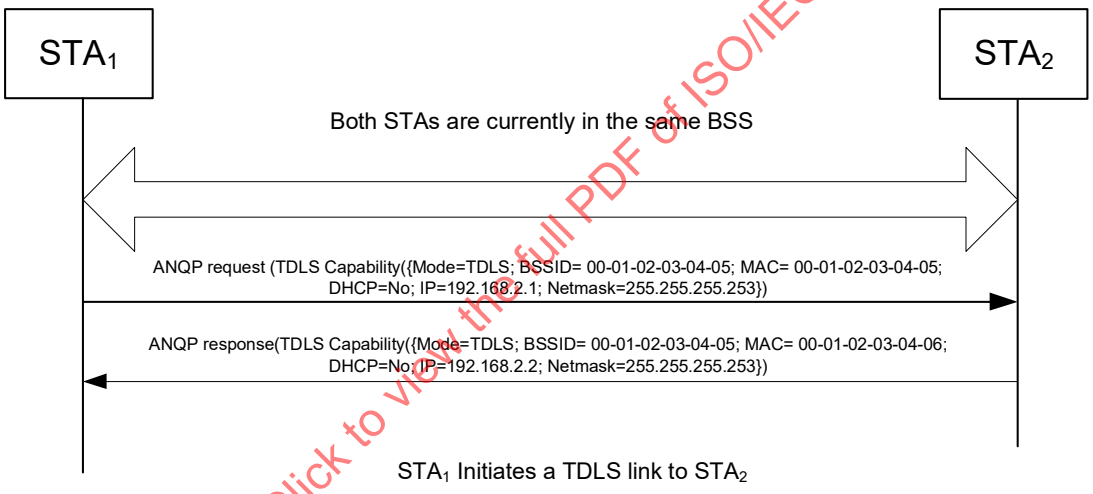

Figure 11-45—Example TDLS Capability discovery using ANQP

The mechanism shall work as follows:

a) STA1 determines the MAC address of STA2.

b) STA1 sends an ANQP request to STA2. The ANQP request includes a TDLS Capability ANQP-element.

c) STA2 receives the ANQP request and updates the TDLS Capability ANQP-element based on its own capabilities that is returned in the ANQP response to STA1.

11.22.3.3.11 Venue URL procedure

The Venue URL ANQP-element is used to provide web page advertising services or information particular to the venue.

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This ANQP-element is to be used in conjunction with the Venue Name ANQP-element, to provide extra information about the venue. Typical operation is to use the Venue Name ANQP-element to determine the list of available venues advertised by a STA, and then the Venue URL ANQP-element is used, if required, to determine a list of Venue URLs, each entry corresponding to the Venue Name entry in the list returned by the Venue Name ANQP-element.

11.22.3.3.12 Advice of Charge procedure

The Advice of Charge ANQP-element is used to provide financial cost advertisements in the form of Advice of Charge plan information. The plan information is provided on a per NAI realm basis, so that each authentication realm can advertise the charge associated with obtaining network access. This information might assist with a decision about proceeding with access. Plan information for the special NAI realm "*" is indicated, if none of the explicit NAI realms are currently applicable.

The use and operation of the Plan information schema is outside the scope of this standard.

As ANQP-elements are transmitted in the clear, prior to STA association, one or more Protected Dual of Public Action frames should be used after association to verify this information.

11.22.3.3.13 Local Content procedure

The Local Content ANQP-element is used to provide local content URLs. Each URL points to local content information that might be relevant, for example by providing information about terms and conditions for BSS access, when automated login procedures are being used.

Several URLs can be provided in the Local Content ANQP-element, each corresponding to a separate state. This allows the STA to display differing local content (e.g., terms and conditions, failure warning information, help page), through the STA association procedure.

For example, the Local Content ANQP-element may return two Local Content Duple fields with values of the State field corresponding to "Not authenticated" and "Failure during authentication." The requesting STA may display the contents of the local web page indicated by the first URL ("Not authenticated") showing terms and conditions of BSS access. If a subsequent association fails, then the requesting STA may display the contents of the local web-page indicated by the second URL ("Failure during authentication") showing a help page.

11.22.3.3.14 Query AP List procedure

The Query AP List ANQP-element is used by a requesting STA to perform a single ANQP request to an AP, using the procedures defined in 11.22.3.3.1 requesting the ANQP information on each AP indicated in the AP list. The requesting STA shall only include Info IDs in the Query List ANQP-element that have the sole ANQP-element type of S as shown in Table 11-14. Info IDs that have an ANQP-element type of Q shall not be included in the Query AP List ANQP-element (e.g., the Info ID for Vendor Specific ANQP-element shall not be included).

A responding STA that encounters an unknown or reserved ANQP Info ID value in a Query AP List ANQP-element shall ignore that ANQP Info ID and shall parse any remaining ANQP Info IDs.

In the response to a Query AP List, the Query Response field contains an AP List Response ANQP-element. The AP List Response contains multiple query response reports for the APs indicated in the Query AP List. If the responding AP does not provide the requested information for all APs specified in the Query AP List, or for all the requested Info IDs, the STA interprets it as that information not available. How the information obtained from the AP list is used by the STA is left to the implementation and is beyond the scope of this specification.

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11.22.3.3.15 CAG procedure

The CAG ANQP-element is used by a requesting STA to perform an ANQP request to retrieve the Info IDs contained within the CAG associated with ANQP, or ANQP with Service Information Registry, and the current ANQP CAG Version associated with these Info IDs. If the requesting STA to perform an ANQP request to retrieve the Info IDs related both to ANQP and to ANQP with Service Information Registry, the requesting STA shall use separate CAG ANQP-elements. For this purpose, a requesting STA shall use the procedures defined in 11.22.3.3.1 and 11.22.3.3.2 and shall include in the ANQP request the Info ID of the CAG ANQP-element as shown in Table 11-14. When a responding AP receives a Query List ANQP-element that contains the Info ID of CAG ANQP-element, the responding STA shall include in the GAS Query Response frame a CAG ANQP-element containing the ANQP CAG Version and the Info IDs of the ANQP-elements that are in the CAG associated with ANQP, or ANQP with Service Information Registry, in the increasing order of the Info ID values. If the responding STA receives Info IDs related both to ANQP and to ANQP with Service Information Registry, the responding STA shall include separate CAG ANQP-elements in the ANQP response. The ANQP response also includes the (other) ANQP-elements that a STA requested in the Query List ANQP-element in the increasing order of the Info ID values.

The ANQP CAG Version is an unsigned number and it is incremented when there is any change in the CAG associated with ANQP, or ANQP with Service Information Registry, including a change of the Info ID of the ANQP-elements of the CAG or a change in the values of the ANQP-elements included in the CAG. If the ANQP CAG Version exceeds 255, it is reset to 0.

11.22.3.3.16 Local MAC address policy procedure

The Local MAC Address Policy ANQP-element is used by a non-AP STA to discover the MAC address policy for an ESS. The STA should use a MAC address consistent with the local MAC address policy, as determined from the Local MAC Address Policy ANQP-element and the Local MAC Address Policy field in the Extended Capabilities field. An AP may send a DENIED_LOCAL_MAC_ADDRESS_POLICY_VIOLATION status code in an Association Response frame to a STA with a MAC address that is inconsistent with the MAC address policy.

11.22.3.4 Registered location query protocol (RLQP) procedures

When dot11GDDActivated is true, a STA may use RLQP to retrieve information as defined in Table 9-237 from a peer STA that has transmitted an Advertisement Protocol element indicating support for RLQP (see 9.4.2.92) in a Beacon or Probe Response frame.

If information is not configured for a particular RLQP-element, then a query for that element returns that element with no optional fields.

When RLQP is transmitted between the GDD enabling STA and the RLSS, it uses Ethertype 89-0d frames, as defined in Annex H. RLQP-elements are contained in GAS Query Request and GAS Query Response frames as specified in 9.4.6 and the Advertising Protocol element with an Advertising Protocol tuple whose Advertisement Protocol ID field is set to the value of RLQP specified in Table 9-237. When an RLQP-element is transmitted between the GDD dependent STA and its GDD enabling STA, it might use a Protected Dual of Public Action frame, but it does not use an Ethertype 89-0d frame.

In some regulatory domains, the GDD enabling STA may be required to have secured connection with the RLSS. When security is required by regulation, the Ethertype 89-0d frame body may employ corresponding security features. Alternatively, various security protocols may also be selected by setting the Ethertype field to respective values. The IEEE Registration Authority provides a public listing of Ethertypes and other identifiers at https://regauth.standards.ieee.org/standards-ra-web/pub/view.html#registries.

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11.22.4 Interworking procedures: IEEE 802.21 MIS support

IEEE Std 802.21-2017 enables the optimization of services when performed between heterogeneous IEEE 802 networks. IEEE Std 802.21.1-2017 defines a handover service, which is used in conjunction with IEEE Std 802.21-2017.

STAs with dot11InterworkingServiceActivated equal to true and dot11GasAdvertisementId equal to MIS Information Service (see Table 9-237) shall support the transmission and reception of IEEE 802.21 MIIS queries for STAs in all states. STAs with dot11InterworkingServiceActivated equal to true and dot11GasAdvertisementId equal to MIS Command and Event Services Capability Discovery (see Table 9-237) shall provide support for IEEE 802.21 MICS/MIES capability discovery for non-AP STAs in all states.

Additionally, support for IEEE 802.21 MIIS query and IEEE 802.21 MICS/MIES capability discovery to non-AP STA's in the associated state is provided by the STA forwarding IP datagrams destined for the MIS point of service to the IEEE 802.21 MIIS server.

A non-AP STA discovers support for these services by receiving Beacon or Probe Response frames with an Advertisement Protocol element having advertisement protocol ID(s) for MIS Information Service and/or IEEE 802.21 MICS/MIES capability discovery.

A non-AP STA forms an IEEE 802.21 information service query by creating its query request according to the procedures defined in IEEE Std 802.21-2017 and formatting that request into an IEEE 802.21 MIS protocol frame as defined in 8.4 of IEEE Std 802.21-2017. The non-AP STA, using the procedures in 11.22.3.2, posts the query to an IEEE 802.21 Information Server by transmitting the MIS formatted frame in the Query Request field of a GAS Initial Request frame. The Advertisement Protocol ID field in the GAS Initial Request frame is set to the value of IEEE 802.21 MIS Information Service (Table 9-237).

Non-AP STAs in the unauthenticated or unassociated or associated states can use GAS procedures to discover MIS Command and Event Services Capability as specified in Table 9-237.

A non-AP STA forms an IEEE 802.21 MIS Command and Event Service discovery request by encapsulating an MIS_Capability_Discover request into an MIS protocol frame as defined in 8.4 of IEEE Std 802.21-2017. The non-AP STA, using the procedures in 11.22.3.2, posts the discovery request to the network by transmitting the MIS formatted frame in the Query Request field of a GAS Initial Request frame. The Advertisement Protocol ID field in the GAS Initial Request frame is set to the value of MIS Command and Event Services Capability Discovery (Table 9-237). The method by which the AP relays the discovery request to the network is defined in IEEE Std 802.21-2017 and is outside the scope of this standard.

A non-AP STA retrieves the IEEE 802.21 MIS Command and Event Service discovery response according to the procedures in 11.22.3.2. The discovery response is an MIS protocol frame as defined in 8.4 of IEEE Std 802.21-2017.

11.22.5 Interworking procedures: interactions with SSPN

11.22.5.1 General operation

To provide SSPN Interface services, the IEEE 802.11 network interacts with the SSPN corresponding to the user of the non-AP STA either directly or via a roaming relationship. As part of setting up the RSN security association, user policies are communicated to the AP. If dot11SSPNInterfaceActivated is true, these permissions shall be stored in the AP's dot11InterworkingTableEntry for that STA. Thereafter, the AP shall use the dot11InterworkingTableEntry for controlling the service provision to that non-AP STA. User policies from the SSPN affect authentication, authorization, and admission control decisions at the AP. In addition, the AP collects statistics about the non-AP STA and reports the statistics to the SSPN when requested. The SSPN

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may also send service provision instructions to the AP, e.g., to terminate the connection to a non-AP STA. Non-AP STAs do not support the SSPN Interface.

Network deployments typically provide that the AP and the server in the SSPN have a trustworthy channel that can be used to exchange information, without exposure to or influence by any intermediate parties. The establishment of this secure connection between the IEEE 802.11 infrastructure and the SSPN is outside the scope of this standard.

11.22.5.2 Authentication and cipher suites selection with SSPN

When the non-AP STA initiates IEEE 802.1X authentication, the EAP messages are forwarded to the SSPN based on the home realm information provided by the non-AP STA. If the IEEE 802.11 infrastructure is unable to forward the EAP message, the AP when dot11SSPNInterfaceActivated is true shall disassociate the non-AP STA with Reason Code NO_SSP_ROAMING_AGREEMENT.

In addition to the EAP messages, the IEEE 802.11 infrastructure also provides extra information regarding the non-AP STA to the SSPN as defined in R.4.2, e.g., the Cipher Suite supported by non-AP STA, the location of the AP to which the non-AP STA is associated, etc. Such information may be used by the SSPN to make authentication and service provisioning decisions.

In the SSPN Interface Service, the SSPN uses more information than is carried over EAP to decide on the authentication result. The SSPN might reject a connection request if the cipher suites supported by non-AP STA does not meet its security requirements. In this situation, the SME of the AP when dot11SSPNInterfaceActivated is true shall invoke a disassociation procedure as defined in 11.3.5.8 by issuing the MLME-DISASSOCIATE.request primitive. The AP disassociates the corresponding non-AP STA with Reason Code BAD_CIPHER_OR_AKM.

The SSPN might reject the association request based on the location of the non-AP STA, e.g., if the non-AP STA is requesting association to an AP or associated to an AP located in a forbidden zone. In this situation, the SME of the AP when dot11SSPNInterfaceActivated is true shall invoke a disassociation procedure as defined in 11.3.5.8 by issuing the MLME-DISASSOCIATE.request primitive. The AP disassociates the corresponding non-AP STA with Reason Code NOT_AUTHORIZED_THIS_LOCATION.

11.22.5.3 Reporting and session control with SSPN

An AP with dot11SSPNInterfaceActivated equal to true shall create a dot11InterworkingEntry in its dot11InterworkingTable for each STA that successfully associates. Permissions received from the SSPN for each associated STA shall be populated into the table; if no permissions are received from the SSPN for a particular non-AP STA, then the default permissions or an AP's locally defined policy may be used for that STA's dot11InterworkingEntry. If the AP's local policy is more restrictive than an object's permission value received from the SSPN Interface, then the AP's local policy may be enforced instead.

In an AP when dot11SSPNInterfaceActivated is equal to true, the following procedure occurs:

— The non-AP STA's state contained in the dot11InterworkingEntry shall be transmitted to the new AP after a successful transition. The state definition and the protocol used to transfer the state are beyond the scope of this standard. The new AP shall not forward any frames for that non-AP STA until it receives the dot11InterworkingEntry from the prior AP.

— After the state is successfully transmitted to the new AP, the dot11InterworkingEntry for that non-AP STA shall be deleted from the prior AP's dot11InterworkingTable.

An AP with dot11SSPNInterfaceActivated equal to true shall delete the dot11InterworkingEntry for a non-AP STA when it disassociates from the BSS.

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An AP with dot11SSPNInterfaceActivated equal to true shall enforce the dot11InterworkingEntry limits for a particular non-AP STA by comparing the values of octet counters to authorized access limits:

— dot11NonAPStationVoiceOctetCount is compared to dot11NonAPStationAuthMaxVoiceOctets. When the value of the authorized maximum octet count is exceeded, if the ACM subfield for AC_VO is equal to 1, then the HC shall delete all admitted TSs on this access category and deny all subsequent ADDTS Request frames with TID set to 6 or 7; or if the ACM subfield for AC_VO is equal to 0, then the non-AP STA shall be disassociated using the MLME-DISASSOCIATE.request primitive with a reason code of PEER_INITIATED.

— dot11NonAPStationVideoOctetCount is compared to dot11NonAPStationAuthMaxVideoOctets. When the value of the authorized maximum octet count is exceeded, if the ACM subfield for AC_VI is equal to 1, then the HC shall delete all admitted TSs on this access category and deny all subsequent ADDTS Request frames with TID set to 4 or 5; or if the ACM subfield for AC_VI is equal to 0, then the non-AP STA shall be disassociated using the MLME-DISASSOCIATE.request primitive with a reason code of PEER_INITIATED.

— dot11NonAPStationBestEffortOctetCount is compared to dot11NonAPStationAuthMaxBestEffortOctets. When the value of the authorized maximum octet count is exceeded, if the ACM subfield for AC_BE is equal to 1, then the HC shall delete all admitted TSs on this access category and deny all subsequent ADDTS Request frames with TID set to 0 or 3; or if the ACM subfield for AC_BE is equal to 0, then the non-AP STA shall be disassociated using the MLME-DISASSOCIATE.request primitive with a reason code of PEER_INITIATED.

— dot11NonAPStationBackgroundOctetCount is compared to dot11NonAPStationAuthMaxBackgroundOctets. When the value of the authorized maximum octet count is exceeded, if the ACM subfield for AC_BK is equal to 1, then the HC shall delete all admitted TSs on this access category and deny all subsequent ADDTS Request frames with TID set to 1 or 2; or if the ACM subfield for AC_BK is equal to 0, then the non-AP STA shall be disassociated using the MLME-DISASSOCIATE.request primitive with a reason code of PEER_INITIATED.

— dot11NonAPStationHCCAHEMMOctetCount is compared to dot11NonAPStationAuthMaxHCCAHEMMOctets. When the value of the authorized maximum octet count is exceeded, then the HC shall delete all admitted TSs with access policy of HCCA or HEMM and deny all subsequent ADDTS Request frames with access policy equal to HCCA or HEMM.

— The sum of dot11NonAPStationVoiceOctetCount, dot11NonAPStationVideoOctetCount, dot11NonAPStationBestEffortOctetCount, dot11NonAPStationAuthMaxBackgroundOctets, and dot11NonAPStationHCCAHEMMOctetCount is compared to dot11NonAPStationAuthMaxTotalOctets. When the value of the authorized maximum octet count is exceeded, the non-AP STA shall be disassociated using the MLME-DISASSOCIATE.request primitive with a reason code of PEER_INITIATED.

11.22.6 Interworking procedures: emergency services support

Emergency services support provides STAs with the ability to contact authorities in an emergency situation. The following procedures allow the STA to determine whether emergency services are supported by the AP or mesh STA, and whether unauthenticated emergency service access is allowed.

In an AP, when dot11ESNetwork is true, the network is dedicated and limited to accessing emergency services. When dot11ESNetwork is true, the Access Network Type field in the Interworking element shall be set to the value for “Emergency services only network” (see Table 9-236). When dot11ESNetwork is false, the network is not limited to accessing emergency services, and the Access Network Type field in the Interworking element shall be set to a value other than “Emergency services only network.” See Table 11-15.

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Table 11-15—ESR and UESA field settings

Description	ESR	UESA
It is unspecified whether emergency services are reachable.	0	0
Emergency services are only reachable for authenticated STAs.	1	0
Reserved	0	1
Emergency services are reachable for STAs.	1	1

When an AP is located in a regulatory domain that requires emergency location capabilities, the ESR field shall be set to 1; otherwise the ESR field shall be set to 0. When an AP is located in a regulatory domain that requires emergency location capabilities and location capability is enabled on the AP, the Network Type shall be set to "Emergency services only network" (see Table 9-236), if location capability is enabled on the AP; otherwise the ESR field shall not be set to 1 and the Network Type shall not be set to "Emergency services only network". In Beacon and Probe Response frames, location capability is advertised when the Civic Location or Geo Location field in the Extended Capabilities element is set to 1.

In an MBSS, if location capability is supported, the mesh STA shall report its location for emergency services.

When dot11ESNetwork is true in a mesh STA, the ESR shall be set to 1. When that mesh STA receives a Mesh Peering Open frame that includes the Interworking element with the ASRA field equal to 1, it allows access to emergency services and forwards MSDUs to an emergency server.

NOTE—The ASRA bit set to 1, informs the mesh STA to prioritize resources for the emergency call, to proactively find a better path before the link conditions deteriorate below a certain threshold, and/or to change some of the mesh STA's behavior (for example, to disable any power save features).

When dot11ESNetwork is false in a mesh STA, the ESR shall be set to 0. When that mesh STA receives a Mesh Peering Open frame that includes the Interworking element with the ASRA field equal to 1, it is unable to support the mesh peering of emergency services and does not forward MDSUs to an emergency server.

11.22.7 Interworking procedures: emergency alert system (EAS) support

The EAS provides alerts, typically issued by authorities. The Interworking Procedures EAS support enables the alerts to be transmitted upon request from APs to non-AP STAs. Subsequent to advertisement in Beacon and Probe Response frames, a non-AP STA uses GAS queries to retrieve an EAS message from the network according to the following procedures.

When dot11EASActivated is true, EAS operation shall be supported. When EAS operation is not supported, dot11EASActivated shall be false.

When the IEEE 802.11 infrastructure is informed of the availability of an EAS message (the mechanism by which is outside the scope of this standard), an AP with dot11EASActivated equal true shall advertise the availability of the EAS message by including an Emergency Alert Identifier element (see 9.4.2.96) for that message in its Beacon and Probe Response frames. The AP shall include one instance of an Emergency Alert Identifier element in its Beacon and Probe Response frames for each active EAS Message. The Emergency Alert Identifier element provides an Alert Identifier Hash value, a unique indicator of the EAS Message of the alert to the non-AP STA. The Alert Identifier Hash value allows the non-AP STA to determine whether this is a new alert.

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NOTE—The same value of hash will be computed by each AP in an ESS and by each AP in different ESSs. Thus a non-AP STA, which can download emergency alert messages when in a preassociated state, can unambiguously determine that it has already downloaded the message, avoiding unnecessary duplicates.

When an EAS Message has expired (the mechanism by which is outside the scope of this standard), an AP with dot11EASActivated equal true shall remove the corresponding instance of an Emergency Alert Identifier element from its Beacon and Probe Response frames.

The Alert Identifier Hash in the Emergency Alert Identifier element shall be computed using HMAC-SHA-1-64 hash algorithm as shown in 9.4.2.96.

After receiving an Alert Identifier Hash value for an EAS Message that has not already been retrieved from the network, a non-AP STA having dot11EASActivated equal true can retrieve the EAS message from the AP as follows:

— The procedures defined in 11.22.3.2, transmit the Alert Identifier Hash of the desired message in the Query request field of a GAS Initial Request frame. The Advertisement Protocol ID field in the GAS Initial Request frame is set to the value for EAS (see Table 9-237).
— The Query response is a message formatted in accordance with OASIS EDXL (see OASIS Standard EDXL-DE).
— A URI is formed by concatenating the Emergency Alert URI with the hexadecimal numerals of the Alert Identifier Hash converted to lowercase ASCII encoded characters and the ".xml" file extension. For example, if the Emergency Alert URI is http://eas.server.org and the Alert Identifier Hash is 0x1234567890abcdef, then the URI would be http://eas.server.org/1234567890abcdef.xml (the mechanism by which the URI is retrieved is outside the scope of this standard). The XML file is formatted in accordance with OASIS EDXL. The non-AP STA retrieves the Emergency Alert URI (see 9.4.5.16) using an ANQP request according to the procedures in 11.22.3.3. This method is recommended for non-AP STAs in the associated state.

11.22.8 Interworking procedures: support for the advertisement of roaming consortiums

APs can assist non-AP STAs performing network discovery and selection through the advertisement of a Roaming Consortium element. The Roaming Consortium element contains information identifying an SSP or group of SSPs (i.e., a roaming consortium) whose security credentials might be used to authenticate with the AP transmitting this element. An SSP or group of SSPs can register for and obtain an OI using the procedures described in IEEE SA FAQs—IEEE Registration Authority [B15]. Note that a non-AP STA may also use GAS procedures defined in 11.22.3.3.3 to retrieve a Roaming Consortium ANQP-element, which might contain more OIs than the Roaming Consortium element.

APs having dot11InterworkingServiceActivated equal true and having one or more entries in the dot11RoamingConsortiumTable shall include the Roaming Consortium element in Beacon and Probe Response frames. An AP shall only include an OI in the dot11RoamingConsortiumTable, if, in conjunction with an AS, the AP is capable of successfully authenticating a non-AP STA that holds valid security credentials for the SSPN identified by that OI. Methods used by the AP to authenticate the non-AP STA include, but are not limited to, RSNA algorithms and Open System authentication.

A non-AP STA might have a locally stored binding between an OI and a set of security credentials with which it can authenticate to the network identified by the OI, that is, the SSPN. The method by which this binding is obtained is outside the scope of this standard. A non-AP STA might select from that list of credentials when authenticating to the BSS.

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11.22.9 Interworking procedures: support for QoS mapping from external networks

Maintaining proper end-to-end QoS is an important factor when providing interworking service. This is because the external networks might employ different network-layer (Layer 3) QoS practices. For example, the use of a particular differentiated services code point (DSCP) for a given service might be different between different networks. To provide proper QoS over-the-air in the IEEE 802.11 infrastructure, the mapping from DSCP to UP for the corresponding network needs to be identified and made known to the STAs. If an inconsistent mapping is used then:

— Admission control at the AP may incorrectly reject a service request, because the non-AP STA used the incorrect UP.
— Non-AP STAs might use the incorrect value for User Priority in TSPEC and TCLAS elements.
— The user might be given a different QoS over the IEEE 802.11 network than expected, e.g., a lower QoS might be provided than the STA expected.

Therefore, APs with dot11QosMapActivated equal true shall set the QoS Map field in the Extended Capabilities element to 1; APs with dot11QosMapActivated equal false shall set the QoS Map field in the Extended Capabilities element to 0. The AP's SME causes the QoS mapping to be available to higher layer protocols or applications so they will be able to set the correct priority in an MA-UNITDATA.request primitive.

For frames transmitted by an AP belonging to an admitted TS, the UP obtained from the TS's TCLAS element shall be used instead of the UP derived from the QoS mapping. For frames transmitted by an AP belonging to an admitted TS not having a TCLAS element, the UP shall be derived from the QoS mapping.

Non-AP STAs, when dot11QosMapActivated is equal true shall set the QoS Map field in the Extended Capabilities element to 1. An AP receiving an Association Request frame or Reassociation Request frame when the QoS Map field in the Extended Capabilities element is equal 1 shall include the QoS Map element in the corresponding Association Response frame or Reassociation Response frame as defined in 9.3.3.6 or 9.3.3.8, respectively. Upon receiving the QoS Map element, the non-AP STA's SME causes the QoS mapping to be available to higher layer protocols or applications so they will be able to set the correct priority in an MA-UNITDATA.request primitive.

When the AP's SME detects a change in the QoS mapping information, it shall update the non-AP STA with the new QoS Map element. It accomplishes this update by invoking the MLME-QOS-MAP.request primitive.

When the MAC entity at the non-AP STA receives a QoS Map Configure frame from the AP, the MLME shall issue an MLME-QOS-MAP.indication primitive to its SME.

When the non-AP STA's SME receives the QoS Map response, it shall make the QoS Map available to higher layers so that in turn, they can invoke the MA-UNITDATA.request primitive with the correct priority.

11.23 Preassociation discovery (PAD) procedures

11.23.1 General

There are two types of PAD procedures: unsolicited and solicited. The unsolicited PAD procedure is described in 11.23.2, and the solicited PAD procedure is described in 11.23.3.

When dot11UnsolicitedPADActivated or dot11SolicitedPADActivated is true, a non-AP and non-PCP STA may use PAD procedures to allow the SIC to discover the availability of services that the same non-AP and non-PCP STA may access when associated. While the specification of service-specific information is outside

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the scope of this standard, the service-specific information in the BSS is proxied by a SIR (see 4.5.9.2.4), which might be collocated with the AP or PCP.

A non-AP STA with dot11SolicitedPADActivated set to true may set dot11MACPrivacyActivated to true (see 12.2.10).

An AP advertises support for PAD by setting the PAD field of the Extended Capabilities element to 1 in its Beacon and Probe Response frames.

A PCP advertises support for PAD by setting the PAD field of the Extended Capabilities element to 1 in its DMG Beacon, Announce, and Probe Response frames.

11.23.2 Unsolicited PAD procedure

When dot11UnsolicitedPADActivated is true, an AP shall advertise services from an SIR using a Service Hint element or a Service Hash element, or both, in Beacon and Probe Response frames. Each service may be advertised using either a Service Hint element or a Service Hash element, but not both, in a Beacon or Probe Response frames.

When dot11UnsolicitedPADActivated is true, a PCP shall advertise services from an SIR using a Service Hint element or a Service Hash element, or both, in DMG Beacon, Announce, or Probe Response frames. Each service may be advertised using either a Service Hint element or a Service Hash element, but not both, in DMG Beacon, Announce, or Probe Response frames.

A Service Hint element is used to advertise the presence of one or more services reachable via a BSS with a probability of matching a wrong service as indicated in the False Positive Probability Range subfield of the Service Hint element. A Service Hash element is used to advertise the presence of one or more services reachable via a BSS with a negligible probability of matching a wrong service. The mechanism for selecting which of a Service Hash or Service Hint element to use to advertise a particular service is beyond the scope of this standard.

When dot11UnsolicitedPADActivated is true, a non-AP and non-PCP STA searching for a service shall perform the following steps for each BSS:

a) From the received Beacon, DMG Beacon, Announce, or Probe Response frames, process the Service Hash elements to generate a list of services reachable via the BSS, and process the Service Hint elements to determine the parameters of the bloom filter.
b) Construct a list comprising service hash values for each service being searched. Then determine the bit positions in the Bloom Filter Array field that will be set to 1 for each service in the list.
c) For each service being searched, determine whether there is a matched service within the list of services, based on either of the following:
   1) The service hash value in the list of services matches the corresponding service hash value constructed in step b).
   2) The values of the bit positions of the Bloom Filter Bit Array field of the Service Hint element, as determined in step b), are all equal to 1.

The non-AP and non-PCP STA may use the resulting information about which services are reachable as input to network discovery and selection procedures. The non-AP and non-PCP STA might proceed with the solicited PAD procedure (see 11.23.3) or authentication and association procedure (see 11.3) based on the indicated false positive probability and the requirements of the service or the SIC (see the examples in Annex Y).

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11.23.3 Solicited PAD procedure

When dot11SolicitedPADActivated is true, a non-AP and non-PCP STA may transmit to an AP or PCP a Service Information Request ANQP-element to request information from the SIR about services reachable via the BSS. A non-AP and non-PCP STA may use the Interworking and PAD fields of the Extended Capabilities element received from the AP or PCP to determine whether that AP or PCP supports Solicited PAD.

NOTE—An Interworking field value of 1 implies support for ANQP.

The Service Information Request ANQP-element is used by a non-AP and non-PCP STA to request detailed information about services reachable via the BSS; see examples illustrated in Annex Y.

When dot11SolicitedPADActivated is true, a non-AP and non-PCP STA may send a Service Information Request ANQP-element (see 9.4.5.27) to obtain information about a matching service. The Service Information Request ANQP-element shall include one or more Service Information Request Tuple subfields. Each Service Information Request Tuple subfield shall include a service hash within the Service Hash subfield and a Service Information Request Attribute subfield that is a service-specific request.

When dot11SolicitedPADActivated is true, an SIR shall use the information from the Service Information Request ANQP-element to determine whether the requested service(s) are reachable via the BSS. If matching services are found, corresponding to the Service Hash subfield, the SIR shall respond by requesting the AP or PCP to transmit a Service Information Response ANQP-element that contains a Service Information Response Tuple subfield for each service that satisfies the request. The Service Information Response ANQP-element contains detailed information about the services. When there is no matching service corresponding to the Service Hash subfield in an individually addressed GAS Initial Request frame, the SIR shall respond by requesting the AP or PCP to transmit a Service Information Response ANQP-element containing zero Service Information Response Tuple subfields.

The SIC receives service information from the contents of the Service Information Response ANQP-element. The non-AP and non-PCP STA may use the service information regarding which services are reachable as input to network discovery and selection procedures. The non-AP and non-PCP STA might proceed with the authentication and association procedure (see 11.3) (see examples illustrated in Annex Y).

11.23.4 Service hash procedure

A service hash is generated from a service name after all single octet uppercase alphabetic characters in the service name are converted into corresponding lowercase characters. A service name is defined in IETF RFC 6335.

A service hash contained in the Service Hash subfield of the Service Hash element, or in the Service Information Request ANQP-element, or in the Service Information Response ANQP-element, or a service hash used to map into the Bloom Filter Bit Array is generated as follows:

service hash = L(SHA-256(service name), 0, 48)

For example, a service hash for the service name of "_ipp._tcp" is created as follows: The service hash contained in the Service Hash subfield of the Service Hash element, the Service Information Request ANQP-element, and the Service Information Response ANQP-element is "bfd39037d25c," and the service hash used as input to compute the Bloom Filter Bit Array field is "0xbfd39037d25c.".

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11.23.5 Bloom filter hash function operation

The Bloom filter for a set of service hashes is created as described below.

Let *m* denote the number of bits in the Bloom filter, and let *k*–1 be the setting of the Number Of Hash Functions subfield in the Bloom Filter information field (see 9.4.2.237), i.e., *k* is the number of Bloom filter hash functions (out of a maximum of 16) used by the Bloom filter. For example, when the Number Of Hash Functions subfield is equal to 1, *k* = 2, the first two hash functions are used (*j* =0x00,0x01).

Create the Bloom filter as follows:

a) Set all bits in the Bloom filter to 0.

b) For each service hash in the set of service hashes, compute the *k* bit positions by setting *j* = 0, …*k*–1, in the function H(*j*,X,*m*) shown below. Set the bits at the *k* computed bit positions to 1. Note that, in some cases, different values of *j* may return the same bit position.

Let H(*j*,X,*m*) denote the Bloom filter hash function,

where

j is the Bloom filter hash function prepend parameter used in the computation; *j* is a single octet and ranges from 0x00 to 0x0F

X is the service hash that is mapped into the Bloom Filter Bit Array field (see 11.23.4 for procedures for generating a service hash used to map into the Bloom Filter Bit Array field)

m is the size, in number of bits, of the Bloom filter; how the size of the Bloom filter is determined is out of the scope of this standard

H(*j*,X,*m*) is computed as follows:

Step 1: Compute A(*j*,X) = [*j* || X].

Step 2: Compute B(*j*,X) = CRC32(A(*j*,X)) & 0x0000FFFF. In other words, obtain the least significant 2 octets of the 32-bit CRC of A(*j*,X), where CRC32() is the same 32-bit CRC as defined in 9.2.4.8.

Step 3: H(*j*,X,*m*) = B(*j*,X) mod *m*.

11.24 Quality-of-service Management frame (QMF)

11.24.1 General

11.24.1.1 Overview

A QMF STA shall set dot11QMFActivated and dot11QosOptionImplemented to true. The QMF STA shall assign an access category to each Management frame according to the access category assignments indicated in the QMF policy that has been configured using the configuration procedures described in 11.24.2.

A QMF STA shall set the QMFActivated subfield in the Extended Capabilities element to 1.

A Management frame shall be transmitted as an IQMF when all five of the following conditions are met:

— The RA of the Management frame corresponds to an individual MAC address.

— The frame is transmitted by a QMF STA.

— The transmitting STA has previously received an Extended Capabilities element from the STA corresponding to the RA of the frame being transmitted.

— The most recently received such Extended Capabilities element indicated that the STA is a QoS STA and has the value of 1 in the QMFActivated subfield.

— The frame is not a time priority Management frame.

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A QMF AP shall transmit a Management frame as a GQMF when all three of the following conditions are met:

— The RA of the Management frame corresponds to a group MAC address.
— The transmitting STA has received an Extended Capabilities element that has the QMFActivated subfield equal to 1 from every member of the BSS corresponding to the BSSID field of the Management frame.
— The frame is not a time priority Management frame.

A non-AP QMF STA shall transmit a Management frame as a GQMF when all three of the following conditions are met:

— The RA of the Management frame corresponds to a group MAC address.
— The transmitting STA has received an Extended Capabilities element that has the QMFActivated subfield equal to 1 from its associated AP.
— The frame is not a time priority Management frame.

A Management frame shall not be transmitted as an IQMF or GQMF, except as defined above.

NOTE—This standard assumes that all APs in an ESS are configured consistently for QMF service when GQMF has been enabled for use by associated non-AP STAs.

When the QMFActivated subfield is zero in the most recently received Extended Capabilities element from a destination STA, or when an Extended Capabilities element has not been received from a destination STA, a transmitting QMF STA shall transmit individually addressed Management frames to that destination STA using access category AC_VO.

If the QMFActivated subfield in the most recently received Extended Capabilities element from a destination QMF STA is equal to 1, but no QMF Policy element has been received from the destination QMF STA, and, if associated, no QMF Policy element has been received from the QMF AP with which the STA is associated, then a QMF STA shall transmit all IQMFs to the destination QMF STA using the default QMF policy access categories defined in Table 11-16. Otherwise, the QMF STA shall transmit individually addressed Management frames as defined in the QMF policy included in the QMF Policy element accepted from the destination QMF STA. In either case, the transmitted Management frames are IQMFs, and the transmitting QMF STA shall indicate the access category used to transmit the frame in the ACI subfield of the sequence number field.

A QMF STA in an unassociated state shall transmit all group-addresses Management frames as non-QMF. An associated QMF STA shall follow the QMF policy dictated by its associated AP for transmitting GQMFs as described in 11.24.2. The specific access category assignments of different Management frames in a nondefault QMF policy are beyond the scope of this document. The transmitting QMF STA shall indicate the access category used to transmit GQMFs in the ACI subfield of the sequence number field.

Time priority Management frames, when not sent as an immediate response, shall be transmitted using AC_VO.

A QMF STA shall not modify the access category of an IQMF or GQMF frame after an initial transmission of the frame has been performed, regardless of any subsequent modification to the QMF policy under which the STA is operating.

11.24.1.2 Default QMF policy

The default QMF policy is defined in Table 11-16. It defines the access category of each Management frame based on management subtype value, category value, and action value. QMFs not included in this table shall be assigned an access category AC_BE.

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Table 11-16—Default QMF policy

Description	Management Frame Subtype value from Table 9-1	Category value from Table 9-51	Action field	QMF access category
(Re)Association Request/Response	0000–0011	N/A	N/A	AC_VO
Probe Request (individually addressed)	0100	N/A	N/A	AC_VO
Probe Request (group addressed)	0100	N/A	N/A	AC_BE
Probe Response	0101	N/A	N/A	AC_BE
Timing Advertisement	0110	N/A	N/A	AC_BE
Beacon, ATIM, Disassociation, Authentication, Deauthentication	1000–1100	N/A	N/A	AC_VO
Spectrum management	1101	0	0–3	AC_BE
Spectrum management—channel switch announcement	1101	0	4	AC_VO
QoS	1101	1	0–3	AC_VO
Block Ack	1101	3	0–2	AC_VO
Public	1101	4	0, 1, 3, 5–6, 8–9	AC_BE
Public—DSE deenablement, extended channel switch announcement	1101	4	2, 4	AC_VO
Public—measurement pilot	1101	4	7	AC_VO
Public—TDLS Discovery Response	1101	4	14	AC_VO
Public—Fine Timing Measurement Request	1101	4	32	AC_VO
Public—Fine Timing Measurement	1101	4	33	AC_VO
Public—FILS	1101	4	34	AC_VO
Public—CDMG	1101	4	35–42	AC_BE
Public—Interworking	1101	4	43, 44	AC_VI
Public—FST	1101	4	45	AC_VO
Radio measurement	1101	5	0–5	AC_BE
Fast BSS Transition	1101	6	0–4	AC_VO

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Table 11-16—Default QMF policy *(continued)*

Description	Management Frame Subtype value from Table 9-1	Category value from Table 9-51	Action field	QMF access category
HT	1101	7	0–3	AC_VO
HT	1101, 1110	7	4–7	AC_VO
SA Query	1101	8	0–1	AC_VO
Protected Dual of Public Action	1101	9	1–2, 5–6, 8–9	AC_BE
Protected Dual of Public Action—extended channel switch announcement	1101	9	4	AC_VO
WNM	1101	10	0–24	AC_BE
Unprotected WNM	1101	11	0–1	AC_BE
Mesh Action—HWMP Mesh Path Selection	1101	13	1	AC_VO
Mesh Action—Congestion Control	1011	13	3	AC_VO
Mesh Action	1101	13	0, 2, 4–10	AC_BE
Multihop Action	1101	14	0–1	AC_BE
Self Protected	1101	15	0–5	AC_VI
DMG	1101	16	0–22	AC_BE
Reserved (used by the Wi-Fi Alliance [a])	1101	17	All	AC_BE
Fast Session Transfer	1101	18	0–5	AC_VO
Robust AV Streaming	1101	19	0–3	AC_BE
Unprotected DMG	1101	20	0–1	AC_VO
VHT	1101, 1110	21	0–2	AC_VO
Unprotected S1G	1101	22	0, 1, 2, 4–9	AC_BE
Unprotected S1G	1101	22	3, 11	AC_VI
S1G	1101	23	0, 3	AC_VO
S1G	1101	23	1, 2	AC_BE
Flow Control	1101	24	0, 1	AC_VO
Control Response MCS Negotiation	1101	25	0, 1	AC_BE
FILS	1101	26	0	AC_VO
CDMG	1101	27	0–5	AC_BE
CMMG	1101	28	0	AC_BE

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Table 11-16—Default QMF policy *(continued)*

Description	Management Frame Subtype value from Table 9-1	Category value from Table 9-51	Action field	QMF access category
CMMG	1101	28	1	AC_VO
GLK	1101	29	0	AC_BE
Vendor-specific Protected	1101	126	N/A	AC_BE
Vendor-specific	1101	127	N/A	AC_BE

[a] See http://www.wi-fi.org.

11.24.2 QMF policy advertisement and configuration procedures

11.24.2.1 Overview

QMF policies are exchanged and implemented between two QMF STAs. A STA's QMF policy is advertised and exchanged using the QMF Policy element described in 9.4.2.119.

A non-AP QMF STA operating in a BSS shall not transmit a QMF Policy frame to an AP.

The access category for a QMF that is transmitted by a non-AP QMF STA to a peer QMF STA shall be determined from the QMF policy received from the peer if a QMF policy has been received from the peer. Otherwise, the default policy shall be used. The access category for a QMF that is transmitted by a QMF AP is determined from the QMF policy configured at that AP.

In a BSS or MBSS, the access category for any Management frame may be reconfigured. For example, vendor-specific and vendor-specific protected Management frames might be reconfigured to suit the vendor application requirements.

11.24.2.2 QMF policy change in an infrastructure BSS or in an MBSS

A QMF Policy Change frame is transmitted by a QMF STA to request a change to the QMF policy that the requesting QMF STA will use for transmitting Management frames to the peer QMF STA in an infrastructure BSS or in an MBSS.

A STA may transmit a QMF Policy Change frame to request a change in the QMF policy for transmitting to a peer STA. A non-AP QMF STA that receives a QMF Policy Change frame may either accept or reject the request. An associated non-AP QMF STA may transmit a QMF Policy Change to the QMF AP in its BSS only if the Extended Capabilities element received from the AP has its QMFReconfigurationActivated subfield equal to 1. If the AP rejects the request, the associated QMF STA shall not request the same policy reconfiguration from the AP during the lifetime of its association.

An AP shall respond to a QMF Policy Change frame received from an associated STA by transmitting a QMF Policy frame. If the QMFReconfigurationActivated subfield is zero in the Extended Capabilities element in the Beacon frame, an AP that receives a QMF Policy Change frame from an associated STA shall respond with a QMF Policy frame, with Status Code set to REQUEST_DECLINED. If the QMFReconfigurationActivated subfield is 1 in the Extended Capabilities element in the Beacon frame, an AP that receives a QMF Policy Change frame from an associated STA shall evaluate the QMF Policy included in the frame, and shall respond to the request with the resulting QMF Policy element and Status Code set to SUCCESS if it accepts the policy change, or REQUEST_DECLINED if it rejects the policy change. A QMF AP may transmit a QMF Policy

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frame with Status Code set to SUCCESS to an associated QMF STA without having first received a QMF Policy Change frame from that STA.

If an accept status is received in a QMF Policy frame within dot11QMFPolicyChangeTimeout of having transmitted a QMF Policy Change frame with the same dialog token to the STA that transmitted the QMF Policy frame, then the requesting QMF STA shall transmit any subsequently queued Management frames to the peer QMF STA in accordance with the changes to the QMF policy that were indicated in the QMF Policy Change frame.

If a reject status is received in a QMF Policy frame within dot11QMFPolicyChangeTimeout of having transmitted a QMF Policy Change frame with the same dialog token to the STA that transmitted the QMF Policy frame as a response to a QMF Policy Change frame, then the configuration change request is rejected and the requesting QMF STA shall continue to transmit Management frames to the peer QMF STA in accordance with the previously configured QMF policy. The requesting QMF STA shall not transmit a QMF Policy Change frame with a previously rejected QMF policy to a peer QMF STA within dot11QMFPolicyChangeTimeout from the time the requesting STA received the rejection frame.

If the requesting STA does not receive a QMF Policy frame in response to a QMF Policy Change frame within dot11QMFPolicyChangeTimeout, then the requesting STA shall continue to transmit frames according to the previously configured QMF policy.

If a QMF STA has received an Extended Capabilities element with the QMFReconfigurationActivated subfield equal to 0 or has not received an Extended Capabilities element from a destination QMF STA, the QMF STA shall not transmit a QMF Policy Change frame to the destination QMF STA.

A QMF mesh STA or a QMF AP may set dot11QMFReconfigurationActivated to true or false. A non-AP QMF STA in an infrastructure BSS shall set dot11QMFReconfigurationActivated to true and shall set the QMFReconfigurationActivated subfield to 1 in transmitted (re)association requests. A non-AP QMF STA with dot11QMFReconfigurationActivated equal to true shall accept any received QMF Policy frame from its associated AP. A QMF STA with dot11QMFReconfigurationActivated equal to false shall respond with a QMF Policy frame, with the current QMF Policy element and Status Code set to REQUEST_DECLINED.

The QMFReconfigurationActivated subfield shall be set to one in the Extended Capabilities element when dot11QMFReconfigurationActivated is true. The QMFReconfigurationActivated subfield shall be set to 0 in the Extended Capabilities element when dot11QMFReconfigurationActivated is false.

The SME of a peer QMF STA uses the MLME-QMFPOLICY primitives (see 6.3.81.2 to 6.3.81.3) to transmit a QMF Policy frame to a peer STA. The SME of a peer STA uses the MLME-QMFPOLICY.request primitive to transmit a QMF Policy frame to a peer STA. The MLME of a peer QMF STA shall set the dialog token to 0 and set the Status Code to SUCCESS when the QMF Policy frame is transmitted unsolicited to the peer STA.

The SME of a peer QMF STA uses the MLME-QMFPOLICYCHANGE primitives (see 6.3.81.4 to 6.3.81.7) to exchange the QMF Policy Change and QMF Policy frames. The SME of a peer STA uses the MLME-QMFPOLICYCHANGE.request primitive to transmit a QMF Policy Change frame to a peer STA. The value of the dialog token in the MLME-QMFPOLICYCHANGE.request primitive shall be set to a value in the range 1 to 255.

The SME of the peer STA evaluates the QMF policy and uses the MLME-QMFPOLICYCHANGE.response primitive to transmit a QMF Policy frame to the STA including the result of the QMF policy change. The value of the dialog token in the MLME-QMFPOLICYCHANGE.response primitive shall be set to the value of the dialog token received in the corresponding MLME-QMFPOLICYCHANGE.indication primitive.

When the QMF STA SME receives an MLME-QMFPOLICYCHANGE.confirm primitive or MLME-QMFPOLICY.indication primitive with Result Code of SUCCESS, it shall set the new QMF policy using the MLME-QMFPOLICYSET.request primitive.

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An AP for which dot11AlternateEDCAActivated is true shall not use the alternate video (A_VI) nor alternate voice (A_VO) transmit queues in its QMF policy.

11.24.2.3 QMF policy configuration in an infrastructure BSS

A QMF AP shall include the QMF Policy element in Beacon frames that it transmits. Non-AP QMF STAs acquire QMF policy configuration information from QMF Policy elements received in Beacon, Association Response, Reassociation Response, Probe Response, and QMF Policy frames. The interpretation of the QMF Policy element is described in 11.24.3.

An associated QMF STA transmitting QMFs shall transmit those frames in accordance with the QMF policy received from its associated AP in the following order of precedence, from highest to lowest:

— QMF policy defined in an unsolicited QMF Policy frame from the associated QMF AP or the QMF Policy Change frame that resulted in a successful response QMF Policy frame from the associated AP, whichever occurred most recently

— QMF policy defined in the QMF Policy element received in the successful (Re)Association Response frame

All unassociated QMF STAs transmitting Management frames to a QMF AP shall transmit those frames to the AP in accordance with the QMF policy in the most recently received Beacon or Probe Response frame from that AP. If no frame containing a QMF Policy element has been received from the AP prior to the transmission of the Management frame(s), then the Management frame(s) shall be transmitted using the access categories of the default QMF policy defined in Table 11-16.

A QMF STA shall transmit all Management frames that are individually addressed to non-QMF STAs using access category AC_VO.

A QMF AP shall set a QMF policy for the transmission of QMFs to its associated STAs. The QMF policy used by the AP for transmission of QMFs to associated STAs is not required to be the same as the QMF policy it advertises.

If the QMFReconfigurationActivated subfield is equal to 1 in the Extended Capabilities element of the Beacon or Probe Response frame transmitted by the AP, an associated QMF STA may use the QMF Policy Change frame to request a change in its existing QMF policy.

11.24.2.4 QMF policy configuration in an IBSS or OCB

QMF STAs in an IBSS or OCB shall use the default QMF policy for all individually addressed Management frames transmitted to other QMF STAs in the IBSS or OCB.

11.24.2.5 QMF policy configuration in an MBSS

A QMF STA operating in an MBSS shall set the QMFActivated subfield in the Extended Capabilities element to true. The Mesh Beacon frame shall not include a QMF Policy element. The QMF in an MBSS policy shall be set on a per link basis between two QMF STAs.

The QMF Policy Change and QMF Policy frames are used by QMF STAs in an MBSS to configure QMF policy. See 11.24.2.2.

A QMF STA shall always accept the QMF policy from the QMF Policy frame transmitted by the peer QMF STA and shall transmit all individually addressed Management frames destined to the peer QMF STA using the received QMF policy.

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A QMF STA may request a change in the QMF policy from a peer QMF STA by transmitting a QMF Policy Change to the peer QMF STA. The peer QMF STA may accept or reject this change request. If the peer QMF STA accepts the change, it shall respond with a QMF Policy frame with Status Code set to SUCCESS and the QMF STA shall transmit IQMFs using the new QMF policy to the peer QMF STA. If the peer QMF STA rejects the change, it shall respond with QMF Policy frame with Status Code set to REQUEST_DECLINED and the QMF STA shall continue transmitting IQMFs according to the previously configured QMF policy.

If a QMF STA does not receive a QMF Policy frame from a peer QMF STA, it shall transmit Management frames to that peer STA using the default QMF policy.

QMF STAs in an MBSS shall not include policies for group addressed Management frames in the QMF Policy Config Request.

11.24.3 Interpreting QMF access categories

The QMF Policy element, as defined in 9.4.2.119, indicates the transmit access categories of different Management frames. A QMF Policy element with Length field of value 1 means that the access category of all Management frames is defined in the default QMF policy in Table 11-16.

When the Individually Addressed subfield is 1, then the QACM applies to IQMFs. When the Group Addressed subfield is 1, then the QACM applies to GQMFs. A STA shall not transmit a QMF Policy element with both the Individually Addressed and Group Addressed subfields set to 0 in any of the included QACM subfields.

The QMF Policy element contains zero or more QACM fields. When included in the QMF Policy element, each QACM field indicates the access category of a group of Management frames. Using the description from Table 11-17, access categories for all Management frames belonging to either a given subtype or a given action category may be indicated in a single QACM field. When multiple Action frames of the same Category are to be mapped to the same Access Category, this is indicated by setting multiple bits in the Action Value Bitmap. For example, setting Bit 0 and Bit 1 indicates Event Request/Response frames when the Management Frame Subtype subfield refers to Management frames of subtype Action and the Category Value subfield refers to the WNM category. The QACM field also may be used to indicate the access category of a single management frame subtype.

Table 11-17—QMF policy description for valid combination of optional fields in the QACM field

QACM field Length subfield	Action frame category	Action Value Bitmap subfield	Description
0	Not included	Not included	Policy to be applied to all Management frames of the corresponding subtype
1	Included	Not included	Policy to be applied to all Action frames of corresponding category value
≥ 2	Included	Included	Policy to be applied only to Action frames indicated via the action value bitmap for Management frames of the subtype indicated in the Management Frame Subtype subfield and the category value indicated in the Action Frame Category subfield in the corresponding QACM field

A QMF STA that received a QMF Policy element from its associated QMF AP shall discard any previously received QMF Policy elements. If a Management frame is indicated in multiple QACM fields, the access category of the Management frame is determined by the access category defined in the last QACM field in the QMF Policy that contains the access category assignment of the corresponding Management frame. For

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example, if an QACM field sets the entire WNM category to access category AC_BE and a later QACM field sets Event Request/Report of WNM category to AC_BK, then all Action frames of WNM category are transmitted using access category AC_BE with the exception of Event Requests/Reports, which are transmitted using access category AC_BK.

11.25 Robust AV streaming

11.25.1 Robust AV streaming dependencies

When dot11RobustAVStreamingImplemented is true, the STA is a robust AV streaming STA. The attribute dot11QosOptionImplemented shall be true in a robust AV streaming STA.

11.25.2 SCS procedures

The stream classification service (SCS) is a service that may be provided by an AP to its associated STAs that support SCS. In SCS, the AP classifies incoming individually addressed MSDUs based upon parameters provided by the non-AP STA.

The classification allows the UP, drop eligibility, and EDCA transmit queue to be selected for all MSDUs matching the classification.

Implementation of SCS is optional for a STA. A STA that implements SCS shall set its dot11SCSImplemented to true. A STA with dot11SCSActivated equal to true shall support stream classification and shall set to 1 the SCS field of the Extended Capabilities elements that it transmits. If dot11SCSActivated is true, dot11SCSImplemented shall be true.

A non-AP STA that supports SCS may request use of SCS by sending an SCS Request frame that includes an SCS Descriptor element with the Request Type field set to “Add” or “Change.” The SCS Descriptor List field in the SCS Descriptor element identifies how MSDUs are classified and the priority to assign to MSDUs that match this classification. If the TCLAS Processing element is present in an SCS Descriptor element, the Processing subfield shall have a value of 0 or 1. An AP shall decline any SCS Request frame where a TCLAS Processing element is present and the Processing subfield does not have a value of 0 or 1.

Each SCS stream is identified by an SCSID. This SCSID is used by a non-AP STA to request creation, modification, or deletion of an SCS stream. The SCSID is used by an AP to identify an SCS stream in SCS responses.

Upon receipt of an SCS Request frame from an associated non-AP STA, the AP shall respond with a corresponding SCS Response frame. A value of SUCCESS shall be set in the corresponding Status field of the SCS Status duple in the SCS Response frame when the AP accepts the SCS request for the requested SCSID. A value of REQUEST_DECLINED, REQUESTED_TCLAS_NOT_SUPPORTED_BY_AP, or INSUFFICIENT_TCLAS_PROCESSING_RESOURCES shall be set in the corresponding SCS Status field of the SCS Status duple in the SCS Response frame when the AP denies the SCS request for the requested SCSID.

If the AP declines a request to change a previously accepted SCSID, the previously accepted classification for this SCSID continues to operate.

If the requested SCS is accepted by the AP, the AP shall process subsequent incoming individually addressed MSDUs from the DS or WM that match the TCLAS elements and optional TCLAS Processing element classifier specified in the SCS Descriptor element.

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A match of the classifier is defined as follows:

— When the Processing subfield of the TCLAS Processing element is 0, the classifier matches all of the parameters in the TCLAS elements in the SCS Descriptor element.

— When the Processing subfield of the TCLAS Processing element is 1 or the TCLAS Processing element is not present, the classifier matches if the parameters match at least one of the TCLAS elements in the SCS Descriptor element.

The processing of matching MSDUs depends upon the access policy assigned to the MSDU:

— For matching MSDUs that are not part of a TS (as described in 11.4), the User Priority subfield of the Intra-Access Category Priority element is used as the UP of these MSDUs.

— For matching MSDUs that are part of a TS (as described in 11.4), the TID and UP classification of these MSDUs shall follow the rules specified in 11.4.8.

— If dot11AlternateEDCAActivated is true, for matching MSDUs that are not part of a TS (as described in 11.4) or for MSDUs that are part of a TS that uses EDCA or HEMM as the access policy, the Alternate Queue subfield of the Intra-Access Category Priority element is used to select whether the primary EDCA transmit queue or alternate EDCA transmit queue is used for these MSDUs.

— All matching MSDUs have their DEI set using the value from the Drop Eligibility subfield of the Intra-Access Category Priority element in the DEI subfield of the HT Control field, as defined in 9.2.4.6.

A non-AP STA may request the termination of an accepted SCS stream by sending an SCS Request frame with the Request Type field set to “Remove” and the requested SCSIDs in the SCS Descriptor element. The Length field of the SCS Descriptor element is set to 0; and no Intra-Access Priority, TCLAS, or TCLAS Processing elements shall be included in the SCS Descriptor element.

Upon reception of a request to terminate a previously accepted SCS stream, the AP shall cease to apply the classifier related to this SCSID. The AP shall send an SCS Response frame to confirm the termination of the SCS stream identified by the SCSID, by including the SCSID and a value of “Terminate” in the Status field of an SCS Status duple in an SCS Response frame and the dialog token in the SCS Response frame set to the value from the SCS Request frame that requested termination.

The AP may send an unsolicited SCS Response frame at any time to cancel a granted SCS stream identified by the SCSID, by including the SCSID and a value of “Terminate” in the Status field of an SCS Status duple in an SCS Response frame and the dialog token in the SCS Response frame set to 0.

11.25.3 MSCS procedures

The mirrored stream classification service (MSCS) is a service that may be provided by an AP to its associated STAs that support MSCS. In MSCS, the AP classifies incoming individually addressed MSDUs from the DS or WM that are destined for a non-AP STA based upon classifier masks provided by that non-AP STA. The AP sets the UP of the MSDUs in the classified streams based on the UP of individually addressed MSDUs in the corresponding mirror (reverse direction) stream from the non-AP STA to the AP.

Implementation of MSCS is optional for a STA. A STA that supports MSCS sets its dot11MSCSActivated to true, and shall set to 1 the Mirrored SCS field of the Extended Capabilities elements that it transmits. When dot11MSCSActivated is true, dot11QosOptionImplemented shall be true.

An MSCS setup is initiated by a non-AP STA’s SME. How it does this, and how it selects the MSCS Descriptor parameters, is out of scope of this standard. Setup of an MSCS uses the MLME primitives defined in 6.3.116.

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A non-AP STA that supports MSCS may request use of MSCS, or request to update parameters of the currently active MSCS, by sending an MSCS Request frame that includes an MSCS Descriptor element with the Request Type field set to "Add" or "Change", respectively. A non-AP STA that supports MSCS may request use of MSCS by sending a (Re)Association Request frame that includes an MSCS Descriptor element with the Request Type field set to "Add". The MSCS Descriptor element identifies how MSDUs are classified into streams and indicates parameters that determine the priority to assign to the classified MSDUs.

In a TCLAS Mask element in an MSCS Descriptor element, the Classifier Type subfield shall be set to a value that corresponds to a classifier of MSDUs, i.e., less than or equal to 5, or equal to 10.

Upon receipt of an MSCS Request frame from an associated non-AP STA, or receipt from a non-AP STA of a (Re)Association Request frame containing an MSCS Descriptor element, the AP shall respond with a corresponding MSCS Response frame or with a (Re)Association Response frame containing an MSCS Descriptor element, respectively. When the AP accepts the MSCS request in response to an MSCS Request frame, it shall set the Status field in the MSCS Response frame to "SUCCESS" and shall not include an MSCS Descriptor element in the frame. When the AP accepts the MSCS request in response to a (Re)Association Request frame, it shall set the Status field in the MSCS Status subelement of the MSCS Descriptor element of the (Re)Association Response frame to "SUCCESS" and set the Request Type field to "Add".

A value of REQUEST_DECLINED, REQUESTED_TCLAS_NOT_SUPPORTED, or INSUFFICIENT_TCLAS_PROCESSING_RESOURCES shall be set in the Status field in the MSCS Response frame or in the MSCS Status subelement of the MSCS Descriptor element of the (Re)Association Response frame, when the AP declines the MSCS request; an MSCS Descriptor element is optionally present in the MSCS Response frame for this case. If an MSCS Descriptor element is present in an MSCS Response frame that does not indicate a status of "SUCCESS", the Request Type field is set to "Change" and the element indicates a suggested set of parameters that could be accepted by the AP in response to a subsequent request by the non-AP STA. In the MSCS Descriptor element of a (Re)Association Response frame with a value in the Status field other than "SUCCESS" the Request Type field is set to "Add" if no suggested set of parameters is indicated, or set to "Change" if the element indicates a suggested set of parameters that could be accepted by the AP in response to a subsequent request by the non-AP.

The AP shall decline an MSCS request with the Request Type field set to "Add" or "Change" if a TCLAS Mask element is not present. When the AP does not accept an MSCS request in response to an MSCS Request frame with a Request Type field value of "Change", the existing MSCS is unchanged.

An AP has a maximum of one active MSCS per non-AP STA. A non-AP STA shall not sent an MSCS request to an AP with the Request Type field set to "Add" if MSCS is currently active with that AP. An AP shall decline an MSCS request with the Request Type field set to "Add" if MSCS is currently active for the requesting non-AP STA.

If MSCS for a non-AP STA is currently active and the AP declines an MSCS request from the non-AP STA with Request Type field set to "Change", the previously accepted parameters continue to apply.

If the request is accepted by the AP, MSCS for the non-AP STA becomes active. Incoming MSDUs whose DA parameter value maps to an RA equal to the MAC address of the non-AP STA are classified above the AP's MAC sublayer and are sent to the MAC through the MAC SAP using the MA-UNITDATA.request primitive with the priority parameter equal to the assigned UP, based on the parameters specified in the MSCS Descriptor element. The following procedure is used:

a) The classifier parameters and associated masks of the MSCS are determined according to the TCLAS Mask element(s) in the MSCS Descriptor element as follows:
   — For TCLAS Mask elements indicating a classifier type value less than or equal to 5, but not equal to 3, the classifier parameters specified by that element are indicated by the Classifier Mask subfield; there is no associated mask for these parameters.

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— For TCLAS Mask elements indicating classifier type 3, the classifier parameter specified by that element is equal to the set of octets defined by the Filter Offset subfield and length of the (reserved) Filter Value subfield; the associated mask for the parameter is specified in the Filter Mask subfield.

— For TCLAS Mask elements indicating classifier type 10, the classifier specified by that element is equal to the set of octets defined by the Protocol Number or Next Header subfield and the length of the (reserved) Filter Value subfield; the associated mask for the parameter is specified in the Filter Mask subfield.

— The classifier parameters and associated masks of the MSCS comprise all the classifier parameters and associated masks specified by all the TCLAS Mask elements in the MSCS Descriptor element.

b) The mirror classifier parameters and associated masks are determined as follows:

— If source (Ethernet) address is a classifier parameter, destination (Ethernet) address is a mirror classifier parameter; there is no associated mask for this parameter.

— If destination (Ethernet) address is a classifier parameter, source (Ethernet) address is a mirror classifier parameter; there is no associated mask for this parameter.

— If source IP address is a classifier parameter, destination IP address is a mirror classifier parameter; there is no associated mask for this parameter.

— If destination IP address is a classifier parameter, source IP address is a mirror classifier parameter; there is no associated mask for this parameter.

— If source port is a classifier parameter, destination port is a mirror classifier parameter; there is no associated mask for this parameter.

— If destination port is a classifier parameter, source port is a mirror classifier parameter; there is no associated mask for this parameter.

— If any other parameter is a classifier parameter, the same parameter is a mirror classifier parameter; if the classifier parameter has an associated mask then the mirror classifier parameter has the same associated mask.

c) A logical list is maintained, initially empty, of variables *UP{tuple}*, where each variable represents a user priority associated with a value *tuple* of the masked classifier parameters. Monitoring of incoming individually addressed MSDUs as indicated by the MA-UNITDATA.indication primitive begins. If an MSDU is received that is not part of a TS (as described in 11.4) and the SA parameter value is equal to the MAC address of the non-AP STA and the priority parameter is equal to an integer value in the range 0 to 7 and the service class parameter is equal to QoSAck, the MSDU's UP is determined per 5.1.1.3 and, if the UP is equal to one of the UPs specified in the User Priority bitmap subfield of the MSCS Descriptor element, the following steps are performed:

1) Determine *m_tuple* of the received MSDU, which is equal to the tuple of all mirror classifier parameters of the MSDU masked by the associated masks [see item b) above]. If the MSDU has no value for one or more of the mirror classifier parameters, the remaining steps are not performed.

2) Determine *tuple* corresponding to the received MSDU, by mapping all the masked values of parameters in *m_tuple* per the relationships described in item b) above.

3) Add or update the variable *UP{tuple}* in the list, setting the value of the variable to the UP of the received MSDU. When a variable is updated (i.e., when a variable corresponding to the same *tuple* already exists in the list), the previous value of the variable is discarded.

If a period equal to the value of the Stream Timeout subfield of the MSCS Descriptor element has elapsed since a given variable in the list was last updated, that variable may be removed from its maintained list.

d) In parallel, classification begins of incoming MSDUs from the DS or WM whose DA parameter value maps to an RA equal to the MAC address of the non-AP STA. The following steps are performed for each such MSDU:

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1) Determine *tuple* of the MSDU, which is equal to the tuple of all the classifier parameters of the MSDU masked by the associated masks (see (a) above). If the MSDU does not have a value for one or more of the classifier parameters, the remaining steps are not performed.
2) If variable *UP{tuple}* exists in the list for this value of *tuple*, and the MSDU is not part of a TS (as described in 11.4), and the MSDU is not part of an SCS stream (see 11.25.2), assign the MSDU a UP equal to min(*UP{tuple}, UPLim*), where *UPLim* is the value of the User Priority Limit subfield of the MSCS Descriptor element.

NOTE 1—The maintenance of the logical list of variables *UP{tuple}* described above is a logical description of a required process. The specific implementation of this process is vendor specific and is not required to match the description above.

NOTE 2—When MSCS does not assign a UP to an MSDU that is not part of a TS or an SCS stream, the UP of the MSDU might be set by other mechanisms such as interworking QoS mapping from DSCP values (e.g., see R.3).

NOTE 3—It is recommended that a non-AP STA using MSCS sets the UP of MSDUs it transmits to its associated AP in a way that does not cause the variables *UP{tuple}* maintained by the AP to change excessively often. This helps to minimize management overhead on the AP, and also minimizes the possibility of MSDUs with the same value of *tuple* being delivered to the higher layers out of order during the transition of the UP of those MSDUs. Note that the requirements for ordering of MSDUs with the same TID value in the MAC sublayer (see 5.1.3) are unaffected by MSCS.

A non-AP STA may request the termination of a currently active MSCS by sending an MSCS Request frame with the Request Type field set to "Remove" in the MSCS Descriptor element. Upon reception of a request to terminate the active MSCS, the AP shall cease to apply the corresponding classifiers and processing related to the active MSCS and delete the maintained list of variables *UP{tuple}*. The AP shall send an MSCS Response frame to confirm the termination of the MSCS, by including a value of "TCLAS_PROCESSING_TERMINATED" in the Status field of an MSCS Response frame and the dialog token in the MSCS Response frame set to the value from the MSCS Request frame that requested termination; an MSCS Descriptor element is not present in the response.

The AP may send an unsolicited MSCS Response frame at any time to cancel an active MSCS, by including a value of "TCLAS_PROCESSING_TERMINATED", "TCLAS_PROCESSING_TERMINATED_INSUFFICIENT_QOS", "TCLAS_PROCESSING_TERMINATED_POLICY_CONFLICT" or "TCLAS_RESOURCES_EXHAUSTED" in the Status field of an MSCS Response frame and the dialog token in the MSCS Response frame set to 0. The MSCS Descriptor element is optionally present; if present the Request Type field is set to "Change" and the element indicates a suggested set of parameters that could be accepted by the AP in response to a subsequent request by the recipient non-AP STA.

11.26 Procedures to manage OBSS

11.26.1 General

QLoad Report elements, HCCA TXOP Update Count elements, HCCA TXOP Advertisement action frames, and HCCA TXOP Response frames are designed to mitigate the effects of OBSSs and provide the means to

— Advertise QoS load information for channel selection
— Extend the admission control and scheduled mechanisms to a distributed environment
— Enable the coordination of scheduled HCCA TXOPs between HCs operating with OBSSs

OBSS APs are APs that are using the same primary channel and that are able to receive or obtain frames from each other, including Beacon frames. These frames are received directly or via associated STAs that support the Beacon request capability (as indicated by the Beacon Passive Measurement Capability Enabled bit or the Beacon Active Measurement Capability Enabled bit being set in the RM Enabled Capabilities element in the (Re)Association Request frame). An AP might scan other channels as part of its channel selection process or

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might request associated STAs that support the Beacon request capability to perform an off-channel Beacon request measurement, and these procedures might provide QLoad Report elements received from APs operating on other channels. Subclause T.3 provides an example of using QLoad Reports from adjacent channels.

NOTE 1—These OBSS procedures might use unauthenticated Beacon frames and Public Action frames. Implementations might choose to use additional heuristics (e.g., a history of collaboration and traffic monitoring) to determine the authenticity of this information.

NOTE 2—These OBSS procedures are intended for stationary and portable APs (see 4.2.4).

11.26.2 QLoad Report element

11.26.2.1 Introduction

The QLoad Report element is contained in QLoad Report frames or Protected QLoad Report frames that are provided by an AP and, optionally, periodically in the Beacon frame. The QLoad Report frame is transmitted, upon the receipt of a QLoad Request frame by an AP for which dot11QLoadReportActivated is true, to the STA that sent the QLoad Request frame. An AP shall not send a QLoad Request frame or Protected QLoad Request frame to another AP that has QLoad Report field set to 0 in its Extended Capabilities element. The Protected QLoad Report frame is transmitted, upon the receipt of a Protected QLoad Request frame when dot11ProtectedQLoadReportActivated is true, to the STA that sent the Protected QLoad Request frame. An AP for which dot11ProtectedQLoadReportActivated is false shall discard any received Protected QLoad Request or Protected QLoad Report frames.

Whenever there is a change in the contents of the QLoad Report element and there is no pending delay period for an unsolicited QLoad Report frame, an unsolicited QLoad Report frame should be transmitted with the RA field set to the broadcast address, after a randomly selected delay between 1 and dot11QLoadReportDelay seconds. After this delay, the AP shall transmit an unsolicited QLoad Report frame that contains the most recently available QLoad information. When dot11QLoadReportActivated is true, the QLoad Report element shall be included in the Beacon frame every dot11QLoadReportIntervalDTIM DTIMs. When dot11QLoadReportActivated is false, the QLoad Report element shall not be included in Beacon frames.

11.26.2.2 Calculating field values

The value of the Potential Traffic Self field represents the potential QoS traffic of this BSS; therefore, the value in the Mean subfield shall always be greater than or equal to the value of the Mean subfield in the Allocated Traffic Self field.

The AP shall include in the Allocated Traffic Self field all accepted and not deleted TSPECs as they are sent by non-AP STAs. At the deletion of each such TSPEC, the AP shall remove the TSPEC from its Allocated Traffic Self field.

The number of active AC_VI and AC_VO streams shall be provided in the Allocated Traffic Self field. For each admitted admission control TSPEC, the AP calculates a medium time, as described in K.2.2. This medium time, however, does not include the medium access overhead that, in turn, is related to the number of streams. This access overhead is further discussed in T.2.7, and a recommendation is given for its value.

An example of a method of calculating the values for the Mean and Standard Deviation subfields in the Potential Traffic Self field is given in T.2.3.

The Sharing Policy field is used to indicate the currently active policy for sharing the medium with OBSSs. Setting the Sharing Policy field to “Static” indicates that the share of the total available medium time of an AP does not change when the value of the Allocated Traffic Shared field changes. Setting the Sharing Policy field

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to "Dynamic" indicates that the share of the total available medium time of an AP might change when the value of the Allocated Traffic Shared field changes. If the Sharing Policy field has the value "Vendor Specific," then the QLoad Report element shall contain a Vendor Specific subelement.

If the value of the Overlap field changes, the share of the total available medium time of an AP might change for both static and dynamic sharing policies.

The value of the Potential Traffic Self field represents the potential QoS traffic of this AP and, therefore, shall always be greater than or equal to the values represented by the Allocated Traffic Self field.

The Allocated Traffic Self field contains the mean and standard deviation values of the total EDCA admission control and HCCA traffic that the AP has allocated at any one time and contains the number of AC_VI and AC_VO EDCA admission control streams. As each stream is added or deleted, the AP shall calculate the new value of the Allocated Traffic Self field. A recommended method for calculating the Allocated Traffic Self field mean and standard deviation values is given in T.2.4.

The Allocated Traffic Shared field is calculated from the Allocated Traffic Self fields for all APs that overlap with the AP performing the calculation, including the Allocated Traffic Self field of the AP performing the calculation. A recommended method for summing the Allocated Traffic Self field values is given in T.2.4.

The EDCA Access Factor is the total traffic bandwidth requirement for all of the OBSSs expressed as a fraction that may be greater than 1. An implementation might calculate the EDCA Access Factor from the summation of the Potential Traffic Self field values of all of the APs that are overlapping, as follows:

a) Sum all of the Potential Traffic Self field values for all OBSSs, including self, in order to calculate the peak traffic requirement in multiples of 32 µs per second. As the Potential Traffic Self field value is expressed in terms of mean and standard deviations, it is possible to sum the Potential Traffic Self field values as a composite stream. A suggested method for this summation is given in T.2.3.
b) Sum all of the HCCA Peak field values from all OBSSs, including self, in order to calculate the peak HCCA traffic requirement, in multiples of 32 µs per second.
c) Subtract the value derived in step b) from the value derived in step a). This value is the EDCA traffic.
d) Sum the AC_VO and AC_VI streams reported in its own QLoad report and all of the QLoad reports of OBSSs. Based upon the number of EDCA streams, an EDCA Overhead Factor can be estimated to account for the medium access time requirements. EDCA Overhead Factor is further discussed in T.2.3, and a recommendation is given for its value.
e) Multiply together the EDCA traffic from step c) and the EDCA Overhead Factor to obtain a value that represents the total peak bandwidth requirement for the OBSSs. This value is in multiples of 32 µs per second.
f) Convert the total peak bandwidth requirement to a fraction that is rounded down to a multiple of 1/64 (8 bits). This value is the EDCA Access Factor. An example for this conversion is given in T.2.6.

The HCCA Peak field value is the sum of the all of the medium times of active TS that use the HCCA or HEMM access policy over a 1 s period for all of the HCCA TSPECs included in the QLoad field. The TXOP time, scheduled by the HC, multiplied by the reciprocal of its SI, is termed the *HCCA medium time*. The HCCA Peak field value is the summation of the HCCA medium times that the HC has scheduled, in multiples of 32 µs.

The HCCA Access Factor is the total HCCA TXOP medium time requirement for all of the OBSSs expressed as a fraction that may be greater than 1. An implementation might calculate the HCCA Access Factor from the summation of the HCCA Peak field values of all of the APs that in an OBSS, by summation of all of the

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HCCA Peak field values for all APs in OBSSs and converting this summation to a fraction that is rounded down to 1/64 (8 bits). An example for this conversion is given in T.2.8.

11.26.2.3 Requesting QLoad Reports using radio measurement requests

If an AP has associated STAs that support passive or active beacon measurement (as indicated by the Beacon Passive Measurement Capability Enabled bit or the Beacon Active Measurement Capability Enabled bit being set in the RM Enabled Capabilities element), it may use the neighbor report capability of these associated STAs to attempt to retrieve QLoad Report elements from APs with which the AP is unable to exchange frames directly.

The AP sends a Radio Measurement Request frame that contains a Measurement Request element to an associated STA that supports neighbor reporting and beacon reporting. This Measurement Request element has the Measurement Type field set to "Beacon request" (as defined in Table 9-98), and the BSSID field of the Measurement Request field of the Beacon request frame (as defined in Figure 9-188) is set to the wildcard BSSID. There shall be a Request subelement in the Measurement Request field of the Beacon request frame that contains the Element ID of the QLoad Report element (as defined in Table 9-92) and may contain other element IDs. The SSID subelement shall not be included in the Request subelement of the Measurement Request field of the Beacon request.

Depending upon the signaled enabled radio measurement capabilities of the associated STA, the AP may use either the passive or active measurement mode. The Channel Number field should be set to the primary channel number that is currently being used by the AP, but may be set to other values if off-channel beacon measurement is supported by the STA to which the measurement request is to be sent.

If the measurement request is accepted, the requested STA performs the measurement request (as described in 11.10). The subsequent Radio Measurement Report frame contains beacon reports for successful measurements. These beacon reports might contain QLoad Report elements inside a Reported Frame Body subelement, if the reporting STA received QLoad Report elements from the Beacon or Probe Response frames that it received from neighboring APs. The contents of these QLoad Report elements can then be used in calculating Allocated Traffic Shared, EDCA Access Factor, and HCCA Access Factor field values as described in 11.26.2.2.

11.26.3 HCCA TXOP negotiation

The procedures described in this subclause allow HCCA APs to cooperatively create new HCCA schedules that do not collide.

When sharing with at least one other HCCA AP, each sharing AP for which dot11RobustAVStreamingImplemented is true shall set its dot11HCCWmax to a value of at least 3.

HCCA APs that are able to directly exchange frames without the use of a third-party STA and signal support for unprotected or protected TXOP negotiation (as indicated by the Unprotected TXOP Negotiation or Protected TXOP Negotiation field equal to 1 in the Extended Capabilities element in Beacon frames) coordinate their TXOP schedules using HCCA TXOP Advertisement and HCCA TXOP Response frames. In this subclause, an HCCA AP in an OBSS that is able to directly exchange frames without the use of a third-party STA is referred to as a *collaboration candidate*.

The HCCA TXOP Update Count element is included in the Beacon frame to indicate that an HCCA TXOP schedule has changed. The Update Count field of the HCCA TXOP Update Count element is incremented (modulo 256) each time a TS with an access policy of HCCA or HEMM is created or deleted. An HCCA AP for which dot11PublicHCCATXOPNegotiationActivated is true or dot11ProtectedHCCATXOPNegotiationActivated is true shall advertise the Duration, Service Interval, and Start Time subfields for each HCCA TXOP reservation in a TXOP Reservation field as described in 9.4.1.43.

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An HCCA AP for which dot11PublicTXOPNegotiationActivated is true or dot11ProtectedTXOPNegotiationActivated is true shall be able to maintain one or more dot11APCEntry(s) for each collaboration candidate in the dot11APCTable. These fields indicate the schedules that the AP should try to avoid using when creating schedules for new TS requests.

Before accepting a TSPEC request that has the Access Policy subfield of the TSPEC element equal to "HCCA" or "HEMM," an HC for which dot11PublicTXOPNegotiationActivated is true or dot11ProtectedTXOPNegotiationActivated is true should examine all dot11APCEntry(s) that are present in the dot11APCTable.

When an AP with dot11PublicHCCATXOPNegotiationActivated true or with dot11ProtectedHCCATXOPNegotiationActivated true receives a TSPEC request that has the Access Policy subfield of the TSPEC element equal to "HCCA" or "HEMM," it shall send an HCCA TXOP advertisement to each collaboration candidate. These HCCA TXOP advertisements shall have the TXOP Reservation field set to the TXOP that the AP is attempting to schedule.

An AP with dot11ProtectedTXOPNegotiationActivated true shall send the HCCA TXOP advertisement using a Protected HCCA TXOP Advertisement frame to each collaboration candidate that indicates support for protected HCCA TXOP negotiation (as indicated by the Protected TXOP Negotiation field equal to 1 in the Extended Capabilities element in Beacon frames from the collaboration candidate).

An AP with dot11PublicTXOPNegotiationActivated true shall send the HCCA TXOP advertisement using an HCCA TXOP Advertisement frame to each collaboration candidate that indicates support for unprotected HCCA TXOP negotiation (as indicated by the Unprotected TXOP Negotiation field equal to 1 in the Extended Capabilities element in Beacon frames from the collaboration candidate) unless the HCCA TXOP advertisement has already been transmitted to this collaboration candidate using a Protected HCCA TXOP Advertisement frame.

NOTE—When peer APs have both unprotected and protected TXOP negotiation activated, protected TXOP negotiation is used.

The AP shall not send an ADDTS Response frame to the requesting STA until one of the following conditions occurs:

a) The AP has received an HCCA TXOP Response frame, with the Status field equal to SUCCESS, from all of the APs to which HCCA TXOP advertisements were sent.
b) At least two Beacon frames have been received from all of the APs to which HCCA TXOP advertisements were sent.
c) A Beacon frame containing the HCCA TXOP Update Count element is received from all of the APs to which HCCA TXOP advertisements were sent.
d) A period of three dot11BeaconPeriod TU has elapsed.

If an AP receives another TSPEC request while waiting for one of the above conditions to occur, it shall delay processing this additional TSPEC request until one of the above conditions occurs.

An AP with dot11PublicTXOPNegotiationActivated false shall discard any received HCCA TXOP Advertisement frames. An AP with dot11ProtectedTXOPNegotiationActivated true shall discard any received unprotected HCCA TXOP Advertisement frames from a peer AP with which it has an active security association.

Upon reception of an unprotected HCCA TXOP Advertisement frame, an AP with dot11PublicTXOPNegotiationActivated true shall discard all dot11APCEntry(s) from the dot11APCTable that have dot11APCEntryMACAddress equal to the MAC address of the AP that sent the HCCA TXOP Advertisement frame and shall prepare a response using the procedures below.

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An AP with dot11ProtectedTXOPNegotiationActivated false shall discard any received Protected HCCA TXOP Advertisement frames.

An AP with dot11ProtectedTXOPNegotiationActivated true that does not have an active security association with a peer AP that indicates support for protected HCCA TXOP negotiation shall use the AP PeerKey protocol (as defined in 12.10.2) and authenticated mesh peering exchange (AMPE) (as defined in 14.5) to negotiate security parameters and create a new PMKSA and PTKSA to secure the Protected HCCA TXOP Advertisement frames. The use of AMPE proves possession of the PMK (generated using the procedures described in 12.10.2) and implicitly the private key that corresponds to the peer's public key.

Upon reception of a valid Protected HCCA TXOP Advertisement frame, an AP with dot11ProtectedTXOPNegotiationActivated true shall discard all dot11APCEntry(s) from the dot11APCTable that have dot11APCEntryMACAddress equal to the MAC address of the AP that sent the Protected HCCA TXOP Advertisement frame and shall prepare a response using the procedures below.

If the (Protected) HCCA TXOP Advertisement frame has not been discarded due to the procedures above, the AP shall create a dot11APCEntry in the dot11APCTable for each TXOP reservation in the Active TXOP Reservations field of the (Protected) HCCA TXOP Advertisement frame.

If the (Protected) HCCA TXOP Advertisement frame has not been discarded due to the procedures above, the AP shall inspect its HCCA schedule to check whether the TXOP reservations number given in the Pending TXOP Reservations field of the HCCA TXOP Advertisement frame is in conflict with an existing accepted HCCA TXOP, allocated by itself. If there is no conflict, the AP shall send an HCCA TXOP Response frame with the Status field set to SUCCESS and create a dot11APCEntry for each TXOP reservation in the Pending TXOP Reservations field in the HCCA TXOP Advertisement frame.

If the HCCA advertisement was sent using an unprotected Public Action frame, the HCCA TXOP response shall be sent using an unprotected Public Action frame.

If the HCCA advertisement was sent using a Protected HCCA TXOP Advertisement frame, the HCCA TXOP response shall be sent using a Protected HCCA TXOP Response frame.

If the AP detects that the TXOP given in the (Protected) HCCA TXOP Advertisement frame is in conflict with an existing accepted HCCA TXOP and this AP is not itself currently processing an ADDTS request, it shall send a (Protected) HCCA TXOP Response frame with the Status field set to "TS_SCHEDULE_CONFLICT," the Alternate Schedule field set to a period of time that does not conflict with any currently accepted HCCA TXOPs, and the Avoidance Request field absent. The Duration subfield of the Alternate Schedule field should be greater than or equal to the Duration subfield of the Schedule field in the (Protected) HCCA TXOP Advertisement frame. The Duration subfield of the Alternate Schedule field may be less than the Duration subfield of the Schedule field in the (Protected) HCCA TXOP Advertisement frame when there is an insufficient period of time that does not conflict with currently accepted HCCA TXOPs.

If the AP detects that the TXOP given in the (Protected) HCCA TXOP Advertisement frame is in conflict with an in-progress ADDTS request for an HCCA TXOP for which HCCA TXOP Response frames have not been received, it shall send a (Protected) HCCA TXOP Response frame with the Status field set to "TS_SCHEDULE_CONFLICT" and the Alternate Schedule and Avoidance Request fields set according to the following rules:

— If MIX(MAC_r) < MIX(MAC_i), the Alternate Schedule field is set to a value that does not conflict with any accepted HCCA TXOPs and also does not conflict with the TXOP of the in-progress ADDTS request. The Avoidance Request field is set to the TXOP of the in-progress ADDTS request.

— If MIX(MAC_r) > MIX(MAC_i), the Alternate Schedule field is set to the value from the TXOP Reservation field from the HCCA TXOP Advertisement frame. The Avoidance Request field is set

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to a time period that does not conflict with any accepted HCCA TXOPs nor the TXOP in the Alternate Schedule field and has sufficient duration and service interval to meet the requirements of the in-progress ADDTS request.

where

MAC_r is the MAC address of the AP that received the HCCA TXOP Advertisement frame

MAC_i is the MAC address of the AP that sent the HCCA TXOP Advertisement frame

The MIX function takes the 6 octets of a MAC address and computes a new 6-octet value:

$$\text{MIX}(MAC) = MAC[4] \,||\, MAC[5] \,||\, MAC[0] \,||\, MAC[1] \,||\, MAC[2] \,||\, MAC[3]$$

For the purpose of the comparisons shown above, the resulting 6-octet value is converted to a positive integer treating the first octet as the most significant octet of the integer.

Table 11-18 provides a summary of the values used in an HCCA TXOP Response frame.

Table 11-18—Contents of HCCA TXOP Response frame

Case	Status code	Alternate Schedule field	Avoidance Request field
No conflict with existing or in-progress schedules	SUCCESS	Not present	Not Present
Conflicts with existing schedule; no ADDTS request in progress	TS_SCHEDULE_ CONFLICT	Period of time that does not conflict with any currently accepted HCCA TXOPs	Not Present
Conflict with in-progress schedules, $\text{MIX}(MAC_r) < \text{MIX}(MAC_i)$	TS_SCHEDULE_ CONFLICT	Period of time that does not conflict with any currently accepted HCCA TXOPs nor the in-progress ADDTS request	Schedule of in-progress ADDTS request
Conflict with in-progress schedules, $\text{MIX}(MAC_r) > \text{MIX}(MAC_i)$	TS_SCHEDULE_ CONFLICT	Same schedule that was in the HCCA TXOP Advertisement frame	Period of time that does not conflict with any currently accepted HCCA TXOPs nor the period given in the Alternate Schedule field

The AP shall keep a record of the TXOP proposed in the Alternate Schedule field in a TXOP avoidance record and should avoid scheduling any new HCCA TXOPs in this proposed period until any of the following conditions occurs:

- A period of dot11HCCATXOPBeaconTimeout multiplied by dot11BeaconPeriod TUs has elapsed.
- The AP with dot11PublicTXOPNegotiationActivated true receives an unprotected HCCA TXOP Advertisement frame from the AP to which the unprotected HCCA TXOP Response frame was sent.
- The AP with dot11ProtectedTXOPNegotiationActivated true receives a Protected HCCA TXOP Advertisement frame from the AP to which the Protected HCCA TXOP Response frame was sent.

If an AP with dot11PublicTXOPNegotiationActivated true receives an unprotected HCCA TXOP Response frame with the Status field equal to “TS_SCHEDULE_CONFLICT,” the AP should create a new schedule for the TSPEC request using the suggestion provided in the HCCA TXOP Response frame. If an AP with

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dot11ProtectedTXOPNegotiationActivated true receives a Protected HCCA TXOP Response frame with the Status field equal to "TS_SCHEDULE_CONFLICT," the AP should create a new schedule for the TSPEC request using the suggestion provided in the Protected HCCA TXOP Response frame.

If an AP creates a new schedule in response to a (Protected) HCCA TXOP Response frame, it shall send a new HCCA TXOP advertisement to each collaboration candidate, using the procedures previously defined in this subclause.

After one or more HCCA TXOP Advertisement frame transmissions that cause the reception of an HCCA TXOP Response frame with the Status field equal to "TS_SCHEDULE_CONFLICT," the AP may terminate the HCCA TXOP advertisement procedure and respond to the ADDTS Request frame with a status code not equal to SUCCESS (decline the ADDTS Request) or a status code equal to SUCCESS (accept the ADDTS request regardless of potential HCCA TXOP conflicts).

11.26.4 HCCA AP timing synchronization for HCCA TXOP advertisement

11.26.4.1 General

HCCA APs in OBSSs for which dot11PublicHCCATXOPNegotiationActivated is true or dot11ProtectedHCCATXOPNegotiationActivated is true synchronize their TSF timing so that the HCCA TXOP advertisement scheme does not suffer from time differences between the clocks of the overlapping APs.

In order to use HCCA TXOP advertisement, the AP maintains synchronization with its APs in OBSSs. HCCA APs that use HCCA TXOP advertisement shall use a DTIM interval with a duration of $2^n \times 100$ TU where n a non-negative integer less than or equal to 5.

NOTE—The DTIM interval of the form $2^n \times 100$ TU has been chosen to facilitate the verification that HCCA TXOP reservations do not overlap. The restriction that n be less than or equal to 5 has been chosen so that the range of the HCCA TXOP start time in the reservation (see 9.4.1.43) is compatible with the maximal DTIM interval length.

11.26.4.2 Timing offset

An HCCA AP with dot11PublicHCCATXOPNegotiationActivated true or dot11ProtectedHCCATXOPNegotiationActivated true shall update the timing offset value based on time stamps from the received Beacon frames from HCCA APs that have an entry in the dot11APCTable. The timing offset value is calculated using Equation (11-7).

$$T_{offset} = T_T - T_R \tag{11-7}$$

where

T_{offset} is the timing offset value
T_T is the value in the Timestamp field in the received Beacon frame from the overlapping HCCA AP
T_R is the Beacon frame reception time measured using the HCCA AP's TSF timer

The offset value is represented as 2s complement. The unit of the offset value is microseconds. The HCCA AP shall keep the T_{offset} value calculated from the latest Beacon frame received from each AP in an OBSS.

11.26.4.3 Clock drift adjustment

When dot11RobustAVStreamingImplemented is true and dot11PublicHCCATXOPNegotiationActivated is true, the HCCA AP shall examine the reception time of the Beacon frames from overlapping HCCA APs with which it maintains synchronization and adjust its TSF timer to compensate the relative timing error among overlapping HCCA APs caused by the clock drift. The HCCA AP adjusts its TSF so that its TSF counting frequency is aligned to the AP with the lowest TSF counting frequency.

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The HCCA AP shall operate the following clock drift compensation procedure:

a) If the HCCA AP does not have a valid T_{offset} value obtained from the previous Beacon frame reception from a particular overlapping HCCA AP, it shall not operate the clock drift compensation for that AP.

b) When the HCCA AP receives a Beacon frame from one of the overlapping HCCA APs with which it maintains synchronization, the HCCA AP shall calculate the clock drift amount $T_{ClockDrift}$ by comparing the T_{offset} obtained previously for this overlapping HCCA AP and the T_{offset} obtained from the Beacon frame reception. See Equation (11-8).

$$T_{ClockDrift} = T_{offset,1} - T_{offset,0} \quad (11\text{-}8)$$

where

$T_{ClockDrift}$ is the clock drift amount represented as 2s complement, in microseconds
$T_{offset,1}$ is the T_{offset} obtained from the previous reception
$T_{offset,0}$ is the T_{offset} obtained from the current frame reception

c) The HCCA AP shall calculate the $T_{ClockDrift}$ value for all overlapping HCCA APs with which it maintains synchronization and select the largest $T_{ClockDrift}$ value. If the largest $T_{ClockDrift}$ is greater than zero, it shall suspend its TSF timer for the duration of the largest $T_{ClockDrift}$. The HCCA AP shall suspend its TSF timer frequently enough that the delay during a single beacon period does not exceed 0.08% of its beacon interval.

NOTE—This clock drift compensation procedure is not intended to maintain a strict synchronization. It aims to stop TBTT drifting away among overlapping HCCA APs to allow some jitter of TSF timer.

11.27 DMG beamformed link and BSS maintenance

11.27.1 Beamformed link maintenance

A pair of DMG STAs that have established a beamformed link can maintain this link. This subclause describes procedures that allow a pair of DMG STAs to maintain a beamformed link that was established between them.

A beamformed link is established as a result of the most recent success of the procedures specified in 10.42.2 if the STAs completed the SLS phase or as a result of the most recent success of the procedures specified in 10.42.6.4 if the STAs completed the BRP phase.

A DMG STA shall negotiate the value of dot11BeamLinkMaintenanceTime using the procedures specified in 10.42.6.2 or may leave it undefined as specified in 9.5.6.

If the dot11BeamLinkMaintenanceTime has been defined as described in 9.5.6, a DMG STA shall implement a beam link maintenance timer to control each beamformed link. The STA shall keep one beam link maintenance timer per beamformed link. After it is set, the beam link maintenance timer shall count down. The timer shall be stopped when it reaches the value zero. The beam link maintenance timer of a beamformed link shall be halted during the following periods of time:

— BTI and A-BFT of a beacon interval
— SPs and CBAPs in which the STA does not participate
— When any of the STAs involved in the beamformed link is in doze state

The beam link maintenance timer shall be set to dot11BeamLinkMaintenanceTime when the source DMG STA and destination DMG STA successfully complete the BRP if the beam refinement phase is performed (10.39.3) or the source DMG STA and destination DMG STA successfully complete the SLS (10.42.2) if the beam refinement phase is skipped as defined in 10.39.3.

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A DMG AP or PCP shall set the beam link maintenance timer to dot11BeamLinkMaintenanceTime when it receives a response from the non-AP and non-PCP DMG STA during the ATI or when it receives an SPR frame as a response to a Poll frame, if these frames are received using the beamformed link established with the non-AP and non-PCP DMG STA.

The non-AP and non-PCP DMG STA shall set the beam link maintenance timer to the dot11BeamLinkMaintenanceTime when it receives a request from the DMG AP or PCP during the ATI or when it receives a Poll or a Grant frame, if these frames are received using the beamformed link established with the DMG AP or PCP.

The initiator DMG STA shall set the beam link maintenance timer to the dot11BeamLinkMaintenanceTime when an immediate response or acknowledgment (Ack, BlockAck, DMG CTS, DMG DTS) has been received from the recipient DMG STA of the beamformed link.

The recipient DMG STA shall set the beam link maintenance timer to the dot11BeamLinkMaintenanceTime after the transmission of the immediate response or acknowledgment (Ack, BlockAck, DMG CTS, DMG DTS) has been completed to the initiator DMG STA of the beamformed link.

To prevent expiration of the beam link maintenance timer when a DMG STA does not have MSDUs to send, the STA shall transmit QoS Null frames to maintain a beamformed link.

Following the expiration of the beamlink maintenance time (specified by the current value of dot11BeamLinkMaintenanceTime), the destination DMG STA of the SP shall configure its receive antenna to a quasi-omni antenna pattern for the remainder of the SP and during any SP following the expiration of the beamlink maintenance time.

Any time after dot11BeamLinkMaintenanceTime has elapsed, the source DMG STA of the SP may initiate an ISS to restore the beamformed link with the destination DMG STA of the SP following the rules defined in 10.42.2. The source DMG STA may initiate the ISS before expiration of dot11BeamLinkMaintenanceTime.

The responder DMG STA of the beamformed link in the CBAP shall configure its receive antenna to a quasi-omni antenna pattern following the expiration of dot11BeamLinkMaintenanceTime except when it is involved in a frame exchange with another STA.

Any time after dot11BeamLinkMaintenanceTime has elapsed, the initiator DMG STA of the beamformed link in the CBAP may initiate an ISS to restore the beamformed link with the responder STA following the rules defined in 10.42.2. The initiator STA may initiate the ISS before expiration of dot11BeamLinkMaintenanceTime.

If a DMG STA detects degradation in the link quality between itself and another STA, the STA can use beam tracking or beam refinement to improve the link quality. The STA can request the AP or PCP to schedule an SP to perform BF with the other STA or use a CBAP to perform BF. The STA can use the A-BFT to perform BF if the other STA is its AP or PCP. A DMG AP or PCP can perform BF with a non-AP and non-PCP STA during a CBAP or by scheduling an SP between the AP or PCP and the non-AP and non-PCP STA through an Extended Schedule element transmitted in a DMG Beacon or Announce frame.

If the link quality between a DMG AP or PCP and a non-AP and non-PCP DMG STA degrades, but the STA can still receive DMG Beacon frames with the Next A-BFT field equal to 0, the STA should improve the link quality by performing RSS during the A-BFT period as described in 10.42.5.

A DMG STA may use the value of the parameter LAST_RSSI in the RXVECTOR of a received frame to decide to initiate beamforming with a peer STA if the value of the LAST_RSSI parameter is different from zero (10.3.2.3.3).

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Figure 11-46 illustrates the operation of the beam link maintenance timer for an example involving STA-A and STA-B. In beacon interval *n*, STA-A and STA-B successfully perform beamforming and set up the beam link maintenance timer. In beacon interval *n*+1, the STAs have two SPs established between them. The beam link maintenance timer is halted and released according to the rules described above. Once the timer beam link maintenance timer expires, the STAs redo beamforming.

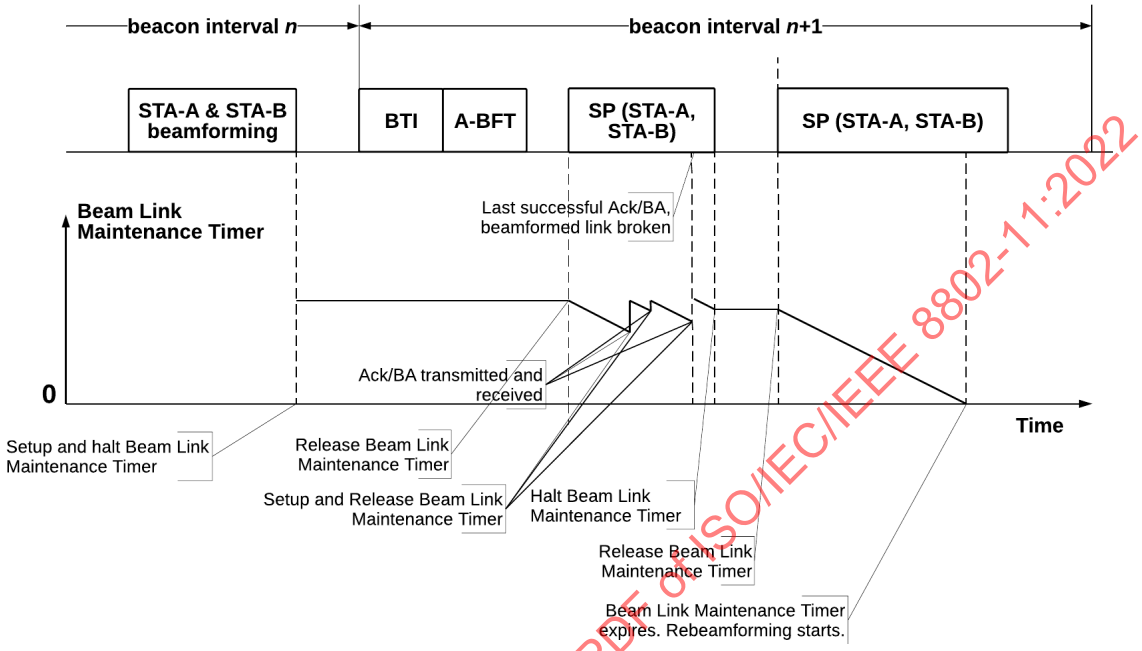

Figure 11-46—Example of beamformed link maintenance

11.27.2 PCP Handover

11.27.2.1 General

A STA is PCP handover capable if the PCP Handover field in the STA's DMG Capabilities element (9.4.2.127) is 1. The STA is PCP handover incapable otherwise.

The PCP handover process allows the information pertinent to the operation of the PBSS to be distributed to suitable PCP handover capable STA(s) and for a PCP handover capable STA to take over the PCP responsibilities from the PCP explicitly or implicitly.

The information pertinent to the operation of a PBSS includes STA information and pseudo-static scheduling information.

The STA information comprises the STA's AID, MAC address, and DMG Capabilities element. The PCP may relay the information to all STAs in the PBSS by using the Information Response frame.

The pseudo-static scheduling information comprises pseudo-static SP and CBAP allocations carried in the Extended Schedule element (9.4.2.131).

A PCP handover capable STA supports two types of PCP Handover, explicit and implicit. In explicit PCP handover, the PCP explicitly selects and schedules the transfer of PCP responsibilities to another PCP handover capable STA as described in 11.27.2.2. In implicit PCP handover the PCP distributes the Next PCP List element (9.4.2.140) in its DMG Beacon or Announce frames and maintains the content of the

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Next PCP List element to facilitate the implicit handover process described in 11.27.2.3. The PCP may determine the priority of next PCPs and update the next PCP list based on information contained within a STA's DMG Capabilities element.

If there is at least one PCP handover capable STA in the PBSS, the NextPCP List element contains an ordered list of one or more PCP handover capable STAs that can take over the role of the PCP during implicit handover. The ordering of STAs in the NextPCP List is specified in decreasing priority order and the criteria for updating the NextPCP List are implementation specific. The PCP shall increment the Token field of the NextPCP List by 1 every time the list is changed. If there are no PCP handover capable STAs in the PBSS, the length of the NextPCP List element is 0, and implicit PCP handover cannot be performed.

When a PCP handover capable STA takes over the PCP responsibilities of a PBSS, the pseudo-static scheduling information shall remain unchanged. Any outstanding request for resource allocation is lost and STAs that have outstanding requests for allocation may request the resource allocation again.

In explicit PCP handover, the PCP shall use the value of the PCP factor when selecting the candidate PCP (see 11.1.4.3.10).

Following a PCP handover, a non-PCP STA shall attempt to transmit a frame to the new PCP within dot11MaxLostBeacons beacon intervals. If the new PCP does not receive at least one frame from an associated non-PCP STA for dot11MaxLostBeacons beacon intervals following a PCP handover, it should disassociate the STA from the PBSS.

11.27.2.2 Explicit handover procedure

The PCP may transmit a Handover Request frame to a non-PCP STA that is handover capable. Upon receiving a Handover Request, a non-PCP STA becomes the candidate PCP. If the handover request is accepted, the candidate PCP shall transmit a Handover Response frame to the PCP with the Handover Result field set to 0. If the handover request is rejected, the candidate PCP shall transmit a Handover Response frame to the PCP with the Handover Result field set to 1, 2, or 3 and cease to be the candidate PCP.

A non-PCP STA that is handover capable may transmit a Handover Request frame to the PCP of the PBSS if the PCP is handover capable. Upon transmission of the Handover Request frame, the non-PCP STA becomes the candidate PCP. If the handover request is accepted, the PCP shall transmit a Handover Response frame to the candidate PCP with the Handover Result field set to 0. If the handover request is rejected, the PCP shall transmit a Handover Response frame to the candidate PCP with the Handover Result field set to 1, 2, or 3, and the candidate PCP shall cease to be a candidate PCP.

Following the transmission or reception of a successful Handover Response frame, a candidate PCP should request STA information and pseudo-static scheduling information from the PCP using an Information Request frame within the next dot11NbrOfChangeBeacons beacon intervals. The candidate PCP should also request SPs to perform beamforming and, if appropriate, establish a security association with other associated STAs prior to the completion of PCP handover.

Following the reception or transmission of a Handover Response frame, the PCP shall transmit a PCP Handover element within every DMG Beacon or Announce frame for each of the next dot11NbrOfChangeBeacons beacon intervals with the Old BSSID field set to the BSSID of the PBSS, the New PCP Address field set to the MAC address of the candidate PCP, and the Remaining BIs field set to the number of beacon intervals remaining until the candidate PCP takes over the role of PCP for the PBSS. The initial value of the Remaining BIs field shall be equal to the Handover Remaining BI field value last transmitted by the PCP in a Handover Request frame to the candidate PCP or equal to the Handover Remaining BI field value last received by the PCP in a Handover Request frame from the candidate PCP, whichever is later. A non-PCP STA receiving a DMG Beacon or Announce frame containing the PCP Handover element shall set the STA's local countdown counter to the value of the Remaining BIs field contained in the PCP Handover element. The

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STA shall then decrease the local countdown counter by one at each TBTT, and shall use the candidate PCP's address contained in the New PCP Address field within the PCP Handover element as the new beacon filter address once the STA's local countdown reaches zero. When the countdown timer equals zero, the candidate PCP shall assume the role of PCP.

11.27.2.3 Implicit handover procedure

Upon receiving the NextPCP List element, a PCP handover capable STA that finds its AID as the AID entry *i* in the NextPCP List element received from the PCP becomes the implicit candidate PCP *i*. Upon detecting a Token value contained in the NextPCP List element that is different from the value of the last Token received from the PCP, each implicit candidate PCP should request STA information and pseudo-static scheduling information from the PCP by transmitting an Information Request frame addressed to the PCP (11.28.1).

The implicit handover process is triggered at the implicit candidate PCP *i* when the implicit candidate PCP *i* fails to receive a DMG Beacon or Announce frames from the PCP for (*i* × dot11ImplicitHandoverLostBeacons) beacon intervals. When triggered, the implicit candidate PCP *i* shall send at least one DMG Beacon frame during each of the next dot11MaxLostBeacons BTIs if the following conditions are met:

— No DMG Beacon or Announce frames are received from the PCP.

— No DMG Beacon frame carrying a PCP Handover element with the Old BSSID field equal to the BSSID of the PBSS is received from an implicit candidate PCP with a smaller index on the NextPCP List.

Each DMG Beacon frame sent by the implicit candidate PCP *i* shall contain a PCP Handover element with the Old BSSID field set to the BSSID of the PBSS from which control is being taken, i.e., the previous PBSS, the New PCP Address field set to its MAC address, and the Remaining BIs field initially set to dot11MaxLostBeacons and decremented by 1 at each TBTT. A member non-PCP STA of the PBSS, after failing to receive a DMG Beacon or Announce frame for dot11MaxLostBeacons beacon intervals, should associate with the new PCP sending a DMG Beacon frame containing the PCP Handover element with Old BSSID field equal to the BSSID of the previous PBSS and the smallest Remaining BIs field value. The implicit candidate PCP that successfully transmits a DMG Beacon frame with the Remaining BIs field within the PCP Handover element equal to 0 completes the implicit handover by scheduling, if appropriate, pseudo-static SPs between its member STAs following the pseudo-static scheduling information it obtained from the previous PBSS.

To avoid disruptions to pseudo-static SPs due to implicit handover, the value of dot11ImplicitHandoverLostBeacons should be lower than dot11MaxLostBeacons.

11.28 DMG BSS peer and service discovery

11.28.1 Information Request and Response

A STA may request information about either a single STA in the BSS or about all of the STAs in the BSS by sending an Information Request frame (9.6.19.4). If the STA is requesting information about only a single STA in the BSS, it shall set the Subject Address field in the Information Request frame to the MAC address of that STA. If the STA is requesting information about all of the STAs in the Infrastructure BSS and PBSS, it shall set the Subject Address field in the Information Request frame to the broadcast address and shall transmit the Information Request frame to the AP and PCP.

A STA may transmit an Information Request frame with the Length field of the Request element set to 0 and with no Extended Request element present to another STA in the BSS to determine if the destination DMG STA is still present in the PBSS and is within range of the sending STA.

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A STA may transmit an Information Request frame including its STA Capability element and other elements. A non-PCP and non-AP STA shall not include in the Information Request frame the capability information corresponding to another STA.

The STA may transmit an Information Response frame (9.6.19.4) either unsolicited or as a response to an Information Request frame. If a STA is providing information about a single STA in the BSS, it shall set the Subject Address field in the Information Response frame to the MAC address of that STA. If a STA is providing information about all of the STAs in the PBSS, it shall set the Subject Address field in the Information Response frame to the broadcast address.

A STA processes a received Information Request frame as follows:

— Each element that is listed in a Request element, Extended Request element, or Vendor Specific Request element and that is supported by the STA shall be included in the Information Response frame. An element that is listed in a Request element, Extended Request element, or Vendor Specific Request element and that is not supported by the STA shall not be included.

— If dot11RadioMeasurementActivated is true and the RCPI element was requested, an RCPI element containing the RCPI of the Probe Request frame shall be included. If no measurement result is available, the RCPI value shall be set to indicate "Measurement not available" (see Table 9-176).

— If dot11RadioMeasurementActivated is true and the RSNI element was requested, an RSNI element containing the RSNI of the Probe Request frame shall be included. If no measurement result is available, the RSNI value shall be set to indicate that a measurement is not available (see 9.4.2.40).

A STA shall send an Information Response frame with no requested or provided elements in response to an Information Request frame that solicits information about a single target STA, as identified by the Subject Address field within the Information Request frame, if

— The target STA is not a member of the PBSS and the STA sending the Information Response frame is the PCP of the PBSS, or AP of the Infrastructure BSS and PBSS, or

— The STA sending the Information Response frame is a non-PCP and non-AP STA and is not the target STA.

In all other cases, the STA shall send the Information Response frame with the information requested by the requesting STA.

11.28.2 Peer Service Discovery

An AP or PCP may provide different types of information to a non-AP and non-PCP STA upon request. To query available services in a BSS, a non-AP and non-PCP STA shall send either an Information Request frame or a Probe Request frame to the AP or PCP (11.28.1). The Information Request and Information Response frames are robust Management frames, while the Probe Request and Probe Response frames are not.

Upon receiving the Information Request frame, the AP or PCP shall respond with an Information Response frame only if all of the following three criteria are true:

a) The SSID in the Information Request frame is the wildcard SSID or the specific SSID of the AP's or PCP's BSS.

b) The BSSID field in the Information Request frame is the wildcard BSSID or the BSSID of the AP or PCP's BSS.

c) The DA field in the Information Request frame is the MAC address of the AP or PCP.

The AP or PCP transmits the Information Response frame to the address of the non-AP and non-PCP STA that generated the Information Request.

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11.29 Changing DMG BSS parameters

11.29.1 General

This subclause describes the methods used by the AP or PCP to change certain key characteristics of the BSS. It also describes a method for a non-AP and non-PCP STA to make a recommendation on those characteristics to the AP or PCP.

The AP or PCP delivers the DMG BSS Parameter Change element to STAs holding pseudo-static SPs and STAs in power save mode before a DMG BSS parameter change.

The AP or PCP shall initiate a DMG BSS parameter change by including a DMG BSS Parameter Change element (9.4.2.126) in its DMG Beacon or Announce frames. The AP or PCP places the DMG BSS Parameter Change element in every DMG Beacon or Announce frame after the DMG BSS Parameter Change element is first included in the frame, stopping in the DMG Beacon or Announce frame immediately after the DMG BSS parameter change takes effect.

11.29.2 Moving the TBTT

The AP or PCP may move the TBTT and hence move the entire beacon interval. Moving the beacon interval means that except for the beacon interval in which the change takes effect, the beacon interval duration is unchanged while the position of the TBTT is moved.

The TBTT shall not be moved by an amount that is larger than the value in the Beacon Interval field present in DMG Beacon and Announce frames in which the DMG BSS Parameter Change element is sent.

To move the TBTT to an intended new TBTT, the AP or PCP shall insert the DMG BSS Parameter Change element in DMG Beacon frames and/or Announce frames with the Move field set to 1 (9.4.2.126). The DMG Beacon frames and/or the Announce frames containing the DMG BSS Parameter Change element shall be sent at each TBTT dot11NbrOfChangeBeacons times before the TBTT is changed as indicated in the TBTT offset field.

At each transmission of the DMG BSS Parameter Change element, the TBTT Offset field shall be set to a value equal to the lower order 4 octets of the intended new TBTT.

The value of dot11NbrOfChangeBeacons shall be greater than dot11MaxLostBeacons.

NOTE—As defined in 11.1.2.1, the PCP transmits at least one DMG Beacon frame to each associated STA within a time interval that is not longer than dot11BeaconPeriod × dot11MaxLostBeacons TUs.

Announce frames shall be used to deliver the DMG BSS Parameter Change element to all STAs participating in pseudo-static SPs.

The Beacon Interval field of DMG Beacon frames and the Announce frames sent at the dot11NbrOfChangeBeacons+1 TBTT shall be set to the difference of the intended new TBTT and the TBTT where the DMG Beacon or Announce frames were sent.

STAs associated with an AP or PCP that moves the TBTT shall not transmit during the beacon interval that precedes a new TBTT if the transmission time ends at the TBTT or later, even if the SP or the CBAP were scheduled in the beacon interval.

At the intended new TBTT that is dot11NbrOfChangeBeacons+2 TBTTs after the DMG BSS Parameter Change element is first transmitted, the TSF timer is reset to 0 as defined in 11.1.3.3.

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An AP or PCP member of an AP or PCP cluster that wishes to move its TBTT shall set the TBTT Offset field to an empty Beacon SP allocated by its S-AP or S-PCP as defined in 10.40.

Figure 11-47 illustrates the process in moving the TBTT position.

Figure 11-47—Moving the TBTT position

11.29.3 Changing beacon interval duration

The AP or PCP may change the duration of its beacon interval during the BSS operation.

To change its beacon interval, the AP or PCP shall insert the DMG BSS Parameter Change element into DMG Beacon frames and/or Announce frames with the Size field set to 1 and the BI Duration field set to the duration of the beacon interval following this DMG BSS parameter change. The TBTT Offset field shall be set to the lower order 4 octets of the TBTT at dot11NbrOfChangeBeacons+1 TBTT position when this DMG BSS parameter change takes effect.

The DMG Beacon frames and/or the Announce frames shall be sent at each TBTT dot11NbrOfChangeBeacons times before the beacon interval is changed as indicated in the BI Duration field of the DMG BSS Parameter Change element.

At each transmission of the DMG BSS Parameter Change element the TBTT Offset field shall be set to a value equal to the lower order 4 octets of the intended TBTT.

The value of dot11NbrOfChangeBeacons shall be greater than dot11MaxLostBeacons.

Announce frames shall be used to deliver the DMG BSS Parameter Change element to all STAs participating in pseudo-static SPs.

The AP or PCP that shortens the beacon interval shall not schedule SP and CBAP allocations that use more time than allowed in the beacon interval indicated in the BI Duration field of the DMG BSS Parameter Change element.

The beacon interval shall be set to the value of the BI Duration field of the DMG BSS Parameter Change element at the dot11NbrOfChangeBeacons+1 TBTT. At this TBTT, the TSF timer is reset to 0 as defined in 11.1.3.3.

If the AP or PCP sets the Move and the Size fields to 1 in the same DMG BSS Parameter Change element, it shall set the TBTT Offset field and proceed as defined in 11.29.2. The beacon interval shall be set to the value of the BI Duration field of the DMG BSS Parameter Change element at the new TBTT as defined in 11.29.2.

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Figure 11-48 illustrates the process in changing the beacon interval duration.

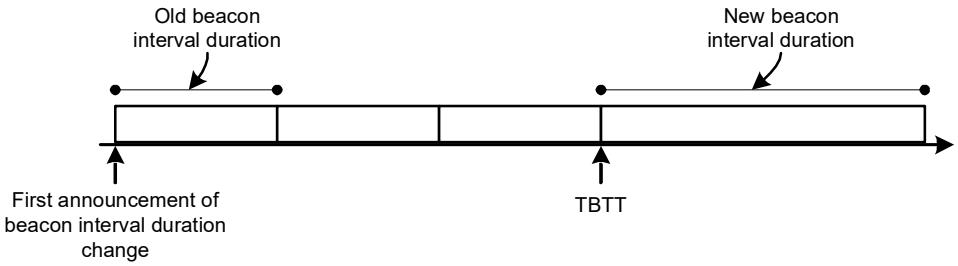

Figure 11-48—Changing beacon interval duration

11.29.4 Maintaining synchronization in an AP or PCP cluster

A S-AP or S-PCP shall update the Clustering Control field transmitted in the DMG Beacon frame if the DMG BSS parameter change modifies the allocation of the Beacon SPs (10.40). If the Clustering Control field is modified as a result of a DMG BSS parameter change, the S-AP or S-PCP shall transmit the updated Clustering Control field in every DMG Beacon frame in which the DMG BSS Parameter Change element is transmitted.

An AP or PCP member of an AP or PCP cluster receiving a S-AP or S-PCP DMG Beacon frame with a DMG BSS Parameter Change element indicating a change in the beacon interval duration or TBTT time shall immediately insert the appropriate DMG BSS Parameter Change element into its DMG Beacons if the S-AP or S-PCP's DMG BSS parameter change causes a modification in the allocation of the Beacon SPs.

If an AP or PCP is required to change the beacon interval or/and TBTT to participate in an AP or PCP cluster or to change the beacon interval or/and TBTT as a result of its S-AP's or S-PCP's parameters change (see 10.40), it shall follow the procedures in 11.29.2 and 11.29.3.

11.29.5 Recommending DMG BSS parameters to the AP or PCP

A non-AP and non-PCP STA may make a recommendation for DMG BSS parameters to the AP or PCP by including a DMG BSS Parameter Change element in an Information Request or Information Response frame sent to the AP or PCP.

A non-AP and non-PCP STA may recommend a shift in TBTT by setting the Move subfield in the Change Type Bitmap field of the DMG BSS Parameter Change element to 1 and setting the TBTT Offset field to the value of the 4 least significant octets of the non-AP and non-PCP STA's TSF timer at the recommended first changed TBTT. The non-AP and non-PCP should select a value for the TBTT Offset field that gives the AP or PCP enough time to exercise the change. Similarly, a non-AP and non-PCP STA may recommend a beacon interval duration to the AP or PCP by setting the Size subfield in the Change Type Bitmap field of the DMG BSS Parameter Change element to 1 and setting the BI Duration field to the recommended beacon interval duration in TUs.

An AP or PCP that receives an Information Request frame or an unsolicited Information Response frame from a non-AP and non-PCP STA containing a DMG BSS Parameter Change element may use the information within the element to change the DMG BSS parameters. When receiving an Information Request frame that includes the DMG BSS Parameter Change element, AP or PCP responds with an Information Response frame as specified in 11.28.1. If the AP or PCP changes the BSS parameters in the transmitted Information Response frame, the AP or PCP shall include a DMG BSS Parameter Change element reflecting the BSS parameter changes and shall use the procedure defined in 11.29.2 and 11.29.3, as appropriate, to change the BSS parameters. If the AP or PCP decides not to change the BSS parameters, it shall not include a DMG BSS Parameter Change element in the transmitted Information Response frame.

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11.30 Spatial sharing and interference mitigation for DMG STAs

11.30.1 General

This subclause describes mechanisms to enable spatial sharing and interference mitigation within a PBSS/infrastructure BSS and in a uncoordinated OBSS environment.

Spatial sharing mechanisms allow SPs belonging to different STAs in the same spatial vicinity to be scheduled concurrently over the same channel, and for interference mitigation. Alternatively, the AP or PCP can use CBAPs to mitigate interference.

The SPSH and Interference Mitigation field in the DMG Capabilities element indicates whether a STA supports spatial sharing.

A STA that supports spatial sharing, as indicated in the SPSH and Interference Mitigation field equal to 1 in the STA's DMG Capabilities element, shall support the directional channel quality measurements described in 9.4.2.20.16 and 9.4.2.21.15.

An AP or PCP may use the beamforming training information between any pair of STAs within the BSS obtained through the SSW Report element (9.4.2.222) to achieve spatial sharing and interference mitigation. The AP or PCP can transmit an Information Request frame (9.6.19.4) addressed to a STA for a response with an SSW Report element (9.4.2.222) contained in an Information Response frame (9.6.19.5). A non-AP and non-PCP STA can also send an unsolicited Information Response frame with an SSW Report element after the STA has completed the beamforming procedure with at least another STA. The SSW Report element may be used to facilitate the selection of candidates for spatial sharing as described in W.1.

11.30.2 Spatial sharing and interference assessment

The AP or PCP should request STAs to perform and report spectrum and radio resource measurements described in 11.10 to assess the possibility to perform spatial sharing and for interference mitigation.

The AP or PCP should use the directional channel quality described in 9.4.2.20.16 and 9.4.2.21.15 to assess the possibility for spatial sharing of SPs.

An SP to be assessed for spatial sharing with other scheduled (existing) SPs or considered to be reallocated in the beacon interval is hereby termed as a candidate SP. There might be multiple candidate and existing SPs at one time, and an SP may simultaneously assume the role of candidate and existing SP depending upon the context it is used for spatial sharing and interference assessment.

STAs that participate in an SP and that support spatial sharing should perform beamforming training with each other before engaging in any other communication or performing any measurements described in this subclause.

The AP or PCP should request source DMG STA and destination DMG STA involved in a candidate SP to perform measurements for the purpose of spatial sharing with an existing SP only after the STAs have beamforming trained with each other. The AP or PCP can infer that the STAs in a candidate SP have a beamformed link with each other if the Beamforming Training field within the DMG TSPEC used to set up the candidate SP was set to 1 and at least one beacon interval has elapsed since the candidate SP was first scheduled.

If the AP or PCP transmits a Directional Channel Quality request to a STA involved in a candidate SP to assess the possibility for spatial sharing with another existing SP, it shall set the Target STA to the corresponding peer STA's MAC address involved in the candidate SP and shall set the Measurement Method field to indicate ANIPI.

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If the candidate SP has already been allocated channel time, the AP or PCP should additionally transmit a Directional Channel Quality request to the STAs involved in the existing SP to assess the possibility for spatial sharing with the candidate SP. In the Directional Channel Quality request, the AP or PCP shall set the Target STA to the corresponding peer STA involved in the existing SP and shall set the Measurement Method field to indicate ANIPI.

NOTE—When the AP or PCP transmits a Directional Channel Quality request to a STA of an existing SP, it intends to assess the channel quality during transmission by STAs belonging to the candidate SP. Similarly, when the AP or PCP transmits a Directional Channel Quality request to a STA of a candidate SP, it intends to assess the channel quality during transmission by STAs belonging to the existing SP.

If a recipient STA that receives a Directional Channel Quality request frame is already beamformed trained with the target STA specified by the AID field within the frame, then the recipient STA shall carry out the measurement employing the same receive antenna configuration as is used by the recipient STA when receiving frames from the target STA. If the AID field is set to the broadcast AID or an unknown AID, then the recipient STA shall perform the measurements using a quasi-omni antenna pattern.

Figure 11-49 illustrates an example of spatial sharing assessment between two SPs. In this example, SP1 is the existing SP and SP2 is the candidate SP. The AP or PCP transmits a Directional Channel Quality request to STAs C and D to measure over SP1's channel allocation, and transmits a Directional Channel Quality request to STAs A and B to measure over SP2's channel allocation. The relation of the Measurement Start Time and Measurement Duration fields in the Directional Channel Quality request message is shown in Figure 11-49, while the field Number of Time Blocks is the ratio (Measurement Duration/Measurement Unit).

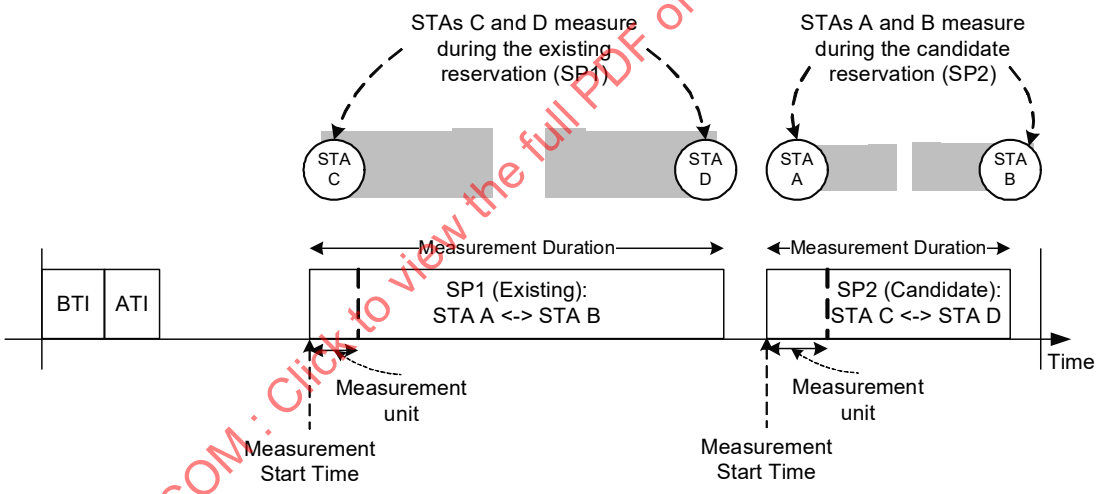

Figure 11-49—Example of spatial sharing assessment

If a non-AP and non-PCP STA receives a Directional Channel Quality request from its AP or PCP, it should perform the measurements as indicated in the request and shall report back to the AP or PCP using the Directional Channel Quality report. The report shall be formatted and transmitted as per specified in the Directional Channel Quality request. The non-AP and non-PCP STA shall set the Report Mode field (9.4.2.21) in the report frame to indicate whether it performed the measurement as requested by the AP or PCP.

11.30.3 Achieving spatial sharing and interference mitigation

An AP or PCP can estimate the channel quality across STAs participating in the BSS and implement spatial sharing and interference mitigation based on the results of the measurements performed by the STAs associated with the AP or PCP.

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An AP or PCP should schedule a candidate SP that overlaps with an existing SP in its beacon interval only after it receives a Directional Channel Quality report from the STAs involved in the candidate SP.

If a candidate SP is already scheduled in the beacon interval, the AP or PCP should schedule this candidate SP time-overlapping with an existing SP in its beacon interval only after it receives a Directional Channel Quality report from the STAs involved in the existing SP.

The AP or PCP should schedule a candidate SP during a period of time in the beacon interval where the PBSS/infrastructure BSS performance is expected to be maximized. The determination of performance maximization should be based on measurement reports received by the AP or PCP, but is implementation dependent and beyond the scope of this standard.

The decision process at the AP or PCP to perform spatial sharing of a candidate and an existing SP is implementation dependent and beyond the scope of this standard.

The candidate SP is referred to as a *time-overlapped SP* following the allocation by the AP or PCP of a candidate SP overlapping in time with an existing SP.

Figure 11-50 illustrates an example of the resulting SP schedule in the beacon interval for the spatial sharing between the two SPs shown in Figure 11-49.

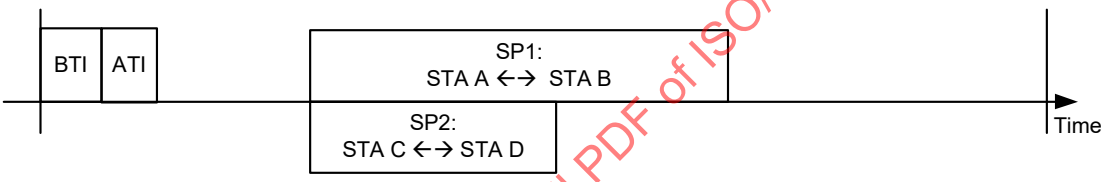

Figure 11-50—Example of spatial sharing between SP1 and SP2

The AP or PCP should periodically transmit a Directional Channel Quality request to each spatial sharing capable STA involved in a time-overlapped and existing SP scheduled under spatial sharing. In the Directional Channel Quality request that the AP or PCP transmits to each STA, the AP or PCP shall set the Target STA to the peer STA involved in the same SP and shall set the Measurement Method field to indicate RSNI.

If a spatial sharing capable non-AP and non-PCP STA receives a Directional Channel Quality request from its AP or PCP, it should perform the measurements as indicated in the request and shall report the results back to the AP or PCP using the Directional Channel Quality report. The report shall be formatted and transmitted as per specified in the corresponding Directional Channel Quality request.

The AP or PCP should stop the spatial sharing of two or more SPs if it determines that the link quality of any of the links involved in the spatial sharing has dropped below acceptable levels. This determination should be based on Directional Channel Quality reports received by the AP or PCP, but is implementation dependent and beyond the scope of this standard.

The STA may include the Traffic Scheduling Constraint Set field with the ADDTS Request frame sent to the AP or PCP for the purpose of interference mitigation. The AP or PCP should consider the information in the Traffic Scheduling Constraint Set field specified by a STA in its SP schedule.

Specific algorithms to realize spatial sharing and interference mitigation among SPs between different STAs is implementation dependent and beyond the scope of this standard.

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11.30.4 PBSS and infrastructure BSS stability in OBSS scenarios

Except when performing FST (11.31), the AP or PCP limits the frequency with which it changes the operating PBSS/infrastructure BSS channel to alleviate the instability and ripple effect that might result from frequent channel changes in OBSS scenarios. Upon a channel switch, the AP or PCP of a PBSS/infrastructure BSS shall select a random number, N, uniformly distributed between [0, SwitchInterval-1] and shall not attempt a new channel switch until N beacon intervals have elapsed since the preceding channel switch. The initial value of SwitchInterval is aMinSwitchInterval and it is doubled upon every new channel switch up to a maximum value of aMaxSwitchInterval. The AP or PCP resets SwitchInterval to aMinSwitchInterval if it remains on the same operating channel for a minimum of aMaxSwitchInterval consecutive beacon intervals.

NOTE—The AP or PCP can keep the SP schedule stable across beacon intervals and minimize schedule changes. This is to allow for STAs to associate with the PBSS/infrastructure BSS or add or modify their SP reservations. Stability in the allocation schedule in a beacon interval allows a PBSS/infrastructure BSS to assess the interference pattern produced by OBSSs and adapt to the environment by scheduling SPs over periods of time in the beacon interval when less interference is expected.

11.31 Multi-band operation

11.31.1 General

A device is multi-band capable if the value of dot11MultibandImplemented is true. A multi-band capable device is said to be a member of a BSS when one or more of the STAs in the device is a member of the BSS. A STA that is part of a multi-band capable device advertises the capability by including the Multi-band element in Beacon, DMG Beacon, (Re)Association Request, (Re)Association Response, Information Request, Information Response, Probe Request, Probe Response, Announce, FST Setup Request, FST Setup Response, TDLS Discovery Request, TDLS Discovery Response, TDLS Setup Request, and TDLS Setup Response frames.

Except for the FST Setup Request and FST Setup Response frames, which shall not include more than one Multi-band element, a STA may include more than one Multi-band element in any one of these frames if it is part of a device that supports more than two bands or channels. If an AP or PCP includes one or more Multi-band elements within a (Re)Association Response frame with Status Code equal to DENIED_WITH_SUGGESTED_BAND_AND_CHANNEL or a Probe Response frame, the order in which these elements appear in the frame indicate the order, in terms of frequency band and channel number, that the device that includes the STA addressed by the frame should attempt join the BSS following the rules applicable to the respective frequency band and channel (see 11.1). For each Multi-band element contained in the frame starting from the first one and proceeding in increasing order, the STA should attempt to join the BSS using the BSSID indicated by the BSSID field, frequency band indicated by the Band ID field and channel number indicated by the Channel Number field provided the Beacon Interval and the Channel Number fields in the Multi-band element are both nonzero.

NOTE—The first Multi-band element in the frame can refer to the current operating frequency band and channel.

A multi-band capable device shall set the Band ID and Operating Class fields within a Multi-band element to specify a frequency band it supports. If the multi-band capable device is or intends to operate in the band indicated within the Multi-band element, it shall set the Channel Number field to indicate the channel of operation within that band. If the multi-band capable device is a member of a BSS both on the channel indicated in the Channel Number field within the Multi-band element and also in the channel on which this element is transmitted, then the multi-band capable device shall set the TSF Offset field within a Multi-band element to the difference between the TSF of the BSS of which the STA is member on the channel indicated in the Channel Number field of this element and the TSF of the BSS corresponding to the BSSID indicated in the Address 3 field of the MPDU in which this element is transmitted. In all other cases, the TSF Offset field shall be set to 0.

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In each band/channel, a multi-band capable device may use the same or different MAC addresses. When the STA MAC Address Present field is equal to 1 in a Multi-band element, the STA MAC Address field in the Multi-band element specifies the MAC address that the STA uses in the band and channel that are indicated in the Multi-band element. If the STA MAC Address Present field is 0, the MAC address that the STA uses in the frequency band and channel that are indicated in the Multi-band element is the same as the address the STA uses in the current operating band and channel.

11.31.2 General FST rules

The FST session (see 4.9.4) transition is managed by the FST session setup protocol. A multi-band capable device participates as an initiator or as a responder in the FST session setup. Depending on the STA's behavior during the FST session setup, the FST session can be operational in one band, or may be transferred to another band or channel in the same band, or can be operational in multiple bands and/or channels simultaneously and in this case MSDUs can be transmitted in different bands and/or channels any time an MSDU arrives at the MAC SAP. If a multi-band capable device is operational in more than one band/channel simultaneously, the STA may use the FST session setup protocol to change the operation to a single channel.

An FST session between an initiator and a responder is identified by a fast session transfer session identifier. The value of the fast session transfer session identifier is allocated by the initiator of an FST session and shall remain unchanged whether the FST session is operational in one band or more than one band simultaneously. The value of the fast session transfer session identifier shall be unique for an initiator and responder pair, and there shall be no more than one FST session between an initiator and responder pair. An initiator or responder may change the fast session transfer session identifier of its existing FST session by tearing down the existing FST session (11.31.4) and setting up a new one with a different fast session transfer session identifier value. The fast session transfer session identifier is signaled in the FSTS ID field. See 9.4.2.145, 9.6.20.4, 9.6.20.5, and 9.6.20.6.

The FST session addressing mode is transparent if both initiator and responder of the FST session use the same MAC address in the frequency bands/channels involved in the FST. The FST session addressing mode is nontransparent if either the initiator or responder use different MAC addresses in the different frequency bands/channels involved in the FST session. When transparent FST is used, the STA shall present a single MAC SAP to higher layers for all frequency bands/channels in which it uses that MAC address.

When transparent fast session transfer is used, use of Authentication is unnecessary, and use of Association is disallowed, between the initiator and the responder.

An FST is allowed if the FST Setup Request and FST Setup Response frames are permitted to be transmitted as indicated in 11.3.3.

A multi-band capable device should deliver all fragments, if any, of an MSDU of an FST session before it transfers the FST session.

A multi-band capable device shall include in any transmitted FST Setup Request frame and in any transmitted FST Setup Response frame, all the elements that are applicable to the band, PHY and channel number indicated within its most recently transmitted Multi-band element that was transmitted on the same band and channel number on which it is transmitting the FST Setup Request or FST Setup Response frames. If a Multi-band element is present in the transmitted FST Setup Request or FST Setup Response frames, the Multi-band element is considered as the most recently transmitted Multi-band element.

If a Session Transition element and a Multi-band element are present in the same frame and the values of the Operating Class and Channel Number fields within the Multi-band element are both nonzero, the Band ID field related to the new band within the Session Transition element shall be the same as the Band ID field within the Multi-band element.

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11.31.3 FST setup protocol

11.31.3.1 General

A STA supports the FST protocol if the FST Not Supported subfield within the STA's Multi-band element is 0. A STA should not transmit an FST Setup Request frame to a peer STA that does not support the FST protocol. A STA that does not support the FST protocol shall ignore a received FST Setup Request frame.

The FST setup protocol comprises four states and rules for how to move from one state to the next. The states are Initial, Setup Completed, Transition Done, and Transition Confirmed. In the Initial state, the FST session is operational in one or both bands/channels. In the Setup Completed state, both initiator and responder are ready to change their currently operating band(s)/channel(s). An FST session can be fully or partially transferred to another band/channel. The Transition Done state enables both initiator and responder to operate in the other band/channel if the LLT field was zero. Both initiator and responder have to successfully communicate in the new band/channel to reach the Transition Confirmed state. The state transition diagram of the FST setup protocol is shown in Figure 11-52.

Figure 11-51 depicts the procedure of the FST setup protocol that drives the state machine shown in Figure 11-52. The figure is an example of only the basic procedure and is not meant to be exhaustive of all possible uses of the protocol. In the figure, MLME 1 and MLME 2 represent any two MLMEs of a multi-band capable device according to the reference model described in 4.9.4. The FST Setup Request and FST Setup Response frame exchange is repeated as necessary until both the FST initiator and FST responder successfully move to the Setup Completed state, as described below. Figure 11-51 illustrates this behavior.

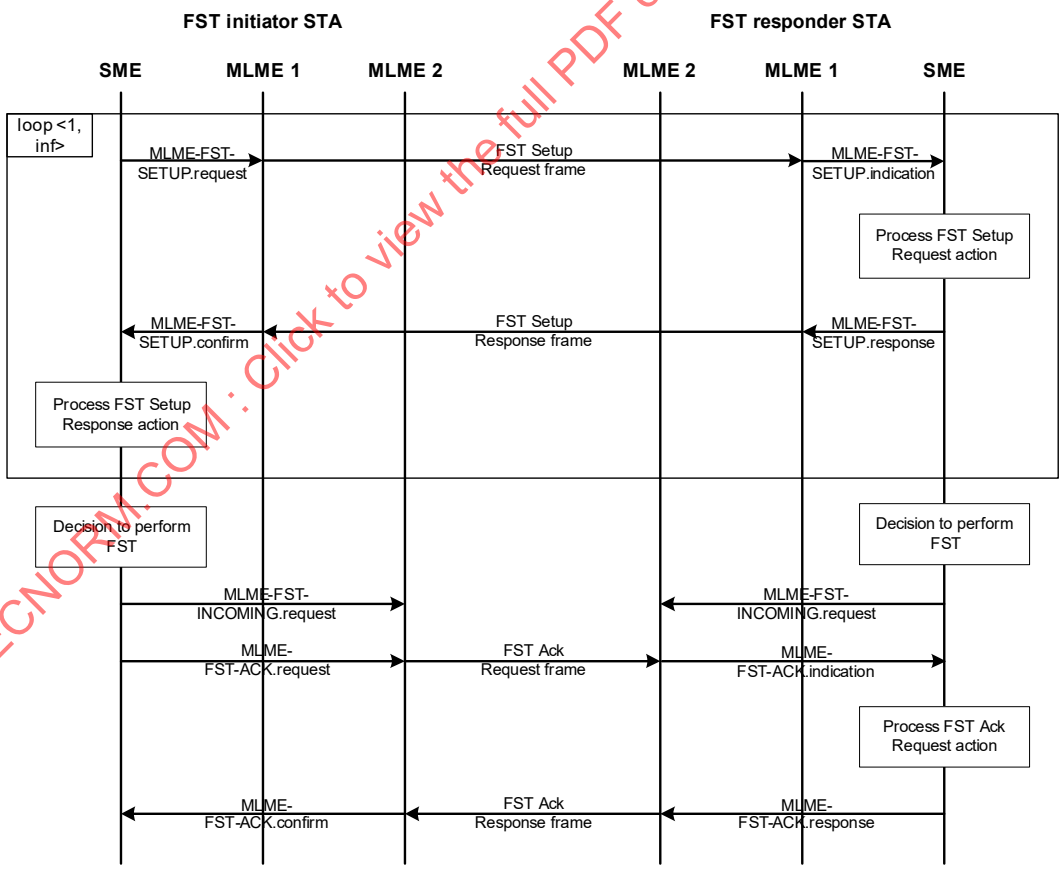

Figure 11-51—Procedure of the FST setup protocol

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To establish an FST session in the Initial state and transfer it to the Setup Completed state of the FST setup protocol (Figure 11-52), an initiator and responder shall exchange FST Setup Request and FST Setup Response frames. An FST session exists in Setup Completed state, Transition Done state, or Transition Confirmed state. In the Initial and in the Setup Completed states, the old band/channel represents the frequency band/channel from which the FST session is to be transferred, and the new band/channel represents the frequency band/channel to which the FST session is to be transferred. In the Transition Done state, the new band/channel represents the frequency band/channel on which the FST Ack Request and FST Ack Response frames, if any, are transmitted, and the old band/channel represents the frequency band/channel from which the FST session is being transferred.

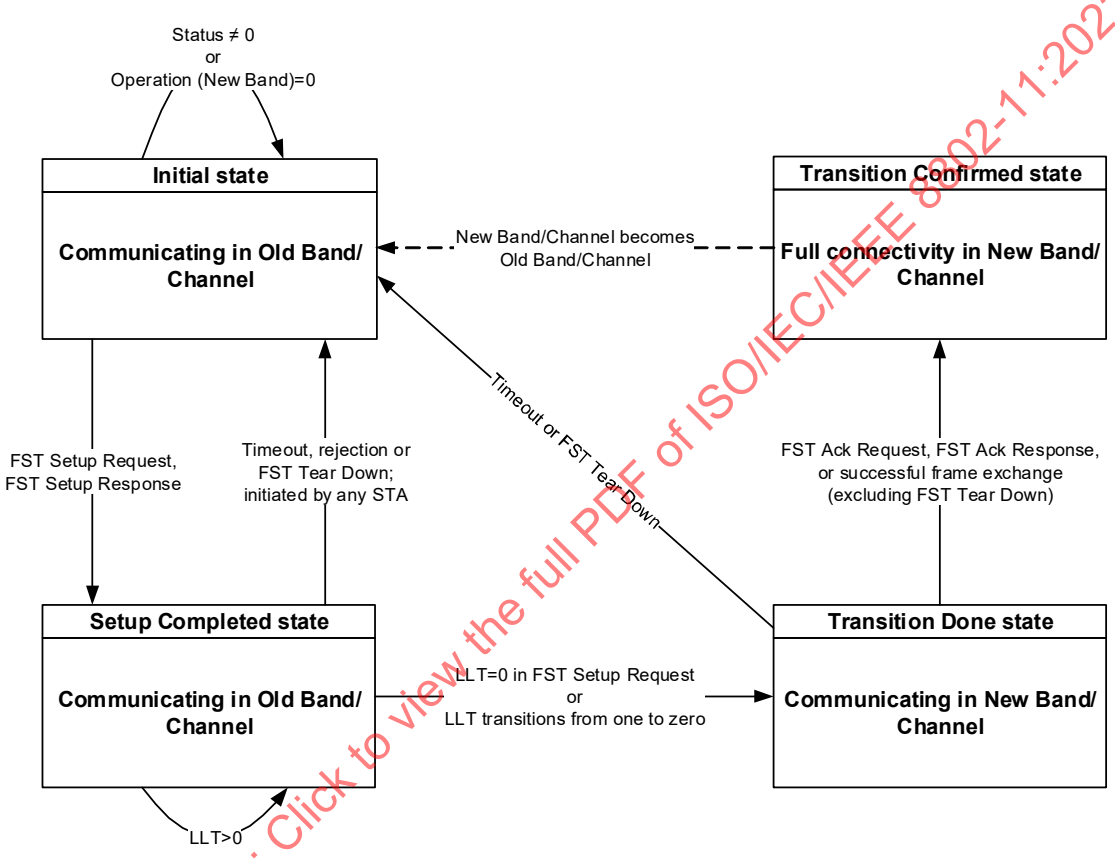

Figure 11-52—States of the FST setup protocol

The responder shall set the Status Code field to SUCCESS if it accepts the FST Setup Request, shall set the Status Code to REJECTED_WITH_SUGGESTED_CHANGES (see 9.4.1.9) to indicate that one or more parameters of the FST Setup Request frame are invalid and shall suggest alternative parameters, shall set the Status Code to PENDING_ADMITTING_FST_SESSION or PENDING_GAP_IN_BA_WINDOW to indicate that an FST setup request is pending, and shall set the Status Code field to REQUEST_DECLINED to reject an FST Setup Request frame.

A responder that is also an enabling STA (see 11.11) may set the Status Code to REJECT_DSE_BAND to indicate that the FST Setup Request frame is rejected because it was initiated by a dependent STA (see 11.11) that is requesting transition to a frequency band subject to DSE procedures. In this case, if the responder is the enabling STA for the dependent STA, the responder may include a Timeout Interval element in the FST Setup Response frame to indicate the period in TUs before which it initiates an FST Setup with the dependent STA. The Timeout Interval Type field within the Timeout Interval element shall be set to 4. The responder can use

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the parameters in the FST Setup Request frame received from the dependent STA to initiate an FST Setup with the initiator.

A responder that is also a dependent STA and not enabled shall reject all received FST Setup Request frames for transitioning to a frequency band subject to DSE procedures, except if the transmitter of the FST Setup Request frame is the enabling STA of the dependent STA.

11.31.3.2 Transitioning between states

A state transition within the FST setup protocol is controlled by the State Transition Timer (STT). Each STA maintains an STT for each FST session. A STA shall move to the Initial state when the STT moves from 1 to 0 (other than set to 0) or upon reception or transmission of an FST Teardown frame.

The initiator shall set the STT to the value of the FSTSessionTimeout field at successful transmission of an FST Setup Request frame and at each Ack frame sent in response to an FST Setup Response frame with the Status Code field equal to PENDING_ADMITTING_FST_SESSION or PENDING_GAP_IN_BA_WINDOW. The initiator shall set the STT to 0 at the transmission of an Ack frame sent in response to an FST Setup Response frame with the Status Code field equal to SUCCESS.

The responder shall set the STT to the value of the FSTSessionTimeout field at successful transmission of an FST Setup Response frame. The responder shall set the STT to 0 at each transmission of an Ack frame sent in response to an FST Setup Request. The responder should send an FST Setup Response frame no later than FSTSessionTimeout after the transmission of an Ack frame sent in response to an FST Setup Request frame or successful transmission of an FST Setup Response frame with the status code field equal to PENDING_ADMITTING_FST_SESSION or PENDING_GAP_IN_BA_WINDOW. In the latter case, the responder shall transmit the unsolicited FST Setup Response frame to the initiator.

There might be multiple FST Setup Request and FST Setup Response frame transmissions by the initiator and the responder, respectively, until the FST session between these STAs becomes established. At each transition, or attempt to transition, from the Initial state to the Setup Completed state, the initiator and responder shall perform the following procedure:

a) The initiator sends an FST Setup Request frame to the responder.

b) Upon receipt of an FST Setup Request frame, the responder shall respond with an FST Setup Response frame unless it has a pending FST Setup Request frame addressed to the initiator and the responder has a numerically larger MAC address (see 12.7.1.1 for comparison of MAC addresses) than the initiator's MAC address, in which case, the responder shall ignore the received FST Setup Request.

c) If, after the reception of the acknowledgment to the initiator's FST Setup Request frame, the initiator receives an FST Setup Request frame from the responder, the initiator shall not respond with an FST Setup Response frame if its MAC address is numerically larger (see 12.7.1.1 for comparison of MAC addresses and see 11.1.4.3.10) than the responder's MAC address. Otherwise, if its MAC address is numerically smaller than the responder's MAC address, it becomes the responder and shall respond with an FST Setup Response frame and shall not send the FST Setup Request frame during the current FST.

d) The initiator shall not move to the Setup Completed state if at least one of the following conditions is met:

   1) The initiator does not receive an FST Setup Response frame from the responder within the STT.

   2) The Status Code field in the received FST Setup Response frame from the responder is different from SUCCESS.

   3) A state-specific exception in Table 11-19 takes place.

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e) The initiator shall move to the Setup Completed state if none of conditions d(1), d(2), and d(3) is met.

f) The responder shall not move to the Setup Completed state if at least one of the following conditions is met:

1) The responder does not receive the acknowledgment to its transmitted FST Setup Response frame

2) The Status Code field in the FST Setup Response frame it transmitted to the initiator was different from SUCCESS.

3) The value of the Setup and Operation subfields within the Session Transition element in the transmitted FST Setup Response frame results in a status different from any of the rows shown in Figure 11-20, in which case the responder shall set the Status Code field with the transmitted FST Setup Response frame to REQUEST_DECLINED.

4) The resulting status of the Operation subfield in the New Band field is 0.

g) The responder shall move to the Setup Completed state if none of conditions f)1), f)2), f)3), and f)4) is met.

Table 11-19—Exceptions for the initiator

State	Condition	Meaning	Next state
Initial	FST Setup Response frame with Status Code PENDING_ADMITTING_FST_SESSION	Pending, responder in process of admitting FST session.	Initial
Initial	FST Setup Response frame with Status Code PENDING_GAP_IN_BA_WINDOW	Pending, block ack window at the responder has gaps.	Initial
Initial	FST Setup Response frame with Status Code REJECTED_WITH_SUGGESTED_CHANGES	One or more parameters of the FST Setup Request frame is invalid and the responder suggests alternative parameters.	Initial
Initial	FST Setup Response frame with Status Code REQUEST_DECLINED	Responder rejects the request. One particular case is that values of the operating class and channel number fields within the Multi-band element, if any, received in the FST Setup Request frame is different from the corresponding fields within the Multi-band element, if any, transmitted in the following FST Setup Response.	Initial
Initial	FST Setup Response frame with Status Code REJECT_DSE_BAND	Responder rejects the request since the initiator is a dependent STA and the request is for transitioning to a frequency band subject to DSE procedures. In the rejection, the responder can include a Timeout Interval element.	Initial
Initial	Resulting status is different from shown in Table 11-20	The responder is not able to complete the setup.	Initial
Initial	Resulting status of the Operation field in the New Band field is 0 in Table 11-20	The operation in the new band is disabled.	Initial

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Table 11-19—Exceptions for the initiator *(continued)*

State	Condition	Meaning	Next state
Setup Completed	FST Setup Response frame with Status Code SUCCESS and LLT field within the FST Setup Request frame is greater than zero	The STA is ready to switch to the new band if the link is lost in the old band.	Setup Completed
Setup Completed	Transmission or reception of FST Teardown frame	Termination of FST session.	Initial

If, upon transition to the Setup Completed state, the LLT field within the last successful FST Setup Request frame received by the responder or transmitted by the initiator was equal to 0, the initiator and responder shall immediately move to the Transition Done state.

If, upon transition to the Setup Completed state, the LLT field within the last successful FST Setup Request frame received by the responder or transmitted by the initiator was greater than 0, the initiator and responder shall proceed as follows:

— If the last FST Setup Request or FST Setup Response frames exchanged between the initiator and responder included a Switching Stream element, then all of the streams within the Switching Stream element that have the LLT Type field set to 1 shall be switched using the Stream-based Link Loss Countdown, and all of the streams within the Switching Stream element that have the LLT Type field set to 0 shall be switched using the STA-based Link Loss Countdown.

— If the neither the FST Setup Request nor the FST Setup Response frames exchanged between the initiator and responder included a Switching Stream element, then the streams shall be switched using the STA-based Link Loss Countdown.

The state transition for the STA, if STA-based, or the stream, if stream-based, from the Setup Completed state to the Transition Done state shall occur immediately after the corresponding Link Loss countdown timer transitions from 1 to 0 within any of the initiator or responder of the FST session.

An initiator and responder shall perform the STA-based and stream-based Link Loss Countdown as follows:

— STA-based Link Loss Countdown: Both initiator and responder shall remain in the Setup Completed state and start a Link Loss countdown timer with an initial value of LLT×32 μs. The Link Loss countdown is reloaded with the value of LLT×32 μs every time that an individually addressed frame is received from the peer STA of the FST session.

— Stream-based Link Loss Countdown: Both the initiator and responder shall start a Link Loss countdown timer with an initial value of LLT×32 μs for each stream identified within the Switching Stream element. The Link Loss countdown for a stream is reloaded with the value of LLT×32 μs every time that an individually addressed frame for that stream is received from the peer STA of the FST session.

Before leaving the Setup Completed state, an initiator and/or responder that is performing a full FST may transmit an FST Setup Response frame in the old band/channel with the Status Code field set to PERFORMING_FST_NOW and with the RA field set to the broadcast address to notify other STAs in the BSS of the STA's forthcoming full FST.

Table 11-20 shows the FST session status at each state transition. The Setup and Operation subfields shown in Table 11-20 are present within the Session Transition element. When the value of a subfield in the FST Setup Request frame is different from the value of that same subfield in the following FST Setup Response

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frame, the resulting status shall be the logical AND of the value of the corresponding subfields in both the FST Setup Request and the FST Setup Response frames.

Table 11-20—FST status at state transition

From State	Old band resulting status		New band resulting status		To State	Definition
	Setup	Operation	Setup	Operation		
Initial	1	1	0	0	Initial	New band setup and operation are disabled.
Initial	1	1	1	0	Initial	New band operation is disabled, the setup is kept alive.
Initial	0	0	1[a]	1	Setup Completed	FST session is operational in new band.
Initial	1[a]	1	1[a]	1	Setup Completed	FST session is operational in both bands.
Initial	1	0	1[a]	1	Setup Completed	FST session is operational in new band; FST session in old band is kept alive.
Setup Completed	Unchanged	Unchanged	Unchanged	Unchanged	Transition Done	No status changes.
Transition Done	Unchanged	Unchanged	Unchanged	Unchanged	Transition Confirmed	No status changes.

[a] The value of this field remains unchanged during the FST.

Upon transition to the Transition Done state and if transparent FST is used, the association state (see 11.3.1) of the STA corresponding to the old band/channel is transferred to the STA corresponding to the new band/channel.

To transition from the Transition Done state to the Transition Confirmed state, the initiator and responder shall perform the following procedure within the channel number of the operating class and band ID specified in the Multi-band element negotiated during the FST session setup:

a) The state transition is controlled by the State Transition Timer (STT). Each STA of the FST session has its own STT. The initiator shall transition to the Initial state when its STT transitions from 1 to 0, but not when the STT is set to 0. The responder shall transition to the Initial state when its STT transitions from 1 to 0, but not when the STT is set to 0.

   The initiator shall set the STT to the value of the FSTSessionTimeout field at successful transmission of an FST Ack Request frame or at transmission of any individually addressed MPDU to the responder. The initiator shall set the STT to 0 at the transmission of an Ack frame sent in response to an FST Ack Response frame from the responder or at reception of an Ack frame received in response to a frame sent to the responder.

   The responder shall set the STT to FSTSessionTimeout at transmission of an FST Ack Response frame or at transmission of any other individually addressed MPDU to the initiator. The responder shall set the STT to 0 at the reception of an Ack frame received in response to a transmitted FST Ack

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Response frame or at the reception of any individually addressed frame sent by the initiator. The responder shall transmit an FST Ack Response frame to the initiator no later than FSTSessionTimeout after the transmission of an Ack frame sent in response to an FST Ack Request frame from the initiator.

b) The SME of both the initiator and responder generates an MLME-FST-INCOMING.request primitive that includes the parameters of the FST. This primitive shall be generated to the MLME associated with the channel number, operating class, and band ID specified in the Multi-band element negotiated during the FST session setup. This primitive notifies the MLME of an impending FST.

c) The initiator shall send an FST Ack Request frame or may send any other individually addressed MPDU to the responder.

NOTE 1—Depending on the BSS configuration in the new band/channel, the initiator might have to associate and/or authenticate with the BSS before it is allowed to transmit a frame to the responder.

d) Upon receipt of an FST Ack Request frame, the responder shall respond to the initiator with an FST Ack Response frame.

NOTE 2—Depending on the BSS configuration in the new band/channel, the responder might have to associate and/or authenticate with the BSS before it is allowed to transmit a frame to the initiator.

e) The initiator shall move to the Transition Confirmed state

1) Upon transmission of an Ack frame sent in response to any individually addressed frame, including an FST Ack Response frame, received from the responder; or

2) When the initiator receives an Ack frame from the responder to any non-FST Ack Request frame the initiator transmitted to the responder.

f) The responder shall move to the Transition Confirmed state

1) When the responder receives an Ack frame in response to any individually addressed frame, including an FST Ack Response frame, sent to the initiator; or

2) Upon transmission of an Ack frame sent in response to any individually addressed non-FST Ack Request frame.

Following the transition to the Transition Confirmed state, a STA shall adopt the role indicated in the STA Role field corresponding to the channel number, operating class and band ID that was last transmitted to the peer STA within the Multi-band element. If the STA was operating within a PBSS, was the initiator of the FST session, and the new role of the STA is as an IBSS STA, then the STA shall be a DFS Owner of the IBSS.

In case the transition to the Transition Confirmed state was the result of a Stream-based Link Loss Countdown, the stream shall remain in the Transition Confirmed state until all of the streams included within the corresponding Switching Stream element reach the Transition Confirmed state. Once all streams within the corresponding Switching Stream element reach the Transition Confirmed state or the FST session ceases to exist, the STA moves to the Initial state.

If neither the initiator nor the responder perform in the role of AP or PCP as indicated through the STA Role field within the Multi-band element corresponding to the new band for that STA, one of the STAs can initialize a new BSS (11.1) on the new band for communication between the STAs.

If the Switch Intent field in the last Session Transition element transmitted to a responder is 1, an initiator may switch to the new band and channel indicated in the last transmitted FST Setup Request frame and Multi-band element, respectively, if at least one of the following conditions is satisfied:

— The Status Code field within the FST Setup Response frame received in response to the transmitted FST Setup Request frame is equal to REQUEST_DECLINED.

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— The initiator moves to the Initial state due to the STT at the initiator moving from 1 to 0.
— The initiator moves to the Initial state due to the reception of an FST Teardown frame from the responder.

Immediately before an initiator switches to a new band and/or channel, the initiator shall disassociate and delete all TS and block ack agreement(s) it has with a responder for which at least one of the above conditions is met.

Following the successful fast session transfer to a new band, the STA of the FST session shall follow the medium access rules applicable to the new band.

11.31.3.3 FST TS switching

If a STA transmitting an FST Setup Request frame or an FST Setup Response frame does not intend to switch all its streams, then the STA shall include the Switching Stream element in the transmitted frame to indicate which streams are requested to be transferred to the other band/channel. If the FST Setup Request frame includes a Switching Stream element, the FST Setup Response frame should include a Switching Stream element. If the FST Setup Request frame does not include a Switching Stream element, the FST Setup Response frame may include a Switching Stream element. If the STA transmitting the Switching Stream element has not set up a stream in the band indicated in the New Band ID field within this element, it shall set the Stream ID In New Band Valid field to 0. A STA may set up a stream in any band/channel by transmitting ADDBA Request or ADDTS Request frames that include the Multi-band element.

If a STA transmits an ADDTS Request frame to another STA with which it has established an FST session and the ADDTS Request frame is transmitted in a band or channel different from the band or channel to which the ADDTS request is intended to apply, the ADDTS Request frame shall include the Multi-band element with the Band ID, Operating Class, and Channel Number fields set to indicate to which channel the ADDTS Request frame applies. In addition, if these STAs use the nontransparent mode for FST, the STA transmitting the ADDTS Request frame sets the STA MAC Address Present field to 1 and the STA MAC Address field to the MAC address that the STA uses in the band and channel number that are indicated in the Multi-band element contained in the ADDTS Request frame. Similar to the ADDTS Request frame, the Multi-band element shall be included in the ADDBA Request, ADDTS Response, ADDBA Response, DELTS, and DELBA frames when these frames are transmitted in a band or channel different from the band or channel to which they are intended to apply.

When using transparent mode to transfer an FST session corresponding to a TID/TSID, the Direction subfield within the TSPEC element, if any, used to set up the TID/TSID should not be set to indicate a bidirectional link. This enables the SME to use the TID/TSID in conjunction with the source and destination MAC addresses in both the old and new frequency band/channel to uniquely identify the FST session.

If any of the ADDTS variants is used to switch the TS, then the PTP TSPEC or the DMG TSPEC shall be used when the TS is being established to operate in a DMG BSS, and the Basic TSPEC shall be used when the TS is being established to operate in a non-DMG BSS irrespective of the band and channel used to communicate the ADDTS frames and the DMG ADDTS frames.

The rules defined below apply when the ADDTS frames or the DMG ADDTS frames are used to switch TS. When the ADDTS frames and the DMG ADDTS frames are used, then the ADDTS requester and the ADDTS responder provide the functions defined for the ADDBA originator and the ADDBA recipient, respectively.

If the ADDBA recipient includes the Switching Stream element in any of the FST Setup Request or FST Setup Response frames and if the Stream ID In New Band Valid field within the Switching Stream element is 0, the ADDBA originator should issue the DELBA frame to reject the block ack agreements indicated in the Stream ID In Old Band field. If the originator intends to establish new block ack agreements in the band indicated in

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the Multi-band element sent by the recipient and with the recipient MAC address indicated in the Multi-band element sent by the recipient, the originator shall transmit an ADDBA Request frame addressed to the recipient.

The originator may include the Multi-band element and the Ethernet type TCLAS element in the ADDBA Request frame. If the MAC Addresses of the originator and recipient to be used in the new band are different from the MAC addresses used in the old band, then the ADDBA Request frame sent in the old band to establish a block ack agreement in the new band shall include the Multi-band and the TCLAS elements. The resulting block ack agreement, if established, applies to the band and channel identified in the Multi-band element included in the ADDBA Request frame. The BlockAck is identified by the TID/TSID and MAC addresses of the originator and the recipient used in the band and channel indicated in the Multi-band element included in ADDBA Request and ADDBA Response frames.

The ADDBA Request frame may be issued in the old band and channel, and the corresponding ADDBA Response frame may be transmitted in the band and channel indicated in the Multi-band element within the ADDBA Request frame.

The following rules for establishment of a multi-band block ack agreement shall apply:

a) If the TA and/or the RA fields of the ADDBA Request frame are different from the originator MAC address and/or the recipient MAC address, respectively, used in the channel and band where the block ack agreement should operate, then the originator shall set the Source Address field and the Destination Address field of the classifier to the originator MAC address and the recipient MAC address, respectively, to be used in the band and channel indicated in the Multi-band element included in the ADDBA Request frame.

b) If the TA and RA are equal to the originator MAC address and the recipient MAC address, respectively, then the Multi-band element, if any, included in the ADDBA Request frame shall indicate the band and channel over which the block ack agreement is to operate. The TCLAS element shall not be included in this ADDBA Request frame.

c) The Multi-band element should not be included in the ADDBA Request frame if in the case b) the ADDBA Request frame is issued in the same band and channel over which the block ack agreement is to operate.

d) If the TA and/or the RA fields of the ADDBA Response frame are different from the recipient MAC address and/or the originator MAC address, respectively, to be used in the channel and band where the block ack agreement should operate, then the recipient shall set the Source Address field and the Destination Address field of the classifier to the recipient MAC Address and the originator MAC address, respectively, to be used in the band and channel indicated in the Multi-band element included in the ADDBA Response frame. The indicated band and channel shall be equal to the band and channel indicated in the Multi-band element of the ADDBA Request frame.

e) If the TA and RA fields are equal to the recipient MAC address and the originator MAC address, respectively, then the Multi-band element, if any, included in the ADDBA Response frame shall indicate the band and channel over which the block ack agreement is to operate. The indicated band and channel shall be equal to the band and channel indicated in the Multi-band element of the ADDBA Request frame. The TCLAS element shall not be included in the ADDBA Response frame.

f) The Multi-band element should not be included in the ADDBA Response frame if in case e) the ADDBA Response frame is issued in the same band and channel over which the block ack agreement is to operate.

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11.31.4 FST teardown

At the Setup Completed state or Transition Done state, a STA may transmit an FST Teardown frame to its peer STA of the FST session in order to tear down an FST session that was previously set up using the FST Setup Request/Response frame exchange. Upon transmission or reception of an FST Teardown frame, the initiator and responder move to the Initial state (11.31.3). When moving to the Initial state and if the Switch Intent field in the last Session Transition element transmitted to a responder is 1, the initiator behaves as described in 11.31.3.2.

11.31.5 On-channel Tunneling (OCT) operation

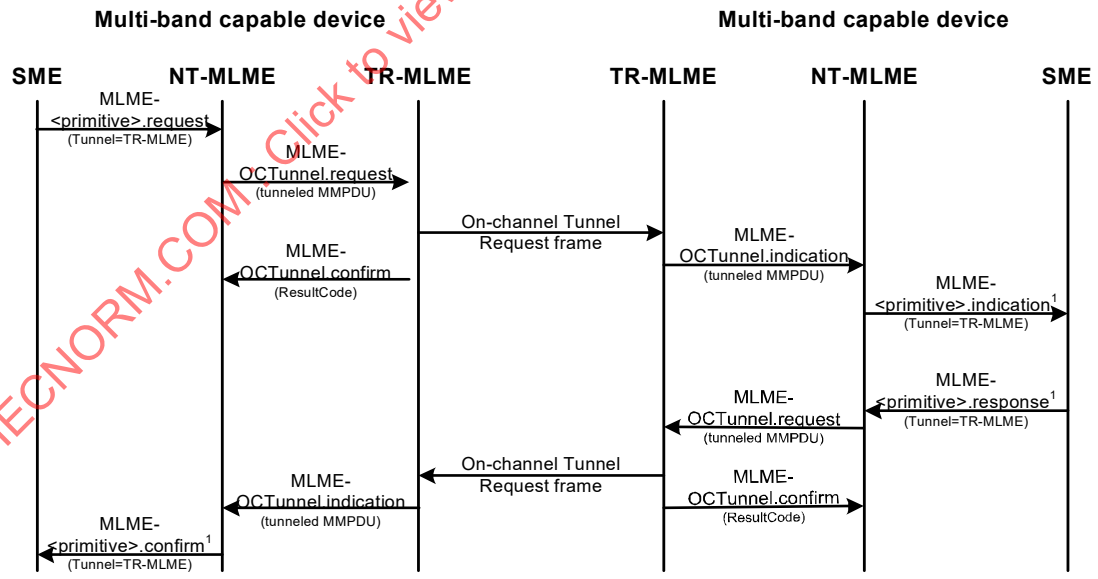
OCT allows a STA of a multi-band capable device to transmit an MMPDU that was constructed by a different STA of the same device. An MMPDU transmitted this way is referred to as an *OCT MMPDU*. The MLME of the nontransmitting STA that constructs or is the destination of an OCT MMPDU is referred to as an *NT-MLME*. The MLME of the STA that transmits or receives an OCT MMPDU over the air is referred to as a *TR-MLME*. An NT-MLME that constructs an OCT MMPDU destined to a peer NT-MLME does so according to the capabilities of the STA that contains the peer NT-MLME.

NOTE 1—OCT can be used in conjunction with or independent from the FST setup protocol.

A STA supports OCT if the OCT Not Supported subfield within the STA's Multi-band element is 0. A STA should not perform OCT with a peer STA that does not support OCT. A STA that does not support OCT shall ignore a received OCT MMPDU.

Figure 11-53 depicts the overall OCT procedure. In this figure, <primitive> refers to the name of any of the MLME primitives defined in 6.3 that meets all of the following conditions:

— Includes a peer Multi-band element. The peer Multi-band element is used to identify the peer NT-MLME.
— Includes a local Multi-band element. The local Multi-band element is used to identify the local TR-MLME.



[1] Primitive invoked if defined. If not defined, invocation is not present.

Figure 11-53—On-channel tunneling procedure

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An MLME primitive meeting all of the above conditions is referred to as an *OCT MLME primitive*.

NOTE 2—MLME-AUTHENTICATE, MLME-ASSOCIATE, and MLME-REASSOCIATE are examples of primitives that are OCT MLME primitives.

The OCT procedure can be used both with the OCT MLME primitives and to transmit a response to an On-channel Tunnel Request frame tunneling a Probe Request frame. The Timestamp field of the Probe Response frame tunneled in an On-channel Tunnel Request frame is reserved.

To perform the OCT procedure, the values of the Band ID, Channel Number and BSSID fields in a Multi-band element or OCT Source element are used to identify an MLME. All other fields in the Multi-band element shall be reserved.

Except for the following cases, the values of the Band ID, Channel Number and BSSID fields in a Multi-band element or OCT Source element are used by an NT-MLME to deliver messages to a TR-MLME through the OCTunnel.request primitive, and are used by a TR-MLME to deliver messages to an NT-MLME through the OCTunnel.indication primitive:

— If the BSSID field is the wildcard BSSID, an MLME (either TR-MLME or NT-MLME) shall not use the BSSID field in selecting the MLME to deliver a message and shall, instead, invoke the corresponding primitive for all MLMEs that match the Band ID and Channel Number fields.
— If the OCT MLME request primitive is the MLME-SCAN.request primitive with ScanType parameter set to ACTIVE and that includes the ChannelList parameter, the NT-MLME shall not use the Channel Number field within the Multi-band local parameter of the MLME-SCAN.request primitive in selecting the TR-MLME to deliver a message and shall, instead, invoke the OCTunnel.request primitive at the TR-MLME(s) that match the Band ID field and BSSID field within Multi-band local parameter, and the channels specified in the ChannelList parameter.
— If the Channel Number field is 0 and the OCT MLME request primitive is not the MLME-SCAN.request primitive with ScanType parameter set to ACTIVE and that includes the ChannelList parameter, an MLME (either TR-MLME or NT-MLME) shall not use the Channel Number field in selecting the MLME to deliver a message and shall, instead, invoke the corresponding primitive for all MLMEs that match the Band ID and BSSID fields.
— If the Channel Number field is 0 and the OCT MLME request primitive is not the MLME-SCAN.request primitive with ScanType parameter set to ACTIVE and that includes the ChannelList parameter, and the BSSID field is the wildcard BSSID, an MLME (either TR-MLME or NT-MLME) shall use neither the BSSID field nor the Channel Number field in selecting the MLME to deliver a message and shall, instead, invoke the corresponding primitive for all MLMEs that match the Band ID field.

In the following procedure, a “request tunneled MMPDU” is an MMPDU generated in the context of an MLME.request primitive. A “response tunneled MMPDU” is an MMPDU generated in the context of an MLME.response primitive.

To transmit a tunneled MMPDU, the SME of a multi-band capable device generates an OCT MLME request primitive that includes the peer Multi-band element and the local Multi-band element. If the OCT MLME request primitive is the MLME-SCAN.request primitive with ScanType parameter set to ACTIVE, the BSSID field within the peer Multi-band element shall be set to the value of the BSSID parameter in the MLME-SCAN.request primitive and the BSSID field within the local Multi-band element shall be set to an individual MAC address.

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An NT-MLME receiving an OCT MLME request primitive shall

— As defined in this standard, process the request and construct an OCT MMPDU corresponding to the primitive in question. The NT-MLME shall not transmit any frame as a result of this primitive.

— Generate an MLME-OCTunnel.request primitive with parameters including the OCT MMPDU, the Multi-band peer parameter set to the peer Multi-band element and the OCT source parameter set to the OCT Source element identifying the NT-MLME.

An NT-MLME does not issue an MLME-OCTunnel.request primitive if a selected TR-MLME does not exist. A TR-MLME does not issue an MLME-OCTunnel.indication primitive if a selected NT-MLME does not exist.

A single OCT MLME request primitive received by an NT-MLME may result in the invocation of one or more MLME-OCTunnel.request primitives at TR-MLME(s). Each invocation shall be towards a different TR-MLME.

A TR-MLME receiving an MLME-OCTunnel.request primitive with a request tunneled MMPDU shall transmit an On-channel Tunnel Request frame addressed to the peer TR-MLME and which includes the tunneled MMPDU. The peer TR-MLME(s) is identified by the PeerSTAAddress parameter of the MLME-OCTunnel.request primitive. The On-channel Tunnel Request frame shall not be group addressed. Once the On-channel Tunnel Request frame is transmitted and acknowledged or attempts to transmit the frame are abandoned, the TR-MLME shall issue an MLME-OCTunnel.confirm primitive, with the appropriate result code, to inform the NT-MLME of the outcome of the frame transmission.

A receiving TR-MLME shall ignore the received On-channel Tunnel Request frame if that frame is not targeting an NT-MLME in the same multi-band capable device as the TR-MLME.

NOTE 3—The mechanism for a TR-MLME to forward an OCT MMPDU received in an On-channel Tunnel Request frame to an NT-MLME not in the same multi-band capable device as the TR-MLME is outside the scope of this standard.

A TR-MLME receiving an On-channel Tunnel Request frame carrying a request tunneled MMPDU shall generate an MLME-OCTunnel.indication primitive with the Multi-band local parameter set to the Multi-band element identifying the TR-MLME, the OCT source parameter set to the value of the OCT Source field contained in the On-channel Tunnel Request frame and the Tunneled RXVECTOR parameter set to the RXVECTOR of the On-channel Tunnel Request frame. The MLME-OCTunnel.indication primitive shall be generated to the NT-MLME identified by the peer Multi-band element contained within the received On-channel Tunnel Request frame.

An NT-MLME receiving an MLME-OCTunnel.indication primitive carrying a request tunneled MMPDU shall

— As defined in this standard, process the OCT MMPDU parameter of the primitive as if the MMPDU had been received over the air, with the exception that an acknowledgment, if any, shall not be sent as a response to the reception of the MMPDU.

— Generate an OCT MLME indication primitive, if one is defined, corresponding to the frame type of tunneled MMPDU. This primitive is generated to the SME of the STA, which processes the MMPDU as defined in this standard. The Multi-band local parameter of the OCT MLME indication primitive shall be set to the value of the Multi-band local parameter of the MLME-OCTunnel.indication primitive and the Multi-band peer parameter shall be set to the value of the OCT source parameter of the MLME-OCTunnel.indication primitive.

In the case of a .request/.indication primitive, the process stops here. Otherwise, the process continues as described below.

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The peer SME responds to the reception of an OCT MLME indication primitive by generating the corresponding OCT MLME response primitive. This response includes the peer Multi-band element and the local Multi-band element.

An NT-MLME receiving an OCT MLME response primitive, if one is defined, or generating a response by itself, if no OCT MLME response primitive is defined (e.g., MLME-SCAN.response is not defined), shall

— As defined in this standard, process the response and construct an OCT MMPDU corresponding to the primitive in question. The NT-MLME shall not transmit any frame as a result of this primitive.

— Generate an MLME-OCTunnel.request primitive with parameters including the OCT MMPDU, the Multi-band peer parameter set to the peer Multi-band element and the OCT source parameter set to the OCT Source element identifying the NT-MLME. If no OCT MLME response primitive is defined, the Multi-band peer parameter shall be set to the value of the OCT source parameter received in the corresponding MLME-OCTunnel.indication primitive. The MLME-OCTunnel.request primitive shall be generated to the TR-MLME identified by the local Multi-band element specified in the OCT MLME response primitive, if one is defined, or to the TR-MLME identified by the Multi-band local parameter of the MLME-OCTunnel.indication primitive that triggered this response, if no OCT MLME response primitive is defined.

A TR-MLME receiving an MLME-OCTunnel.request primitive with a response tunneled MMPDU shall transmit an On-channel Tunnel Request frame addressed to the peer TR-MLME that includes the tunneled MMPDU. The peer TR-MLME(s) is identified by the PeerSTAAddress parameter of the MLME-OCTunnel.request primitive. Once the On-channel Tunnel Request frame is transmitted and acknowledged or attempts to transmit the frame are abandoned, the TR-MLME shall issue an MLME-OCTunnel.confirm primitive, with the appropriate result code, to inform the NT-MLME of the outcome of the frame transmission.

A TR-MLME receiving an On-channel Tunnel Request frame carrying a response tunneled MMPDU shall generate an MLME-OCTunnel.indication primitive with the Multi-band local parameter set to the Multi-band element identifying the TR-MLME, the OCT source parameter set to the value of the OCT Source field contained in the On-channel Tunnel Request frame and the Tunneled RXVECTOR parameter set to the RXVECTOR of the On-channel Tunnel Request frame. The MLME-OCTunnel.indication primitive shall be generated to the NT-MLME identified by the peer Multi-band element contained within the received On-channel Tunnel Request frame.

An NT-MLME receiving an MLME-OCTunnel.indication primitive carrying a response tunneled MMPDU shall

— Process the OCT MMPDU parameter of the primitive as if the MMPDU had been received over the air.

— Generate an OCT MLME confirm primitive, if one is defined, corresponding to the frame type of the tunneled MMPDU. This primitive is directed at the SME and has the Multi-band local parameter set to the value of the Multi-band local parameter of the MLME-OCTunnel.indication primitive and the Multi-band peer parameter set to the value of the OCT source parameter of the MLME-OCTunnel.indication primitive. If the OCT MLME confirm primitive is the MLME-SCAN.confirm primitive and the NT-MLME did not scan all the channels specified in the corresponding MLME-SCAN.request primitive, the ResultCode parameter in the MLME-SCAN.confirm primitive shall be set to PARTIAL_SCAN and the ScannedChannelList parameter shall list all channels that have been scanned.

An NT-MLME receiving an MLME-OCTunnel.confirm primitive shall:

— As defined in this standard, take action, if there is one, based on the success or otherwise of the OCT MMPDU transmission by the TR-MLME.

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Figure 11-54 and Figure 11-55 illustrate the complete forwarding of OCT messages based on the procedure described above in this subclause. Figure 11-54 depicts the forward path, i.e., from a requesting multi-band device (MBD) that initiates the OCT procedure with a responding MBD. Figure 11-55 depicts the return path, i.e., from a responding MBD that generates an OCT MMPDU in response to an OCT MMPDU from a requesting MBD.

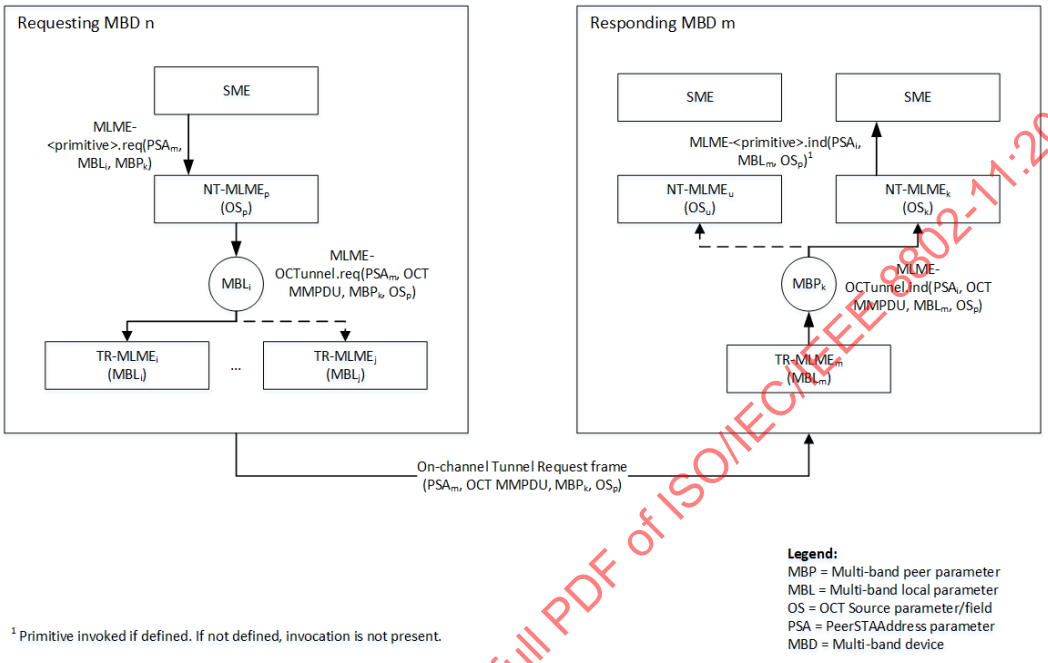

Figure 11-54—Forward path of OCT messages based on OCT parameters

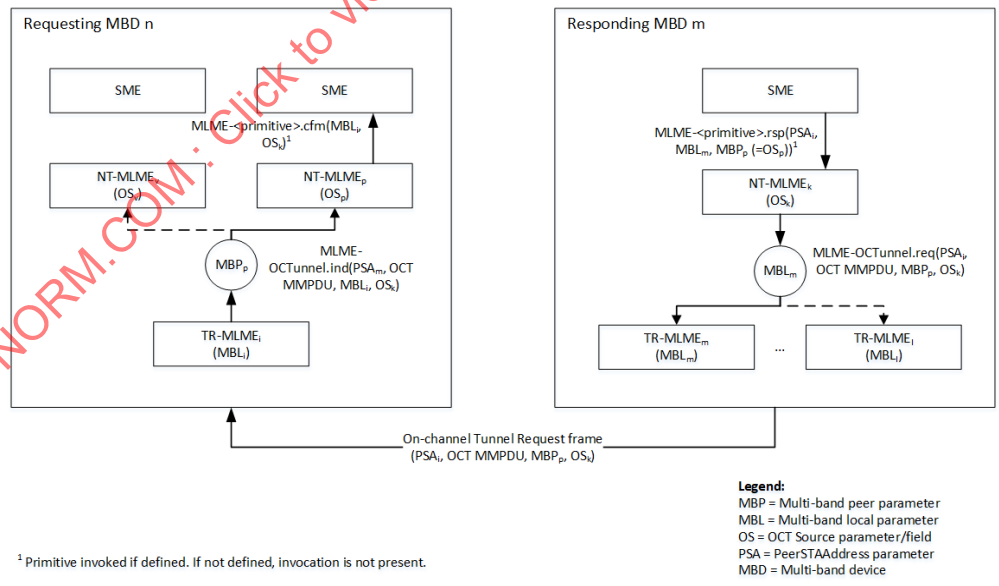

Figure 11-55—Return path of OCT messages based on OCT parameters

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11.31.6 FST payload

When FST Action frames are forwarded by an AP, FST uses Ethertype 89-0d frames as defined in Annex H. In this case, the FST payload contains an FST Action frame body as is specified in 9.6.20.

11.32 MMSL cluster operation

11.32.1 Introduction

A STA is MMSL cluster capable if it includes an MMS element in its most recent transmission of (Re)Association Request, (Re)Association Response, ADDTS Request, ADDTS Response, Probe Request, Probe Response, Information Request, or Information Response frames.

An MM-SME coordinated STA shall be MMSL cluster capable, except for an MM-SME that coordinates two STAs where one STA is a member AP or member PCP in a centralized AP or PCP cluster and the other STA is associated to the S-AP of the centralized AP or PCP cluster.

NOTE—In the centralized clustering case, the two STAs in the MM-SME are communicating with different MAC entities with different SMEs, so there is no individual link for MMSL.

A non-MM-SME coordinated STA may be MMSL cluster capable.

An MMSL cluster capable STA shall include an MMS element in transmitted (Re)Association Request and (Re)Association Response frames.

As described in 4.9.3, an MM-SME may coordinate multiple MACs (and their respective STAs).

Each STA coordinated by the same MM-SME may be used for the MMSL cluster setup and maintenance.

The PCP may deliver an MMS element that includes a MAC address that is equal to the BSSID and other MAC addresses that are not equal to the BSSID. The MAC addresses that are not the BSSID shall not be used to request and respond to association, reassociation, probing, and scheduling services provided by the PCP.

If a non-AP and non-PCP STA has delivered an MMS element to the AP or PCP, the non-AP and non-PCP STA shall not send an ADDTS Request frame to the AP or PCP with the TA field equal to a MAC address that was not included in the delivered MMS element.

If an MM-SME coordinated STA is associated with an AP or PCP that allocates one single AID to all STAs advertised in the MMS element sent by the MM-SME coordinated STA, the AID can be also used to identify the MMSL cluster. If the AID is provided for one of the advertised STAs of the MM-SME coordinated STA, then the same AID applies to all STAs whose addresses are referenced in the delivered MMS element and the Single AID field is set as per Table 9-269.

Table 11-21 covers the possible cases of the AID use for MMSL cluster identification.

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Table 11-21—Setting of Single AID field

MMSL cluster configuration	Is the Single AID allocated to the MM-SME coordinated STA A?	Is the Single AID allocated to the MM-SME coordinated STA B?	AID identification of MMSL cluster
Non-AP and non-PCP MM-SME coordinated STA A is associated to PCP MM-SME coordinated STA B.	Yes	Yes	Yes
Non-AP and non-PCP MM-SME coordinated STA A and non-AP and non-PCP MM-SME coordinated STA B are both associated to the same BSS.	Yes	Yes	Yes
Non-AP and non-PCP MM-SME coordinated STA A is associated to a BSS and non-AP and non-PCP MM-SME coordinated STA B is not associated to the BSS.	Yes	No	No
Non-AP and non-PCP MM-SME coordinated STA A and non-AP and non-PCP STA B are both associated to the same BSS.	Yes	NA	Yes
Non-AP and non-PCP MM-SME coordinated STA A is associated to a BSS and one MAC entity of non-AP and non-PCP MM-SME coordinated STA B is associated to the same BSS.	Yes	NA	Yes

11.32.2 MMSL cluster setup

11.32.2.1 General

To establish an MMSL cluster, an MMS element of an MM-SME coordinated STA that lists its advertised STAs shall be delivered to the peer STA. The peer STA may be an MM-SME coordinated STA or a non-MM-SME coordinated STA. An MMSL cluster is identified by one of the following:

a) Advertised MAC addresses of the MAC entities of two MM-SME coordinated STAs
b) Advertised MAC addresses of the MAC entities of an MM-SME coordinated STA and of a non-MM-SME coordinated STA

In both cases, the MMS element shall be exchanged between the STAs to set up the MMSL cluster agreement.

If an MMSL cluster capable non-MM-SME coordinated STA receives an ADDTS Request frame that includes an MMS element, the SME of the non-MM-SME coordinated STA shall include the received MMS element in the MLME-ADDTS.response primitive used to send the ADDTS Response frame if the SME accepts the MMSL cluster setup. The SME of the non-MM-SME coordinated STA may set the MMS Element Owner field to "no Owner" in the MMS element included in an MLME-ASSOCIATE.request primitive and MLME-ADDTS.request primitive to establish the MMSL cluster with an MM-SME coordinated STA.

The MMS element shall be exchanged between the STAs of the MMSL cluster only once per MMSL cluster setup.

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11.32.2.2 MMSL cluster setup of non-AP and non-PCP MM-SME coordinated STA with AP or PCP

The Association Request and Response frames are used to establish an MMSL cluster between a non-AP and non-PCP MM-SME coordinated STA and an AP or PCP. If the AP or PCP is not an MM-SME coordinated STA, the AP or PCP shall include the MMS element received from the non-AP and non-PCP MM-SME coordinated STA in the Association Response frame sent as response. If the AP or PCP is an MM-SME coordinated STA, the AP or PCP should include its own MMS element that contains its advertised MAC entities in the Association Response frame and shall not include the MMS element received from the non-AP and non-PCP MM-SME coordinated STA in the Association Response frame. The AP or PCP shall not respond with any MMS element if it is not MMSL cluster capable.

The setup of the MMSL cluster fails if the Association Response frame does not contain the MMS element.

11.32.2.3 MMSL cluster setup of non-AP and non-PCP STA with another non-AP and non-PCP STA

If a non-AP and non-PCP MM-SME coordinated STA associated with an AP or PCP has established an AID identified MMSL cluster with the AP or PCP, the non-AP and non-PCP MM-SME coordinated STA shall not use a MAC address that was not included in the MMS element delivered to the AP or PCP to establish an MMSL cluster with another non-AP and non-PCP MM-SME coordinated STA associated with the same AP or PCP.

An ADDTS Request/Response frame exchange with a PTP TSPEC shall be used to establish the MMSL cluster between non-AP and non-PCP MM-SME coordinated STAs and between a non-AP and non-PCP MM-SME coordinated STA and a non-AP and non-PCP non-MM-SME coordinated STA.

A non-AP and non-PCP MM-SME coordinated STA shall include an MMS element that contains its advertised MAC entities in transmitted ADDTS Request frames. If the non-AP and non-PCP STA is not an MM-SME coordinated STA, the non-AP and non-PCP STA should include the MMS element with the MMS Element Owner field set to “no Owner” in the ADDTS Request frame.

The non-AP and non-PCP MM-SME coordinated STA shall include its own MMS element that contains its advertised MAC entities in transmitted ADDTS Response frames. The non-MM-SME coordinated STA may include the MMS element of the MM-SME coordinated STA from which it received an ADDTS Request frame in the ADDTS Response frame sent as response. The non-MM-SME coordinated STA shall not respond with any MMS element if it is not MMSL cluster capable.

The setup of the MMSL cluster fails if the ADDTS Response frame does not contain the MMS element.

11.33 DMG coexistence with non-IEEE-802.11 systems

This subclause describes the features available in this standard to improve coexistence with other DMG systems, including IEEE Std 802.15.3™-2016 [B21].

The same common channelization that is defined in other DMG standards and specifications is adopted (20.3.1). In regulatory domains where 2 or more channels are defined, a DMG STA should support at least 2 channels.

An AP should not start an infrastructure BSS on a channel where the signal level is at or above aDMGDetectionThres or upon detecting a valid IEEE 802.15.3 CMS preamble at a receive level greater than or equal to –60 dBm.

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If a DMG STA is capable of performing directional channel measurements (11.30) to detect non-IEEE-Std-802.11 transmissions on a channel, it can report the results of the measurements to the STA's AP or PCP.

If a DMG STA detects a non-IEEE-802.11 transmission on its channel or if the AP or PCP receives a report (11.10) from a DMG STA on a non-IEEE-802.11 transmission, the following mechanisms might be used to mitigate interference:

- Change operating channel (11.8)
- Beamforming (10.42)
- Reduce transmit power (11.7)
- Perform FST (11.31)
- Move the TBTT (11.29.2), and thus the beacon interval, in the case of an AP or PCP
- Change the schedule of SPs and CBAPs in the beacon interval (9.4.2.131) in the case of an AP or PCP
- Defer transmission for a later time
- For periods of time in the beacon interval where the STA experiences poor channel quality, the STA can use the Traffic Scheduling Constraint Set field within the DMG TSPEC element (9.4.2.133) to request its AP or PCP to avoid scheduling an SP for that DMG STA during those periods of time in the beacon interval.

11.34 DMG relay procedures

11.34.1 General

Relaying allows a source relay endpoint DMG STA (REDS) to transmit frames to a destination REDS with the assistance of another DMG STA called the *relay DMG STA (RDS)*. Relaying can improve the reliability of communication in a DMG BSS in case the direct link between the source REDS and the destination REDS is disrupted.

A STA is a REDS if both dot11REDSActivated and dot11RelayActivated are true. A REDS shall set the Relay Client field within its Relay Capabilities element to 1. A STA is an RDS if both dot11RDSActivated and dot11RelayActivated are true. An RDS shall set the Relay Supporter field within its Relay Capabilities element to 1. A STA is relay capable if dot11RelayActivated is true and it is either a REDS or an RDS or both, and it is relay incapable otherwise.

A relay capable STA shall advertise its capability by including the Relay Capabilities element in (Re)Association Request, (Re)Association Response, Probe Request, Probe Response, Information Request, and Information Response frames. An AP or relay capable PCP may include the Relay Capabilities element in DMG Beacon frames.

For a STA to operate as a REDS or an RDS in an Infrastructure BSS or PBSS, the following conditions shall be met:

- The STA is a member of the Infrastructure BSS or PBSS.
- The TDDTI field within the DMG STA Capabilities element of the AP or PCP of the BSS is 1.
- The Relay permission field within the Relay Capabilities element of the AP or PCP of the BSS is 1.

A source REDS, a destination REDS, and an RDS can establish the types of relay operation as specified in 10.45.1.

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As needed, in the following subclauses, source REDS, RDS, and destination REDS are expressed as S, R, and D, respectively. Also, a direct link between STA S and STA D can be simply referred to as *S-D link*.

11.34.2 Common relay setup procedures

11.34.2.1 Introduction

This subclause describes the procedures that a source REDS, a destination REDS, and an RDS employ to set up a relay operation among these STAs. These procedures are used for both link switching and link cooperation relays, and shall be performed in the order shown in this subclause.

11.34.2.2 Relay capabilities and RDS discovery procedures

A source REDS can obtain the capabilities of other STAs in the BSS following the STA's association with the BSS or with the transmission of an Information Request frame as described in 11.28.1.

A source DMG STA that intends to set up relay operation with a destination DMG STA shall obtain the capabilities of the destination DMG STA prior to initiating the relay setup procedure with the destination DMG STA. The source DMG STA may attempt to set up relay operation with the destination DMG STA only if both the source DMG STA and destination DMG STA are REDS, and there exists at least one RDS in the BSS.

Upon receiving an MLME-RELAY-SEARCH.request primitive, the source DMG STA can discover a list of RDSs in the BSS by transmitting a Relay Search Request frame to the AP or PCP with the destination REDS AID field set to the AID of the destination DMG STA. The MLME of the AP or PCP receiving a Relay Search Request frame shall generate an MLME-RELAY-SEARCH.indication primitive. Upon receiving an MLME-RELAY-SEARCH.response primitive, the AP or PCP shall transmit a Relay Search Response frame addressed to the requesting STA and shall include in the transmitted frame a list of RDSs in the BSS. The MLME of the source DMG STA receiving a Relay Search Response frame shall generate an MLME-RELAY-SEARCH.confirm primitive. After the transmission of the Relay Search Response frame to the source DMG STA, the AP or PCP shall transmit an unsolicited Relay Search Response frame to the destination DMG STA with the Relay Capable STA Info field of the source DMG STA and the list of RDSs that the AP or PCP included in the last Relay Search Response frame transmitted to the source DMG STA.

11.34.2.3 RDS selection procedure

Following the transmission of a Relay Search Response frame, the AP or PCP should schedule within its Extended Schedule element two SPs for each RDS included in the transmitted Relay Search Response frame:

— An SP having as source DMG STA the source REDS and as destination DMG STA the RDS, and with the Beamforming Training field set to 1. The duration of the SP should be such that the source REDS and RDS can complete BF as described in 10.42.

— An SP having as source DMG STA the RDS and as destination DMG STA the destination REDS, and with the Beamforming Training field set to 1. The duration of the SP should be such that the RDS and the destination REDS can complete BF as described in 10.42.

After the RDS completes BF with both the source REDS and destination REDS, the source REDS shall send a Multi-Relay Channel Measurement Request frame to the RDS, which shall respond with the transmission of a Multi-Relay Channel Measurement Report frame back to the source REDS. Following the reception of this frame, the source REDS should perform BF with the destination REDS as described in 10.42, and once BF is completed the source REDS shall transmit a Multi-Relay Channel Measurement Request frame to the destination REDS. In response, the destination REDS shall transmit a Multi-Relay Channel Measurement Report frame to the source REDS including the channel measurement information between the destination REDS and all RDSs known to the destination REDS. To shorten the time it takes to complete this procedure, STAs can limit BF to the SLS phase only.

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Once this procedure is completed, the source REDS becomes aware of all the channel measurement information between the source REDS and zero or more RDSs and between the destination REDS and zero or more RDSs. The source REDS shall then select a single STA to operate as the RDS between the source REDS and the destination REDS. The selection of the RDS is implementation dependent, and it can be based on information contained within an RDS's Relay Capabilities element and channel measurements.

11.34.2.4 RLS procedure

Following the selection of the RDS to be used between the source REDS and the destination REDS, the source REDS receiving an MLME-RLS.request primitive initiates the RLS procedure by sending an RLS Request frame to the selected RDS. The RLS Request frame includes the capabilities and the AIDs of the source REDS, the destination REDS, and the RDS, and the relay transfer parameter set. Upon receiving the RLS Request frame, the RDS shall transmit an RLS Request frame to the destination REDS containing the same information as received within the frame body of the source REDS's RLS Request frame.

The MLME of the destination REDS receiving a Relay Search Request frame shall generate an MLME-RLS.indication primitive. Upon receiving an MLME-RLS.response primitive, the destination REDS shall transmit an RLS Response frame to the RDS with the destination status code field set to SUCCESS if the destination REDS is willing to participate in the RLS, and set to REQUEST_DECLINED if the destination REDS is not willing to participate in the RLS. Upon receiving the RLS Response frame, the RDS shall transmit an RLS Response frame to the source REDS containing the same information as received within the destination REDS's RLS Response frame, with the exception that the RDS shall set the relay status code field to SUCCESS if the RDS is willing to participate in the RLS, and shall set it to REQUEST_DECLINED if the RDS is not willing to participate in the RLS.

The MLME of the source DMG STA receiving an RLS Response frame from the RDS shall generate an MLME-RLS.confirm primitive. Upon receiving an RLS Response frame with the destination status code and relay status code fields set to SUCCESS, the source DMG STA may transmit an RLS Announcement frame to the AP or PCP to indicate that the RLS procedure was successfully completed. If either or both of the destination status code and relay status code fields are nonzero, the RLS procedure is unsuccessful.

Upon the completion of RLS procedure, the source REDS, the destination REDS, and the RDS can redo BF among them.

11.34.3 Relay operation-type change procedure

The source REDS may change the relay operation type from link switching to link cooperation, and vice-versa, if either one of S-D, or S-R, or R-D links becomes unavailable or for other reasons. Link unavailability can be determined by the source DMG STA not receiving expected frames from the destination REDS. To assist in this decision, the source REDS can use the link adaptation procedure (10.45.4) to obtain the quality of a link.

To change the relay operation type within an SP from link cooperation to link switching in a case that the S-D link becomes unavailable, the source REDS shall transmit a ROC Request frame to the RDS with the Link Cooperation subfield set to 0 and the relay-link subfield set to 1. Upon receiving a ROC Request frame, the RDS shall transmit a ROC Request frame to the destination REDS containing the same information as received within the frame body of the source REDS's ROC Request frame. Following the reception of a ROC Request frame, the destination REDS shall respond with a ROC Response frame to the RDS with the status code field set to SUCCESS if the destination REDS accepts to change the operation into link switching, and set to REQUEST_DECLINED if the destination REDS rejects the request. Upon receiving the ROC Response frame, the RDS shall transmit a ROC Response frame to the source REDS with the status code field set to SUCCESS only if the RDS accepts to change the operation into link switching and the status code field set to

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SUCCESS in the ROC Response frame received from destination REDS. Otherwise, the RDS shall set the status code field to REQUEST_DECLINED. Upon reception of a ROC Response from the RDS with the status code field set to SUCCESS, the source REDS immediately starts to transmit frames to the destination REDS via the RDS relay link.

To change the relay operation type from link cooperation to link switching in other case that the S-R link becomes unavailable, the source REDS shall a ROC Request frame to the destination REDS with the Link Cooperation subfield set to 0 and the relay-link subfield set to 0. Following the reception of a ROC Request frame, the destination REDS shall respond with a ROC Response frame to the source REDS with the status code field indicating the acceptance or rejection of the request. Upon reception of a ROC Response from the destination REDS with the status code field set to SUCCESS, the source REDS starts to transmit frames to the destination REDS via the direct link in link switching.

To change the relay operation type within an SP from link switching to link cooperation, the source REDS shall transmit a ROC Request frame to the destination REDS via the RDS with the Link Cooperation subfield set to 1. Following the reception of a ROC Request frame from the RDS, the destination REDS shall respond with a ROC Response frame to the source REDS via the RDS with the status code field indicating the acceptance or rejection of the request. Upon reception of a ROC Response frame from the RDS with the status code field set to SUCCESS, the source REDS immediately starts to transmit frames to the destination REDS using the RDS in link cooperation. If a TPA procedure was not performed beforehand since the link switching operation has been continued from the start of relay operation, the STA shall perform the TPA procedure before transmitting using link cooperation.

NOTE—As described in 10.45.3.2.3, during the SP in link cooperation operation the destination REDS has its receive antenna pattern such that it simultaneously covers the links toward both the source REDS and the RDS.

11.34.4 Relay teardown

A source REDS that has successfully completed the RLS procedure with a destination REDS may teardown the relay operation between the source REDS, destination REDS and RDS. To do that, the source REDS shall transmit an RLS Teardown frame to the RDS, destination REDS and AP or PCP of the BSS. Within the RLS Teardown frame, the source REDS shall set the source AID field to the AID of the source REDS, the destination AID field to the AID of the destination REDS and the relay AID field to the AID of the RDS.

A RDS may teardown the relay operation between the source REDS, destination REDS and RDS. To do that, the RDS shall transmit an RLS Teardown frame to the source REDS, destination REDS and AP or PCP of the BSS. Within the RLS Teardown frame, the RDS shall set the source AID field to the AID of the source REDS, the destination AID field to the AID of the destination REDS and the relay AID field to the AID of the RDS.

11.35 Quieting adjacent DMG BSSs

11.35.1 General

An AP that supports QAB shall set the QAB Capability field within the AP's Extended Capabilities element to 1 and shall set the QAB Capability field to 0 otherwise. In addition, if an AP supports QAB, the AP shall also support scheduling SPs as defined in 10.39.6.

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11.35.2 Procedure at the requester AP

Upon receipt of an MLME-QAB.request primitive, an AP shall perform the following procedure to start the Quiet Adjacent BSS operation (Figure 11-56):

a) If both the requester and responder APs are QAB capable as indicated by the QAB Capability field within the Extended Capabilities element, the requester AP sends a QAB Request frame indicating the duration, period, offset, and number of the quiet intervals. The requester AP may include multiple Quiet Period Request elements in one frame targeting multiple responder APs.

b) If a QAB Response frame is received with the matching dialog token and request token with a status code set to a value of SUCCESS, the AP has confirmed the responder AP has scheduled the requested quiet periods, and the MLME shall issue an MLME-QAB.confirm primitive indicating the success of the procedure.

c) If a QAB Response frame is received with the matching dialog and request token with a status code set to a value other than SUCCESS, the procedure is considered to have failed, and the MLME shall issue an MLME-QAB.confirm primitive indicating the failure of the procedure.

NOTE—The GAS protocol can be used by an AP to verify the capabilities of another AP.

11.35.3 Procedure at the responder AP

A responder AP shall operate as follows (Figure 11-56):

a) When a QAB Request frame matching the BSSID is received from another AP, the MLME shall issue an MLME-QAB.indication primitive.

b) Upon receipt of the MLME-QAB.response primitive, the AP shall respond by transmitting a QAB Response frame.

   1) If the result code is SUCCESS, the request is accepted. The AP shall use SPs to schedule the quiet period(s) according to the accepted request. The SPs shall have the AP as both source and destination and the AP shall not transmit during the SP. The QAB procedure shall be terminated if the number of quiet intervals exceeds the value of the Repetition Count field. Contained in the transmitted QAB Response frame is the copy of the request token and the BSSID of the AP's BSS.

   2) If the result code is REJECTED, the request has not been fulfilled.

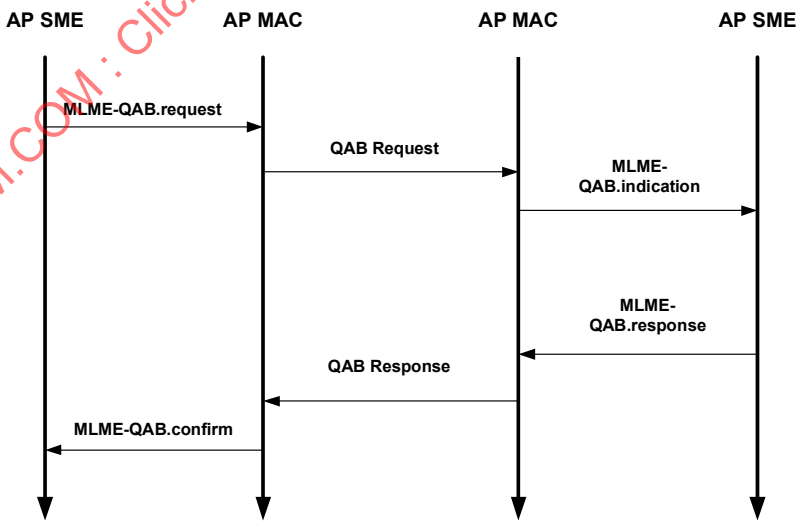

Figure 11-56—Quieting adjacent BSS operation

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11.36 DMG beamforming

Upon receipt of an MLME-BF-TRAINING.request primitive, a STA shall undertake beamforming training with the STA indicated by the PeerSTAAddress parameter according to the procedures defined in 10.42. This training shall start with the SLS and shall include the BRP if and only if the RequestBRP parameter of the MLME-BF-TRAINING.request primitive is true.

A STA receiving MLME-BF-TRAINING.request primitive may act as either initiator or responder in the beamforming training.

If the STA indicated by the PeerSTAAddress parameter of a received MLME-BF-TRAINING.request primitive is an AP or PCP of a BSS in which a STA is a member, the STA receiving the MLME-BF-TRAINING.request primitive may perform beamforming training during the A-BFT as described in 10.42.5. Alternatively, the STA receiving the MLME-BF-TRAINING.request primitive may use an SP or a TXOP to perform ISS as described in 10.42.2.2.

A STA receiving the MLME-BF-TRAINING.request primitive shall issue an MLME-BF-TRAINING.confirm primitive on completion of the requested beamforming training or on timeout as specified in 10.42.

A STA that performs beamforming training with a peer STA at the request of the peer STA shall issue an MLME-BF-TRAINING.indication primitive on completion of that beamforming training, or on timeout as specified in 10.42.

Figure 11-57 illustrates an example of the beamforming training procedure in the DTI for a case where the STA receiving the MLME-BF-TRAINING.request primitive acts as initiator.

Figure 11-58 illustrates an example of the beamforming training procedure in the context of a non-AP and non-PCP STA joining an infrastructure BSS or PBSS. In this scenario, the MLME-BF-TRAINING.request primitive is issued by the STA attempting to associate in order that the link be trained to a degree that allows the over-the-air exchanges necessary for association to succeed.

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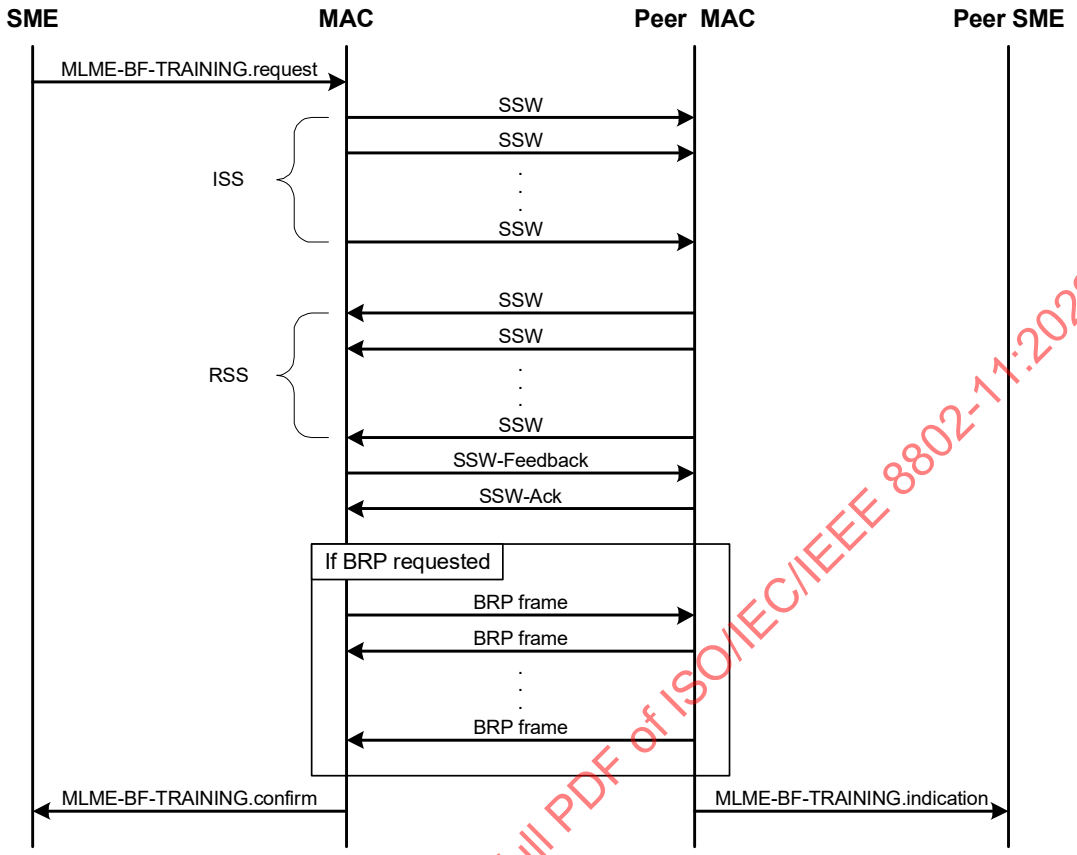

Figure 11-57—Beamforming training procedure in the DTI

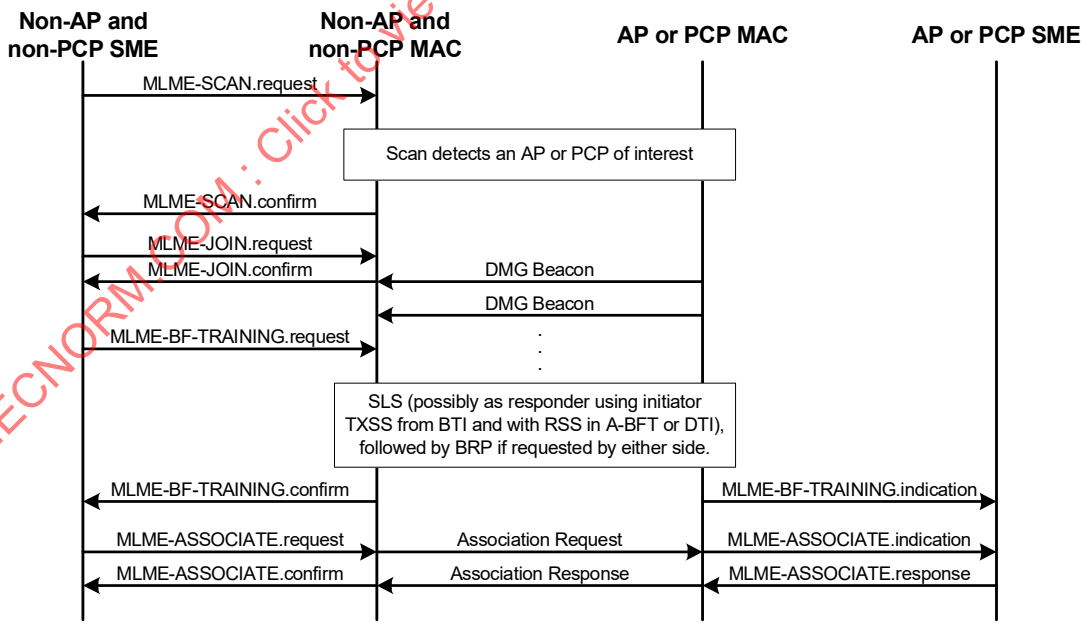

Figure 11-58—Beamforming training when joining an infrastructure BSS or PBSS

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11.37 DMG MAC sublayer attributes

A DMG STA has dot11DMGOptionImplemented equal to true.

The attributes that define some of the MAC characteristics are given in Table 11-22.

Table 11-22—DMG MAC sublayer attribute values

Attribute	Value
aMaxBIDuration	1000 TUs
aMinChannelTime	aMaxBIDuration
aMinBTIPeriod	4
aMinSwitchInterval	2×aMinBTIPeriod
aMaxSwitchInterval	16×aMinSwitchInterval
aTSFResolution	1 µs
aDMGPPMinListeningTime	150 µs
aSSFramesPerSlot	4
aSSDuration	(FSS – 1) × SBIFS + FSS × TXTIME(SSW)
aSSFBDuration	TXTIME(SSW-Feedback)
aRTSTimeoutTime	TXTIME(RTS) + aAirPropagationTime + aRxPHYDelay + aMACProcessingDelay
aDMGTSFAccuracy	20 ppm
aMinNAVTimersNumber	2
aCWminDMGIBSS	3
aMinAllocationDeliveryTime	300 µs
aMaxABFTAccessPeriod	2
aDtime	aSBIFSTime + TXTIME(TPA Request frame)
aRelayTPATime	aSBIFSTime + 2 × aAirPropagationTime + 2 × aDtime + TXTIME(TPA Request frame) + 2 × TXTIME(TPA Response frame)
aMinPPDUDurationForDMGMeasurement	5.27 µs
aDMGDWSValidPeriod	60 seconds

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11.38 VHT BSS operation

11.38.1 Basic VHT BSS functionality

A VHT STA has dot11VHTOptionImplemented equal to true.

A STA that is starting a VHT BSS shall be able to receive and transmit at each of the <VHT-MCS, NSS> tuple values indicated by the Basic VHT-MCS And NSS Set field of the VHT Operation parameter of the MLME-START.request primitive and shall be able to receive at each of the <VHT-MCS, NSS> tuple values indicated

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by the Supported VHT-MCS And NSS Set field of the VHT Capabilities parameter of the MLME-START.request primitive.

A STA for which dot11VHTOptionImplemented is true shall set dot11HighThroughputOptionImplemented to true.

A STA that is a VHT AP or a VHT mesh STA declares its channel width capability in the VHT Capabilities element VHT Capabilities Information field as described in Table 9-271.

A VHT STA shall set the Supported Channel Width Set subfield in its HT Capabilities element HT Capability Information field to 1, indicating that both 20 MHz operation and 40 MHz operation are supported.

At a minimum, a VHT STA sets the Rx MCS Bitmask of the Supported MCS Set field of its HT Capabilities element according to the setting of the Rx VHT-MCS Map subfield of the Supported VHT-MCS And NSS Set field of its VHT Capabilities element as follows: for each subfield Max VHT-MCS For n SS, $1 \le n \le 4$, of the Rx VHT-MCS Map field with a value other than 3 (no support for that number of spatial streams), the STA shall indicate support for HT-MCSs $8\times(n-1)$ to $8\times(n-1)+7$ in the Rx MCS Bitmask, where n is the number of spatial streams, except for those MCSs marked as unsupported as described in 10.6.13.3.

A STA that is a VHT AP or a VHT mesh STA shall set the STA Channel Width subfield in the HT Operation element HT Operation Information field and the Channel Width, Channel Center Frequency Segment 0 and Channel Center Frequency Segment 1 subfields in the VHT Operation element VHT Operation Information field to indicate the BSS bandwidth as defined in Table 11-23.

Table 11-23—VHT BSS bandwidth

HT Operation element STA Channel Width field	VHT Operation element Channel Width field	VHT Operation element Channel Center Frequency Segment 1 subfield	BSS bandwidth
0	0	0	20 MHz
1	0	0	40 MHz
1	1	0	80 MHz
1	1	CCFS1 > 0 and | CCFS1 - CCFS0 | = 8	160 MHz
1	1	CCFS1 > 0 and | CCFS1 - CCFS0 | > 16	80+80 MHz
1	2	0	160 MHz (deprecated)
1	3	CCFS1 > 0 and | CCFS1 - CCFS0 | > 16	80+80 MHz (deprecated)

NOTE 1—CCFS0 represents the value of the Channel Center Frequency Segment 0 subfield.
NOTE 2—CCFS1 represents the value of the Channel Center Frequency Segment 1 subfield.

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The setting of the Channel Center Frequency Segment 0 and Channel Center Frequency Segment 1 subfields is shown in Table 11-24.

Table 11-24—Setting of Channel Center Frequency Segment 0, Channel Center Frequency Segment 1, and Channel Center Frequency Segment 2 subfields

BSS bandwidth	VHT Operation element Channel Width field	Setting of the Channel Center Frequency Segment 0 subfield	Setting of the Channel Center Frequency Segment 1 subfield	Setting of the Channel Center Frequency Segment 2 subfield
20, 40 MHz	0	dot11CurrentChannelCenterFrequencyIndex0	0	0
80 MHz	1	dot11CurrentChannelCenterFrequencyIndex0	0	0
160 MHz (At least Max VHT NSS support)	1	if dot11CurrentPrimaryChannel is greater than dot11CurrentChannelCenterFrequencyIndex0 then dot11CurrentChannelCenterFrequencyIndex0 + 8, else dot11CurrentChannelCenterFrequencyIndex0 − 8	dot11CurrentChannelCenterFrequencyIndex0	0
160 MHz (Less than Max VHT NSS support)	1	if dot11CurrentPrimaryChannel is greater than dot11CurrentChannelCenterFrequencyIndex0 then dot11CurrentChannelCenterFrequencyIndex0 + 8, else dot11CurrentChannelCenterFrequencyIndex0 − 8	0	dot11CurrentChannelCenterFrequencyIndex0
80+80 MHz (At least Max VHT NSS support)	1	dot11CurrentChannelCenterFrequencyIndex0	dot11CurrentChannelCenterFrequencyIndex1	0
80+80 MHz (Less than Max VHT NSS support)	1	dot11CurrentChannelCenterFrequencyIndex0	0	dot11CurrentChannelCenterFrequencyIndex1
160 MHz (deprecated)	2	dot11CurrentChannelCenterFrequencyIndex0	0	0
80+80 MHz (deprecated)	3	dot11CurrentChannelCenterFrequencyIndex0	dot11CurrentChannelCenterFrequencyIndex1	0

NOTE 1—"At least Max VHT NSS support" means that the NSS support at 160 or 80+80 MHz is at least Max VHT NSS, and therefore the secondary 80 or 160 MHz channel center frequency is signaled through CCFS1.

NOTE 2—"Less than Max VHT NSS support" means that the NSS support at 160 or 80+80 MHz is less than Max VHT NSS, and therefore the secondary 80 or 160 MHz channel center frequency is signaled through CCFS2.

NOTE 3—For NSS support, see Table 9-81 and Table 9-272.

A VHT STA shall determine the channelization using the combination of the information in the HT Operation element Primary Channel field and the VHT Operation element VHT Operation Information field Channel Center Frequency Segment 0 and Channel Center Frequency Segment 1 subfields (see 21.3.14).

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A VHT AP or a VHT mesh STA shall set the HT Operation element HT Operation Information field Secondary Channel Offset subfield to indicate the secondary 20 MHz channel as defined in Table 9-190, if the BSS bandwidth is more than 20 MHz.

A VHT STA that is a member of a VHT BSS shall not transmit a 20 MHz VHT PPDU on a channel other than the primary 20 MHz channel, except for a 20 MHz VHT PPDU transmission on an off-channel TDLS direct link as constrained by 11.20.6.5.2.

A VHT STA that is a member of a VHT BSS with a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth shall not transmit a 40 MHz VHT PPDU that does not use the primary 40 MHz channel, except for a 40 MHz VHT PPDU transmission on an off-channel TDLS direct link.

A VHT STA that is a member of a VHT BSS with an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth shall not transmit an 80 MHz VHT PPDU that does not use the primary 80 MHz channel, except for an 80 MHz VHT PPDU transmission on an off-channel TDLS direct link.

A VHT STA that is a member of a VHT BSS with a 160 MHz or 80+80 MHz BSS bandwidth shall not transmit a 160 MHz or 80+80 MHz VHT PPDU that does not use the primary 80 MHz channel and the secondary 80 MHz channel, except for a 160 MHz or 80+80 MHz VHT PPDU transmission on an off-channel TDLS direct link.

A VHT STA shall not transmit to a second VHT STA using a bandwidth that is not indicated as supported in the Supported Channel Width Set subfield in the HT Capabilities element or in the VHT Capabilities Information field of the VHT Capabilities element received from that VHT STA.

A STA shall not transmit an MPDU in a VHT PPDU that exceeds the maximum MPDU length capability indicated in the VHT Capabilities element received from the recipient STA.

A VHT AP shall set the RIFS Mode field in the HT Operation element to 0.

VHT BSS operation with less than Max VHT NSS support is enabled as defined in Table 11-25 and disabled otherwise, in which case the Channel Center Frequency Segment 2 subfield of the HT Operation element shall be 0.

Table 11-25—Extended NSS channel width

HT Operation element STA Channel Width field	VHT Operation element Channel Width field	VHT Operation element CCFS1 field	HT Operation element CCFS2 field	Extended NSS channel width
1	1	0	CCFS2 > 0 and |CCFS2 – CCFS0| = 8 (40 MHz apart)	160 MHz
1	1	0	CCFS2 > 0 and |CCFS2 - CCFS0| > 16 (> 80 MHz apart)	80+80 MHz
1	1	0	CCFS2 > 0 and |CCFS2 – CCFS0| < 8 (< 40 MHz apart)	Reserved

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Table 11-25—Extended NSS channel width *(continued)*

HT Operation element STA Channel Width field	VHT Operation element Channel Width field	VHT Operation element CCFS1 field	HT Operation element CCFS2 field	Extended NSS channel width
1	1	0	CCFS2 > 0 and 8 < |CCFS2 – CCFS0| ≤ 16 (> 40 MHz and ≤ 80 MHz apart)	Reserved

NOTE 1—CCFS0 represents the value of the Channel Center Frequency Segment 0 subfield of the VHT Operation element.

NOTE 2—CCFS2 represents the value of the Channel Center Frequency Segment 2 subfield of the HT Operation element.

When VHT BSS operation with less than Max VHT NSS support is enabled, the NSS support is determined based on the Extended NSS channel width and the VHT Capabilities element per Table 9-272 and Table 9-81.

11.38.2 Channel selection methods for a VHT BSS

Before a STA starts a VHT BSS, the STA shall perform a minimum of dot11VHTOBSSScanCount OBSS scan operations to search for existing BSSs (see 11.38.3).

If an AP or a mesh STA starts a VHT BSS that occupies some or all channels of any existing BSSs, the AP or mesh STA may select a primary channel of the new VHT BSS that is identical to the primary channel of any one of the existing BSSs.

If an AP or a mesh STA selects a primary channel for a new VHT BSS with a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth from among the channels on which no beacons are detected during the OBSS scans, then the selected primary channel meets the following conditions:

— It shall not be identical to the secondary 20 MHz channel of any existing BSSs with a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

— It should not overlap with the secondary 40 MHz channel of any existing BSSs with a 80 MHz, 160 MHz or 80+80 MHz BSS bandwidth.

A STA that is an AP or mesh STA should not start a VHT BSS with a 20 MHz BSS bandwidth on a channel that is the secondary 20 MHz channel of any existing BSSs with a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth, or is overlapped with the secondary 40 MHz channel of any existing BSSs with a 160 MHz or 80+80 MHz BSS bandwidth.

NOTE—An AP or a mesh STA operating a VHT BSS with a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth, on detecting an OBSS whose primary channel is the AP's or the mesh STA's secondary 20 MHz channel, might switch to 20 MHz BSS operation and/or move to a different channel.

11.38.3 Scanning requirements for VHT STA

An OBSS scan operation is a passive or active scan of a set of channels that are potentially affected by VHT BSS operation (see 11.1.4.1). Each channel in the set may be scanned more than once during a single OBSS scan operation. OBSS scans are performed by STAs that start a VHT BSS.

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During an individual scan within an OBSS scan operation, the minimum per-channel scan duration is dot11OBSSScanPassiveDwell TUs (for a passive scan) or dot11OBSSScanActiveDwell TUs (for an active scan). During an OBSS scan operation, each channel in the set is scanned at least once per dot11BSSWidthTriggerScanInterval seconds, and the minimum total scan time (i.e., the sum of the scan durations) per channel within a single OBSS scan operation is dot11OBSSScanPassiveTotalPerChannel TUs (for a passive scan) or dot11OBSSScanActiveTotalPerChannel TUs (for an active scan).

NOTE—The values provided in the previous paragraph are minimum requirements. For some combinations of parameter values the minimum might be exceeded for some parameters in order to meet the minimum value constraints of other parameters.

11.38.4 Channel switching methods for a VHT BSS

A VHT AP announces a switch of operating channel by either of the following:

— Using the Channel Switch Announcement element, Channel Switch Announcement frame, or both, following the procedure described in 11.8.8.2

— Using the Extended Channel Switch Announcement element, Extended Channel Switch Announcement frame, or both, following the procedure described in 11.9

A VHT mesh STA announces a switch attempt of operating channel by either of the following:

— Using the Channel Switch Announcement element, Channel Switch Announcement frame, or both, following the procedure described in 11.8.8.4

— Using the Extended Channel Switch Announcement element, Extended Channel Switch Announcement frame, or both, following the procedure described in 11.9

A VHT AP or a VHT mesh STA may also announce a switch of BSS bandwidth, a new Country String field (possibly including a new Operating Class table number), new operating classes, or new TPC parameters for the BSS that come into effect at the same time as the switch of operating channel.

The New Channel Number field in the Channel Switch Announcement element, Extended Channel Switch Announcement element, Channel Switch Announcement frame, or Extended Channel Switch Announcement frame identifies the primary 20 MHz channel after the switch. The New Channel Number field is set to the value that dot11CurrentPrimaryChannel (see 21.3.14) will have after the switch.

If a Channel Switch Announcement frame is used to announce a switch to a 20 MHz BSS bandwidth, then neither a Wide Bandwidth Channel Switch element nor a Secondary Channel Offset element shall be present in the frame, except that a Secondary Channel Offset element may be present in a Channel Switch Announcement frame if the Secondary Channel Offset field within the Secondary Channel Offset element is set to SCN.

If a Channel Switch Announcement element is used to announce a switch to a 20 MHz BSS bandwidth, then a Wide Bandwidth Channel Switch subelement in a Channel Switch Wrapper element shall not be present in the same frame.

If an Extended Channel Switch Announcement element in a Beacon or Probe Response frame or an Extended Channel Switch Announcement frame is used to announce a switch to a 20 MHz BSS bandwidth, then neither a Wide Bandwidth Channel Switch element nor a Wide Bandwidth Channel Switch subelement shall be present in the same frame.

NOTE 1—A Secondary Channel Offset element is never present with the Extended Channel Switch Announcement element or in the Extended Channel Switch Announcement frame. Instead, the indicated operating class within the Extended Channel Switch Announcement element or frame is used to differentiate between a BSS bandwidth of 20 MHz and a BSS bandwidth greater than 20 MHz as well as indicate the location of the secondary 20 MHz channel. For a switch to a 20 MHz BSS bandwidth, the operating class indicated within the Extended Channel Switch Announcement

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element or frame has a channel spacing of 20 MHz. For a switch to an BSS bandwidth greater than 20 MHz, the operating class indicated within the Extended Channel Switch Announcement element or frame has a channel spacing of 40 MHz.

If a Channel Switch Announcement frame is used to announce a switch to a 40 MHz BSS bandwidth, then the following apply:

— The Secondary Channel Offset element shall be present in the frame.
— The Wide Bandwidth Channel Switch shall not be present in the frame.

If a Channel Switch Announcement element in a Beacon or Probe Response frame is used to announce a switch to a 40 MHz BSS bandwidth, then the Wide Bandwidth Channel Switch subelement in the Channel Switch Wrapper element shall also be present in the same frame.

If an Extended Channel Switch Announcement element in a Beacon or Probe Response frame is used to announce a switch to a 40 MHz BSS bandwidth, then the Wide Bandwidth Channel Switch subelement in the Channel Switch Wrapper element may be present in the same frame.

NOTE 2—The indicated operating class within the Extended Channel Switch Announcement element identifies the bandwidth and the relative position of the primary 20 MHz and secondary 20 MHz channels. Hence a Wide Bandwidth Channel Switch subelement is unnecessary when the Extended Channel Switch Announcement element is used for a channel switch to a 40 MHz bandwidth.

If a Channel Switch Announcement frame is used to announce a switch to an 80 MHz, 80+80 MHz, or 160 MHz BSS bandwidth, then both the Secondary Channel Offset element and the Wide Bandwidth Channel Switch element shall be present in the frame.

If a Channel Switch Announcement element or an Extended Channel Switch Announcement element is used to announce a switch to an 80 MHz, 80+80 MHz, or 160 MHz BSS bandwidth, then a Wide Bandwidth Channel Switch subelement in the Channel Switch Wrapper element shall be present in the same frame.

If an Extended Channel Switch Announcement frame is used to announce a switch to an 80 MHz, 80+80 MHz, or 160 MHz BSS bandwidth, then the Wide Bandwidth Channel Switch element shall be present in the frame.

If an Extended Channel Switch Announcement element or Extended Channel Switch Announcement frame is used to announce a switch to an 80 MHz, 80+80 MHz, or 160 MHz BSS bandwidth, then

— The New Operating Class field identifies the primary 40 MHz channel, and
— The Operating Triplet fields within the New Country subelement or element, respectively, shall indicate all of the operating classes for the switched BSS.

If new BSS TPC parameters are announced that come into effect at the same time as the channel switch, then if an AP, IBSS STA or mesh STA is extended spectrum management capable, it shall include

— At least one New Transmit Power Envelope element in a transmitted Channel Switch Announcement frame or Extended Channel Switch Announcement frame, and
— At least one New Transmit Power Envelope subelement in a transmitted Channel Wrapper element in Beacon and Probe Response frames.

A recipient STA in the BSS that is extended spectrum management capable and that has dot11SpectrumManagementRequired or dot11RadioMeasurementActivated equal to true and that maintains association with the BSS after the switch shall use the parameters in these received elements and subelements in the recipient STA's TPC calculations for the new operating channel and BSS bandwidth (see 11.7). If both New Transmit Power Envelope elements and New Transmit Power Envelope subelements are transmitted for the switch, the set of New Transmit Power Envelope elements and set of subelements shall contain the same set of values for the Local Maximum Transmit Power Unit Interpretation subfield, and New Transmit Power

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Envelope elements and subelements that have the same value of the Local Maximum Transmit Power Unit Interpretation subfield shall also have the same values for their other fields.

If a new country string, new operating classes or both, are coming into effect at the same time as the channel switch, then if an AP, IBSS STA or mesh STA is extended spectrum management capable, it shall include

— A New Country element in a transmitted Extended Channel Switch Announcement frame, and
— A New Country subelement in a transmitted Channel Wrapper element.

The New Country element or subelement shall contain all of the Operating Classes for the BSS after the switch. The New Country element or subelement, transmitted in an Extended Channel Switch Announcement frame or in the same frame as an Extended Channel Switch Announcement element, respectively, shall include one Operating Triplet field that contains the same Operating Class as the New Operating Class field in the Extended Channel Switch Announcement frame or Extended Channel Switch Announcement element. A recipient STA in the BSS that is extended spectrum management capable and that has dot11MultiDomainCapabilityActivated, dot11SpectrumManagementRequired, or dot11RadioMeasurementActivated equal to true and that maintains association with the BSS after the switch shall use the parameters in these received elements and subelements in order to maintain regulatory compliance. If both New Country elements and New Country subelements are transmitted for the switch, their fields shall be the same.

A Channel Switch Wrapper element shall not be included in Beacon or Probe Response frames if the element contains zero subelements.

NOTE 3—Channel Switch Wrapper is not defined to carry subelements in the case of a switch to 20 MHz and when no change to the country string, operating classes or TPC parameters are announced.

A VHT STA uses only the Transmit Power Envelope element, not the Power Constraint element, for TPC of 80 MHz, 160 MHz, and 80+80 MHz transmissions. In the Country element, a VHT STA shall include zero Subband Triplet fields in an Operating/Subband Sequence field that contains an Operating Class field for which the “Channel spacing (MHz)” column in the applicable table in Annex E equals 80 or 160.

An AP that switches the BSS to a lower BSS bandwidth may recalculate the TS bandwidth budget and may delete one or more active TSs by invoking the MLME-DELTS.request primitive with a ReasonCode value of SERVICE_CHANGE_PRECLUDES_TS.

A VHT STA that is an IBSS STA shall not transmit values in the Wide Bandwidth Channel Switch element that change the frequency ordering of the primary 40 MHz channel and the secondary 40 MHz channel from the ordering of the most recently adopted operating channel, if the operating channel includes a secondary 40 MHz channel. A VHT STA that is a member of an IBSS shall not transmit values in the Wide Bandwidth Channel Switch element that change the frequency ordering of the primary 80 MHz channel and the secondary 80 MHz channel from the ordering of the most recently adopted operating channel, if the operating channel includes a secondary 80 MHz channel.

11.38.5 NAV assertion in a VHT BSS

A VHT STA shall update its NAV as described in 10.3.2.4 using the Duration/ID field value in any frame that does not have an RA matching the STA’s MAC address and that was received in a 20 MHz PPDU in the primary 20 MHz channel or received in a 40 MHz PPDU in the primary 40 MHz channel or received in an 80 MHz PPDU in the primary 80 MHz channel or received in a 160 MHz or 80+80 MHz PPDU.

NOTE—The PHY might filter out a PPDU as described in 21.3.20 or not receive a PPDU due to VHT TXOP power saving described in 11.2.3.17. If so, frames in the PPDU are not received by the MAC and have no effect on the NAV.

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11.38.6 VHT STA antenna indication

A VHT STA that does not change its Rx antenna pattern after association shall set the Rx Antenna Pattern Consistency subfield in the VHT Capabilities Information field to 1; otherwise, the STA shall set the Rx Antenna Pattern Consistency subfield in the VHT Capabilities Information field to 0.

A VHT STA that does not change its Tx antenna pattern after association shall set the Tx Antenna Pattern Consistency subfield in the VHT Capabilities Information field to 1; otherwise, the STA shall set the Tx Antenna Pattern Consistency subfield in the VHT Capabilities Information field to 0.

11.38.7 Basic VHT-MCS and NSS set operation

The basic VHT-MCS and NSS set is the set of <VHT-MCS, NSS> tuples that are supported by all VHT STAs that are members of a VHT BSS. It is established by the STA that starts the VHT BSS, indicated by the Basic VHT-MCS And NSS Set field of the VHT Operation parameter in the MLME-START.request primitive. Other VHT STAs determine the basic VHT-MCS and NSS set from the Basic VHT-MCS And NSS Set field of the VHT Operation element in the BSSDescription derived through the scan mechanism (see 11.1.4.1).

A VHT STA shall not attempt to join (MLME-JOIN.request primitive) a BSS unless it supports (i.e., is able to both transmit and receive using) all of the <VHT-MCS, NSS> tuples in the basic VHT-MCS and NSS set.

NOTE—A VHT STA does not attempt to (re)associate with a VHT AP unless the STA supports (i.e., is able to both transmit and receive using) all of the <VHT-MCS, NSS> tuples in the Basic VHT-MCS And NSS Set field in the VHT Operation element transmitted by the AP because the MLME-JOIN.request primitive is a necessary precursor to (re)association.

11.38.8 Extended NSS BW Support Signaling

If dot11VHTExtendedNSSBWCapable is false, a STA shall set the Extended NSS BW Support subfield of the VHT Capabilities Information field to 0 in VHT Capability elements that it transmits, otherwise, the subfield may be set to 1, 2 or 3 as indicated in 9.4.2.157.2.

If dot11VHTExtendedNSSBWCapable is false, a STA shall set the VHT Extended NSS BW Capable subfield of the Supported VHT-MCS And NSS Set field to 0 in VHT Capability elements that it transmits, otherwise, the subfield shall be set to 1.

11.39 Group ID management operation

An AP determines the possible combinations of STAs that can be addressed by a VHT MU PPDU or an S1G MU PPDU by assigning STAs to groups and to specific user positions within those groups.

Assignments or changes of user positions corresponding to one or more Group IDs shall be performed using a Group ID Management frame defined in 9.6.22.3.

A STA may be assigned to multiple groups by setting multiple subfields of the Membership Status Array field (see 9.4.1.54) to 1 in the Group ID Management frame addressed to that STA.

A STA's user position in each group of which the STA is a member is indicated by the associated subfield in the User Position Array field (see 9.4.1.55) in the Group ID Management frame addressed to the STA. For each Group ID, an AP may assign the same user position to multiple STAs. A STA shall have only one user position in each group of which the STA is a member.

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A non-S1G AP may transmit a Group ID Management frame only if dot11VHTOptionImplemented is true. A Group ID Management frame shall not be sent to a VHT STA that does not have the MU Beamformee Capable field in the VHT Capabilities element equal to 1.

An S1G AP shall not transmit a Group ID Management frame to an S1G STA that does not have the MU Beamformee Capable field in the S1G Capabilities element equal to 1.

A Group ID Management frame shall be sent as an individually addressed frame.

A STA's MLME that receives a Group ID Management frame with an RA matching its MAC address shall issue a PHYCONFIG_VECTOR primitive with the GROUP_ID_MANAGEMENT parameter based on the content of the received Group ID Management frame in order to configure the following lookup tables in the PHY:

a) Group ID to Membership Status, denoted by MembershipStatusInGroupID[g] for $1 \leq g \leq 62$
b) Group ID to User Position, denoted by UserPositionInGroupID[g] for $1 \leq g \leq 62$

Group ID values of 0 and 63 are used for SU PPDU and the PHY filtering of such PPDUs is controlled by the PHYCONFIG_VECTOR primitive LISTEN_TO_GID00 and LISTEN_TO_GID63 parameters. The User Position in Group ID information is interpreted by a STA receiving a VHT MU PPDU or an S1G MU PPDU as explained in 21.3.11.4, or 23.3.10.4, respectively.

Transmission of a Group ID Management frame to a STA and any associated acknowledgment from the STA shall complete before the transmission of a VHT MU PPDU and an S1G MU PPDU to the STA.

A VHT MU PPDU and an S1G MU PPDU shall be transmitted to a STA based on the content of the Group ID Management frame most recently transmitted to the STA and for which an acknowledgment was received.

11.40 Notification of operating mode changes

A STA in which dot11OperatingModeNotificationImplemented is true shall set the Operating Mode Notification field in the Extended Capabilities element to 1. A VHT STA shall set dot11OperatingModeNotificationImplemented to true. An S1G STA may set dot11OperatingModeNotificationImplemented to true. A STA in which dot11OperatingModeNotificationImplemented is true is referred to as *operating mode notification capable*.

A STA that is operating mode notification capable and that transmits an Association Request, Reassociation Request, TDLS Setup Response, TDLS Setup Confirm, Mesh Peering Open, or Mesh Peering Confirm frame to a STA that is operating mode notification capable should notify the recipient STA of a change in its operating mode by including the Operating Mode Notification element in the frame.

A first STA that is operating mode notification capable should notify a second STA that is operating mode notification capable of a change in its operating mode by transmitting an Operating Mode Notification frame to the second STA if the first STA has established any of the following with a second STA:

— An association with an AP
— A TDLS link
— A Mesh Peer relationship

NOTE 1—A Notify Channel Width frame or the STA Channel Width field in the HT Operation element is used to signal STA operating channel width changes to and from STAs that are not operating mode notification capable.

The Operating Mode field in the Operating Mode Notification frame or the Operating Mode Notification element together with the Supported Channel Width set field and the Extended NSS BW Support field of the

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VHT Capabilities element indicates the transmitting STA's receive bandwidth and NSS capabilities. See 10.6.13.1.

The notification of a change in supported spatial streams should occur prior to a decrease in the maximum number of spatial streams and following an increase in the maximum number of spatial streams.

The notification of a change in operating bandwidth should occur prior to a decrease in the operating channel width and following an increase in the operating channel width.

A STA shall not transmit an individually addressed frame that contains the Operating Mode field unless the recipient is operating mode notification capable.

A non-S1G AP should notify associated STAs of a change in the maximum number of spatial streams it is able to receive through one or more of the following mechanisms:

— Using individually addressed Operating Mode Notification frames
— Using broadcast Operating Mode Notification frames
— Including the Operating Mode Notification element in Beacon frames for a period of time to allow STAs in PS mode to receive the notification

NOTE 2—A broadcast Operating Mode Notification frame might not be received by a STA in PS mode.

An S1G AP should notify associated STAs of a change in its operating channel width through one or more of the following mechanisms:

— Using the Extended Channel Switch Announcement element, Extended Channel Switch Announcement frame, or both, following the procedure described in 11.9
— Using broadcast Operating Mode Notification frames
— Using individually addressed Operating Mode Notification frames
— Using the Channel Width subfield in the S1G Operation element

NOTE 3—A broadcast Operating Mode Notification frame might not be received by a STA in PS mode.

NOTE 4—An AP cannot change the maximum number of spatial streams it is able to receive from HT STAs that are not operating mode notification capable.

The notification should occur prior to a decrease in the maximum number of spatial streams and following an increase in the maximum number of spatial streams.

An AP should notify associated STAs of a change in its operating channel width through one or more of the following mechanisms:

— Using the Channel Switch Announcement element, Channel Switch Announcement frame or both following the procedure defined in 11.8.8.2
— Using the Extended Channel Switch Announcement element, Extended Channel Switch Announcement frame or both, following the procedure described in 11.9
— Using individually addressed Operating Mode Notification frames and/or Notify Channel Width frames
— Using broadcast Operating Mode Notification frames and/or Notify Channel Width frames
— Using the STA Channel Width field in the HT Operation element and/or Channel Width field in the VHT Operation element

NOTE 5—A broadcast Operating Mode Notification or Notify Channel Width frame might not be received by a STA in PS mode.

The notification should occur prior to a decrease in the operating channel width and following an increase in the operating channel width.

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A VHT AP that has at least one VHT STA associated and that indicates a channel width change using Action frame(s) shall transmit Operating Mode Notification frame(s) to signal the channel width change. A VHT AP that has at least one non-VHT HT STA associated and that indicates a channel width change using Action frame(s) shall transmit Notify Channel Width frame(s) to signal the channel width change.

A VHT STA shall not transmit an individually addressed Notify Channel Width frame to a VHT STA.

A VHT STA associated with a VHT AP shall ignore Notify Channel Width frames received from the VHT AP.

An HT AP that is not a VHT AP that changes its operating channel width shall indicate the new operating channel width in the STA Channel Width field in the HT Operation element. A VHT AP that changes its operating channel width shall indicate the new operating channel width in the Channel Width field in the VHT Operation element and STA Channel Width field in the HT Operation element (see Table 11-23).

An S1G STA shall not transmit a Notify Channel Width frame.

An S1G AP that changes its operating channel width shall indicate the new operating channel width in the Channel Width field in the S1G Operation element.

An AP shall not include the Operating Mode Notification element in Beacon, Probe Response, Association Response, and Reassociation Response frames when not changing the maximum number of spatial streams the AP is able to receive.

A STA shall not transmit an Operating Mode field with the Rx NSS subfield indicating a number of spatial streams not supported by the recipient STA. The number of spatial streams supported by the recipient STA is reported in the Supported Rates and BSS Membership Selectors element, Extended Supported Rates and BSS Membership Selectors element, Supported MCS Set field, Supported VHT-MCS and NSS Set field, or Supported S1G-MCS and NSS Set field transmitted in Management frames by the recipient STA.

A STA shall not transmit an Operating Mode field with the Channel Width subfield indicating a bandwidth not supported by the STA, as reported in the Supported Channel Width Set subfield in the HT Capability Information field, in the VHT Capabilities Information field, or the S1G Capabilities Information field in Management frames transmitted by the STA.

A STA that is operating mode notification capable shall not transmit a PPDU to a STA that uses a bandwidth that is greater than the channel width indicated in the most recently received Operating Mode Notification element or Operating Mode Notification frame from that STA. A STA that is operating mode notification capable shall not transmit a PPDU to a STA that uses a greater number of spatial streams than indicated in the most recently received Operating Mode Notification element or Operating Mode Notification frame received from that STA.

NOTE 6—The number of spatial streams might be further restricted if the receiving STA is in SM power save mode (see 11.2.6).

NOTE 7—To avoid possible frame loss, a VHT or S1G STA that sends an individually addressed Operating Mode Notification frame to a second VHT or S1G STA indicating reduced operating channel width and/or reduced active receive chains can continue with its current operating channel width and active receive chains until it infers that the second STA has processed this notification. The first VHT or S1G STA might make this inference from either of the following:

— By receiving a frame addressed to it from the second VHT or S1G STA in a PPDU with a bandwidth and N_{SS} that are less than or equal to the channel width and N_{SS}, respectively, indicated in the Operating Mode Notification frame
— Based on the passage of time in some implementation dependent way, which is outside the scope of this standard

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NOTE 8—It might take a long time for a STA to change its operating mode following the transmission of the Operating Mode Notification frame and during that time it might not be able to receive frames resulting in frame loss. If a non-AP STA cannot tolerate frame loss during that period it can set the Power Management subfield of the Frame Control field of the Operating Mode Notification frame to 1 to indicate that it has entered power save. When it has completed its operating mode change, it can send another frame (such as a QoS Null) with the Frame Control Power Management subfield set to 0 to indicate that it has exited power save.

11.41 Basic TVHT BSS functionality

The STA that is starting a TVHT BSS shall be able to receive and transmit at each of the <VHT-MCS, NSS> tuple values indicated by the Basic VHT-MCS And NSS Set field of the VHT Operation parameter of the MLME-START.request primitive and shall be able to receive at each of the <VHT-MCS, NSS> tuple values indicated by the Supported VHT-MCS and NSS Set field of the VHT Capabilities parameter of the MLME-START.request primitive.

The basic VHT-MCS and NSS set is the set of <VHT-MCS, NSS> tuples that are supported by all TVHT STAs that are members of a TVHT BSS. It is established by the STA that starts the TVHT BSS. Other TVHT STAs determine the basic VHT-MCS and NSS set from the Basic VHT-MCS And NSS Set field of the TVHT Operation element in the BSSDescription derived through the scan mechanism (see 11.1.4.1).

A TVHT STA shall not attempt to join (MLME-JOIN.request primitive) a BSS unless it supports (i.e., is able to both transmit and receive using) all of the <VHT-MCS, NSS> tuples in the basic VHT-MCS and NSS set.

A STA for which dot11TVHTOptionImplemented is true shall set dot11VHTOptionImplemented to true.

A TVHT AP declares its channel width capability in the VHT Capabilities element VHT Capabilities Information field, as defined in 9.4.2.157.

A TVHT AP shall set the Channel Width subfield in the TVHT Operation Information field to indicate the BSS bandwidth and transmitted PPDU type as defined in Table 11-26.

Table 11-26—TVHT BSS bandwidth

TVHT Operation element Channel Width field	BSS bandwidth	PPDU type
0	TVHT_W	TVHT_MODE_1
1	TVHT_2W	TVHT_MODE_1
		TVHT_MODE_2C
2	TVHT_W+W	TVHT_MODE_1
		TVHT_MODE_2N
3	TVHT_4W	TVHT_MODE_1
		TVHT_MODE_2C
		TVHT_MODE_4C
4	TVHT_2W+2W	TVHT_MODE_1
		TVHT_MODE_2C
		TVHT_MODE_4N

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A TVHT non-AP STA that receives a frame containing a TVHT Operation element shall determine the channelization based on the Channel Center Frequency Segment 0, Channel Center Frequency Segment 1, and Primary Channel Number subfields of the TVHT Operation Information field (see 22.3.14).

A TVHT STA that is a member of a TVHT BSS shall transmit a TVHT_MODE_1 PPDU only on the primary TVHT_W channel, except for a TVHT_MODE_1 PPDU transmission on an off-channel TDLS direct link.

A TVHT STA that is a member of a TVHT BSS with a TVHT_2W, TVHT_4W, or TVHT_W+W BSS bandwidth shall not transmit a TVHT_MODE_2C or TVHT_MODE_2N PPDU that does not use the primary TVHT_W channel and the secondary TVHT_W channel, except for a TVHT_MODE_2C, TVHT_MODE_4C, or TVHT_MODE_2N PPDU transmission on an off-channel TDLS direct link.

A TVHT STA that is a member of a TVHT BSS with a TVHT_4W or TVHT_2W+2W BSS bandwidth shall not transmit a TVHT_MODE_4C or TVHT_MODE_4N PPDU that does not use the primary TVHT_2W channel and the secondary TVHT_2W channel, except for a TVHT_MODE_4C or TVHT_MODE_4N PPDU transmission on an off-channel TDLS direct link.

A TVHT STA shall not transmit to a TVHT STA using a bandwidth that is not indicated as supported in the VHT Capabilities element or Operating Mode Notification frame recently received from that TVHT STA.

In a TVHT BSS, the primary TVHT_W channel is the primary channel.

11.42 Operation under the control of a GDB

11.42.1 General

When a STA implements support for one or more of the procedures described in this subclause, it shall set dot11TVHTOptionImplemented to true. When dot11TVHTOptionImplemented is true and a STA is initialized for operation in a band that requires GDB control, then dot11GDDActivated shall be true.

In some regulatory domains, STAs shall consult a GDB to determine permissible operating frequencies and parameters before transmitting. Such STAs may operate as geolocation database dependent (GDD) enabling STAs, which are required by regulation to provide their identification, geolocation, and other information to the GDB as specified by regulatory authorities. Other STAs are permitted to transmit when enabled by a GDD enabling STA. Such STAs operate as GDD dependent STAs.

Subclause 11.42 describes procedures for STAs when they are operating under the control of a GDB to satisfy regulatory requirements. For operation under such restrictions, GDD dependent STAs operate according to the control procedures of a GDD enabling STA that enables their operation. The frame exchange sequence between GDD enabling STA and GDD dependent STAs for enabling their operation occurs in State 4 (see 11.3.1).

A GDD enabling STA is a STA that is able to access a GDB and to obtain the information about the permitted frequencies and other information for use in its location. A GDD enabling STA or geolocated non-AP STA populates its dot11STALCITable with location information by a means that has received regulatory approval and is outside the scope of this standard. When location information is set in dot11STALCITable, the STA sets dot11GeolocationCapabilityActivated. The current dot11STALCITable allows management access to the location information that is the basis for operation. A GDD enabling STA may transmit a GDD enabling signal and may enable operations of GDD dependent STAs.

A GDD dependent STA is a STA that is under the control of a GDD enabling STA.

The GDD enablement procedure for GDD dependent STAs and the operating rules for GDD enabling and GDD dependent STAs are defined in the following subclauses.

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11.42.2 GDD enabling STA operation

A GDD enabling STA may transmit a GDD enabling signal in-band on an available frequency to indicate that it offers GDD enablement service.

The GDD enabling signal is a Beacon frame with an Extended Capabilities element that contains a Geodatabase Inband Enabling Signal field with a value of 1. A GDD dependent STA shall not transmit any frames before it receives a GDD enabling signal over the air directly from a GDD enabling STA.

In some regulatory domains the GDD enabling STA may be required to have secure authentication or association with the GDD dependent STA before it sends the GDD Enablement Response frame. If required by regulation, the GDD enabling STA may contact a GDB to verify that the requesting GDD dependent STA is authorized to operate in the frequency band.

Upon receipt of a GDD Enablement Request frame from a GDD dependent STA, the GDD enabling STA sends a GDD Enablement Response frame with either of the following results:

a) The Status Code field set to SUCCESS to indicate the successful enablement of the requesting GDD dependent STA

b) The Status Code field set to ENABLEMENT DENIED or INVALID_PARAMETERS or RESTRICTION FROM AUTHORIZED GDB, in which case the GDD enablement request has been denied

A GDD enabling STA may issue an unsolicited GDD Enablement Response frame with a Status Code AUTHORIZATION DEENABLED to notify a GDD dependent STA to cease its transmissions and change its GDD enablement state to *Unenabled*. When an unsolicited GDD Enablement Response frame with a Status Code AUTHORIZATION DEENABLED is transmitted, the WSM element is not included.

11.42.3 GDD dependent STA operation

A GDD dependent STA is configured with a GDD enablement state variable which is set to one of the following three states: *Unenabled*, *AttemptingGDDEnablement*, or *GDDEnabled*. A GDD dependent STA begins operation by setting its GDD enablement state variable to *Unenabled* and operates in receive-only mode within the band, passively scanning channels for a GDD enabling signal from a GDD enabling STA.

A typical state machine implementation of GDD dependent STA operation under GDD is provided in Figure 11-59.

A GDD dependent STA shall not transmit any frames unless it has received a valid GDD enabling signal from a GDD enabling STA.

A GDD dependent STA that is able to receive a valid GDD enabling signal, but has not been enabled by a GDD enabling STA shall not transmit, except to perform GDD enablement with a GDD enabling STA transmitting the GDD enabling signal.

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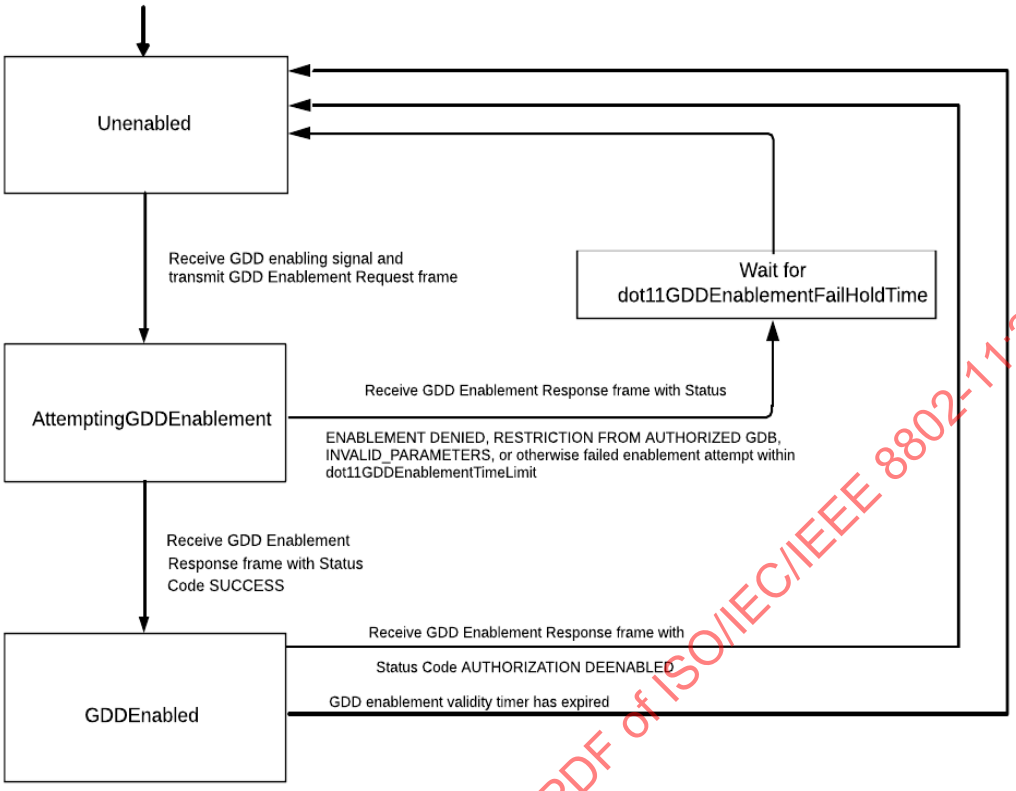

Figure 11-59—GDD dependent STA state transition diagram

A GDD dependent STA shall not transmit any frames other than GDD enablement-related frames and authentication and association frames before it performs the following GDD enablement procedure:

a) The GDD dependent STA changes its GDD enablement state variable to *AttemptingGDDEnablement* after receiving a GDD enabling signal.

b) After authentication and association, the GDD dependent STA securely sends a GDD Enablement Request frame to a GDD enabling STA from which it has received a GDD enabling signal. Based on the input received from the GDD dependent STA, the GDD enabling STA responds with a GDD Enablement Response frame indicating the result for the enablement request.

c) When a GDD dependent STA receives a GDD Enablement Response frame with the Status Code SUCCESS within dot11GDDEnablementTimeLimit, the GDD enablement state variable of the GDD dependent STA is set to *GDDEnabled*. Once it becomes enabled, the GDD dependent STA maintains a GDD enablement validity timer, which is initialized to dot11ContactVerificationSignalInterval.

A GDD dependent STA that has not attained GDD enablement from a GDD enabling STA shall not transmit beyond dot11GDDEnablementTimeLimit, measured from the time of the first PHY-TXSTART.request primitive, while attempting to attain GDD enablement. Then, when the GDD enablement attempt fails within the allowed maximum time, it shall not transmit for dot11GDDEnablementFailHoldTime, before it may again attempt to attain GDD enablement.

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NOTE—A GDD dependent STA might detect several GDD enabling STAs. If the GDD dependent STA is unable to obtain a GDD Enablement Response frame from one GDD enabling STA, it might make further attempts with additional GDD enabling STAs within the maximum time limit of dot11GDDEnablementTimeLimit.

Once in *GDDEnabled* state, the following rules apply to a GDD dependent STA during its operations:

— The GDD dependent STA shall maintain a GDD enablement validity timer. The procedures for maintaining the GDD enablement validity timer are defined in 11.42.8, 11.42.6, and 11.42.4.

— A GDD dependent STA shall cease all transmission when the GDD enablement validity timer has expired. It then changes its GDD enablement state to *Unenabled*.

— A GDD dependent STA shall immediately cease all transmission if it receives an unsolicited GDD Enablement Response frame with a Status Code of AUTHORIZATION DEENABLED from the GDD enabling STA that enabled its operation.

11.42.4 Channel availability query (CAQ) procedure

11.42.4.1 Introduction

This subclause describes a channel availability query procedure that can be used to obtain the list of available channels for the operation of a GDD STA. A STA shall not use the CAQ procedure specified here unless dot11GDDActivated is true.

A GDD dependent STA sends the channel availability query request to a GDD enabling STA to obtain the list of available channels. The CAQ procedure might be initiated by the GDD dependent STA in order to remain in the *GDDEnabled* state during its normal operational mode, as specified in 11.42.3.

The GDD dependent STA sends the Channel Availability Query frame to obtain the new channel availability information when it receives an indication of change in the available channel list for its use, such as from a recent CVS signal (see 11.42.6).

Once the GDD dependent STA receives the response for its Channel Availability Query frame from the GDD enabling STA, it reinitializes the GDD enablement validity timer to dot11ContactVerificationSignalInterval.

A GDD STA that acquires its geolocation position with the accuracy required by the regulatory domain sets dot11GeolocationCapabilityActivated to true. Any STA that operates as a GDD enabling STA might have its geolocation position before it initiates the CAQ procedure. Such a STA might transmit a channel availability query request to another GDD enabling STA. The responding STA generates the CAQ response after communicating to the RLSS, if the Channel Availability Query frame was received in a Channel Availability Query RLQP-element.

NOTE—A GDD enabling STA can send the Channel Availability Query frame to another GDD enabling STA. The responding GDD enabling STA, in such a case, can contact a GDB with the location and identifying parameters sent by the requesting STA.

A GDD enabling STA performs the CAQ procedure to update its channel availability when it determines that its geolocation position has moved beyond the permitted distance or beyond the validity time since its last query, as required by regulation.

STAs might transmit a channel availability query request in the protected dual of a CAQ Public Action frame (see 9.6.7.25, or in a GAS Initial Request frame containing an Channel Availability Query RLQP-element (see 9.4.6.2).

The procedures for channel availability query requesting STA and channel availability query responding STA are specified in 11.42.4.2 and 11.42.4.3.

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In some regulatory domains, CAQ procedures may be conducted in other bands with properly implemented security to meet regulatory requirements. In such cases, CAQ RLQP rather than CAQ Protected Dual of Public Action frames shall be used.

11.42.4.2 CAQ requesting STA

A GDD dependent STA or a GDD enabling STA may initiate a CAQ procedure as a CAQ requesting STA.

A CAQ requesting STA may use RLQP to transmit a CAQ request when it detects RLQP support by its intended CAQ responder in a Beacon or Probe Response frame and to transmit a CAQ request to a STA with which it is associated when the requesting STA detects RLQP support.

Upon receipt of the MLME-GAS.request primitive with an AdvertisementProtocolID value of RLQP and Query parameters with the values of the fields in the RLQP Channel Availability Query element, the requesting STA performs the procedure specified in 11.22.3.2.2 to transmit a GAS Initial Request frame that contains the Channel Availability Query RLQP-element. The specific information items in the Query Request field of the GAS Initial Request frame are defined in 9.4.6.2.

The CAQ requesting STA may send the protected dual of a Channel Availability Query frame where the CAQ responding STA does not support RLQP capability. Upon receipt of the MLME-CHANNELAVAILABILITYQUERY.request primitive with Reason Result Code of 1, the MLME schedules for transmission a Channel Availability Query frame. The specific information items in the protected dual of a CAQ Public Action are defined in 9.6.7.25.

The CAQ requesting STA sets the Reason Result Code field to 1 and provides the Query Info field, as shown in Figure 9-842, to indicate if the Device Identification or Location Information fields are included in the Channel Availability Query frame.

A GDD enabling STA sending the Channel Availability Query frame should provide its device identification information in a format specified in 9.4.4.2.3.

A GDD enabling STA with dot11GeolocationCapabilityActivated equal to true should provide one or more Location Information fields in its Channel Availability Query frame.

A CAQ requesting STA may request a common channel list applicable to a bounded geographic area by providing more than one Device Location Information field in the Channel Availability Query frame. The bounded geographic area is defined by the area surrounded by the given sets of geographic coordinates in the multiple Device Location Information fields.

11.42.4.3 CAQ responding STA

A GDD enabling STA that receives the Channel Availability Query frame performs the role of the CAQ responding STA.

When a GDD enabling STA that has dot11RLSSActivated true receives a Channel Availability Query RLQP-element request, it generates and transmits the Channel Availability Query RLQP-element response to the requesting STA. Upon receipt of the MLME-GAS.response primitive with ResponseInfo parameter having a value of the corresponding field in the CAQ element, the responding STA transmits a Channel Availability Query RLQP-element response.

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The CAQ responding STA generates the response to the CAQ requesting STA based on the result obtained from the RLSS. The specific information items in the Channel Availability Query RLQP-element response are defined in 9.4.6.2 and are set as follows:

- Requester STA Address field set to the MAC address of the STA from which the query was received.
- If no security method is enabled on the connection between the CAQ requesting STA and the CAQ responding STA, the Reason Result Code field is set to 4 (REFUSED).
- Reason Result Code field set to 2 or 3 for successful result or to 4 or 5 for failure, as defined in 9.4.6.2.
- WSM Information field, as defined in 9.4.4.2.6 when the Reason Result Code is set to 2 or 3.

NOTE—For the CAQ process, the RLSS provides the list of available channels for the location(s) provided by the requesting STA in the Channel Availability Query RLQP-element response. In some regulatory domains, the RLSS can perform access to a GDB to derive its response for the Channel Availability Query RLQP-element request and the associated information it provides in its Channel Availability Query RLQP-element response.

A CAQ responding STA might receive a Channel Availability Query frame or its protected dual. Upon receipt of the MLME-CHANNELAVAILABILITYQUERY.response primitive, the MLME schedules for transmission of the response in a Channel Availability Query frame. The Channel Availability Query frame or its protected dual is generated based on the ResultCode and other parameters received from the SME for the Channel Availability Query frame, as follows:

- Requester STA Address field set to the value of the PeerSTAAddress parameter.
- If no security method is enabled on the connection between the CAQ framing STA and the CAQ responding STA, the Reason Result Code field is set to 4 (REFUSED).
- Reason Result Code field set to 2 or 3 for successful result or to 4 or 5 for failure, as defined in 9.4.6.2.
- WSM Information field, as defined in 9.4.4.2.6 when the Reason Result Code is set to 2 or 3.

When a CAQ Responding STA receives the Channel Availability Query frame from a GDD dependent STA, it sets the Reason Result Code field to 2 when the query is successful and provides the WSM information it has obtained for its own location.

When a CAQ Responding STA receives the Channel Availability Query frame from another GDD enabling STA that includes one or more Device Location Information fields in the Channel Availability Query frame, it sets the Reason Result Code field to 2 or 3 when the query is successful and provides the WSM information that is valid for the location of the requesting STA.

When the Channel Availability Query frame contains multiple Device Location Information fields, the WSM information in the CAQ response is applicable for any location within the bounded area defined by the multiple locations. When the Channel Availability Query frame contains two Device Location Information fields, the WSM information in the CAQ response is applicable for any location within the bounded area determined by the uncertainty values of the coordinates of the second Device Location Information field. If no common channels are available to the bounded geographic area defined by multiple locations, CAQ responding STA responds with Reason Result Code field set to 2 (Success with the available channel list result for Device Location Information field) and WSM information applicable to the first Device Location Information field in the Channel Availability Query frame. If one or more common channels are available to the bounded geographic area defined by multiple locations, the CAQ responding STA responds with Reason Result Code field set to 3 (Success with an available channel list result for a bounded geographic area defined by multiple Device Location Information fields) and a corresponding WSM Information field.

When a CAQ responding STA receives the protected Channel Availability Query frame, the response shall be sent using the protected Channel Availability Query frame.

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11.42.5 Channel schedule management (CSM) procedures

11.42.5.1 Introduction

This subclause describes a channel schedule management procedure that can be used to obtain the list of available channels for the operation of a GDD STA. STAs can use the CSM procedure specified here when dot11GDDActivated is true.

Upon receipt of MLME-CHANNELSCHEDULEMANAGEMENT.request primitive, the MLME schedules transmission for a CSM request frame. If the parameter Protected of the MLME-CHANNELSCHEDULEMANAGEMENT.request primitive has the value true, then the CSM request frame as defined in 9.6.7.26 is transmitted in a Protected Dual of Public Action frame; otherwise the CSM request frame is transmitted in a Public Action frame.

Upon receipt of MLME-GAS.request primitive with an AdvertisementProtocolID parameter value of RLQP and Query parameter for a Channel Schedule Management RLQP-element, the requesting STA performs the procedure specified in 11.22.3.2.2 to transmit a GAS Initial Request frame that contains the Channel Schedule Management RLQP-element.

A GDD enabling STA transmits a CSM request to a RLSS to query the schedule information on TV channels. By default, a RLSS is able to provide channel schedule information on TV channels. However, the RLSS may reject the request by responding with Reason Result Code field set to the value for “Request declined by RLSS for unspecified reason.”

A GDD enabling STA transmits a CSM request to a RLSS to query the schedule information on WLAN channels. The RLSS maps channel schedule information from TV channels to WLAN channels and provides the schedule information, as defined in 9.4.4.2.5, to the GDD enabling STA that sent the query to facilitate WLAN operation. A RLSS that is not capable of providing WLAN channel schedule information responds to a request using the CSM response with the Reason Result Code field set to the value for “Request declined by RLSS because of no capability for providing schedule information on WLAN channels.”

A GDD enabling STA transmits a CSM request to another GDD enabling STA that is capable of database access as indicated in the GDD enabling signal. The GDD enabling STA that is capable of database access is able to access the RLSS and obtain the channel schedule information on TV channels. The GDD enabling STA may respond to a request by sending the CSM response with Reason Result Code field set to the value for “Request Declined by the GDD enabling STA because of no capability for providing schedule information on WLAN channels.”

A GDD enabling STA may transmit a CSM request to query WLAN channel information from another GDD enabling STA. A GDD enabling STA responds to a CSM request using a CSM response with the Reason Result Code field set to the value for “Success” if it is capable of providing channel schedule information on WLAN channels obtained from a RLSS and responds with the Reason Result Code field set to the value for “Request declined by the GDD enabling STA because of no capability for providing schedule information on WLAN channels,” otherwise.

When the information in a CSM response is identical to the information in the most recently transmitted CSM response to the same requesting STA, the responding STA can set the Reason Result Code field value CSM element in a query response to “Successful” with no channel schedule changes from the last query of the RLSS and omit both the Channel Schedule Management Mode and Channel Schedule Descriptor fields.

A GDD enabling STA with dot11ChannelScheduleManagementActivated true may send a CSM frame to update the channel schedule information of another GDD enabling STA that receives an available channel list from it.

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The GDD dependent STA shall not transmit a CSM request.

The details of requesting and responding with CSM are provided in 11.42.5.2 and 11.42.5.3.

11.42.5.2 CSM requesting STA

A STA employing RLQP uses the GAS protocol for its CSM procedure with a RLSS. Upon receipt of the MLME-GAS.request primitive with an AdvertisementProtocolID value of RLQP and Query parameter with the value of Channel Schedule Management RLQP-element, the CSM requesting STA transmits an RLQP-element with RLQP ID for CSM in the Query Request field in a GAS Initial Request frame. The specific information items in the Query Request field of the GAS Initial Request frame are generated as follows:

— Reason Result Code field = 0 or 1 as defined in 9.6.7.26.
— Channel Schedule Management Mode field = 0 or 1 as defined in 9.6.7.26.
— Channel Schedule Descriptor field, as defined in 9.4.4.2.5, containing the channel that the STA wants to query.

A STA uses the CSM Public Action frame or its protected dual to query another STA for channel schedule information. Upon receipt of the MLME-CHANNELSCHEDULEMANAGEMENT.request primitive with the CSM parameter of CSM element, the requesting STA transmits a CSM frame. The request frame is generated as follows:

— Reason Result Code field = 0 or 1 as defined in 9.6.7.26.
— Channel Schedule Management Mode field = 0 or 1 as defined in 9.6.7.26.
— Channel Schedule Descriptor field, as defined in 9.4.4.2.5, contains only the channel that the STA wants to query.

11.42.5.3 CSM responding STA

A STA employing RLQP uses the GAS protocol for its CSM procedure with a RLSS. Upon receipt of the MLME-GAS.request primitive with an ResponseInfo parameter value of Channel Schedule Management RLQP-element, the CSM responding STA transmits an RLQP-element with RLQP ID for CSM in the Query Response field in a GAS Initial Response frame or one or more GAS Comeback Response frames. The responding RLQP CSM shall be transmitted in a Protected Dual of Public Action frame if the received CSM is protected. The specific information items in the Query Response field of the GAS Initial Response frame are generated as follows:

— Reason Result Code field = values 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 as defined in 9.6.7.26.
— Channel Schedule Descriptor field, as defined in 9.4.4.2.5, contains the channel and related channel schedule information.

A STA uses CSM Public Action frame or its protected dual to respond to another STA with channel schedule information. Upon receipt of the MLME-CHANNELSCHEDULEMANAGEMENT.request primitive with CSM parameter value of CSM element, the CSM responding STA transmits a CSM frame in response. The responding CSM shall be transmitted in a Protected Dual of Public Action frame if the received CSM is protected. The CSM response frame is generated as follows:

— Reason result code field = values 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 as defined in 9.6.7.26.
— Channel Schedule Descriptor field, as defined in 9.4.4.2.5, contains the channel and related channel schedule information.

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11.42.6 Contact verification signal (CVS)

The Contact Verification Signal frame is transmitted by a GDD enabling STA to establish that its GDD dependent STAs are within the reception range of the GDD enabling STA and to validate the available channel list. A GDD enabling STA with dot11ContactVerificationSignalActivated true shall transmit an individually addressed Protected CVS frame (see 9.6.7.27) to its GDD dependent STAs.

A GDD dependent STA receives a CVS frame transmitted from its GDD enabling STA that provided the WSMs to verify that it is within reception range of that GDD enabling STA. The CVS frame has a Map ID field that indicates whether the WSM has been changed. A GDD dependent STA compares values of the Map ID field in the CVS frame with the Map ID of its existing WSM. If they are the same, then the GDD dependent STA assumes that its WSM is valid, and it sets the GDD enablement validity timer equal to dot11ContactVerificationSignalInterval. If they are different, the WSM is invalid because WSM information has changed. The STA should transmit a Channel Availability Query frame and receive a response in a Channel Availability Query frame that contains an updated WSM. If the GDD dependent STA fails to retrieve the updated WSM, it shall change its GDD enablement state to *unenabled* and stop transmitting over the air after the GDD enablement validity timer has expired.

11.42.7 Network channel control (NCC) procedures

11.42.7.1 Introduction

This subclause describes network channel control procedures that can be used to manage channels for operation of a GDD STA. A STA may use the NCC procedures specified here when dot11GDDActivated is true.

Network channel control utilizes a two-message transaction sequence to allow an NCC responding STA to control the frequency usage in TV bands of an NCC requesting STA's WLAN channels. The first MMPDU sent by the NCC requesting STA asserts identity and requests NCC information. The NCC requesting STA may select its preferred frequencies from its WSM and request usage. The MMPDU sent by the NCC responding STA returns the NCC result. The NCC responding STA might grant permission to use the selected frequencies for multiple WLAN channels to the NCC requesting STA by responding with a Network Channel Control frame (see 9.6.7.30). When responding, the NCC responding STA provides the confirmed WLAN channels and the transmit power constraints as well. The WLAN channels that the NCC responding STA confirms might be the same as or a subset of the network channels listed in the Network Channel Control frame received from the NCC requesting STA.

An NCC requesting STA employing RLQP may send an Network Channel Control frame to the RLSS to request its preferred frequencies given by the WSM for WLAN channels. The NCC requesting STA accomplishes this by transmitting an RLQP-element with the RLQP ID for NCC in the Query Request field in a GAS Initial Request frame. After it receives this frame the NCC responding STA forwards the NCC request to the RLSS. After receiving the NCC request, the RLSS responds and sends an NCC response via the NCC responding STA to the NCC requesting STA. When responding, the RLSS also provides the confirmed WLAN channels and the transmit power constraints. The WLAN channels that the RLSS confirms might be the same as or a subset of the network channels listed in the Network Channel Control request frame received from the NCC requesting STA.

Whenever the WSM has changed due to the update of the database information or detection of the primary service signals, an NCC requesting STAs may transmit a new Network Channel Control frame.

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11.42.7.2 NCC requesting STA

An NCC requesting STA may be a GDD dependent STA. An NCC requesting STA employing RLQP may use the GAS protocol for its NCC procedure with a RLSS. Upon receipt of the MLME-GAS.request primitive with an AdvertisementProtocolID value of RLQP and Query parameter with the value of Network Channel Control RLQP-element, the NCC requesting STA transmits an RLQP-element with Info ID for NCC in the Query Request field in a GAS Initial Request frame. The specific information items in the Query Request field of the GAS Initial Request frame are generated as follows:

— The Requester STA Address field is set to the MAC address of the NCC requesting STA.
— The Responder STA Address field is set to the MAC address of the NCC responding STA.
— The Reason Result code is REQUEST, as defined in 9.4.6.4.
— The Number of Network Channel Control Triplets field, as defined in 9.4.6.4, gives the number of triplets of Operating Class, Channel Number, and Transmit Power Constraint fields.
— The Operating Class and Channel Number fields, with the values defined in E.1, together specify the channel frequency and channel bandwidth for WLAN channels selected by the NCC requesting STA.
— The Maximum Transmit Power field, as defined in 9.4.6.4, is set to the intended maximum transmit power in dBm for operation of the requesting STA.

An NCC Requesting STA might use the Network Channel Control frame or its protected dual to query another STA to request frequency usage in TV bands for WLAN channels. Upon receipt of the MLME-NETWORKCHANNELCONTROL.request primitive, the requesting STA transmits a (protected) Network Channel Control frame. The request frame is generated as follows:

— The Requester STA Address field is set to the MAC address of the NCC requesting STA.
— The Responder STA Address field is set to the MAC address of the NCC responding STA.
— The Reason Result Code is REQUEST, as defined in 9.4.6.4.
— The Number of Network Channel Control Triplets field, as defined in 9.4.6.4, gives the number of triplets of Operating Class, Channel Number, and Transmit Power Constraint fields.
— The Operating Class and Channel Number fields, with the values defined in E.1, together specify the channel frequency and channel bandwidth for WLAN channels selected by the NCC requesting STA.
— The Maximum Transmit Power field, as defined in 9.4.6.4, is set to the intended maximum transmit power in dBm for operation of the requesting STA.

11.42.7.3 NCC responding STA

An NCC responding STA may be a GDD enabling STA. An NCC responding STA employing RLQP may use the GAS protocol for its NCC procedure with a RLSS. Upon receipt of the MLME-GAS.response primitive with a ResponseInfo parameter value of Network Channel Control RLQP-element, the NCC responding STA transmits an RLQP-element with Info ID for NCC in the Query Response field in a GAS Initial Response frame or one or more GAS Comeback Response frames. The specific information items in the Query Response field of the GAS Initial Response frame are generated as follows:

— Requester STA Address field set to the MAC address of the NCC requesting STA.
— Responder STA Address field set to the MAC address of the NCC responding STA.
— Reason Result Code field = values SUCCESS, REFUSED, TOO_MANY_SIMULTANEOUS_REQUESTS, or Continuation frame as defined in 9.4.6.4.
— The Number of Network Channel Control Triplets field, as defined in 9.4.6.4, gives the number of triplets of Operating Class, Channel Number, and Transmit Power Constraint fields.

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— The Operating Class and Channel Number fields, with the values defined in E.1, together specify the channel frequency and channel bandwidth that the NCC responding STA has granted permission to the NCC requesting STA for WLAN operation.
— The Maximum Transmit Power field, as defined in 9.4.6.4, is set to maximum allowable transmit power in dBm of the requesting STA's WLAN operation.

An NCC responding STA may use an Network Channel Control frame or its protected dual to respond to another STA with NCC information. Upon receipt of the MLME-NETWORKCHANNELCONTROL.response primitive with NCC parameter value of NCC element, the NCC responding STA transmits a Network Channel Control frame containing an NCC element. The response frame is generated as follows:

— Requester STA Address field set to the MAC address of the NCC requesting STA.
— Responder STA Address field set to the MAC address of the NCC responding STA.
— Reason Result Code = values SUCCESS, REFUSED, TOO_MANY_SIMULTANEOUS_REQUESTS, or Continuation frame as defined in 9.4.6.4.
— The Number of Network Channel Control Triplets field, as defined in 9.4.6.4, gives the number of triplets of Operating Class, Channel Number, and Transmit Power Constraint fields.
— The Operating Class and Channel Number fields, with the values defined in E.1, together specify the channel frequency and channel bandwidth that the NCC responding STA has granted permission to the NCC requesting STA for WLAN operation.
— The Maximum Transmit Power field, as defined in 9.4.6.4, is set to maximum allowable transmit power in dBm of the requesting STA's WLAN operation.

11.42.8 White space map (WSM)

This subclause describes WSM procedures that can be used to obtain lists of available channels for operation of a GDD STA. STAs can use the WSM procedure specified here when dot11GDDActivated is true.

When dot11WhiteSpaceMapActivated is true, a GDD STA shall follow the procedures in this subclause.

If dot11WhiteSpaceMapActivated is true, a GDD enabling STA transmits a WSM, and a GDD dependent STA can transmit frames only on the available channels indicated in its valid WSM. GDBs can be different according to each regulatory domain and its regulatory requirements. A WSM Type field value of 1 indicates that the WSM is generated from the GDB and the WSM Information field of the WSM element specifies the available information for TVWS, which is country-specific and defined in 9.4.4.2.6.

A GDD enabling STA contacts a GDB to obtain the permissible frequencies and operating parameters before it begins its transmissions. After receiving the WSM information from a GDB, a GDD enabling STA operates in TVWS only in the frequencies that the GDB indicates are available. The GDD enabling STA generates WSMs based on the information from the GDB. It may update WSMs when STAs perform a measurement or receive a measurement report in which a primary service signal is measured on a channel, which is indicated as available from the GDB.

A WSM element includes a list of identified available channels and corresponding maximum allowed transmission powers for each available channel.

When a GDD enabling STA retrieves updated available frequency information, it is able to transmit individually addressed Protected WSM Announcement frames with an updated WSM element to its GDD dependent STAs.

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A GDD dependent STA receiving a WSM element operates on the channels indicated in the WSM. A GDD dependent STA that receives an updated WSM from its GDD enabling STA shall move its channel of operation if it is operating on a channel that has become unavailable in the updated WSM.

A GDD enabling STA transmits a WSM within a GDD Enablement Response frame, CAQ response frame, and WSM Announcement frame. A Device Class field of a WSM in a GDD Enablement Response frame and CAQ response frame is set to a value of a Device Class field in a GDD Enablement Request frame and Channel Availability Query frame, respectively. A Device Class field of WSM in a WSM Announcement frame is set to a value of the Device Class field of a WSM in a GDD Enablement Request frame.

The value of the Map version bits in the Map ID field is increased by (1 mod 127) whenever the GDD enabling STA transmits the updated WSM. The most recently received WSM is used by the WSM receiving STAs. A WSM with a Map version value of 127 indicates that the WSM is for reference only and it does not affect the GDD enablement states of a GDD dependent STA. If the Type bit in the Map ID field is set to 1, the following channel list is a full channel list; and if the Type bit is set to 0, the following channel list is a partial channel list. If a STA receives several WSMs with the same Map version and the Type bit is equal to 0, the STA should construct the whole channel list using the multiple WSMs having the same Map version.

GDD dependent STAs receiving a WSM should scan for existing BSSs on the available channels identified within received WSM element. In TVWS a GDD dependent STA receiving a WSM element shall operate on the channels indicated in the WSM. A GDD dependent STA that has previously received a WSM and that receives an updated WSM from its AP or GDD enabling STA shall move its channel of operation if it is operating on a channel that has become unavailable in the updated WSM.

If dot11WhiteSpaceMapActivated is true, then the enabled GDD dependent STA may send a Probe Request frame on any channel identified in the received WSM element. An AP that has dot11WhiteSpaceMapActivated true and that receives a Probe Request frame should respond with a Probe Response frame containing a WSM element.

11.43 Beacon RSSI

Upon receiving a Beacon frame, a STA measures the received signal strength of the Beacon frame and may store the result in dot11BeaconRssi. If the Beacon frame is received using multiple receive chains, the Beacon RSSI is averaged in linear domain over all active receive chains. The Beacon RSSI is reported in dBm. When operating in frequency bands below 6 GHz, the Beacon RSSI has an accuracy of ± 5 dB (95% confidence interval) within the specified dynamic range of the receiver. Beacon RSSI may be averaged over time using a vendor specific smoothing function.

11.44 Estimated throughput

A STA that has a value of true for dot11EstimatedServiceParametersInboundOptionImplemented is an estimated service parameters ESP Inbound STA. A STA that has a value of true for dot11EstimatedServiceParametersOutboundOptionImplemented is an estimated service parameters ESP Outbound STA. The term ESP STA refers to both ESP Inbound STAs and ESP Outbound STAs.

Entities outside the scope of this standard that control the traffic steering decision of a device might benefit by being able to predict the throughput that might be obtained through a link with a STA. Those same entities might also benefit from having the current estimate of throughput for network selection purposes (e.g., to allow comparison of an estimated throughout with existing throughout). The MLME-ESTIMATED-THROUGHPUT.request and MLME-ESTIMATED-THROUGHPUT.confirm primitives together provide an interface to allow such entities, operating through the SME, to obtain estimates of throughput for MSDUs sent between the STA that corresponds to the PeerMACAddress indicated in the parameter list of the MLME-ESTIMATED-THROUGHPUT.request primitive and this STA.

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When an MLME-ESTIMATED-THROUGHPUT.request primitive is received at the MLME, the MLME can use the parameters provided in the primitive plus the following information to create estimates of throughput per access category to deliver to the SME in the EstimatedThroughputOutbound and EstimatedThroughputInbound parameters of the MLME-ESTIMATED-THROUGHPUT.confirm primitive:

— RSSI measured during reception of Beacon or Probe Response frames transmitted by the STA that corresponds to the MAC entity with the MAC address equal to the PeerMACAddress in the MLME-ESTIMATED-THROUGHPUT.request primitive to this STA
— Number of spatial streams that is expected to be supported on the link between this STA and the STA
— Channel bandwidth
— Estimated air time fraction
— Block ack window size

The Estimated Inbound Air Time Fraction subfield value should be determined using the following assumptions:

— There is sufficient inbound data traffic, destined to the new STA joining the BSS and of the corresponding access category, available to fill the indicated air time
— The new STA joining the BSS does not generate outbound data traffic
— The Data PPDUs transmitted to the new STA joining the BSS are SU PPDUs, even though they might be transmitted as MU PPDUs
— The Data PPDUs transmitted to the new STA joining the BSS are transmitted in EDCA TXOPs of length equal to the duration indicated by dot11QAPEDCATableTXOPLimit for the corresponding access category or, if dot11QAPEDCATableTXOPLimit is 0, equal to the duration indicated by the Data PPDU Duration Target field
— Other than the addition of inbound data traffic destined to the new STA joining the BSS, the characteristics of traffic entering the transmit queues of the STAs accessing the medium do not change if the new STA joins the BSS
— The characteristics of non-EDCA transmissions on the medium (e.g., interferers) do not change if the new STA joins the BSS

The Estimated Outbound Air Time Fraction subfield value should be determined using the following assumptions:

— There is sufficient outbound data traffic, originating from the new STA joining the BSS and of the corresponding access category, available to fill the indicated air time
— No inbound data traffic to the new STA joining the BSS is generated
— The Data PPDUs transmitted by the new STA joining the BSS are SU PPDUs, even though they might be transmitted as MU PPDUs
— The Data PPDUs transmitted by the new STA joining the BSS are transmitted in EDCA TXOPs of length equal to the duration indicated by dot11EDCATableTXOPLimit for the corresponding access category or, if dot11EDCATableTXOPLimit is 0, equal to 5430 μs.
— Other than the addition of outbound data traffic destined to the new STA joining the BSS, the characteristics of traffic entering the transmit queues of the STAs currently accessing the medium do not change if the new STA joins the BSS
— The characteristics of non-EDCA transmissions on the medium (e.g. interferers) do not change if the new STA joins the BSS

If the MLME is incapable of determining a value for the EstimatedThroughputOutbound or EstimatedThroughputInbound parameter for any access category, then the MLME shall return a value of 0 for the value of that parameter for that access category in the MLME-ESTIMATED-THROUGHPUT.confirm primitive.

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If the AverageMSDUSizeOutbound parameter for an access category is equal to 0 in the MLME-ESTIMATED-THROUGHPUT.request primitive, the STA shall include a value of 0 in the EstimatedThroughputOutbound parameter for the corresponding access category in the MLME-ESTIMATED-THROUGHPUT.confirm primitive.

If the AverageMSDUSizeOutbound parameter for an access category is equal to –1 in the MLME-ESTIMATED-THROUGHPUT.request primitive, the STA may use any value for the average MSDU size used in calculating the estimated throughput to be included in the corresponding access category in the EstimatedThroughputOutbound parameter of the MLME-ESTIMATED-THROUGHPUT.confirm primitive, but should use a value of 1500 octets.

If the AverageMSDUSizeInbound parameter for an access category is equal to 0 in the MLME-ESTIMATED-THROUGHPUT.request primitive, the STA shall include a value of 0 in the EstimatedThroughputInbound parameter for the corresponding access category in the MLME-ESTIMATED-THROUGHPUT.confirm primitive.

If the AverageMSDUSizeInbound parameter for an access category is equal to –1 in the MLME-ESTIMATED-THROUGHPUT.request primitive, the STA may use any value for the average MSDU size used in calculating the estimated throughput to be included in the corresponding access category in the EstimatedThroughputInbound parameter of the MLME-ESTIMATED-THROUGHPUT.confirm primitive, but should use a value of 1500 octets.

An ESP Outbound STA should determine a value for EstimatedThroughputOutbound for each AC of a current or potential link with a STA using the equation found in R.7.

An ESP Inbound STA that is a non-AP STA may include a Request element that includes the element IDs of the Estimated Service Parameters Inbound element in transmitted Probe Requests. An ESP Outbound STA or a mesh STA may include a Request element that includes the element IDs of the Estimated Service Parameters Outbound element in transmitted Probe Requests.

An ESP Inbound STA that is an AP or an ESP Inbound STA that is a mesh STA shall include the Estimated Service Parameters Inbound element within Probe Response frames transmitted in response to a Probe Request frame that included a Request element that includes the element ID of the Estimated Service Parameters Inbound element. An ESP Inbound STA that is neither an AP nor a mesh STA may include the Estimated Service Parameters Inbound element within Probe Response frames transmitted in response to a Probe Request frame that included a Request element that includes the element ID of the Estimated Service Parameters Inbound element. An ESP Inbound STA may include the Estimated Service Parameters Inbound element within Probe Response frames transmitted in response to a Probe Request frame that did not include a Request element, or included a Request element that did not include the element ID of the Estimated Service Parameters Inbound element.

An ESP Outbound STA that is an AP or an ESP Outbound STA that is a mesh STA shall include the Estimated Service Parameters Outbound element within Probe Response frames transmitted in response to a Probe Request frame that included a Request element that includes the element ID of the Estimated Service Parameters Outbound element. An ESP Outbound STA that is neither an AP nor a mesh STA may include the Estimated Service Parameters Outbound element within Probe Response frames transmitted in response to a Probe Request frame that included a Request element that includes the element ID of the Estimated Service Parameters Outbound element. An ESP Outbound STA may include the Estimated Service Parameters Outbound element within Probe Response frames transmitted in response to a Probe Request frame that did not include a Request element, or included a Request element that did not include the element ID of the Estimated Service Parameters Outbound element.

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An ESP Inbound STA that is an AP or an ESP Inbound STA that is a mesh STA shall include the Estimated Service Parameters Inbound element within Beacon frames. An ESP Inbound STA that is not an AP may include the Estimated Service Parameters Inbound element within Beacon frames.

An ESP Outbound STA that is an AP or an ESP Outbound STA that is a mesh STA shall include the Estimated Service Parameters Outbound element within Beacon frames. An ESP Outbound STA that is not an AP may include the Estimated Service Parameters Outbound element within Beacon frames.

An ESP STA that transmits an Estimated Throughput element determines the value of the Data PPDU Duration Target field in a manner that is beyond the scope of this standard, but should use a value of 5430 μs. Because the STA transmitting the element is the STA that would be transmitting the PPDUs, that STA should know what parameters it would be likely to use for those transmissions, although variations in this estimate are possible due to the varying capabilities of the STAs receiving the PPDUs and due to dynamic channel conditions. The transmitting STA can adjust multiple transmission parameters to attempt to maintain the targeted duration despite the variations in the receiving STA and operating condition parameters.

11.45 Fast Initial Link Setup (FILS) procedures

11.45.1 General

This subclause describes the Fast Initial Link Setup (FILS) procedures that are used for FILS STAs. FILS is only supported in a non-DMG non-S1G infrastructure BSS.

A FILS STA is a QoS STA and shall set dot11QosOptionImplemented to true.

A FILS non-AP STA shall set the FILS Capability field to 1 in the Extended Capabilities element included in Probe Request and (Re)Association Request frames. A FILS non-AP STA may include FILS Request Parameters or AP-CSN elements in Probe Request frames. A FILS non-AP STA may set the Authentication Algorithm Number field to the value of Fast Initial Link Setup (FILS) authentication in the Authentication frame with the authentication transaction sequence number set to 1 (Authentication Request). A FILS AP advertises its FILS authentication and FILS higher layer setup capabilities by including a FILS Indication element, as specified in 9.4.2.182 and 11.45.4, in Beacon, Probe Response, and FILS Discovery frames.

A FILS AP shall set the FILS Capability field to 1 in the Extended Capabilities element and shall include the FILS Indication element in Beacon frames, Probe Response frames, and (Re)Association Response frames. A FILS AP may transmit FILS Discovery frames.

11.45.2 FILS Discovery frame generation and usage

11.45.2.1 FILS Discovery frame transmission

A FILS AP supporting FILS discovery may generate and transmit FILS Discovery frames. The FILS Discovery frame shall be transmitted at a mandatory PHY rate, and should be transmitted at a basic rate, but shall not be transmitted in a DSSS or HR/DSSS PPDU. The Address 1 field of the FILS Discovery frame shall be set to the broadcast address.

An AP may transmit a FILS Discovery frame as a non-HT duplicate PPDU. When a FILS Discovery frame is transmitted as a non-HT duplicate PPDU, its primary channel shall be indicated by its Primary Channel field.

If an AP transmits a FILS Discovery frame as a non-HT duplicate PPDU in an 80+80 MHz channel bandwidth, the Channel Center Frequency Segment 1 field shall be present in the FILS Discovery frame and shall be set to the channel center frequency of the frequency segment 1 for an 80+80 MHz VHT operating channel.

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A FILS AP should transmit FILS Discovery frame(s) in every beacon interval. The interval between the transmission of a Beacon frame and a subsequent FILS Discovery frame shall be no less than the interval indicated in dot11FILSFDFrameBeaconMinimumInterval. The transmission interval between subsequent FILS Discovery frames by an AP in a beacon interval shall be no less than the interval indicated in dot11FILSFDFrameBeaconMinimumInterval. If dot11FILSFDFrameBeaconMaximumInteval is not equal to 0, and if a Beacon frame or FD frame has not been transmitted by an AP for a period that is equal to dot11FILSFDFrameBeaconMaximumInterval, that AP shall queue for transmission a FD frame or a Beacon frame unless the next TBTT is within a duration indicated by the value of dot11FILSFDFrameBeaconMinimumInterval.

An AP may use the FILS Minimum Rate subfield in the FILS Discovery frame to indicate the minimum rate to be used by the AP and FILS STAs in subsequent transmissions between the AP and FILS STAs.

An AP may include its RSN information in the FD RSN Information subfield of the FILS Discovery frame as described in 12.11.2.2.

11.45.2.2 FILS Discovery frame reception

If a FILS STA has the ReportingOption parameter present in the MLME-SCAN.request primitive and it is not equal to IMMEDIATE or CHANNEL_SPECIFIC, then the STA shall follow the procedures indicated in 11.1.4.1 and not the procedures provided in this clause.

If an AP has indicated the FILS Minimum Rate in the FILS Minimum Rate subfield of a FILS Discovery frame, a scanning FILS STA that receives such a FILS Discovery frame shall use a data rate that is equal or higher than the indicated FILS Minimum Rate in subsequent transmissions between the AP and the FILS STA.

A scanning FILS STA that receives a FILS Discovery frame compares the received SSID or short SSID in the FILS Discovery frame with the SSID parameter or SSID list provided to the STA previously in an MLME-SCAN.request primitive. If the STA has the ReportingOption parameter present in the MLME-SCAN.request primitive and equal to IMMEDIATE and if the SSID in the FILS Discovery frame matches the SSID parameter or one of the SSIDs in the SSID list, the STA shall issue an MLME-SCAN.confirm primitive with the information obtained from the received FILS Discovery frame immediately after the reception of the FILS Discovery frame, with the ResultCode equal to INTERMEDIATE_SCAN_RESULT. If the STA has the ReportingOption parameter in the MLME-SCAN.request primitive equal to CHANNEL_SPECIFIC and if the SSID in the FILS Discovery frame matches the SSID parameter or one of the SSIDs in the SSID list, the STA shall issue an MLME-SCAN.confirm primitive with the information obtained from the received FILS Discovery frame after the STA has completed the scanning of the current channel, with the ResultCode equal to INTERMEDIATE_SCAN_RESULT.

If the received FILS Discovery frame contains the AP-CSN subfield as defined in 11.1.4.3.11 and the non-AP STA maintains previously obtained BSS Configuration Parameter Sets, the non-AP STA shall use the received AP-CSN information as follows:

— The STA shall check if the BSSID in the received FILS Discovery frame is equal to a BSSID in the previously obtained BSS Configuration Parameter Sets.
— If an equal BSSID is found, the STA compares the AP-CSN value in the received FILS Discovery frame to the AP-CSN value associated with the BSSID in the BSS Configuration Parameter Sets.
— If the AP-CSN values are not equal, a FILS non-AP STA may send an individually addressed Probe Request frame including an AP-CSN element, with the value of the AP-CSN associated with the BSSID in the BSS Configuration Parameter set in the non-AP STA.

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— If the AP-CSN values are equal, then the non-AP STA may use the information contained in the BSS Configuration Parameter Set to initiate one or more FILS procedures (as defined in 11.45.3, 11.45.4, and 11.45.5), without waiting for next Beacon frame or Probe Response frame.

— If the non-AP STA has not successfully associated with an AP using the above procedures, it shall follow the procedures specified in 11.3.4.2 and 11.3.4.3.

If a received FILS Discovery frame contains RSN information in the FD RSN Information subfield, a FILS STA may conduct FILS authentication with the AP that transmitted the FILS Discovery frame as described in 12.11.2.

A scanning FILS STA that receives a FILS discovery frame can compute the next TBTT based on the Timestamp subfield of the FILS Discovery Information field (see Figure 9-900 and beacon interval as follows:

$$\text{Next TBTT} = \lceil \text{Timestamp} / (\text{Beacon Interval} \times 1024) \rceil \times (\text{Beacon Interval} \times 1024)$$

11.45.3 Higher layer setup during (re)association procedure

11.45.3.1 General

Higher layer setup, such as IP layer setup, may be performed during a STA's FILS (re)association procedure. Two mechanisms are provided for higher layer setup. One is the higher layer protocol (HLP) encapsulation. The HLP encapsulation, described in 11.45.3.2, shall be supported by all FILS STAs. The other mechanism is the FILS IP address configuration. This is optional for FILS STAs and described in 11.45.3.3. FILS IP address configuration is used to reduce the overhead caused by using the DHCP for the IP address assignment. However, FILS IP Address Assignment method provides a subset of features supported by the DHCP. In Beacon and Probe Response frames the AP advertises support of the FILS IP address configuration by setting the FILS IP Address Configuration bit to 1 in the FILS Indication element (9.4.2.182).

NOTE—The non-AP STA can use the following methods to obtain an IP address: 1) FILS IP address configuration, if supported by the AP. 2) Encapsulating higher layer protocols during association.

Higher layer setup information in (Re)Association Request/Response frames shall be protected by the authenticated encryption with associated data (AEAD) scheme (12.11.2.7).

11.45.3.2 Higher layer protocol encapsulation

The FILS HLP Container element (9.4.2.183) is used for encapsulating higher layer protocol (HLP) packets.

If a non-AP STA uses higher layer protocol encapsulation, the non-AP STA shall construct a FILS HLP Container element for each HLP packet. The non-AP STA may put multiple FILS HLP Container elements into a (Re)Association Request frame as long as they fit in the MMPDU size limit. If the size of the (Re)Association Request frame exceeds the maximum MMPDU size, the non-AP STA shall remove the last FILS HLP Container element from the (Re)Association Request frame until the size of the (Re)Association Request frame does not exceed the maximum MMPDU size. The non-AP STA shall send the HLP packets contained in the removed FILS HLP Container elements as Data frames after association. Then the non-AP STA transmits a (Re)Association Request frame including all of the subjected FILS HLP Container elements. The HLP packet in the FILS HLP Container element can contain any MSDU format defined in 5.1.4. The FILS HLP Container element may be fragmented as described in 10.28.11 if required. The encapsulation procedure is as follows:

a) The non-AP STA fills FILS HLP Container element(s) with the destination MAC address, the source MAC address of the HLP packet and the HLP packet in MSDU format (see 5.1.4). The source MAC address shall be the MAC address of the non-AP STA.

b) The non-AP STA includes the FILS HLP Container element(s) into the (Re)Association Request frame.

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If the AP receives a (Re)Association Request frame including FILS HLP Container element(s), the AP decapsulates the HLP packet(s) but shall not transfer the HLP packet(s) until the key confirmation (see 12.11.2.6) is successfully completed. After successful key confirmation, the AP forwards the HLP packet(s) to the upstream network or BSS according to the destination MAC address of the HLP packet(s). The order of forwarding the HLP packets shall be the same as the order of the FILS HLP Container elements in the (Re)Association Request frame. If the key confirmation fails, the AP discards the HLP packet(s). The AP may filter HLP packets based on rules that are out of scope for this standard. The packet decapsulation procedure for each FILS HLP Container element is as follows:

1) The AP extracts the destination MAC address, the source MAC address and the HLP packet from the FILS HLP Container element;
2) The AP verifies that the extracted source MAC address is equal to the source MAC address of the (Re)Association Request frame. If these are different, the AP shall discard the FILS HLP Container element;
3) The AP constructs the frame in appropriate format to deliver the HLP packet to the upstream network or BSS by using the extracted destination MAC address, source MAC address, and HLP packet.

The AP should wait to a transmit (Re)Association Response frame until dot11HLPWaitTime has elapsed after receiving a (Re)Association Request frame. If, before it transmits a (Re)Association Response frame, the AP receives one or more HLP packets from the upstream network or BSS that have the non-AP STA's MAC address or a group address as the destination address, the AP transmits each HLP packet in a different FILS HLP Container element in the (Re)Association Response frame. The order of the FILS HLP Container elements in the (Re)Association Response frame is same as the order of receiving the HLP packets. If the AP receives HLP packets for the non-AP STA after transmitting a (Re)Association Response frame, the AP transmits the HLP packets as Data frames. If, before it transmits a (Re)Association Response frame, the AP does not receive any HLP packets from the upstream network or BSS that have the non-AP STA's MAC address or a group address as the destination address, the AP shall not transmit any FILS HLP Container elements in the (Re)Association Response frame. The status code in the (Re)Association Response frame is not effected by the presence or absence of a FILS HLP Container element. The packet encapsulation procedure for each FILS HLP Container element is as follows:

- The AP sets the fields of the HLP Container element as follows:
  - The Destination MAC Address field is set to the destination MAC address of the received HLP packet, which is the MAC address of the non-AP STA or a group address.
  - The Source MAC Address field is set to the source MAC address of the received HLP packet.
  - The HLP Packet field is set to the HLP packet in MSDU format (see 5.1.4).
- The AP includes the FILS HLP Container elements into the (Re)Association Response frame.

If the non-AP STA receives a (Re)Association Response frame with one or more FILS HLP Container elements, the non-AP STA performs key confirmation (12.11.2.6) first. After successful key confirmation, the non-AP STA shall generate an MA-UNITDATA.indication primitive for each HLP packet. The order of generating MA-UNITDATA.indication primitive of the HLP packets shall be the same as the order of the FILS HLP Container elements in the (Re)Association Response frame. If the key confirmation fails, the non-AP STA shall discard the HLP packet(s). The packet decapsulation procedure for each FILS HLP Container element is as follows:

- The non-AP STA extracts the destination MAC address, source MAC address, and the HLP packet.
- The non-AP STA shall verify that the extracted destination MAC address is equal to the MAC address of the non-AP STA or group addresses. If the destination MAC address is not for the non-AP STA, the non-AP STA shall discard the FILS HLP Container element.

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— The non-AP STA shall generate an MA-UNITDATA.indication primitive with the following parameters:
  1) source address: The extracted source MAC address
  2) destination address: The extracted destination MAC address
  3) routing information: all
  4) data: The extracted HLP packet
  5) reception status: success
  6) priority: Contention
  7) service class: QoSAck when the destination address is an individual address. QoSNoAck when the destination address is not an individual address

For example, the above procedure can be used for IP address configuration. If the network uses DHCPv4/v6 (IETF RFC 2131, IETF RFC 3315), the FILS HLP Container element can carry DHCPv4/v6 packets. If the network uses IPv6 stateless address autoconfiguration (IETF RFC 4862), it can carry Router Solicitation and Router Advertisement packets (IETF RFC 4861).

11.45.3.3 FILS IP address configuration

In order to request an IP address, a STA may include a FILS IP Address Assignment element in the (Re)Association Request frame or FILS Container frame that it sends to the AP.

The AP may send the IP address assigned to the STA in a FILS IP Address Assignment element (9.4.2.184) that is included in a (Re)Association Response frame or a FILS Container frame. Methods for determining the IP address to be assigned to a STA are out of scope in this standard.

When the AP receives a (Re)Association Request frame including a FILS IP Address Assignment element or a FILS Container frame, the AP initiates a procedure to assign an IP address for the STA using a mechanism that is outside the scope of this standard.

If the STA has included a FILS IP Address Assignment element in the (Re)Association Request frame, then the AP may respond to the STA in one of the following ways:

— If the AP is able to assign an IP address in the (Re)Association Response frame, then the AP sets the IP address assignment pending flag in the IP Address Response Control field of the FILS IP Address Assignment element to 0 and includes the IP Address Data field as defined in 9.4.2.184 in the (Re)Association Response frame. For IPv6 addresses, an AP performs Duplicate Address Detection (IETF RFC 4862) before assigning an IPv6 address for the STA.
— If the AP is unable to assign an IP address in the (Re)Association Response frame, then the AP sets the IP address assignment pending flag in the IP Address Response Control field of the FILS IP Address Assignment element to 1 and sets the IP address request timeout to 0 in (Re)Association Response frame.
— If the AP needs more time to assign an IP address, the AP sets the IP address assignment pending flag in the IP Address Response Control field of the FILS IP Address Assignment element to 1 and sets the IP address request timeout to the maximum estimated time in the unit of seconds, within which the AP tries to assign an IP address to the requesting STA in the (Re)Association Response frame. When the AP is ready with an IP address within IP address request timeout period, then AP shall send the IP address to the STA using a FILS Container frame. If the STA does not receive the FILS Container frame containing IP assignment within IP address request timeout period, then the STA may initiate IP address assignment procedure using a FILS Container frame or mechanisms that are out of scope of this specification. If a STA has initiated an IP address assignment procedure using mechanisms that are out of scope of this specification, due to the expiry of the timeout period, and subsequently receives an FILS container frame containing an IP assignment, it shall discard the IP address assignment received in the FILS container frame.

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The STA may use the MLME-FILSContainer.request primitive to request its IP address again to extend its lifetime and include the requested IP address in an IP Address Assignment element in a FILS Container frame. If the STA has included an IP Address Assignment element in the FILS Container frame, then the AP may respond to the STA using the MLME-FILSContainer.response primitive in one of the following ways:

— If the AP is able to assign an IP address immediately, then the AP sets the IP address assignment pending flag in the IP Address Response Control field of the FILS IP Address Assignment element to 0 and includes the IP Address Data field as defined in 9.4.2.184 in the FILS Container frame.

— If the AP is unable to assign an IP address, then the AP sets the IP address assignment pending flag in the IP Address Response Control field of the FILS IP Address Assignment element to 1 and sets the IP address request timeout to 0 in the FILS Container frame.

— If the AP needs more time to assign an IP address, then the AP sets the IP address assignment pending flag in the IP Address Response Control field of the FILS IP Address Assignment element to 1 and sets the IP address request timeout to the maximum estimated time in the unit of seconds within which it (AP) tries to assign an IP address to the requesting STA in FILS Container frame. When the AP is ready to assign an IP address within IP address request timeout period, then the AP shall send the IP address to the STA using a FILS Container frame. If the STA does not receive the FILS Container frame containing an IP assignment within the IP address request timeout period, then the STA may initiate an IP address assignment procedure using mechanisms that are out of scope of this specification. If a STA has initiated an IP address assignment procedure using mechanisms that are out of scope of this technical specification, due to the expiry of the timeout period, and subsequently receives an FILS container frame containing an IP assignment, it shall discard the IP address assignment received in the FILS container frame.

11.45.4 FILS authentication and higher layer setup capability indications

A FILS AP shall include a FILS Indication element in Beacon and Probe Response frames, and may include a FILS Indication element in FILS Discovery frames. The FILS Indication element indicates properties of the FILS authentication protocol used and whether the AP performs IP address assignment.

An AP can indicate up to 7 realms that indicate the domain names of the server that the AP is capable of participating in an EAP-RP exchange with (see IETF RFC 6696). The realm of an EAP-RP server is the realm portion of the keyName-NA as defined in IETF RFC 6696. For each of the realms, the FILS Indication element carries a 2-octet hash of the network realm. The hash of the realm (IETF RFC 1035 compliant) is computed as follows:

H = L(SHA256(ToLowerCase(D),0,16))

where

H	is the hashed realm name
L	is defined in 1.5
ToLowerCase	is the function that converts upper case characters to lower case
D for a non-AP STA	is NAI Realm used of the EAP-RP server used in EAP-RP authentication

NOTE—Internationalized domain names are first converted to an IETF RFC 1035 compliant ASCII form using the operations defined in IETF RFC 3490.

11.45.5 DILS

11.45.5.1 General

To limit the number of STAs that attempt link setup concurrently, the DILS procedure provides a method for an AP to moderate the rate that non-AP STAs transmit Authentication and (Re)Association Request frames to the AP.

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11.45.5.2 AP procedures for DILS

If dot11DILSImplemented is true, a FILS AP may include the DILS element in Beacon and Probe Response frames, and set the DILS Duration and the optional fields to limit the number of STAs that are allowed to attempt link setup concurrently.

The AP may set a DILS Duration field reserved for FILS at a high priority, and may set the FILS User Priority field, MAC Address Filter field, and/or Vendor Specific field to specify a subset of STAs that may attempt fast initial link setup during the reserved DILS Duration field specified in the element.

An AP may set the FILS User Priority B0, B1, and B2 to 1 to indicate FILS without additional delays for the STAs based on the queued type of traffic as specified in 9.4.2.186.

An AP may set the Bit Pattern Length subfield in the MAC Address Filter field to decide the number of bits used for MAC address filtering, and specify the bit pattern in the Bit Pattern subfield to allow STAs with specific MAC addresses to transmit fast initial link setup frames immediately. The more bits used for MAC address filtering, the fewer STAs are allowed to transmit a fast initial link setup frame immediately. How an AP sets the bit pattern in the Bit Pattern subfield is beyond the scope of this specification.

An AP may set one or more vendor specific criteria in a Vendor Specific field to allow a set of STAs that satisfy the specified criteria to transmit fast initial link setup frames to the AP without additional delays.

11.45.5.3 Non-AP STA procedures for DILS

When a FILS non-AP STA with dot11DILSImplemented value of true receives a Beacon or Probe Response frame that includes a DILS element, the non-AP STA shall check the DILS Flags field to determine if it satisfies the condition specified in each and every optional field that is present. If the non-AP STA satisfies all of the conditions specified in the present optional fields, the non-AP STA shall proceed with a FILS procedure with the AP without additional delays. Otherwise, the non-AP STA shall not associate with the AP until the time specified in the first received DILS Duration field elapses; when it has elapsed the STA may perform link setup with the AP.

When the FILS User Priority field is present, the FILS User Priority condition is satisfied if the non-AP STA has frames with user priority 4–7 in the transmission queue(s) and the FILS User Priority B0 is 1, or if the non-AP STA has frames with user priority 0–3 in their transmission queue(s) and the FILS User Priority B1 is 1, or if the non-AP STA has no frame in their transmission queue(s) and the FILS User Priority B2 is 1. If a STA has frames in multiple queues with different priorities, the STA attempts to associate with the AP based on its highest priority queue.

Any combination of bit values for B0, B1, and B2 is allowed. For instance, B2B1B0=011 indicates that only STAs with traffic are allowed for FILS at a high priority and those STAs with no Data frames in their queues are not allowed. A value of B2B1B0=000 indicates that no FILS station is allowed to join the AP in the next specified time interval.

If a MAC Address Filter field is present, the non-AP STA shall compare its MAC address to the Bit Pattern subfield in the MAC Address Filter field. If the value of the last MAC_ADDR[(47-n+1):47] bits of the non-AP STA's MAC address matches the value of the bits used for MAC address filtering in the Bit Pattern subfield, where n is specified in the Bit Pattern Length subfield, the MAC address condition is satisfied.

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11.46 Support for energy limited STAs

An energy limited (EL) STA is an S1G STA with dot11S1GELOperationActivated equal to true that is powered by a small energy supply and is limited in terms of its ability to transmit or receive in certain intervals of time. An EL STA may indicate these limitations to an S1G STA that intends to communicate with it by using the signaling described in this subclause. The procedure described below increases the likelihood that frame exchanges between these two STAs are performed successfully.

An EL STA receiving MLME-ELOPERATION.request primitive shall include an EL Operation element in Probe Request, TDLS Setup Request, TDLS Setup Response, and (Re)Association Request frames and may send EL Operation frames.

An S1G AP that sets the STA Type Support in the S1G Capabilities element to 2 (i.e., supports only non-sensor STAs), as described in 10.63, may refuse (re)association or can disassociate an EL STA. The S1G AP that refuses (re)association or disassociates an EL STA shall set the Status Code field in the (Re)Association Response frame or in the Disassociation frame to ENERGY_LIMITED_OPERATION_NOT_SUPPORTED.

Upon receipt of an MLME-ELOPERATION.indication primitive, an S1G STA shall maintain two timers, ELMaxAwakeTimer and ELRecoveryTimer according to the procedures defined in 10.62.

11.47 DCS procedure for CDMG BSS

11.47.1 General

Radio regulations that apply to the 60 GHz band in China allow radio local area networks (RLANs) operating in the Chinese 60 GHz band to operate on a 1.08 GHz or a 2.16 GHz channel, which requires a mechanism to coordinate the allocation of operating channel between two CDMG infrastructure BSSs or CDMG PBSSs. This subclause describes such a mechanism, referred to as dynamic channel selection (DCS). This mechanism is used to improve the flexibility and channel efficiency when RLANs operate in Chinese 60 GHz frequency band, in case that there is no available channel or the bandwidth (e.g., 1.08 GHz) of idle channel(s) cannot satisfy the operating requirements of RLANs. This subclause describes the DCS procedures that can be used to satisfy CDMG regulatory requirements.

Figure 11-60 illustrates a number of use cases for DCS procedure:

— In cases 1, 2, and 3, a CDMG AP or PCP that intends to start a new BSS can request one of the two BSSs operating on two occupied 1.08 GHz channels to move to one of the two idle channels. Case 1 for example, the BSS operating on channel 36 can move to channel 37; or the BSS operating on channel 37 can move to channel 35. Then a 2.16 GHz channel 2 or 3 is idle, and the CDMG AP or PCP can start its BSS on it.

— In cases 4 and 5, a CDMG AP or PCP that intends to start a new BSS can request one or two BSSs operating on a 2.16 GHz channel to move to operate on a 1.08 GHz channel. Case 4 for example, the BSS operating on the channel 2 (2.16 GHz) can move to the channel 38 (1.08 GHz). Then the 2.16 GHz channel 2 is idle, and the CDMG AP or PCP can start its BSS on it.

A CDMG STA is DCS capable if the value of dot11DynamicChannelTransferActivated is true. A CDMG DCS capability STA advertises the capability by including the DCS capability element in DMG Beacon, (Re)Association Request, (Re)Association Response, Information Request, Information Response, Probe Request, Probe Response, Announce, DCS Measurement Request, DCS Measurement Response, DCS Request, and DCS Response frames.

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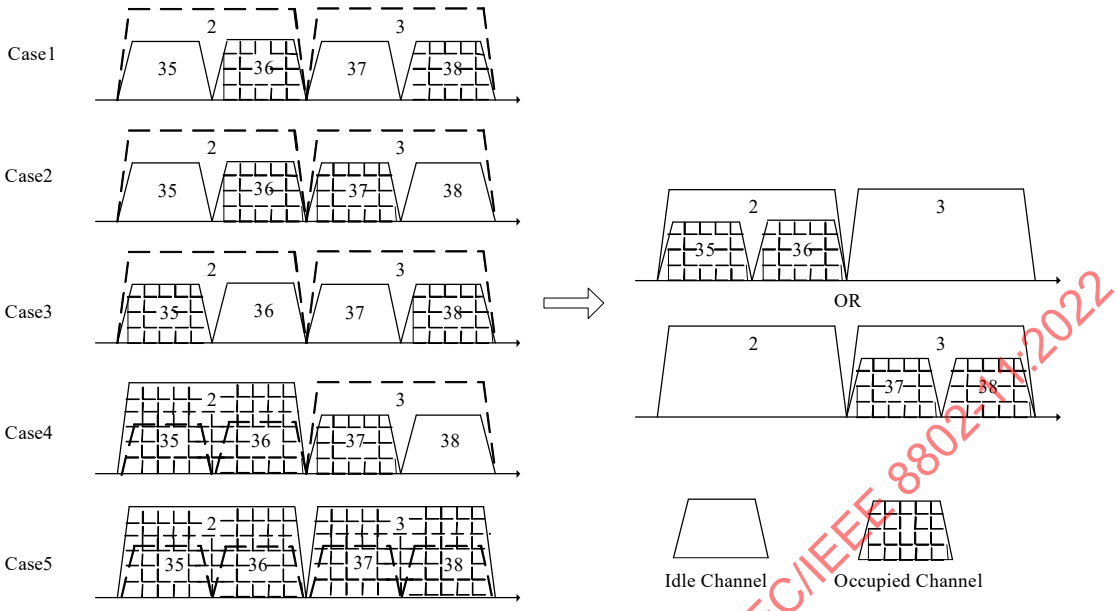

Figure 11-60—Examples of using DCS procedure

A CDMG AP or PCP shall use the DCS procedures defined in 11.47.1 to 11.47.6 if the value of dot11DynamicChannelTransferActivated is true. The value of dot11DynamicChannelTransferActivated shall be set to true when a CDMG AP or PCP requires DCS procedures. The DCS procedures provide for the following:

- Assessing current channel condition (see 11.47.2)
- Requesting of measurements for new channel for the DCS responder BSS (see 11.47.3)
- Reporting of the result of measurements (see 11.47.4)
- Requesting existing BSS to migrate to a new channel (see 11.47.5)
- Operating on the target channel (see 11.47.6)

Figure 11-61 depicts an example of the procedure of the dynamic channel selection. In the figure, the parameter n corresponds to the number of DCS Measurement Request and DCS Measure Response frame exchanges until the requirement of operating channel or bandwidth for the DCS requester AP or PCP is met. The detailed procedure of dynamic channel selection is described in 11.47.2 to 11.47.6.

Although the DCS procedure is defined for CDMG STAs according to the Chinese regulations, it can be used by other STAs defined in IEEE 802.11 specification to negotiate operating channels between BSSs.

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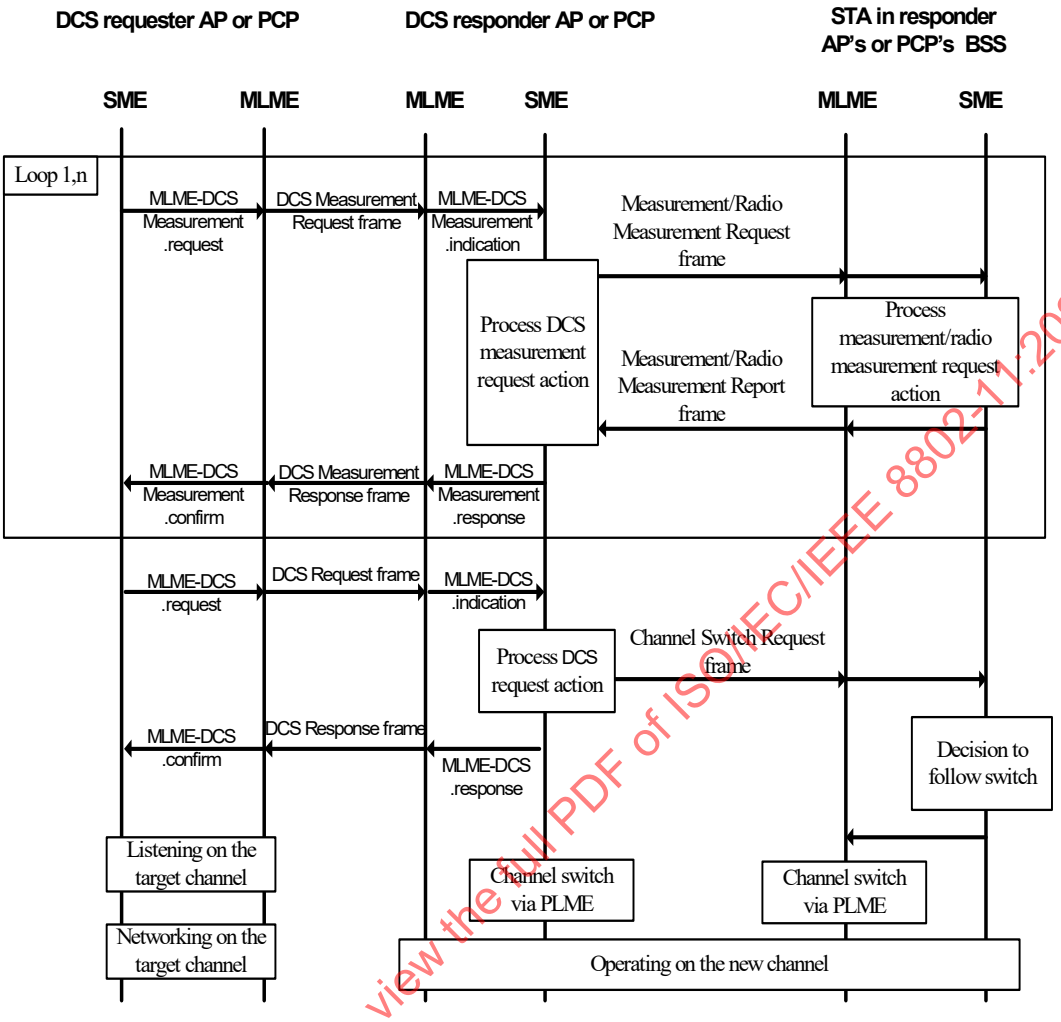

Figure 11-61—Procedure of dynamic channel selection

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11.47.2 Assessing current channel condition

A DCS requester AP or PCP that intends to start a new BSS can assess an available channel passively by performing a channel scan or clear channel assessment (CCA) or by receiving one or more DMG Beacon frames sent by one or more APs or PCPs within one or more existing infrastructure BSSs or PBSSs. If the available channel bandwidth could not satisfy the operating requirements for RLANs, its AP or PCP can use the DCS procedure to request one or more existing infrastructure BSSs or PBSSs to move to a new operating channel.

11.47.3 Requesting measurements for new operating channel

A DCS requester AP or PCP shall send a DCS Measurement Request frame (see 9.6.7.37) to a DCS responder AP or PCP to request one or more STAs in the DCS responder AP's or PCP's BSS to measure all other channels within its supported operating class if the DCS Measurement Request Mode field is equal to 1 or to measure one or more channels indicated by the Optional Subelements field if the DCS Measurement Request

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Mode field is equal to 0. The responder AP or PCP can decide to measure one or more channels requested by the DCS requester AP or PCP after receiving the DCS measurement request. The algorithm to choose the channel to be measured is beyond the scope of this standard.

A DCS responder AP or PCP can use radio measurement procedures (see 11.10) to perform channel measurement.

11.47.4 Reporting measurements

After receiving the results of channel measurement from all STAs, the DCS responder AP or PCP shall transmit a DCS Measurement Response frame (see 9.6.7.38) to the DCS requester AP or PCP to report the results for the received DCS Measurement Request frame. The Measurement Report Mode field is set to 0 to indicate that there is no clear channel to which the DCS responder AP's or PCP's BSS to move within the operating class specified in the following Operating Class field, or the DCS responder AP or PCP has declined the DCS measurement request. The Measurement Report Mode field is set to 1 to indicate that all other channels within the operating class specified in the following Operating Class field are available for the DCS responder AP's or PCP's BSS. The Measurement Report Mode field is set to 2 to indicate that the clear channel that is available to the DCS responder AP's or PCP's BSS is indicated in the Optional Subelements field in the DCS Measurement Response frame.

A DCS Measurement Response frame shall contain the same value of the Dialog Token field as in the corresponding DCS Measurement Request frame.

A DCS responder AP or PCP can assess a DCS measurement request against its capabilities and the impact on its BSS's performance. The DCS responder AP or PCP may refuse the DCS measurement request for some reason such as the BSS is busy. The reasons for refusing a DCS measurement request are beyond the scope of this standard but may include reduced quality of service, unacceptable power consumption, measurement scheduling conflicts, or other significant factors.

11.47.5 Requesting existing BSS to migrate to a new channel

In order to operate on an occupied channel, a DCS requester AP or PCP should use the information of Supported Operating Class and the results of measurements undertaken by a DCS responder AP or PCP and other STA(s) within the same BSS to assist the selection of a new available channel for the DCS responder AP's or PCP's BSS. The algorithm to choose a new channel is beyond the scope of this standard, but shall satisfy applicable regulatory requirements, including uniform spreading rules and channel testing rules. A DCS requester AP or PCP shall request a DCS responder AP or PCP and other STA(s) in its BSS to migrate to a new available channel indicated in the received DCS Measurement Response frame by transmitting a DCS Request frame (see 9.6.7.39) to the DCS responder AP or PCP.

The decision to switch to a new operating channel in a BSS shall be made by a DCS responder AP or PCP. If the DCS responder AP or PCP accepts the DCS request to change the operating channel after receiving a DCS Request frame, the DCS responder AP or PCP shall transmit a DCS Response frame (see 9.6.7.40) to the DCS requester AP or PCP to confirm the received DCS request and then shall inform associated STAs that the AP or PCP is moving to a new channel and maintain the association by advertising the switch using Channel Switch Announcement elements or Extended Channel Switch Announcement element in one or more DMG Beacon frames, Probe Response frames, and Channel Switch Announcement frames until the intended channel switch time.

A DCS responder AP or PCP can assess a DCS request against its capabilities and the impact on its BSS's performance. A DCS request may be refused by a DCS responder AP or PCP for some reason such as the BSS is busy. The reasons for refusing a DCS request are beyond the scope of this standard but may include reduced quality of service, unacceptable power consumption, measurement scheduling conflicts, or other significant factors.

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11.47.6 Networking on the target channel

A DCS requester AP or PCP shall listen on the target channel after the intended channel switch time indicated by the Channel Switch Count field in a DCS Response frame. Once the PHY-CCA.INDICATION primitive indicates that the target channel is idle, the DCS requester AP or PCP can operate on the target channel with other STA(s) in its BSS.

11.48 CMMG BSS operation

11.48.1 Basic CMMG BSS functionality

A CMMG STA has dot11CMMGOptionImplemented equal to true.

A STA that is starting a CMMG BSS shall be able to receive and transmit at each of the <CMMG-MCS, NSS> tuple values indicated by the Basic CMMG-MCS and NSS Set field of the CMMG Operation parameter of the MLME-START.request primitive and shall be able to receive at each of the <CMMG-MCS, NSS> tuple values indicated by the Supported CMMG-MCS and NSS Set field of the CMMG Capabilities parameter of the MLME-START.request primitive.

A STA that is a CMMG AP or a CMMG mesh STA declares its channel width capability in the Supported Channel Width Set subfield of the CMMG Capabilities element CMMG Capabilities Info field as described in Table 9-313.

A STA that is a CMMG AP or a CMMG mesh STA shall set the Channel Width subfield in the CMMG Operation element CMMG Operation Information field to indicate the BSS operating channel width as defined in Table 11-28.

Table 11-28—CMMG BSS operating channel width

CMMG Operation element Channel Width field	BSS operating channel width (MHz)
0	540
1	1080

A CMMG STA that is a member of a CMMG BSS shall not transmit a 540 MHz CMMG PPDU on a channel other than the primary 540 MHz channel of the BSS, except for a 540 MHz CMMG PPDU transmission on an off-channel TDLS direct link as constrained by 11.2.

A CMMG STA shall not transmit to a second CMMG STA using a bandwidth that is not indicated as supported in the CMMG Capabilities element received from that CMMG STA.

11.48.2 Channel selection methods for a CMMG BSS

Before a STA starts a CMMG BSS, the STA shall perform a minimum of dot11CMMGOBSSScanCount OBSS scan operations to search for existing BSSs (see 11.38.3).

If an AP or a mesh STA starts a CMMG BSS that occupies some or all channels of any existing BSSs, the AP or mesh STA may select a primary channel of the new CMMG BSS that is identical to the primary channel of any one of the existing BSSs.

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If an AP or a mesh STA selects a primary channel for a new CMMG BSS with a 1080 MHz operating channel width from among the channels on which no beacons are detected during the OBSS scans, then the selected primary channel meets the following conditions:

— It shall not be identical to the secondary 540 MHz channel of any existing BSSs with a 1080 MHz operating channel width.

NOTE—An AP or a mesh STA operating a CMMG BSS with a 1080 MHz operating channel width, on detecting an OBSS whose primary channel is the AP's or the mesh STA's secondary 540 MHz channel, might switch to 540 MHz BSS operation and/or move to a different channel.

11.48.3 Scanning requirements for CMMG STAs

An OBSS scan operation is a passive or active scan of a set of channels that are potentially affected by CMMG BSS operation (see 11.1). Each channel in the set may be scanned more than once during a single OBSS scan operation. OBSS scans are performed by STAs that start a CMMG BSS.

During an individual scan within an OBSS scan operation, the minimum per-channel scan duration is dot11OBSSScanPassiveDwell TUs (for a passive scan) or dot11OBSSScanActiveDwell TUs (for an active scan). During an OBSS scan operation, each channel in the set is scanned at least once per dot11BSSWidthTriggerScanInterval seconds, and the minimum total scan time (i.e., the sum of the scan durations) per channel within a single OBSS scan operation is dot11OBSSScanPassiveTotalPerChannel TUs (for a passive scan) or dot11OBSSScanActiveTotalPerChannel TUs (for an active scan).

NOTE—The values provided in the previous paragraph are minimum requirements. For some combinations of parameter values, the minimum might be exceeded for some parameters in order to meet the minimum value constraints of other parameter.

11.48.4 Channel switching methods for a CMMG BSS

A CMMG AP announces a switch of operating channel by either of the following:

— Using the Channel Switch Announcement element, Channel Switch Announcement frame, or both, following the procedure described in 11.8.

— Using the Extended Channel Switch Announcement element, Extended Channel Switch Announcement frame, or both, following the procedure described in 11.9).

A CMMG mesh STA announces a switch attempt of operating channel by either of the following:

— Using the Channel Switch Announcement element, Channel Switch Announcement frame, or both, following the procedure described in 11.8.8.4.

— Using the Extended Channel Switch Announcement element, Extended Channel Switch Announcement frame, or both, following the procedure described in 11.9.

A CMMG AP or a CMMG mesh STA may also announce a switch of operating channel width, a new Country String field (possibly including a new Operating Class table number), new operating classes, or new TPC parameters for the BSS that come into effect at the same time as the switch of operating channel.

NOTE 1—Other means to switch the operating channel width are described in 11.40.

The New Channel Number field in the Channel Switch Announcement element, Extended Channel Switch Announcement element, Channel Switch Announcement frame, or Extended Channel Switch Announcement frame identifies the primary 540 MHz channel after the switch. The New Channel Number field is set to the value that dot11CurrentPrimaryChannel (see 25.10) has after the switch.

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If a Channel Switch Announcement element in a Beacon frame or Probe Response frame is used to announce a switch to a 540 MHz operating channel width, then the Wide Bandwidth Channel Switch subelement in a Channel Switch Wrapper element shall not be present in the same frame.

If an Extended Channel Switch Announcement element in a frame or an Extended Channel Switch Announcement frame is used to announce a switch to a 540 MHz operating channel width, then the Wide Bandwidth Channel Switch subelement shall not be present in the same frame.

NOTE 2—The indicated operating class within the Extended Channel Switch Announcement element or frame is used to differentiate between a BSS operating channel width of 540 MHz and a BSS operating channel width greater than 540 MHz as well as indicate the location of the secondary 540 MHz channel. When switching to a 540 MHz operating channel width, the operating class indicated within the Extended Channel Switch Announcement element or frame has a channel spacing of 540 MHz. When switching to an operating channel width greater than 540 MHz, the operating class indicated within the Extended Channel Switch Announcement element or frame has a channel spacing of 1080 MHz.

If a Channel Switch Announcement element is used in a Beacon or Probe Response frame to announce a switch to a 1080 MHz operating channel width, then the Wide Bandwidth Channel Switch subelement in the Channel Switch Wrapper element shall also be present in the same frame.

If an Extended Channel Switch Announcement element is used in a Beacon or Probe Response frame to announce a switch to a 1080 MHz operating channel width, then the Wide Bandwidth Channel Switch subelement in the Channel Switch Wrapper element may be present in the same frame.

NOTE 3—The indicated operating class within the Extended Channel Switch Announcement element identifies the bandwidth and the relative position of the primary 540 MHz and secondary 540 MHz channels. Hence a Wide Bandwidth Channel Switch subelement is unnecessary when the Extended Channel Switch Announcement element is used for a channel switch to a 1080 MHz bandwidth.

If new BSS TPC parameters are announced that come into effect at the same time as the channel switch, then a STA that is a CMMG AP, a CMMG STA in an IBSS, or a CMMG mesh STA in an MBSS shall include

— At least one New CMMG Transmit Power Envelope element in a transmitted Channel Switch Announcement frame or Extended Channel Switch Announcement frame, and
— At least one New CMMG Transmit Power Envelope subelement in a transmitted Channel Wrapper element in Beacon and Probe Response frames.

A recipient CMMG STA in the BSS that has dot11SpectrumManagementRequired or dot11RadioMeasurementActivated equal to true and that maintains association with the BSS after the switch shall use the parameters in these received elements and subelements in the recipient STA's TPC calculations for the new operating channel and operating channel width (see 11.7). If both New CMMG Transmit Power Envelope elements and New CMMG Transmit Power Envelope subelements are transmitted for the switch, the set of New CMMG Transmit Power Envelope elements and set of subelements shall contain the same set of values for the Local Maximum Transmit Power Unit Interpretation subfield, and New CMMG Transmit Power Envelope elements and subelements that have the same value for the Local Maximum Transmit Power Unit Interpretation subfield shall also have the same values for their other fields.

If a new country string, new operating classes or both, are coming into effect at the same time as the channel switch, then a STA that is a CMMG AP, a CMMG STA in an IBSS, or a CMMG mesh STA in an MBSS shall include

— A New Country element in a transmitted Extended Channel Switch Announcement frame, and
— A New Country subelement in a transmitted Channel Wrapper element.

The New Country element or subelement shall contain all the Operating Classes for the BSS after the switch. The New Country element or subelement, transmitted in an Extended Channel Switch Announcement frame or in the same frame as an Extended Channel Switch Announcement element, respectively, shall include

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one Operating Triplet field that contains the same Operating Class as the New Operating Class field in the Extended Channel Switch Announcement frame or Extended Channel Switch Announcement element.

A recipient CMMG STA in the BSS that has dot11MultiDomainCapabilityActivated, dot11SpectrumManagementRequired, or dot11RadioMeasurementActivated equal to true and that maintains association with the BSS after the switch shall use the parameters in these received elements and subelements in order to maintain regulatory compliance. If both New Country elements and New Country subelements are transmitted for the switch, their fields shall be the same.

A Channel Switch Wrapper element shall not be included in Beacon frames or Probe Response frames if the element contains zero subelements.

NOTE 4—Channel Switch Wrapper is not defined to carry subelements in the case of a switch to 540 MHz and when no change to the country string, operating classes, or TPC parameters are announced.

An AP that switches the BSS to a lower operating channel width may recalculate the TS bandwidth budget and may delete one or more active TSs by invoking the MLME-DELTS.

11.48.5 NAV assertion in a CMMG BSS

A CMMG STA shall update its NAV as described in 10.3.2.4 using the Duration/ID field value in any frame that does not have an RA matching the STA's MAC address and that was received in a 540 MHz PPDU in the primary 540 MHz channel or received in a 1080 MHz PPDU.

NOTE—The PHY might filter out a PPDU as described in 25.13 or not receive a PPDU due to TXOP power saving described in 11.2.3.19. If so, frames in the PPDU are not received by the MAC and have no effect on the NAV.

11.48.6 CMMG STAs antenna indication

A CMMG STA that does not change its Rx antenna pattern after association shall set the Rx Antenna Pattern Consistency subfield in the CMMG Capabilities Info field to 1; otherwise, the STA shall set the Rx Antenna Pattern Consistency subfield in the CMMG Capabilities Info field to 0.

A CMMG STA that does not change its Tx antenna pattern after association shall set the Tx Antenna Pattern Consistency subfield in the CMMG Capabilities Info field to 1; otherwise, the STA shall set the Tx Antenna Pattern Consistency subfield in the CMMG Capabilities Info field to 0.

11.48.7 BSS basic CMMG-MCS and NSS set operation

The BSS basic CMMG-MCS and NSS set is the set of <CMMG-MCS, NSS> tuples that are supported by all CMMG STAs that are members of a CMMG BSS. It is established by the STA that starts the CMMG BSS, indicated by the Basic CMMG-MCS and NSS Set field of the CMMG Operation element in the MLME-START.request primitive. Other CMMG STAs determine the BSS basic CMMG-MCS and NSS set from the Basic CMMG-MCS and NSS Set field of the CMMG Operation element in the BSSDescription derived through the scan mechanism (see 11.1.4.1).

A CMMG STA shall not attempt to join (MLME-JOIN.request primitive) a BSS unless it supports (i.e., is able to both transmit and receive using) all the <CMMG-MCS, NSS> tuples in the BSS basic CMMG-MCS and NSS set.

A CMMG STA shall not attempt to (re)associate (MLME-ASSOCIATE.request and MLME-REASSOCIATE. request primitives) with a CMMG AP unless the STA supports (i.e., is able to both transmit and receive using) all the <CMMG-MCS, NSS> tuples in the Basic CMMG-MCS and NSS Set field in the CMMG Operation element transmitted by the AP.

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11.49 Reduced neighbor report

In Beacon and Probe Response frames, a Reduced Neighbor Report element may be transmitted by an AP with dot11TVHTOptionImplemented or dot11FILSActivated true. In FILS Discovery frames, a Reduced Neighbor Report element is optionally sent by a FILS AP. A Reduced Neighbor Report element contains information on neighbor APs. A Reduced Neighbor Report element might not be exhaustive either by choice or by the fact that there may be neighbor APs not known to the AP.

The Reduced Neighbor Report element contains a list of operating classes and primary channels along with TBTT information for the reported neighbor APs on each operating class and primary channel. The operating class is selected from values in Table E-4 filtered by the requirement that, together with the Channel Number field, the primary channel be identifiable.

NOTE 1—For instance, this excludes operating class 128–130.

When the reporting AP cannot obtain an operating class that, together with the Channel Number field, identifies the primary channel from the neighboring AP, then the reporting AP shall report an operating class that, together with a channel number, identifies the primary channel of the reported BSS. Given a choice of operating classes that preserve the identification of the primary channel, the reporting AP should select an operating class that preserves as many behavior limits as possible are known to the reporting AP.

NOTE 2—An operating class might be unavailable because the neighboring AP does not transmit an operating class or the transmitted operating class does not indicate a primary channel.

A Reduced Neighbor Report element includes only channels that are consistent with the Country element in the frame in which the Reduced Neighbor Report element appears. The Reduced Neighbor Report element contents may be derived from the NeighborListSet parameter of the MLME-NEIGHBORREPRESP.request primitive. The contents of the Reduced Neighbor Report element might also be configured or obtained by other means beyond the scope of this standard.

If the Supported Operating Classes element of the STA is included in the Probe Request frame, the reduced neighbor report contains information on neighbor APs whose current operating class matches the supported operating classes in the Probe Request frame.

If the AP is a TVHT AP that transmits a Probe Response frame, the Filtered Neighbor AP subfield in the Neighbor AP Information field shall be set to 1 if the AP determines that the SSID corresponding to every AP in the Neighbor AP Information field matches the specific SSID in the corresponding Probe Response frame; otherwise it shall be set to 0.

NOTE 3—The Filtered Neighbor AP subfield is reserved when the Reduced Neighbor Report element is transmitted by a non-TVHT AP or by a TVHT AP in a frame other than a Probe Response frame (see 9.4.2.170.2).

A serving AP shall include a value less than 255 in the Neighbor AP TBTT Offset subfield if it is able to guarantee an accumulated error of 1.5 TU or better.

A STA that receives a Neighbor AP Information field with an unrecognized TBTT Information Field Type subfield shall ignore the remainder of the Reduced Neighbor Report element.

A STA that receives a Neighbor AP Information field with a recognized TBTT Information Field Type subfield but an unrecognized TBTT Information Length subfield shall ignore that Neighbor AP Information field and continue to process remaining Neighbor AP Information fields.

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11.50 GLK operation

11.50.1 General

GLK STAs are capable of creating general links with other GLK STAs, that can be used as links within an IEEE 802.1Q bridged network. Such links (1) include facilities to send group addressed Data frames to a subset of receiving GLK STAs including use of improved GCR mechanisms, (2) can be mapped to the IEEE 802.1Q Internal Sublayer Service, and (3) provide link metrics appropriate for use by IEEE 802.1Q bridges in making routing decisions.

When dot11GLKImplemented is true, the STA is a GLK STA and dot11QosOptionImplemented shall be true. A STA advertises its GLK capability using the GLK field of the Extended Capabilities element (see 9.4.2.26). dot11GLKImplemented is true if and only if a STA implements the GLK facility.

The Supported Rates and BSS Membership Selectors or Extended Supported Rates and BSS Membership Selectors elements shall include the GLK selector if dot11GLKRequired is true.

If dot11GLKRequired is true, every association or mesh peering created by the STA shall establish a general link.

In an IBSS, if dot11GLKRequired is not true, general links shall not be established.

A GLK STA shall support SYNRA operations as described in 10.65 and 10.66.

11.50.2 Reported general link metrics

The bridge management protocols in IEEE Std 802.1Q require link metrics for each general link. GLK STAs shall provide metrics for their general links as follows:

- dot11GLKLinkRawRate, which is the maximum rate at which the GLK STA is capable of transmitting, given its available features and those of the STA with which it is communicating.
- For a windowed set of link rate samples:
  - The minimum
  - The arithmetic mean
  - The geometric mean
  - The standard deviation
  - A composite link rate

NOTE—The passing of link metrics from a GLK STA to the attached IEEE 802.1Q bridge is implementation dependent.

A GLK STA shall maintain an array of sample window data rates for each of its general links. Each such array consists of rate sample windows R[0] to R[N+1] in units of 100 kb/s, where N is the value of dot11GLKLinkRateSamples. Each sample window covers a time period of dot11GLKLinkRateWindowSize×16 TUs. When the association or peering is created, R[0] to R[N+1] are initialized to the lowest data bit rate the STA is configured to use.

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Every dot11GLKLinkRateWindowSize×16 TUs, the following steps occur in the order given:

Step 1: The data rate sample array is shifted with the value of R[N+1] being discarded, each R[K] is set to the value of R[K-1] for K from N+1 to 1, and R[0] is set as follows:

— Zero if all attempts to transmit data during the window failed.

— The arithmetic mean data rate in units of 100 kb/s of successful transmissions in the window if there were any successful transmissions.

— The data rate that would have been attempted if there were no attempts to transmit data during the window.

Step 2: The minimum, arithmetic mean, geometric mean, and standard deviation of the data rates in the sample array entries are calculated as follows:

— The minimum rate is R_{min}, the array entry with the smallest magnitude.

— The arithmetic mean is

$$R_{\text{avg}} = \left\lfloor \left(\sum_{i=0}^{N+1} R[i] \right) / (N+2) \right\rfloor$$

— The geometric mean is

$$R_{\text{geo}} = \left\lfloor \sqrt[N+2]{\prod_{i=0}^{N+1} (R[i]+1)} \right\rfloor$$

— The standard deviation is

$$R_{\text{std}} = \left\lfloor \sqrt{\left(\sum_{i=0}^{N+1} (R[i] - R_{\text{avg}})^2 \right) / (N+1)} \right\rfloor$$

These are available as dot11GLKLinkMinRate, dot11GLKLinkAvgRate, dot11GLKLinkGeoRate, and dot11GLKLinkSTDRate.

Step 3: A composite data rate is then computed using non-negative weights W as follows:

$$R_{\text{composite}} = \left\lfloor \frac{W_{\text{min}} \times R_{\text{min}} + W_{\text{avg}} \times R_{\text{avg}} + W_{\text{geo}} \times R_{\text{geo}}}{1 + W_{\text{min}} + W_{\text{avg}} + W_{\text{geo}}} \right\rfloor$$

where

W_{min} is dot11GLKLinkRateWmin
W_{avg} is dot11GLKLinkRateWavg
W_{geo} is dot11GLKLinkRateWgeo

Step 4: A rate is then computed from $R_{\text{composite}}$.

$$R_{\text{current}} = \lfloor (R_{\text{composite}} \times 16) / \text{dot11GLKLinkRateScaling} \rfloor$$

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Step 5: The first $R_{reported}$ for a general link is $R_{current}$ as determined in step 4. Subsequent values of $R_{reported}$ are subject to hysteresis based on dot11GLKLinkRateHysteresis. If the previous $R_{reported}$ is greater than the new $R_{current}$ × dot11GLKLinkRateHysteresis/256 and less than the new $R_{current}$ × 256/dot11GLKLinkRateHysteresis, then the new $R_{reported}$ is unchanged from the previous $R_{reported}$. In all other cases, the new $R_{reported}$ is the new $R_{current}$. $R_{reported}$ is available in the per association, direct link, or peering GLK Link dot11GLKLinkRateReported.

In the case of transparent FST, the general link metric is measured relative to the single presented MAC SAP regardless of which PHY is used to exchange MSDUs.

11.51 EPD operation

A STA operating in the 5.9 GHz bands is an EPD STA and dot11EPDimplemented shall be set to true or not present. For an EPD STA not operating in the 5.9 GHz bands, dot11EPDImplemented shall be set to true. For a STA that is not EPD, dot11EPDImplemented shall be set to false or not present. When an EPD STA is not operating in the 5.9 GHz bands the EPD subfield is set to 1 in the Capability Information and DMG STA Capability Information fields.

The Supported Rates and BSS Membership Selectors or Extended Supported Rates and BSS Membership Selectors elements shall include the EPD selector if dot11EPDRequired is true.

See also 5.1.4.

11.52 Beacon frame protection procedures

In an infrastructure BSS, when beacon protection is enabled, the MLME shall provide an encapsulation service for Beacon frames. All Beacon frames shall be submitted to this service for protection processing.

If dot11BeaconProtectionEnabled is true, the AP shall enable beacon protection and set the Beacon Protection Enabled field of the Extended Capabilities element to 1 to indicate that beacon protection is enabled on the transmission of Beacon frames. Otherwise, the field shall be set to 0.

If dot11BeaconProtectionEnabled is true and a non-AP STA receives a BIGTK from the AP with which it is associated, the non-AP STA shall enable beacon protection.

The beacon protection service shall take the following actions:

- Beacon frame protection shall be set using the MLME-SETPROTECTION.request primitive with the Protectlist including a Key Type value of BIGTK. A non-AP STA shall also set the Protect Type value to Rx. An AP shall set the Protect Type value to Tx.
- The BIGTK shall be installed using the MLME-SETKEYS.request primitive with the value BIGTK for the Key Type parameter.
- The Beacon frames shall be encapsulated and protected using BIP (see 12.5.4).
- The protected Beacon frames shall be decapsulated and validated using BIP (see 12.5.4).

If dot11RSNAProtectedManagementFramesActivated is false, dot11BeaconProtectionEnabled shall be set to false.

If OCVC capability is not present in a non-AP STA or if the current AP does not advertise OCVC capability, but beacon protection is enabled, the non-AP STA shall verify that the operating channel information in the first received Beacon frame that has been validated using BIP matches the current operating channel parameters. If there is a mismatch, the non-AP STA shall disassociate from the AP.

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12. Security

12.1 Conventions

Reserved fields and subfields are set to 0 upon transmission and are ignored upon reception.

ASCII and UTF-8 strings are defined in 1.4.

12.2 Framework

12.2.1 Classes of security algorithm

This standard defines two classes of security algorithms for IEEE 802.11 networks:

— Algorithms for creating and using an RSNA, called *RSNA algorithms*
— Pre-RSNA algorithms

NOTE—This standard does not prohibit STAs from simultaneously operating pre-RSNA and RSNA algorithms.

WEP is obsolete. The WEP algorithm is unsuitable for the purposes of this standard.

The use of TKIP is deprecated. The TKIP algorithm is unsuitable for the purposes of this standard.

12.2.2 Security methods

Pre-RSNA security comprises the following algorithms and procedures:

— WEP, described in 12.3.2
— IEEE 802.11 entity authentication, described in 12.3.3

RSNA security comprises the following algorithms and procedures:

— TKIP, described in 12.5.2
— CCMP, described in 12.5.3
— GCMP, described in 12.5.5
— BIP, described in 12.5.4
— RSNA establishment and termination procedures, including use of IEEE 802.1X authentication, described in 12.6 and SAE authentication described in 12.4
— Key management procedures, described in 12.7

The RSN operations in a CMMG BSS shall be the same as the RSN operations in a DMG BSS.

12.2.3 RSNA STA capabilities

When dot11RSNAActivated is true, an RSNA STA shall include the RSNE in Beacon, Probe Response, Information Response, and (Re)Association Request frames and in message 2 and message 3 of the 4-way handshake; shall set the DMG Privacy subfield to 1 within transmitted DMG Beacons; and may include the RSNE in DMG Beacon and Announce frames. A pre-RSNA STA is not capable of creating RSNAs.

All STAs implementing RSNA shall support the RSNE described in 9.4.2.24.

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12.2.4 RSNA establishment

An SME establishes an RSNA in one of six ways:

a) If an RSNA uses authentication negotiated over IEEE Std 802.1X or FILS authentication in an infrastructure BSS, an RSNA STA's SME establishes an RSNA as follows:

   1) It identifies the AP as anRSNA AP from the AP's Beacon, DMG Beacon, Announce, Information Response, or Probe Response frames.
   2) It shall invoke Open System or FILS authentication if the STA is a non-DMG STA.
   3) It negotiates cipher suites during the association process, as described in 12.6.2 and 12.6.3.
   4) It uses IEEE Std 802.1X-2010 to authenticate, as described in 12.6.10 and 12.6.11, or uses FILS authentication to authenticate as described in 12.11.
   5) It establishes one or more temporal keys by executing a key management algorithm, using the protocol defined by 12.7 or 13.
   6) It protects the data link by programming the negotiated cipher suites and the established temporal key into the MAC and then invoking protection. See, for example, 12.5.3 for a description of the RSNA data protection mechanisms.
   7) If the STAs negotiate management frame protection, the SME programs the TK and pairwise cipher suite into the MAC for protection of individually addressed robust Management frames. It also installs the IGTK and IPN for protection of group addressed robust Management frames.
   8) If beacon protection is enabled, the SME programs the BIGTK and BIPN into the MAC for the protection of Beacon frames.

b) If an RSNA is based on a PSK or password in an infrastructure BSS, the SME establishes an RSNA as follows:

   1) It identifies the AP as an RSNA AP from the AP's Beacon, DMG Beacon, Announce, Information Response, or Probe Response frames.
   2) If the RSNA AP advertises support for SAE authentication in its Beacon or Probe Response frames, and the STA has a group defined in the dot11RSNAConfigDLCGroupTable and a password for the AP in the dot11RSNAConfigPasswordValueTable, the STA shall invoke SAE authentication to establish a PMK. If the RSNA AP does not advertise support for SAE authentication in its Beacon and Probe Response frames but advertises support for the alternate form of PSK authentication (see 4.10.3.4), and the STA also supports the alternate form of PSK authentication, the non-DMG STA may invoke Open System authentication and use the PSK as the PMK with the key management algorithm in step 4) below.
   3) It negotiates cipher suites during the association process, as described in 12.6.2 and 12.6.3.
   4) It establishes one or more temporal keys by executing a key management algorithm, using the protocol defined by 12.7.
   5) It protects the data link by programming the negotiated cipher suites and the established temporal key into the MAC and then invoking protection.
   6) If the STAs negotiate management frame protection, the SME programs the TK and pairwise cipher suite into the MAC for protection of individually addressed robust Management frames. It also installs the IGTK and IPN for protection of group addressed robust Management frames.
   7) If beacon protection is enabled, the SME programs the BIGTK and BIPN into the MAC for the protection of Beacon frames.

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c) If an RSNA is based on a PSK or password in an IBSS the SME executes the following sequence of procedures:

   1) It identifies the peer as an RSNA STA from the peer's Beacon, DMG Beacon, Announce, Information Response, or Probe Response frames.

NOTE 1—STAs might respond to a Data frame from an unrecognized STA by sending a Probe Request frame to find out whether the unrecognized STA is an RSNA STA.

   2) If the peer RSNA STA advertises support for SAE authentication in its Beacon and Probe Response frames and the STA has a group defined in the dot11RSNAConfigDLCGroupTable and a password for the peer in the dot11RSNAConfigPasswordValueTable, the STA shall invoke SAE authentication and establish a PMK. If the peer RSNA STA does not advertise support for SAE authentication but advertises support for the alternate form of PSK authentication (see 4.10.3.4), and the STA also supports the alternate form of PSK authentication the STA may invoke Open System authentication if the STA is a non-DMG STA and use a PSK as the PMK with the alternate form of PSK authentication.
   3) Each STA uses the procedures in 12.7, to establish one or more temporal keys and to negotiate cipher suites. Note that two peer STAs might follow this procedure simultaneously. See 12.6.15.
   4) It protects the data link by programming the negotiated cipher suites and the established temporal key and then invoking protection.

d) If an RSNA uses authentication negotiated over IEEE Std 802.1X in an IBSS, an RSNA capable STA's SME establishes an RSNA as follows:

   1) It identifies the peer as an RSNA STA from the peer's Beacon, DMG Beacon, Announce, Information Response, or Probe Response frames.

NOTE 2—STAs might respond to a Data frame from an unrecognized STA by sending a Probe Request frame to find out whether the unrecognized STA is an RSNA STA.

   2) It may invoke Open System authentication if the STA is a non-DMG STA.
   3) Each STA uses IEEE Std 802.1X-2010 to authenticate with the AS associated with the other STA's Authenticator, as described in 12.6.10 and 12.6.11.

NOTE 3—Two peer STAs might follow this procedure simultaneously.

   4) Each SME establishes one or more temporal keys by executing a key management algorithm, using the protocol defined in 12.7. Hence two such key management algorithms are happening in parallel between any two STA's Supplicants and Authenticators.
   5) Both STAs use the agreed-upon temporal key portion of the PTK and pairwise cipher suite from one of the exchanges to protect the link. Each STA uses the GTK established by the exchange it initiated to protect the group addressed frames it transmits.

e) In order to associate with a PCP in a PBSS, an RSNA STA's SME establishes an RSNA with the PCP following the RSNA establishment steps in an infrastructure BSS in accordance with method a) and b) above, as appropriate, with the PCP taking the role of the AP.

f) When an RSNA STA chooses not to associate with a peer in a PBSS, its SME establishes an RSNA with the peer following the RSNA establishment steps in an IBSS in accordance with method c) or d) above, as appropriate, with the caveat that the RSNA authentication and key management algorithm is executed only once between the peers.

The time a security association takes to set up shall be less than dot11RSNAConfigSATimeout. The security association setup starts when initiated by the SME and completes when the MLME-SETPROTECTION.request primitive is invoked. The action the STA takes on the timeout is a policy decision. Some options include retrying the security association setup or trying another STA. This timeout allows

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recovery when one of the STAs setting up a security association fails to respond correctly to setting up the security association. It also allows recovery in IBSS when one of the two security associations fails because of a security association timeout.

An RSNA STA shall not associate if Shared Key authentication was invoked prior to RSN association.

12.2.5 RSNA assumptions and constraints

An RSNA assumes the following:

a) Each STA can generate cryptographic-quality random numbers. This assumption is fundamental, as cryptographic methods require a source of randomness. See J.5 for suggested hardware and software methods to achieve randomness suitable for this purpose.

b) When IEEE 802.1X authentication is used, the specific EAP method used performs mutual authentication. This assumption is intrinsic to the design of RSN in IEEE 802.11 LAN and cannot be removed without exposing both the STAs to man-in-the-middle attacks. EAP-MD5 is an example of an EAP method that does not meet this constraint (see IETF RFC 3748). Furthermore, the use of EAP authentication methods where server and client credentials are not differentiated reduces the security of the method to that of a PSK due to the fact that malicious insiders might masquerade as servers and establish a man-in-the-middle attack.

   In particular, the mutual authentication requirement implies an unspecified prior enrollment process (e.g., a long-lived authentication key or establishment of trust through a third party such as a certification authority), as the STA needs to be able to identify the ESS or IBSS as a trustworthy entity and vice versa. The STA shares authentication credentials with the AS utilized by the selected AP or, in the case of PSK, the selected AP. The SSID provides an unprotected indication that the selected AP's authentication entity shares credentials with the STA. Only the successful completion of the IEEE 802.1X EAP or PSK authentication, after association, validates any such indication that the AP is connected to an authorized network or service provider.

c) The mutual authentication method needs to be strong, meaning impersonation attacks are computationally infeasible when based on the information exposed by the authentication. This assumption is intrinsic to the design of RSN.

d) The AP and AS have a trustworthy channel between them that can be used to exchange cryptographic keys without exposure to any intermediate parties.

e) An IEEE 802.1X AS never exposes the common symmetric key to any party except the AP with which the STA is currently communicating. This is a very strong constraint. It implies that the AS itself is never compromised. It also implies that the IEEE 802.1X AS is embedded in the AP or that the AP is physically secure and the AS and the AP lie entirely within the same administrative domain. This assumption follows from the fact that if the AP and the AS are not collocated or do not share pairwise key encryption keys directly, then it is impossible to assure the non-AP STA that its key, which is distributed by the AS to the AP, has not been compromised prior to use.

f) A STA never shares with a third party a common symmetric key that it shares with a peer. Doing so destroys the utility of the key for detecting MPDU replay and forgery.

g) The Supplicant and the Authenticator generate a different, fresh PTK for each session between the pair. This assumption is fundamental, as reuse of any PTK would enable compromise of all the data protected by that key.

h) The destination STA chosen by the transmitter is the correct destination. For example, Address Resolution Protocol (ARP) and Internet Control Message Protocol (ICMP) are methods of determining the destination STA's MAC address that are not secure from attacks by other members of the ESS. One of the possible solutions to this problem might be for the STA to send or receive only frames whose final DA or SA are the AP and for the AP to provide a network layer routing function. However, such solutions are outside the scope of this standard.

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An HT STA shall not use either of the pairwise cipher suite selectors: "Use group cipher suite" or TKIP to communicate with another HT STA.

NOTE—Because a VHT STA is also an HT STA, the elimination of TKIP also applies to VHT STAs.

12.2.6 Requirements for the Protected Frame field

The Protected Frame field shall be set to 1 in the following:

— Data frames that are protected using the mechanisms specified in Clause 12.
— Individually addressed protected robust Management frames.
— Authentication frames with Authentication Algorithm Number field equal to 1 (Shared Key) and Authentication Transaction Sequence Number field equal to 3.

It shall be set to 0 in all other frames.

12.2.7 Requirements for management frame protection

The robust Management frames are Disassociation, Deauthentication, and robust Action frames.

Action frames specified with "No" in the "Robust" column of Table 9-51 are not robust Management frames and shall not be protected.

When management frame protection is negotiated, all group addressed robust Management frames shall be encapsulated using the procedures defined in 11.12.

When beacon protection is enabled, protected Beacon frames shall be encapsulated using the procedures defined in 11.52.

12.2.8 Emergency service establishment in an RSN

An AP or mesh STA that supports RSNAs and has the ESR bit set to 1 and the UESA bit set to 1 in the Interworking element in Beacon and Probe Response frames supports both RSNAs and emergency services associations (see 11.3.5.2) simultaneously.

In an infrastructure BSS, the STAs with emergency services association should discard all group addressed frames they receive, as they do not possess the Group Key and therefore are not able to decrypt group addressed frames. In an RSNA enabled BSS that has one or more STAs associated with an emergency services association, an AP should avoid transmitting unprotected group addressed frames in order not to disturb the operation of STAs that are in possession of Group Key. One possible way of achieving this is to support the Proxy ARP service in the AP, as defined in 11.21.14. In addition, it is recommended that an AP supporting emergency services association should also support DMS to convert group addressed frames to individually addressed frames and transmit them to STAs associated using the emergency services association. STAs using emergency services association might request DMS if needed.

12.2.9 Requirements for Operating Channel Validation

When OCVC capability is present, a STA shall advertise this capability in RSNE and shall include operating channel information and validate the Operating Channel Information (OCI) received from an OCVC capable peer in certain protected messages used for key establishment and confirmation.

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A STA with OCVC capability validates that the channel information in received OCI matches its current operating channel parameters by:

— Verifying that the maximum bandwidth used by the STA to transmit or receive PPDUs to/from the peer STA from which the OCI was received is no greater than the bandwidth of the operating class specified in the Operating Class field of the received OCI

— Verifying that the primary channel used by the STA to transmit or receive PPDUs to/from the peer STA from which the OCI was received is equal to the Primary Channel Number field (for the corresponding operating class)

— Verifying that, when 40 MHz bandwidth is used by the STA to transmit or receive PPDUs to/from the peer STA from which the OCI was received, the nonprimary 20 MHz used matches the operating class (i.e., upper/lower behavior) specified in the Operating Class field of the received OCI

— Verifying that, if operating an 80+80 MHz operating class, the frequency segment 1 channel number used by the STA to transmit or receive PPDUs to/from the peer STA from which the OCI was received is equal to the Frequency Segment 1 Channel Number field of the OCI.

If the NT-MLME of a STA with OCVC capability processes an MMPDU containing OCI received in an MLME-OCTunnel.indication primitive (see 11.31.5):

— The above validation is performed with respect to the expected or current channel used by the STA to transmit or receive PPDUs to/from the peer STA over the WM (i.e., not using the OCT procedure), and

— In addition, the STA verifies that the OCI contains the OCT Operating Class, OCT Primary Channel Number and OCT Frequency Segment 1 Channel Number fields, and uses the OCT information in those fields to perform the above validation with respect to the channel used by the STA corresponding to the TR-MLME from which the MLME-OCTunnel.indication primitive was received to transmit or receive PPDUs containing On-channel Tunnel Request frames to/from the STA corresponding to the TR-MLME used by the peer STA.

If a STA with OCVC capability receives a frame from a peer STA which is not on the same primary channel (or frequency segment 1 channel number) used by the STA to receive PPDUs from the peer STA, or has bandwidth that exceeds the maximum bandwidth used by the STA to receive PPDUs from the peer STA, the frame is discarded.

12.2.10 Requirements for support of MAC privacy enhancements

MAC privacy enhancements are enabled on a non-AP STA when dot11MACPrivacyActivated is set to true. The STA shall periodically change its MAC address to a random value while not associated to a BSS. The STA shall construct the randomized MAC address from the locally administered address space as defined in IEEE Std 802-2014 and IEEE Std 802c™-2017. However, the non-AP STA shall not change its MAC address during a transactional exchange, for example, transmitting Public Action frames for preassociation discovery, or during the creation of state on an AP using preassociation capabilities, for example, RSN preauthentication or FT over-the-DS. The smaller the period of MAC address change, down to a single transmitted frame per MAC address, the greater the privacy these enhancements afford. The actual period used when changing a MAC address is implementation dependent and outside the scope of this standard.

If such a non-AP STA starts any transaction that establishes state bound to a MAC address and might elect to establish an association or establish transaction state with a discovered BSS, it shall check the value of dot11LocallyAdministeredMACConfig and shall configure its MAC address according to the rules of the local address space prior to the start of the transaction. State created with an AP using a prior MAC address, for instance, RSN preauthentication state or FT state established over-the-DS, is bound to the MAC address used when that state was created. Prior to establishing an association to the AP, the non-AP STA shall change its MAC address to the MAC address used when the state was created.

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The SME of the non-AP STA may change the MAC address by generating an MLME-UPDATEMACADDRESS.request primitive containing the new MAC address. On receipt of an MLME-UPDATEMACADDRESS.request primitive, the MLME shall attempt to update the MAC address that is to be used by the MAC entity and shall generate an MLME-UPDATEMACADDRESS.confirm primitive to notify the SME whether the MAC address has been changed to the new value.

Every time a MAC address is changed to a new random value, counters in all sequence number spaces used to identify each MSDU or MMPDU shall be reset (see 10.3.2.14.2) and the STA shall set the TXVECTOR parameter SCRAMBLER_RESET to RESET_SCRAMBLER on the next transmitted PPDU.

The non-AP STA connecting to an infrastructure BSS shall retain a single MAC address for the duration of its connection across an ESS. A PMKSA created as part of an RSNA will contain the MAC address used to create the PMKSA. The non-AP STA that supports PMKSA caching shall, if necessary, change its MAC address back to that value when attempting a subsequent association to the ESS using PMKSA caching.

To construct a random MAC address, the STA shall select a randomized MAC address according to IEEE Std 802-2014 and IEEE Std 802c-2017.

To avoid leakage of possibly sensitive network identifying information, STAs should refrain from transmitting Probe Request frames containing preferred SSID values and, instead, use passive scanning or transmit Probe Request frames containing the wildcard SSID.

When dot11MACAddressPolicyActiviated is true, an AP shall set the MAC Address Policy field in the Extended Capabilities field to 1, indicating the existence of a MAC address policy. When dot11MACAddressPolicyActivated is false, an AP STA shall set the MAC Address Policy field in the Extended Capabilities field to 0, indicating that local MAC addresses are not restricted.

A non-AP STA that receives from an AP an Extended Capabilities field with the Local MAC Address Policy subfield set to 1 should, unless it has previously stored the MAC address policy for the ESS, discover that policy, using the MAC Address Policy ANQP-element, before sending any Association Request frame to that AP using a local MAC address as the TA.

12.3 Pre-RSNA security methods

12.3.1 Status of Pre-RSNA security methods

Except for Open System authentication, all pre-RSNA security mechanisms are obsolete. Support for them might be removed in a later revision of the standard.

Open System Authentication and Open System Deauthentication shall not be used between mesh STAs.

12.3.2 Wired equivalent privacy (WEP)

12.3.2.1 WEP overview

WEP-40 was defined as a means of protecting (using a 40-bit key) the confidentiality of data exchanged among authorized users of a WLAN from casual eavesdropping. Implementation of WEP is optional. The same algorithms have been widely used with a 104-bit key instead of a 40-bit key in fielded implementations; this is called *WEP-104*. The WEP cryptographic encapsulation and decapsulation mechanics are the same whether a 40-bit or a 104-bit key is used. The term WEP by itself refers to either WEP-40 or WEP-104.

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12.3.2.2 WEP MPDU format

Figure 12-1 depicts the encrypted frame body as constructed by the WEP algorithm.

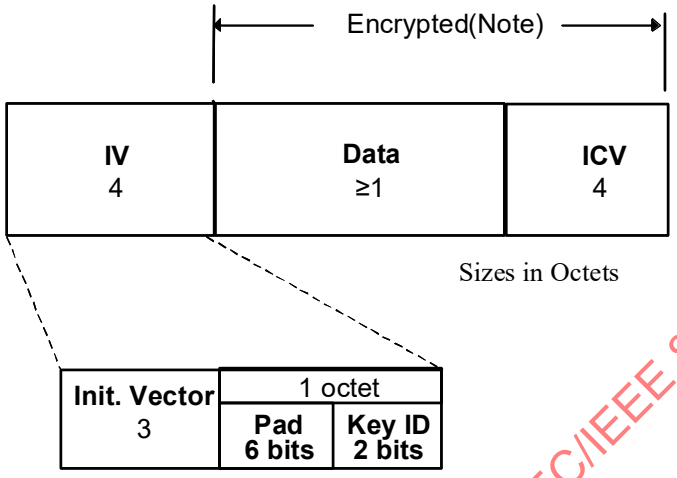

Figure 12-1—Construction of expanded WEP MPDU

The ordering conventions defined in 9.2.2 apply to the IV field and its subfields and to the ICV field. The Key ID subfield contents select one of four possible secret key values for use in decrypting this frame body. When key-mapping keys are used, the Key ID field is reserved.

Interpretation of these bits is discussed further in 12.3.3.3. The contents of the Pad subfield shall be 0. The Key ID subfield occupies the 2 MSBs of the last octet of the IV field, while the Pad subfield occupies the 6 LSBs of this octet.

12.3.2.3 WEP state

WEP uses encryption keys only; it performs no data authentication. Therefore, it does not have data integrity keys. WEP uses two types of encryption keys: key-mapping keys and default keys.

A key-mapping key is an unnamed key corresponding to a distinct transmitter address-receiver address <TA,RA> pair. Implementations shall use the key-mapping key if it is configured for a <TA,RA> pair. In other words, the key-mapping key shall be used to WEP-encapsulate or -decapsulate MPDUs transmitted by TA to RA, regardless of the presence of other key types. When a key-mapping key for an address pair is present, the WEP Key ID subfield in the MPDU is reserved.

A default key is an item in a four-element MIB array called *dot11WEPDefaultKeys*, named by the value of a related array index called *dot11WEPDefaultKeyID*. If a key-mapping key is not configured for a WEP MPDU's <TA,RA> pair, WEP shall use a default key to encapsulate or decapsulate the MPDU. On transmit, the key selected is the element of the dot11DefaultKeys array given by the index dot11WEPDefaultKeyID—a value of 0, 1, 2, or 3—corresponding to the first, second, third, or fourth element, respectively, of dot11WEPDefaultKeys. The value the transmitter encodes in the WEP Key ID subfield of the transmitted MPDU shall be the dot11WEPDefaultKeyID value. The receiver shall use the Key ID subfield of the MPDU to index into dot11WEPDefaultKeys to obtain the correct default key. All WEP implementations shall support default keys.

NOTE—Many implementations also support 104-bit WEP keys. These are used exactly like 40-bit WEP keys: a 24-bit WEP IV is prepended to the 104-bit key to construct a 128-bit WEP seed, as explained in 12.3.2.4.3. The

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resulting 128-bit WEP seed is then consumed by the ARC4 stream cipher. This construction based on 104-bit keys affords no more assurance than the 40-bit construction, and its implementation and use are in no way condoned by this standard. Rather, the 104-bit construction is noted only to document de facto practice.

The default value for all WEP keys shall be null. WEP implementations shall discard the MSDU and generate an MA-UNITDATA-STATUS.indication primitive with transmission status indicating that a frame shall not be encapsulated with a null key in response to any request to encapsulate an MPDU with a null key.

12.3.2.4 WEP procedures

12.3.2.4.1 WEP ICV algorithm

The WEP ICV shall be computed using the CRC-32, as defined in 9.2.4.7, calculated over the plaintext MPDU Data (PDU) field.

12.3.2.4.2 WEP encryption algorithm

A WEP implementation shall use the ARC4 stream cipher from RSA Security, Inc. as its encryption and decryption algorithm. ARC4 uses a pseudorandom number generator (PRNG) to generate a key stream that it exclusive-ORs (XORs) with a plaintext data stream to produce cipher text or to recover plaintext from a cipher text.

12.3.2.4.3 WEP seed construction

A WEP implementation shall construct a per-MPDU key, called a *seed*, by concatenating an encryption key to an IV.

For WEP-40, bits 0–39 of the WEP key correspond to bits 24–63 of the seed, and bits 0–23 of the IV correspond to bits 0–23 of the seed, respectively. The bit numbering conventions in 9.2.2 apply to the seed. The seed shall be the input to ARC4, in order to encrypt or decrypt the WEP Data and ICV fields.

NOTE—For WEP-104, bits 0–103 of the WEP key correspond to bits 24–127 of the seed, and bit 0–23 of the IV correspond to bits 0–23 of the seed, respectively.

The WEP implementation encapsulating an MPDU's plaintext data should select a new IV for every MPDU it WEP-protects. The IV selection algorithm is unspecified. The algorithm used to select the encryption key used to construct the seed is also unspecified.

The WEP implementation decapsulating an MPDU shall use the IV from the received MPDU's Init Vector subfield. See 12.3.2.4.5 for the specification of how the decapsulator selects the key to use to construct the per-MPDU key.

12.3.2.4.4 WEP MPDU cryptographic encapsulation

WEP shall apply three transformations to the plaintext MPDU to effect the WEP cryptographic encapsulation. WEP computes the ICV over the plaintext data and appends this after the MPDU data. WEP encrypts the MPDU plaintext data and ICV using ARC4 with a seed constructed as specified in 12.3.2.4.3. WEP encodes the IV and key identifier into the IV field, prepended to the encrypted Data field.

Figure 12-2 depicts the WEP cryptographic encapsulation process. The ICV shall be computed and appended to the plaintext data prior to encryption, but the IV encoding step may occur in any order convenient for the implementation.

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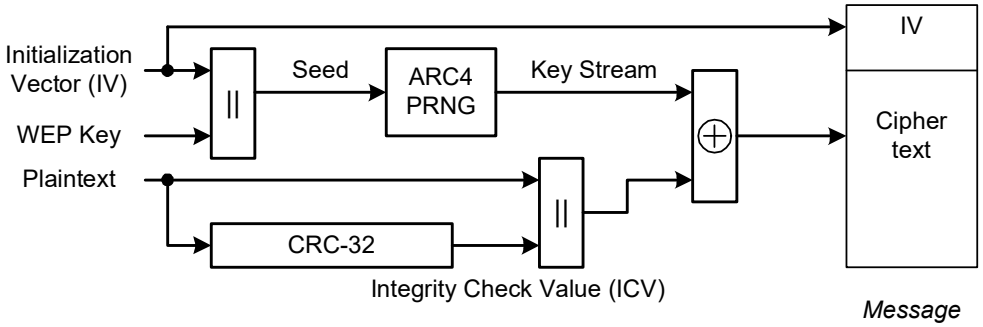

Figure 12-2—WEP encapsulation block diagram

12.3.2.4.5 WEP MPDU decapsulation

WEP shall apply three transformations to the WEP MPDU to decapsulate its payload. WEP extracts the IV and key identifier from the received MPDU. If a key-mapping key is present for the <TA,RA> pair, then this shall be used as the WEP key. Otherwise, the key identifier is extracted from the Key ID subfield of the WEP IV field in the received MPDU, identifying the default key to use.

WEP uses the constructed seed to decrypt the Data field of the WEP MPDU; this produces plaintext data and an ICV. Finally WEP recomputes the ICV and bitwise compares it with the decrypted ICV from the MPDU. If the two are bitwise identical, then WEP removes the IV and ICV from the MPDU, which is accepted as valid. If they differ in any bit position, WEP generates an error indication to MAC management. MSDUs with erroneous MPDUs (due to inability to decrypt) shall not be passed to LLC.

Figure 12-3 depicts a block diagram for WEP decapsulation. Unlike cryptographic encapsulation, the decapsulation steps shall be in the indicated order.

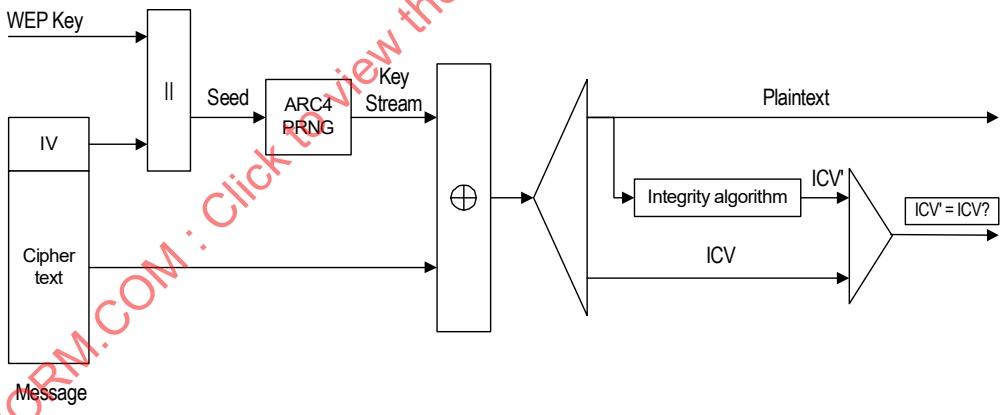

Figure 12-3—WEP decapsulation block diagram

12.3.3 Pre-RSNA authentication

12.3.3.1 Overview

In an infrastructure BSS, a non-DMG STA shall complete an IEEE 802.11 authentication exchange prior to association. A DMG STA not in an IBSS shall complete an IEEE 802.11 authentication exchange prior to association when an authentication algorithm other than the Open System authentication algorithm is requested. A DMG STA shall not perform an IEEE 802.11 authentication exchange using the Open System authentication algorithm. An IEEE 802.11 authentication exchange is optional in an IBSS.

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All Authentication frames shall be individually addressed, as IEEE 802.11 authentication is performed between pairs of STAs, i.e., group addressed authentication is not allowed. Deauthentication frames are advisory and may be sent as group addressed frames.

Shared Key authentication is obsolete and support for this mode might be subject to removal in a future revision of the standard. Shared Key authentication is distinct from FILS Shared Key authentication.

12.3.3.2 Open System authentication

12.3.3.2.1 General

Open System authentication is a null authentication algorithm.

Any non-DMG STA requesting Open System authentication can be authenticated if dot11AuthenticationAlgorithmsTable at the peer STA includes an entry with dot11AuthenticationAlgorithm equal to openSystem and dot11AuthenticationAlgorithmActivated equal to true.

A STA may decline to authenticate with another requesting STA. Open System authentication is the default authentication algorithm for a pre-RSNA STA.

Open System authentication utilizes a two-message authentication transaction sequence. The first message asserts identity and requests authentication. The second message returns the authentication result. If the result is "successful," the STAs shall be declared mutually authenticated.

In the description in 12.3.3.2.2 and 12.3.3.2.3, the STA initiating the authentication exchange is referred to as the *requester*, and the STA to which the initial frame in the exchange is addressed is referred to as the *responder*. The specific items in each of the messages described in the following subclauses are defined in 9.3.3.11, Table 9-40, and Table 9-41.

12.3.3.2.2 Open System authentication (first frame)

Upon receipt of an Open System MLME-AUTHENTICATE.request primitive, the requester shall construct an Open System authentication request carried in an Authentication frame and transmit it to the responder.

12.3.3.2.3 Open System authentication (final frame)

Upon receipt of an Authentication frame requesting Open System authentication, the responder may authenticate the requester using the following procedure:

a) Issue an MLME-AUTHENTICATE.indication primitive to inform the SME of the authentication request.
b) Construct and transmit a response carried in an Authentication frame with the fields as defined in 9.3.3.11 and the status field as defined in 9.4.1.9.

If dot11AuthenticationAlgorithmTable does not include an entry with dot11AuthenticationAlgorithm equal to openSystem and dot11AuthenticationAlgorithmActivated equal to true, the result code shall not take the value "successful."

12.3.3.3 Shared Key authentication

12.3.3.3.1 General

Shared Key authentication seeks to authenticate STAs as either a member of those who know a shared secret key or a member of those who do not.

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Shared Key authentication may be used if WEP has been selected and shall not be used otherwise.

This mechanism uses a shared key delivered to participating STAs via a secure channel that is independent of IEEE Std 802.11. This shared key is set in a write-only MIB attribute with the intent to keep the key value internal to the STA.

A STA shall not initiate a Shared Key authentication exchange unless dot11PrivacyOptionImplemented is true.

In the description in 12.3.3.3.2 to 12.3.3.3.6, the STA initiating the authentication exchange is referred to as the *requester*, and the STA to which the initial frame in the exchange is addressed is referred to as the *responder*. The specific items in each of the messages described in the following subclauses are defined in 9.3.3.11, Table 9-40, and Table 9-41.

12.3.3.3.2 Shared Key authentication (first frame)

Upon receipt of a Shared Key MLME-AUTHENTICATE.request primitive, the requester shall construct a Shared Key authentication request carried in an Authentication frame and transmit it to the responder.

12.3.3.3.3 Shared Key authentication (second frame)

Upon receipt of an Authentication frame requesting Shared Key authentication, the responder may authenticate the requester using the procedure here and in the following two frames:

a) Issue an MLME-AUTHENTICATE.indication primitive to inform the SME of the authentication request.
b) Before sending the second frame in the Shared Key authentication sequence, the responder shall use WEP to generate a string of octets to be used as the authentication challenge text.
c) Construct and transmit to the requester a response carried in an Authentication frame with the fields as defined in 9.3.3.11 and the status field as defined in 9.4.1.9.

If the status code is not SUCCESS, this shall be the last frame of the transaction sequence; and the content of the challenge text field is unspecified.

If the status code is SUCCESS, the following additional information items shall have valid contents:

— Authentication algorithm dependent information = The challenge text
— This authentication result shall be of fixed length of 128 octets. The field shall be filled with octets generated by the WEP PRNG. The actual value of the challenge field is unimportant, but the value shall not be a static value.

12.3.3.3.4 Shared Key authentication (third frame)

The requester shall copy the challenge text from the second frame into a third Authentication frame. The third frame shall be transmitted to the responder after cryptographic encapsulation by WEP, as defined in 12.3.2, using the shared key.

12.3.3.3.5 Shared Key authentication (final frame)

The responder shall WEP-decapsulate the third frame as described in 12.3.2. If the WEP ICV check is successful, the responder shall compare the decrypted contents of the Challenge Text field with the challenge text sent in second frame. If they are the same, then the responder shall transmit an Authentication frame to the requester with a successful status code in the final frame of the sequence. If the WEP ICV check fails or challenge text comparison fails, the responder shall respond with an unsuccessful status code in final frame.

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12.3.3.3.6 Shared key MIB attributes

To transmit a Management frame of subtype Authentication, with an Authentication Transaction Sequence Number field value of 2, the MAC shall operate according to the following decision tree:

if dot11PrivacyOptionImplemented is false **then**
the MMPDU is transmitted with a sequence of 0 octets in the Challenge Text field and a status code value of UNSUPPORTED_AUTH_ALGORITHM
else
the MMPDU is transmitted with a sequence of 128 octets generated using the WEP PRNG and a key whose value is unspecified and beyond the scope of this standard and a randomly chosen IV value (note that this is typically selected by the same mechanism for choosing IV values for transmitted Data frames) in the Challenge Text field and a status code value of SUCCESS (the IV used is immaterial and is not transmitted). Note that there are cryptographic issues involved in the choice of key/IV for this process as the challenge text is sent unencrypted and, therefore, provides a known output sequence from the PRNG.
endif

To receive a Management frame of subtype Authentication, with an Authentication Transaction Sequence Number field value of 2, the MAC shall operate according to the following decision tree:

if the Protected Frame subfield of the Frame Control field is 1 **then**
respond with a status code value of CHALLENGE_FAILURE
else
if dot11PrivacyOptionImplemented is true **then**
if there is a mapping in dot11WEPKeyMappings matching the MMPDU's source **then**
if that key is null **then**
respond with a frame whose Authentication Transaction Sequence Number field is 3 that contains the appropriate authentication algorithm number, a status code value of CHALLENGE_FAILURE, and no Challenge Text field, without encrypting the contents of the frame
else
respond with a frame whose Authentication Transaction Sequence Number field is 3 that contains the appropriate authentication algorithm number, a status code value of SUCCESS, and the identical Challenge Text field, encrypted using that key, and setting the Key ID subfield in the IV field to 0
endif
else
if dot11WEPDefaultKeys[dot11WEPDefaultKeyID] is null **then**
respond with a frame whose Authentication Transaction Sequence Number field is 3 that contains the appropriate authentication algorithm number, a status code value of CHALLENGE_FAILURE, and no Challenge Text field, without encrypting the contents of the frame
else
respond with a frame whose Authentication Transaction Sequence Number field is 3 that contains the appropriate authentication algorithm number, a status code value of SUCCESS, and the identical Challenge Text field, WEP-encapsulating the frame under the key dot11WEPDefaultKeys[dot11WEPDefaultKeyID], and setting the Key ID subfield in the IV field to dot11WEPDefaultKeyID
endif
endif
else
respond with a frame whose Authentication Transaction Sequence Number field is 3 that contains the appropriate authentication algorithm number, a status code value of

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UNSUPPORTED_AUTH_ALGORITHM, and no Challenge Text field, without encrypting the contents of the frame
endif
endif

When receiving a Management frame of subtype Authentication, with an Authentication Transaction Sequence Number field value of 3, the MAC shall operate according to the following decision tree:

if the Protected Frame subfield of the Frame Control field is 0 **then**
respond with a status code value of CHALLENGE_FAILURE
else
if dot11PrivacyOptionImplemented is true **then**
if there is a mapping in dot11WEPKeyMappings matching the MMPDU's source **then**
if that key is null **then**
respond with a frame whose Authentication Transaction Sequence Number field is 4 that contains the appropriate authentication algorithm number and a status code value of CHALLENGE_FAILURE without encrypting the contents of the frame
else
WEP-decapsulate with that key, incrementing dot11WEPICVErrorCount and responding with a status code value of CHALLENGE_FAILURE if the ICV check fails
endif
else
if dot11WEPDefaultKeys[dot11WEPDefaultKeyID] is null **then**
respond with a frame whose Authentication Transaction Sequence Number field is 4 that contains the appropriate authentication algorithm number and a status code value of CHALLENGE_FAILURE without encrypting the contents of the frame
else
WEP-decapsulate with dot11WEPDefaultKeys[dot11WEPDefaultKeyID], incrementing dot11WEPICVErrorCount and responding with a status code value of CHALLENGE_FAILURE if the ICV check fails
endif
endif
else
respond with a frame whose Authentication Transaction Sequence Number field is 4 that contains the appropriate authentication algorithm number and a status code value of CHALLENGE_FAILURE
endif
endif

dot11PrivacyInvoked shall not take the value of true if dot11PrivacyOptionImplemented is false. Setting dot11WEPKeyMappings to a value that includes more than dot11WEPKeyMappingLengthImplemented entries is illegal and shall have an implementation-specific effect on the operation of the data confidentiality service. Note that dot11WEPKeyMappings may contain from zero to dot11WEPKeyMappingLengthImplemented entries.

The values of the attributes in the aPrivacygrp should not be changed during the authentication sequence, as unintended operation may result.

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12.4 Authentication using a password

12.4.1 SAE overview

STAs, both AP STAs and non-AP STAs, may authenticate each other by proving possession of a password. Authentication protocols that employ passwords need to be resistant to off-line dictionary attacks.

Simultaneous authentication of equals (SAE) is a variant of *Dragonfly*, a password-authenticated key exchange based on a zero-knowledge proof. SAE is used by STAs to authenticate with a password; it has the following security properties:

— The successful termination of the protocol results in a PMK shared between the two STAs.
— An attacker is unable to determine either the password or the resulting PMK by passively observing an exchange or by interposing itself into the exchange by faithfully relaying messages between the two STAs.
— An attacker is unable to determine either the password or the resulting shared key by modifying, forging, or replaying frames to an honest, uncorrupted STA.
— An attacker is unable to make more than one guess at the password per attack. This implies that the attacker cannot make one attack and then go offline and make repeated guesses at the password until successful. In other words, SAE is resistant to dictionary attack.
— Compromise of a PMK from a previous run of the protocol does not provide any advantage to an adversary attempting to determine the password or the shared key from any other instance.
— Compromise of the password does not provide any advantage to an adversary in attempting to determine the PMK from the previous instance.

Unlike other authentication protocols SAE does not have a notion of an “Initiator” and “Responder” or of a “Supplicant” and “Authenticator.” The parties to the exchange are equals, with each side being able to initiate the protocol. Each side may initiate the protocol simultaneously such that each side views itself as the “initiator” for a particular run of the protocol. This is necessary to address the unique nature of MBSSs.

The parties involved are called *STA-A* and *STA-B*. They are identified by their MAC addresses, STA-A-MAC and STA-B-MAC, respectively. STAs begin the protocol when they discover a peer by receiving Beacon or Probe Response frame(s), or when they receive an Authentication frame indicating SAE authentication from a peer.

SAE is an RSNA authentication protocol and is selected according to 12.6.2.

SAE shall be implemented on all mesh STAs to facilitate and promote interoperability.

12.4.2 Assumptions on SAE

SAE uses two functions, H and CN, that are instantiated with hash functions in HMAC form. H takes a salt and an input key; CN takes a key, a counter, and a sequence of data. Each piece of data passed to CN is converted to an octet string and concatenated before being concatenated to the counter and passed, along with the key, to the hash function.

H(salt, ikm) = HMAC-Hash(salt, ikm)

CN(key, counter, X, Y, Z, …) = HMAC-Hash(key, counter || D2OS(X) || D2OS(Y) || D2OS(Z) || …)

where HMAC-Hash is a specific hash function in HMAC form and D2OS() represents the data to octet string conversion functions in 12.4.7.2. Each invocation of CN() specifies the format of the counter.

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If used with the looping technique described in 12.4.4.2.2 and 12.4.4.3.2, H and CN are instantiated with SHA-256. If used with the direct hashing technique described in 12.4.4.2.3 and 12.4.4.3.3, H and CN are instantiated with a hash function from Table 12-1 depending on the size of the prime defining the group being used with SAE.

Table 12-1—Hash algorithm based on length of prime

ECC prime length	FFC prime length	Hash algorithm
p ≤ 256	p ≤ 2048	SHA-256
256 < p ≤ 384	2048 < p ≤ 3072	SHA-384
384 < p	3072 < p	SHA-512

12.4.3 Representation of a password

Passwords are used in SAE to deterministically compute a secret element in the negotiated group, called a password element. The input to this process needs to be in the form of a binary string. For the protocol to successfully terminate, it is necessary for each side to produce identical binary strings for a given password, even if that password is in character format. There is no canonical binary representation of a character and ambiguity exists when the password is a character string. To eliminate this ambiguity, a STA shall represent a character-based password as a UTF-8 string that is processed according to the OpaqueString profile of IETF RFC 8265, the output of which is an octet string. The octet string representation of the password, after being processed, is stored in the dot11RSNAConfigPasswordValueTable. When a "password" is called for in the description of SAE that follows the credential from the dot11RSNAConfigPasswordValueTable is used.

Similarly, to address ambiguity when identifying passwords, a STA shall represent a password identifier as a UTF-8 string that is processed according to the UsernameCasePreserved profile of IETF RFC 8265, the output of which is an octet string that is stored in the dot11RSNAConfigPasswordValueTable. When a "password identifier" is called for in the description of SAE that follows, the identifier from the dot11RSNAConfigPasswordValueTable is used.

In an infrastructure BSS for which an SAE AKM is indicated, the AP shall set the SAE Password Identifiers In Use subfield of the Extended Capabilities field of the Extended Capabilities element to 1 if any entry in the dot11RSNAConfigPasswordValueTable has a non-NULL dot11RSNAConfigPasswordIdentifier, and shall set it to 0 otherwise. Similarly, an AP shall set the SAE Password Identifiers Used Exclusively subfield of the Extended Capabilities field of the Extended Capabilities element to 1 if every entry in the dot11RSNAConfigPasswordValueTable has a non-NULL dot11RSNAConfigPasswordIdentifier and shall set it to 0 otherwise.

12.4.4 Finite cyclic groups

12.4.4.1 General

SAE uses discrete logarithm cryptography to achieve authentication and key agreement. Each party to the exchange derives ephemeral public and private keys with respect to a particular set of domain parameters that define a finite cyclic group. Groups may be based on either finite field cryptography (FFC) or on elliptic curve cryptography (ECC). Each component of a group is referred to as an *element*. Groups are negotiated using an identifying number from a repository maintained by IANA as "Group Description" attributes for IETF RFC 2409 (IKE) [B14][B30]. The repository maps an identifying number to a complete set of domain parameters for the particular group. Not all groups defined in this repository are suitable. Only FFC groups whose prime is at least 3072 bits and ECC groups defined over a prime field whose prime is at least 256 bits are suitable for use with SAE. ECC groups defined over a characteristic 2 finite field or ECC groups with a

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co-factor greater than 1 shall not be used with SAE (see NIST Special Publication 800-57). For the purpose of interoperability, a STA shall implement support for group 19, an ECC group defined over a 256-bit prime order field.

More than one group may be configured on a STA for use with SAE by using the dot11RSNAConfigDLCGroupTable. Configured groups are prioritized in ascending order of preference. If only one group is configured, it is, by definition, the most preferred group.

NOTE—The preference of one group over another is a local policy issue.

SAE uses three arithmetic operators defined for both FFC and ECC groups, an operation that takes two elements to produce a third element (called the *element operation*), an operation that takes an integer (called *scalar*) and an element to produce a second element (called the *scalar operation*), and an operation that takes an element to produce a second element (called the *inverse operation*). The convention used here is to represent group elements in uppercase bold italic and scalar values in lowercase italic. The element operation takes two elements, $\boldsymbol{X}$ and $\boldsymbol{Y}$, to produce a third element, $\boldsymbol{Z}$, and is denoted $\boldsymbol{Z}$ = elem-op($\boldsymbol{X}$,$\boldsymbol{Y}$); the scalar operation takes a scalar, x, and an element, $\boldsymbol{Y}$, to produce a second element $\mathbf{Z}$ and is denoted $\boldsymbol{Z}$ = scalar-op(x,$\boldsymbol{Y}$); the inverse operation takes an element, $\boldsymbol{X}$, to produce a second element, $\boldsymbol{Z}$, and is denoted $\boldsymbol{Z}$ = inverse-op($\boldsymbol{X}$).

scalar-op(x,$\boldsymbol{Y}$) is defined as successive iterations of elem-op($\boldsymbol{Y}$, $\boldsymbol{Y}$). That is, it is possible to define scalar-op(1, $\boldsymbol{Y}$) = $\boldsymbol{Y}$ and for $x > 1$, scalar-op(x, $\boldsymbol{Y}$) = elem-op(scalar-op(x-1, $\boldsymbol{Y}$), $\boldsymbol{Y}$). The specific definition of elem-op($\mathbf{X}$,$\boldsymbol{Y}$) depends on the type of group, either ECC or FFC.

12.4.4.2 Elliptic curve cryptography (ECC) groups

12.4.4.2.1 ECC group definition

ECC groups used by SAE are defined by the sextuple (p, a, b, $\boldsymbol{G}$, r, h) where p is a prime number, a and b specify the elliptic curve defined by the equation, $y^2 = x^3 + ax + b \bmod p$, $\boldsymbol{G}$ is a generator (a base point on the elliptic curve), r is the prime order of $\boldsymbol{G}$, and h is the co-factor. Elements in ECC groups are the points on the elliptic curve defined by their coordinates—(x, y)—that satisfy the equation for the curve and the identity element, the so-called "point at infinity."

The element operation in an ECC group is addition of two points on the curve resulting in a third point on the curve. For example, the point $\boldsymbol{X}$ is added to the point $\boldsymbol{Y}$ to produce the point $\boldsymbol{Z}$:

$\boldsymbol{Z} = \boldsymbol{X} + \boldsymbol{Y}$ = elem-op($\boldsymbol{X}$,$\boldsymbol{Y}$)

The scalar operation in an ECC group is multiplication of a point on the curve by a scalar resulting in a second point on the curve. For example, the point $\boldsymbol{Y}$ is multiplied by the scalar x to produce the point $\boldsymbol{Z}$:

$\boldsymbol{Z} = x\boldsymbol{Y}$ = scalar-op(x,$\boldsymbol{Y}$)

The inverse operation in an ECC group is inversion of a point on a curve resulting in a second point on the curve. A point on an elliptic curve is the inverse of a different point if their sum is the "point at infinity." In other words:

elem-op($\boldsymbol{X}$, inverse-op($\boldsymbol{X}$)) = "point at infinity"

ECC groups make use of a mapping function, F, that maps a point (x, y) that satisfies the curve equation to its x-coordinate—i.e., if $\boldsymbol{P} = (x, y)$ then F($\boldsymbol{P}$) = x. Function F is not defined with the identity element as input.

NOTE—SAE protocol operations preclude function F from ever being called with the identity element, i.e., the "point at infinity."

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12.4.4.2.2 Generation of the password element with ECC groups by looping

If the AP does not indicate support for the SAE hash-to-element in its Extended RSN Capabilities field or the SAE initiator does not set the status code to SAE_HASH_TO_ELEMENT in its SAE Commit message, the password element of an ECC group (***PWE***) shall be generated in the following random hunt-and-peck fashion.

NOTE 1—This method cannot be used with a password identifier.

The password and a counter, represented as a single octet and initially set to 1, are used with the peer identities to generate a password seed. The password seed shall then be stretched using the key derivation function (KDF) from 12.7.1.6.2 to a length equal to the bit length of the prime number, p, from the elliptic curve domain parameters with the Label being the string "SAE Hunting and Pecking" and with the Context being the prime number. If the resulting password value is greater than or equal to the prime number, the counter shall be incremented, a new password seed shall be derived and the hunting-and-pecking shall continue. Otherwise, it shall be used as the x-coordinate of a candidate point (x, y) on the curve satisfying the curve equation, if such a point exists. If no solution exists, the counter shall be incremented, a new password-seed shall be derived and the hunting-and-pecking shall continue. Otherwise, there are two possible solutions: (x, y) and $(x, p - y)$. The password seed shall be used to determine which one to use: if the least significant bit (LSB) of the password seed is equal to that of y, the ***PWE*** shall be set to (x, y); otherwise, it shall be set to $(x, p - y)$.

In order to minimize the possibility of side-channel attacks that attempt to determine the number of interactions of the "hunting-and-pecking" loop required for a given <password, STA-A-MAC, STA-B-MAC> tuple, implementations should perform at least k iterations regardless of whether ***PWE*** is discovered or not. The value k may be set to any non-negative value and should be set to a sufficiently large number to effectively guarantee the discovery of ***PWE*** in less than k iterations. If ***PWE*** is discovered in less than k iterations a random "password" can be used in subsequent iterations to further obfuscate the true cost of discovering ***PWE***.

NOTE 2—The probability that one requires more than n iterations of the "hunting and pecking" loop to find ***PWE*** is roughly $(r/2p)^n$, which rapidly approaches 0 as n increases.

Algorithmically this process is described as follows:

```
found = 0;
counter = 1
Length = len(p)
base = password
do {
        pwd-seed = H(MAX(STA-A-MAC, STA-B-MAC) || MIN(STA-A-MAC, STA-B-MAC),
                base || counter)
        pwd-value = KDF-Hash-Length(pwd-seed, "SAE Hunting and Pecking", p)
        if (pwd-value < p)
        then
                if (pwd-value^3 + a × pwd-value + b) is a quadratic residue modulo p
                then
                        if (found==0)
                        then
                                x = pwd-value
                                save = pwd-seed
                                found = 1
                                base = a new random number
                        fi
                fi
        fi
        counter = counter + 1
} while ((counter ≤ k) or (found==0))
```

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$y = \text{sqrt}(x^3 + ax + b) \bmod p$
if (LSB(*save*) == LSB(*y*))
then
    PWE = (*x*, *y*)
else
    PWE = (*x*, *p* – *y*)
fi

where

KDF-Hash-*Length*	is the key derivation function defined in 12.7.1.6.2 using the hash algorithm identified by the AKM suite selector (see Table 9-151); the context passed to KDF-Hash-Length, *p*, is the octet string representation of the prime per 12.4.7.2.2.
len()	returns the length of its argument in bits

Checking whether a value is a quadratic residue modulo a prime can leak information that can be used in launching a side-channel attack. Therefore, a STA should use this blinding technique in determining a quadratic residue to address the possibility of a side-channel attack.

The blinding technique involves multiplication of the value with a random number so the value being checked for quadratic residue modulo a prime can take on all numbers between 1 and *p*–1 with equal probability. The blinded value is multiplied by a quadratic residue or quadratic nonresidue depending on the value of a coin flip and the result is checked whether the result is a quadratic residue or quadratic nonresidue, respectively.

This technique involves creation of a quadratic residue, *qr*, and quadratic nonresidue, *qnr*, prior to beginning of the hunting-and-pecking loop. These values can be chosen at random by checking their legendre symbol:

do {
    qr = random() mod *p*
} while (LGR(*qr* | *p*) is not equal to 1)

do {
    qnr = random() mod *p*
} while (LGR(*qnr* | *p*) is not equal to -1)

The blinding technique of determining whether a value, *v*, is a quadratic residue modulo a prime, *p*, is then:

r = (random() mod (*p* – 1)) + 1
num = (*v* × *r* × *r*) mod *p*
if (LSB(*r*) == 1)
then
    num = (*num* × *qr*) mod *p*
    if (LGR(*num* | *p*) == 1)
    then
        v is a quadratic residue modulo *p*
    fi
else
    num = (*num* × *qnr*) mod *p*
    if (LGR(*num* | *p*) == –1)
    then
        v is a quadratic residue modulo *p*
    fi
fi
v is a quadratic nonresidue modulo *p*

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The values *qr* and *qnr* may be used for all loops in the hunting-and-pecking process but a new value for *r* shall be generated each time a quadratic residue is checked.

12.4.4.2.3 Hash-to-curve generation of the password element with ECC groups

An SAE peer, e.g. a mesh STA or an AP, indicates support for direct hashing to obtain an ECC password element by setting the SAE hash-to-element bit to 1 in the Extended RSN Capabilities field in all Beacon and Probe Response frames. A STA that uses a password identifier shall use the hash-to-curve method. An SAE initiator that has identified a peer that supports this technique (through receipt of Beacon or Probe Response frames) shall derive a secret element, PT, according to the following technique and indicate this by setting the status code in the SAE Commit message to SAE_HASH_TO_ELEMENT. An SAE initiator shall not indicate support for this form of element derivation unless its peer has already signalled support for this method. If an SAE Commit message is received with status code equal to SAE_HASH_TO_ELEMENT the peer shall generate the PWE using the following technique and reply with its own SAE Commit message with status code set to SAE_HASH_TO_ELEMENT.

The direct hashing technique to derive an element of an ECC group is the Simplified Shallue-Woestijne-Ulas (SSWU) deterministic hash-to-curve method. The SSWU method is called twice with two distinct functions to produce two points on the elliptic curve. The two points are summed to create a secret element PT.

This method works for all Weierstrass elliptic curves whose constants a and b are both not equal to zero. Other curves shall not be used with the hash-to-curve method.

The hash-to-curve method uses HKDF (IETF RFC 5869) with the hash algorithm taken from Table 12-1 based on the length of the prime of the ECC group to perform both functions. First HKDF-Extract is passed a salt in the form of the SSID for which the password is to be used, the password, and optionally a password identifier to produce and intermediary password seed. The resulting seed is passed to HKDF-Expand to produce two distinct strings using different labels. Both values are reduced modulo p, the prime defining the curve, and then passed to SSWU to produce distinct points, *P1* and *P2*, whose sum is *PT*.

This secret *PT* is stored until needed to generate a session specific PWE (see 12.4.5.2).

Algorithmically, this process is as follows:

len = *olen(p)* + $\lfloor (olen(p))/2 \rfloor$
pwd-seed = HKDF-Extract(*ssid*, *password* [|| *identifier*])

pwd-value = HKDF-Expand(*pwd-seed*, "*SAE Hash to Element u1 P1*", *len*)
u1 = *pwd-value* modulo *p*
P1 = SSWU(*u1*)

pwd-value = HKDF-Expand(*pwd-seed*, "*SAE Hash to Element u2 P2*", *len*)
u2 = *pwd-value* modulo *p*
P2 = SSWU(*u2*)

PT = elem-op(*P1*, *P2*)

where

HKDF-Extract() and HKDF-Expand()	are the functions defined in IETF RFC 5869, instantiated with the hash algorithm from Table 12-1
ssid	is an octet string that represents the SSID with which the password is to be used
olen()	returns the length of its argument in octets

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[|| *identifier*]	indicates the optional inclusion of a password identifier, if present
SSWU(*u*)	is a call to the Simple SWU routine passing in parameter *u*

The SSWU method produces two values, *x1*, and *x2*, at least one of which will represent an abscissa of a point on the curve. If *x1* is the abscissa, then *x1* becomes the x-coordinate otherwise *x2* becomes the x-coordinate. The equation of the curve with the x-coordinate produces the square of the y-coordinate which is recovered by taking the square root. The two possible results of the square root are discriminated by checking its least significant bit with the least significant bit of u. The result is a point on the curve.

The SSWU method takes a curve-specific parameter, *z*, which is determined from the following formula, given *p*, *a*, and *b*, from the curve's domain parameter set:

Assign a counter, *ctr*, the value 1. If the following conditions are true for $n = ctr$ then $z = ctr$. Otherwise, if they are true for $n = -ctr$ then $z = -ctr$. Otherwise increment *ctr* and repeat until a value for *z* is found.

i) *n* is not a quadratic residue modulo *p*
ii) *n* is not –1
iii) the polynomial $x^3 + a \times x + b - n$ is irreducible
iv) $(b/(n \times a))^3 + a \times (b/(n \times a)) + b$ is a quadratic residue modulo *p*

Values for some defined groups based on their IANA-assigned values are listed in Table 12-2.

Table 12-2—Unique curve parameter

Curve name	IANA value	z
NIST p256	19	–10
NIST p384	20	–12
NIST p521	21	–4
NIST p192	25	–5
NIST p224	26	31
Brainpool p256	28	–2
Brainpool p384	29	–5
Brainpool p512	30	7

Algorithmically, the Simplified SWU method is:

SSWU(*u*) {
$m = (z^2 \times u^4 + z \times u^2)$ modulo *p*
$l = \text{CEQ}(m, 0)$
$t = inv0(m)$
$x1 = \text{CSEL}(l, (b / (z \times a) \text{ modulo } p), ((-b/a) \times (1 + t)) \text{ modulo } p)$
$gx1 = (x1^3 + a \times x1 + b)$ modulo *p*
$x2 = (z \times u^2 \times x1)$ modulo *p*
$gx2 = (x2^3 + a \times x2 + b)$ modulo *p*

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l = *gx1* is a quadratic residue modulo *p*
v = CSEL(*l*, *gx1*, *gx2*)
x = CSEL(*l*, *x1*, *x2*)
y = sqrt(*v*)

l = CEQ(LSB(*u*), LSB(*y*))
P = CSEL(*l*, (*x*,*y*), (*x*, *p* – *y*))
output P
}

where

p, *a*, and *b*	are all defined in the domain parameter set for the curve
z	is a curve-specific parameter from Table 12-2
inv0(*x*)	is calculated as $x^{(p-2)}$ modulo *p*
x	is a quadratic residue if $x^{((p-1)/2)}$ modulo *p* is zero or one
LSB(*x*)	returns the least significant bit of *x*
CSEL(*x*,*y*,*z*)	operates in constant time and returns *y* if *x* is true and *z* otherwise
CEQ(*x*,*y*)	operates in constant time and returns true if *x* equals *y* and false otherwise

All operations in the SSWU algorithm shall be done in constant time.

NOTE—For curves based on a prime, *p*, such that $p = 3 \bmod 4$ the square root can be implemented with a single modular exponentiation of (*p*+1)/4, that is sqrt(w) = $w^{(p+1)/4}$ modulo *p*.

12.4.4.3 Finite field cryptography (FFC) groups

12.4.4.3.1 FFC group definition

FFC groups used by SAE are defined by the triple (*p*, ***G***, *r*), where *p* is a prime number, ***G*** is a generator, and *r* is the prime order of ***G*** mod *p*. An element, ***B***, in an FFC group satisfies $\boldsymbol{B} = \boldsymbol{G}^i \bmod p$ for some integer *i*. This special property differentiates elements from scalars, even though both elements and scalars can be represented as non-negative integers less than the prime modulus p. The notation convention of 12.4.4 signifies this difference between an element and a scalar in an FFC group. The identity element for an FFC group is the value 1 mod *p*.

The element operation in an FFC group is modular multiplication of two elements of this group resulting in a third element of this group. For example, the element ***X*** is multiplied by the element ***Y*** to product the element ***Z***:

$\boldsymbol{Z} = (\boldsymbol{XY}) \bmod p$ = elem-op(***X***,***Y***)

The scalar operation in an FFC group is modular exponentiation of an element of this group by a scalar resulting in a second element of this group. For example, the point ***Y*** is raised to the power *x* to produce the element ***Z***:

$\boldsymbol{Z} = \boldsymbol{Y}^x \bmod p$ = scalar-op(*x*,***Y***)

Some FFC groups in the IANA repository are based on *safe primes*, i.e., a prime, *p*, of the form $p = 2q + 1$, where *q* is also a prime number. For these FFC groups, the group generated by ***G*** always has order $r = (p - 1)/2$ and thus is uniquely derived from context. For other FFC groups, the parameter *r* shall be explicitly stated as part of the domain parameters.

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The inverse operation in an FFC group is modular inversion of an element of this group producing a second element in this group. An element ***Z*** is the inverse of a second element ***X*** of this group if their modular product is the identity element of the FFC group. In other words:

elem-op(***X***, inverse-op(***X***)) = 1 mod *p*

In contrast to ECC groups, FFC groups do not need a mapping function that maps an element of the FFC group to an integer (since those elements are already non-negative integers less than the prime number, *p*). However, for sake of uniform protocol definition, function F with FFC groups is defined as the identity function—i.e., if *x* is an element of the FFC group then F(*x*) = *x*.

12.4.4.3.2 Generation of the password element with FFC groups by looping

If the AP does not indicate support for the SAE hash-to-element in its Extended RSN Capabilities field or the SAE initiator does not set the status code to SAE_HASH_TO_ELEMENT in its SAE Commit message, the password element of an FFC group (***PWE***) shall be generated in the following random hunt-and-peck fashion.

NOTE—This method cannot be used with a password identifier.

The password and a counter, represented as a single octet and initially set to 1, are used with the two peer identities to generate a password seed. The password seed shall then be stretched using the key derivation function (KDF) from 12.7.1.6.2 to a length equal to the bit length of the prime number, *p*, from the group domain parameters with the Label being the string "SAE Hunting and Pecking" and the Content being the prime number. If the resulting password value is greater than or equal to the prime number, the counter shall be incremented, a new password seed shall be derived, and the hunting-and-pecking shall continue. Otherwise, it shall be raised to the power (*p* – 1) / *r* (where *p* is the prime number and *r* is the order) modulo the prime number to produce a candidate ***PWE***. If the candidate ***PWE*** is greater than 1, the candidate ***PWE*** becomes the ***PWE***; otherwise, the counter shall be incremented, a new password seed shall be derived, and the hunting-and-pecking shall continue.

Algorithmically this process is described as follows:

```
found = 0;
counter = 1
Length = len(p)
do {
        pwd-seed = H(MAX(STA-A-MAC, STA-B-MAC) || MIN(STA-A-MAC, STA-B-MAC),
                password || counter)
        pwd-value = KDF-Hash-Length(pwd-seed, "SAE Hunting and Pecking", p)
        if (pwd-value < p)
        then
                PWE = pwd-value^((p-1)/r) mod p
                if (PWE > 1)
                then
                        found = 1
                fi
        fi
        counter = counter + 1
} while (found==0)
```

where

KDF-Hash-*Length*	is the key derivation function defined in 12.7.1.6.2 using the hash algorithm identified by the AKM suite selector (see Table 9-151); the context passed to KDF-Hash-Length, *p*, is the octet string representation of the prime per 12.4.7.2.2
len()	returns the length of its argument in bits

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12.4.4.3.3 Direct generation of the password element with FFC groups

An SAE peer indicates support for direct hashing to obtain the FFC password element by setting the SAE hash-to-element bit to 1 in the Extended RSN Capabilities field in all Beacon and Probe Response frames. A STA that uses a password identifier shall use the direct hashing technique. An SAE initiator that has identified a peer that supports the following technique (through receipt of Beacon or Probe Response frames) shall derive PT according to the following technique and indicate this by setting the status code in the SAE Commit message to SAE_HASH_TO_ELEMENT. An SAE initiator shall not indicate support for this form of PWE derivation unless its peer has already signalled support. If an SAE Commit message is received with status code equal to SAE_HASH_TO_ELEMENT the peer shall generate the PWE using the following technique and reply with its own SAE Commit message with status code set to SAE_HASH_TO_ELEMENT.

The direct hashing technique uses HKDF (IETF RFC 5869) with the hash algorithm taken from Table 12-1 based on the length of the prime of the FFC group.

To perform the direct hashing technique, HKDF (IETF RFC 5869) is passed a salt in the form of the SSID for which the password is to be used, the password, optionally a password identifier, as an input key, a constant label "SAE Hash to Element", and the length of the prime to produce a password value. The resulting password value shall be reduced into a range such that $1 < pwd\text{-}value < p$. Then, it shall be raised to the power $(p\text{-}1) / q$ and reduced modulo p (where p is the prime number and q is the order). This will ensure PT is a generator of order either 1 (if $PT = 1$) or q (for all other values). The probability of PT taking the value 1 is to be neglected.

This secret PT is stored until needed to generate a session specific PWE.

Algorithmically, this process is as follows:

$len = olen(p) + \lfloor (olen(p))/2 \rfloor$
pwd-seed = HKDF-Extract(*ssid*, *password* [|| *identifier*])
pwd-value = HKDF-Expand(*pwd-seed*, "SAE Hash to Element", *len*)

pwd-value = (*pwd-value* modulo (p – 2)) + 2

$PT = pwd\text{-}value^{(p\text{-}1)/q}$ modulo p

where

HKDF-Extract() and HKDF-Expand()	are the functions defined in IETF RFC 5869, instantiated with the hash algorithm from Table 12-1
ssid	is an octet string that represents the SSID with which the password is to be used
olen()	returns the length of its argument in octets
[|| *identifier*]	indicates the optional inclusion of a password identifier, if present
p and q	are defined in the domain parameter set for the group

This secret PT is stored until needed to generate a session specific PWE (see 12.4.5.2).

12.4.5 SAE protocol

12.4.5.1 Message exchanges

The protocol consists of two message exchanges, a commitment exchange and a confirmation exchange. The commitment exchange is used to force each party to the exchange to commit to a single guess of the password. The confirmation exchange is used to prove that the password guess was correct. Authentication frames are

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used to perform these exchanges (see 9.3.3.11 and 12.4.7.3). The rules for performing these exchanges are specified by the finite state machine in 12.4.8.

When a party has sent its message in the commit exchange it is said to have *committed* and when it has sent its message in the confirmation exchange it has *confirmed*. The following rules are ascribed to the protocol:

— A party may *commit* at any time
— A party *confirm*s after it has *committed* and its peer has *committed*
— A party *accept*s authentication after a peer has *confirmed*
— The protocol successfully *terminates* after each peer has *accepted*

12.4.5.2 PWE and secret generation

Prior to beginning the protocol message exchange, the secret element ***PWE*** and two secret values are generated.

When a STA supports directly hashing to a group element (according to 12.4.4.2.3 or 12.4.4.3.3) it computes a secret element, PT, offline at provisioning time for all groups it wishes to support with that password. Prior to initiating SAE to a STA which also supports the direct form of hashing to a group element, or upon receipt of an SAE Commit message indicating it was generated using a direct form of hashing to a group element, it shall generate the PWE by hashing the two peer MAC addresses to produce a digest, reducing the digest modulo the order of the particular group, *r*, interpreting the reduced digest as an integer and using it with the secret element to generate the PWE:

val = H(0^n*, MAX(STA-A-MAC, STA-B-MAC) || MIN(STA-A-MAC, STA-B-MAC))*
val = val modulo *(r – 1) + 1*
PWE = scalar-op(val, PT)

where 0^n is a salt of all zeros whose length equals the length of the digest from the hash function used to instantiate H() (see Table 12-1).

If a STA does not support a direct form of hashing to a group element, it generates the PWE after selecting a group, either the most preferred group if the STA is initiating SAE to a peer, or the group from a received SAE Commit message if the STA is responding to a peer. The ***PWE*** shall be generated for that group (according to 12.4.4.2.2 or 12.4.4.3.2, depending on whether the group is ECC or FFC, respectively) using the identities of the two STAs and the configured password.

After generation of the ***PWE***, each STA shall generate a secret value, *rand*, and a temporary secret value, *mask*, each of which shall be chosen randomly such that $1 < rand < r$ and $1 < mask < r$ and (*rand* + *mask*) mod *r* is greater than 1, where *r* is the (prime) order of the group. If their sum modulo r is not greater than 1, they shall both be irretrievably deleted and new values shall be randomly generated. The values *rand* and *mask* shall be random numbers produced from a quality random number drawn from a uniform distribution generator. These values shall never be reused on distinct protocol runs.

12.4.5.3 Construction of an SAE Commit message

The scalar and element in an SAE Commit message shall be produced using ***PWE*** and secrets generated in 12.4.5.2, as follows:

commit-scalar = (*rand* + *mask*) mod *r*
COMMIT-ELEMENT = inverse-op(scalar-op(*mask*, ***PWE***))

This message shall be transmitted to the peer as described in 12.4.7. The temporary secret *mask* may be deleted at this point.

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12.4.5.4 Processing of a peer's SAE Commit message

If the peer's SAE Commit message contains a password identifier, the value of that identifier shall be used in construction of the password element (PWE) for this exchange. If a password identifier is present in the peer's SAE Commit message and there is no password with the given identifier a STA shall fail authentication.

If the peer's SAE Commit message contains a Rejected Groups element, the list of rejected groups shall be checked to ensure that all of the groups in the list are groups that would be rejected. If any groups in the list would not be rejected then processing of the SAE Commit message terminates and the STA shall reject the peer's authentication. While the rejected groups are appended to the Rejected Groups element as they are rejected (see 12.4.7.4) there is no inherent order to the groups in the list. The order in which they are sent and received shall be retained when deriving keys.

Upon receipt of a peer's SAE Commit message both the scalar and element shall be verified.

If the scalar value is greater than 1 and less than the order, r, of the negotiated group, scalar validation succeeds; otherwise, it fails. Element validation depends on the type of group. For FFC groups, the element shall be an integer greater than 1 and less than the prime number p minus 1, $(p - 1)$, and the scalar operation of the element and the order of the group, r, shall equal 1 modulo the prime number p. If either of these conditions does not hold, element validation fails; otherwise, it succeeds. For ECC groups, both the x- and y-coordinates of the element shall be non-negative integers less than the prime number p, and the two coordinates shall produce a valid point on the curve satisfying the group's curve definition, not being equal to the "point at the infinity." If either of those conditions does not hold, element validation fails; otherwise, element validation succeeds.

If either scalar validation or element validation fails, the STA shall reject the peer's authentication. If both the scalar and element from the peer's SAE Commit message are successfully validated, a shared secret element, K, shall be derived using the scalar and element (*peer-commit-scalar* and ***PEER-COMMIT-ELEMENT***, respectively) from the peer's SAE Commit message and the STA's secret value.

$$\boldsymbol{K} = \text{scalar-op}(\mathit{rand}, (\text{elem-op}(\text{scalar-op}(\mathit{peer\text{-}commit\text{-}scalar}, \boldsymbol{PWE}), \boldsymbol{PEER\text{-}COMMIT\text{-}ELEMENT})))$$

If the shared secret element, $\boldsymbol{K}$, is the identity element for the negotiated group (the value one for an FFC group or the point-at-infinity for an ECC group) the STA shall reject the peer's authentication. Otherwise, a secret value, k, shall be computed as:

$$k = \text{F}(\boldsymbol{K})$$

The entropy of k shall then be extracted using H to produce *keyseed*. The key derivation function from 12.7.1.6.2 shall then be used with the hash algorithm identified for H() (see 12.4.2) to derive a key confirmation key, KCK, and a pairwise master key, PMK, from *keyseed*. If used with the looping method of PWE generation (see 12.4.4.2.2 and 12.4.4.3.2), both the KCK and PMK shall be 256 bits in length. If used with AKMs 00-0F-AC:8 or 00-0F-AC:9 and the direct hashing technique of PWE generation (see 12.4.4.2.3 and 12.4.4.3.3), the KCK shall be the length of the digest generated by H() and the PMK shall be 256 bits in length. Use of other AKMs with the direct hashing technique will require definition of the length of the PMK. If both SAE Commit messages indicated a status code of SAE_HASH_TO_ELEMENT, a salt consisting of the concatenation of the rejected groups from each peer's Rejected Groups element shall be passed to the KDF; those of the peer with the highest MAC address go first (if only one sent a Rejected Groups element then the salt will consist of that list). If neither peer sent a Rejected Groups element or the status code was not SAE_HASH_TO_ELEMENT, the salt shall consist of a series of octets of the value zero whose length equals the length of the digest of the hash function used to instantiate H().

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keyseed = H(*salt*, *k*)
context = (*commit-scalar* + *peer-commit-scalar*) mod *r*
Length = *Q* + 256
kck_and_pmk = KDF-Hash-*Length*(*keyseed*, "SAE KCK and PMK", *context*)
KCK = L(*kck_and_pmk*, 0, *Q*)
PMK = L(*kck_and_pmk*, *Q*, 256)

where

salt	is either a series of 0 octets or a list of rejected groups (see 12.4.7.4)
KDF-Hash-*Length*	is the key derivation function defined in 12.7.1.6.2 using the hash algorithm defined for H()
Q	is the length of the digest of the H(), the hash function used
context	is treated as an integer and converted into an octet string of length *m* such that $2^{8m} > r$ according to 12.4.7.2.2

The PMK identifier is defined as follows:

PMKID = L(*context*, 0, 128)

12.4.5.5 Construction of an SAE Confirm message

A peer generates a confirmation, *confirm*, and inserts it into an SAE Confirm message by passing the KCK, the current value of the *send-confirm* counter (see 9.4.1.37), the scalar and element from the sent SAE Commit message, and the scalar and element from the received SAE Commit message to the confirmation function CN.

confirm = CN(KCK, *send-confirm, commit-scalar,* ***COMMIT-ELEMENT***, *peer-commit-scalar,* ***PEER-COMMIT-ELEMENT***)

The *send-confirm* counter shall be encoded according to 9.2.2. The elements and scalars shall be in the format they were encoded in when transmitted in an SAE Commit message as described in 12.4.7.4. The message shall be transmitted to the peer as described in 12.4.7.

12.4.5.6 Processing of a peer's SAE Confirm message

Upon receipt of a peer's SAE Confirm message a *verifier* is computed, which is the expected value of the peer's confirmation, *peer-confirm*, extracted from the received an SAE Confirm message. The *verifier* is computed by passing the KCK, the peer's send-confirm counter from the received an SAE Confirm message (see 9.4.1.37), the scalar and element from the received SAE Commit message, and scalar and element from the sent SAE Commit message to the confirmation function CN.

verifier = CN(KCK, *peer-send-confirm, peer-commit-scalar,* ***PEER-COMMIT-ELEMENT***, *commit-scalar,* ***COMMIT-ELEMENT***)

The *peer-send-confirm* shall be encoded according to 9.2.2. The elements and scalars shall be in the format they were encoded in when transmitted in an SAE Commit message as described in 12.4.7.4. If the *verifier* differs from the *peer-confirm,* verification of the peer's SAE Confirm message shall fail.

12.4.6 Anti-clogging tokens

A STA is required to do a considerable amount of work upon receipt of an SAE Commit message. This opens up the possibility of a distributed denial-of-service attack by flooding a STA with bogus SAE Commit messages from forged MAC addresses. To prevent this from happening, a STA shall maintain an *Open* counter in its SAE state machine indicating the number of open and unfinished protocol instances (see 12.4.5.1). When

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that counter hits or exceeds dot11RSNASAEAntiCloggingThreshold, the STA shall respond to each SAE Commit message with a rejection that includes an Anti-Clogging Token field statelessly bound to the sender of the SAE Commit message. The sender of the SAE Commit message shall then include the Anti-Clogging Token field in a subsequent SAE Commit message.

The Anti-Clogging Token field is a variable length value that statelessly binds the MAC address of the sender of an SAE Commit message. The length of the Anti-Clogging Token field need not be specified because the generation and processing of the Anti-Clogging Token field is solely up to one peer. To the other peer in the SAE protocol, the Anti-Clogging Token field is merely an opaque blob whose length is insignificant. An Anti-Clogging Token field should not exceed 256 octets.

NOTE—A suggested method for producing Anti-Clogging Token fields is to generate a random secret value each time the state machine variable hits dot11RSNASAEAntiCloggingThreshold and pass that secret and the MAC address of the sender of the SAE Commit message to the random function H to generate the token.

As long as the state machine variable *Open* is greater than or equal to dot11RSNASAEAntiCloggingThreshold all SAE Commit messages that do not include a valid Anti-Clogging Token field shall be rejected with a request to repeat the SAE Commit message and include the token (see 12.4.5.1).

Since the Anti-Clogging Token field is of fixed size and the size of the *peer-commit-scalar* and ***PEER-COMMIT-ELEMENT*** are inferred from the finite cyclic group being used, it is straightforward to determine whether a received SAE Commit message includes an Anti-Clogging Token field or not.

Encoding of the Anti-Clogging Token field and its placement with respect to the *peer-commit-scalar* and ***PEER-COMMIT-ELEMENT*** is described in 12.4.7.4.

12.4.7 Framing of SAE

12.4.7.1 General

SAE Commit messages and SAE Confirm messages are sent and received by an SAE protocol using Authentication frames.

12.4.7.2 Data type conversion

12.4.7.2.1 General

This protocol requires elements in finite cyclic groups to be converted to octet strings prior to transmission and back again upon receipt. To convert an element into an octet string, the first step is to represent the element in integer format and then employ an integer-to-octet string conversion prior to transmission. To convert an octet string into an element requires an octet string to integer conversion and then representing the integer(s) as an element.

12.4.7.2.2 Integer to octet string conversion

An integer, x, shall be converted into an octet string whose length is the smallest integer m such that $2^{8m} > x$ by first representing x in its binary form and then converting the result to an octet-string.

Given x, m, represent x as a sequence of x_{m-i} base 2^8:

$$x = x_{m-1} \times 2^{8(m-1)} + x_{m-2} \times 2^{8(m-2)} + \ldots + x_1 \times 2^8 + x_0$$

then let the octet M_i have the value x_i for $0 \le i \le m-1$, and the octet string shall be $M_{m-1} \| M_{m-2} \| \ldots \| M_1 \| M_0$.

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12.4.7.2.3 Octet string to integer conversion

An octet string shall be converted into an integer by viewing the octet string as the base 2^8 representation of the integer.

$$x = \sum_{i=1}^{m} 2^{8(m-i)} \times \mathrm{M}_{m-i}$$

12.4.7.2.4 Element to octet string conversion

For ECC groups, each element, except the "point at infinity," is a point on the elliptic curve satisfying the curve equation and consists of two components: an x-coordinate and a y-coordinate. To convert this point to an octet string, each component shall be treated as an integer and converted into an octet string whose length is the smallest integer m such that $2^{8m} > p$, where p is the prime number specified by the elliptic curve domain parameters, according to 12.4.7.2.2. The point shall be represented as the concatenation of the x-coordinate and the y-coordinate, each represented as an octet string of length m octets, and is $2m$ octets long.

For FFC groups each element is a non-negative integer less than the prime number p specified by the FFC domain parameters. To convert this element into an octet string, it shall be treated directly as an integer and converted into an octet string whose length is the smallest integer m such that $2^{8m} > p$, where p is the prime number specified by the domain parameters, according to 12.4.7.2.2.

12.4.7.2.5 Octet string to element conversion

To convert an octet string into a point on an elliptic curve it is necessary to divide it into two octet strings of equal length m. If the length of the octet string does not evenly divide by two, conversion shall fail. Each octet string of length m shall be converted to an integer according to 12.4.7.2.3. The first octet string conversion produces an integer that becomes the x-coordinate of the point and the second octet string conversion produces an integer that becomes the y-coordinate of the point. If either integer equals 0 or is greater than or equal to p, the prime from the elliptic curve domain parameters, conversion shall fail. If the resulting (x, y) point does not satisfy the equation of the curve, or produces the "point at infinity," conversion shall fail.

To convert an octet string into an element in a prime modulus group the octet string shall be converted into an integer according to 12.4.7.2.3 and the integer shall be used directly as the group element.

12.4.7.3 Authentication transaction sequence number for SAE

An SAE Commit message shall use authentication transaction sequence number 1. An SAE Confirm message shall use authentication transaction sequence number 2.

12.4.7.4 Encoding and decoding of SAE Commit messages

An SAE Commit message shall be encoded as an Authentication frame with an Authentication Algorithm Number field set to 3, a Transaction Sequence Number of 1 and a Status Code of SUCCESS or SAE_HASH_TO_ELEMENT. Status codes not equal to SUCCESS or SAE_HASH_TO_ELEMENT indicate a rejection of a peer's SAE Commit message and are described in 12.4.7.6.

An SAE Commit message shall consist of a Finite Cyclic Group field (9.4.1.42) indicating a group, a Scalar field (9.4.1.39) containing the scalar, and an FFE field containing the element (9.4.1.40). If the SAE Commit message is in response to an Anti-Clogging Token field request (see 12.4.7.6), the Anti-Clogging Token field is present (see 9.4.1.38). When the PWE is derived using the hash-to-element method, the Anti-Clogging Token field is encapsulated in an Anti-Clogging Token Container element; otherwise, the Anti-Clogging Token field is included in the frame outside of an element as described in Table 9-41. If a password identifier is

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used in generation of the password element (PWE) the Password identifier element shall be present and the identifier shall be encoded as a UTF-8 string in the Identifier portion of the element (see 9.4.2.216). If an SAE Commit message with status code set to SAE_HASH_TO_ELEMENT is being sent in response to rejection of a previous SAE Commit message with status code set to UNSUPPORTED_FINITE_CYCLIC_GROUP, the group that was rejected shall be appended, after the rejected groups from previous attempts if applicable, to the Rejected Groups field of the Rejected Groups element. Each rejected group shall be represented as an unsigned 16-bit integer using the bit ordering conventions of 9.2.2.

When transmitting an SAE Commit message, the scalar and element shall be converted to octet strings and placed in the Scalar field and FFE field, respectively. The scalar shall be treated as an integer and converted into an octet string of length m such that $2^{8m} > r$, where r is the order of the group, according to 12.4.7.2.2, and the element shall be converted into (an) octet string(s) according to 12.4.7.2.4. When receiving an SAE Commit message the component octet strings in the Scalar field and FFE field shall be converted into a scalar and element, respectively, according to 12.4.7.2.3 and 12.4.7.2.5, respectively.

12.4.7.5 Encoding and decoding of SAE Confirm messages

An SAE Confirm message shall be encoded as an Authentication frame with an Authentication Algorithm Number field set to 3, a Transaction Sequence Number of 2 and a Status Code of SUCCESS. Status codes not equal to SUCCESS indicate rejection of a peer's SAE Confirm message and are described in 12.4.7.6.

An SAE Confirm message shall consist of a Send-Confirm field (9.4.1.37) and a Confirm field (9.4.1.41) containing the output of the random function as described in 12.4.5.5. When transmitting an SAE Confirm message the output of the random function shall be treated as an integer and converted into an octet string of length m, where m is the block size of the random function, according to 12.4.7.2.2 and placed in the Confirm field. When receiving an SAE Confirm message, the octet string in the Confirm field shall be converted into an integer representing the peer's SAE Confirm message according to 12.4.7.2.3.

12.4.7.6 Status codes

An SAE Commit message with a status code not equal to SUCCESS or SAE_HASH_TO_ELEMENT shall indicate that a peer rejects a previously sent SAE Commit message. An unsupported finite cyclic group is indicated with a status code of UNSUPPORTED_FINITE_CYCLIC_GROUP, "Authentication is rejected because the offered finite cyclic group is not supported." An unknown password identifier is indicated with a status code of UNKNOWN_PASSWORD_IDENTIFER, "Authentication is rejected because the password identifier is unknown." An Anti-Clogging Token field is requested by transmitting an SAE Commit message with a status code of ANTI_CLOGGING_TOKEN_REQUIRED, "Anti-Clogging Token Requested," with the Anti-Clogging Token field occupying the Token field of the Authentication frame.

An SAE Confirm message, with a status code not equal to SUCCESS, shall indicate that a peer rejects a previously sent SAE Confirm message. An SAE Confirm message that was not successfully verified is indicated with a status code of CHALLENGE_FAILURE.

12.4.8 SAE finite state machine

12.4.8.1 General

The protocol is instantiated by the finite state machine in Figure 12-4. Each instance of the protocol is identified by a tuple consisting of the local MAC address and the peer MAC address. The model in which SAE is defined consists of a parent process, managed by the SME, which receives messages, and dispatches them to the appropriate protocol instance, also managed by the SME. The parent process manages a database of protocol instances indexed by the peer identity. Protocol instances maintain state, receive events from the parent process, send events to itself, and output data.

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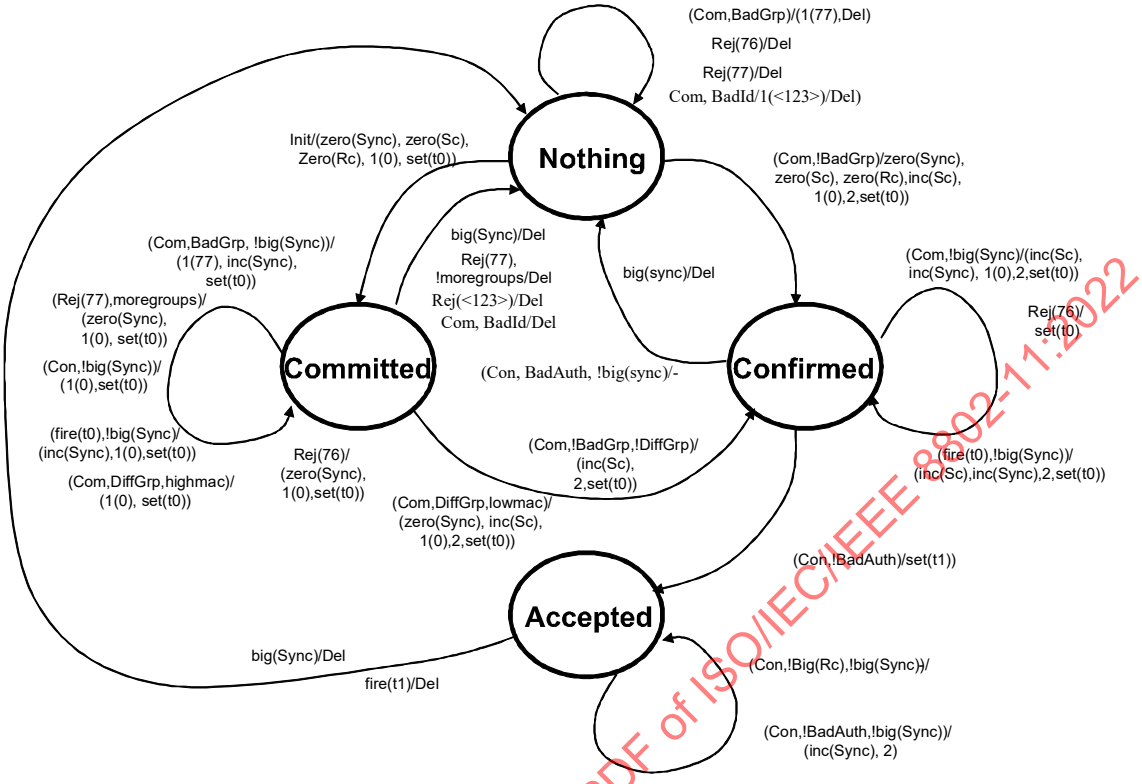

Figure 12-4—SAE finite state machine

NOTE—Figure 12-4 does not show all state machine transitions. A full description of the SAE finite state machine is in 12.4.8.6.2 to 12.4.8.6.6.

The parent process instantiates protocol instances upon receipt of SAE messages and initiation by SME. The parent process also maintains a counter of the number of protocol instances created.

12.4.8.2 States

12.4.8.2.1 Parent process states

The parent process is in a continuous quiescent state.

12.4.8.2.2 Protocol instance states

Each protocol instance is in one of the following four states:

— *Nothing.* The *Nothing* state represents the initial state of a freshly allocated protocol instance or the terminal state of a soon-to-be deallocated protocol instance. Freshly created protocol instances will immediately transition out of *Nothing* state depending on the reason for their creation. Protocol instances that transition into *Nothing* state shall immediately be irretrievably deleted.

— *Committed.* In the *Committed* state, the finite state machine has sent an SAE Commit message and needs both SAE Commit and SAE Confirm messages from the peer.

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— *Confirmed.* In the *Confirmed* state, the finite state machine has sent both an SAE Commit message and an SAE Confirm message and received an SAE Commit message. It awaits an SAE Confirm message.
— *Accepted.* In the *Accepted* state, the protocol instance has both sent and received an SAE Commit message and an SAE Confirm message and the protocol instance has finished.

12.4.8.3 Events and output

12.4.8.3.1 Parent process events and output

The parent process receives events from three sources: the SME, protocol instances, and received frames.

The SME signals the following events to the parent SAE process:

— *Initiate.* An *Initiate* event is used to instantiate a protocol instance to begin SAE with a designated peer.
— *Kill.* A *Kill* event is used to remove a protocol instance with a designated peer.

Protocol instances send the following events to the SAE parent process:

— *Fail.* The peer failed to be authenticated.
— *Auth.* The peer was successfully authenticated.
— *Del.* The protocol instance has had a fatal event.

Receipt of frames containing SAE messages signals the following events to the SAE parent process:

— *Authentication frame with Transaction Sequence number 1.* This event indicates that an SAE Commit message has been received from a peer STA.
— *Authentication frame with Transaction Sequence number 2.* This event indicates that an SAE Confirm message has been received from a peer STA.

The parent process generates Authentication frames with Authentication transaction sequence 1 and a Status of 76 indicating rejection of an Authentication attempt because an Anti-Clogging Token field is required.

12.4.8.3.2 Protocol instance events and output

The protocol instance receives events from the parent SAE process.

— *Com.* Indicates receipt of an SAE Commit message (authentication transaction sequence number 1) with a status of 0.
— *Con.* Indicates receipt of an SAE Confirm message (authentication transaction sequence number 2) with a status of 0.
— *Init.* Indicates that the protocol instance should begin negotiation with a specified peer.
— *Rej(N).* Indicates receipt of a rejected SAE Commit message with status *N*.

In addition, protocol instances receive *fire(X)* events indicating the expiration of timer *X*. Upon expiration of a timer and generation of a *fire()* event, the expired timer is not reset.

The protocol instance generates output from the following events:

— *1(N).* Indicates generation of an SAE Commit message (authentication transaction sequence number 1) with status *N*.
— *2.* Indicates generation of an SAE Confirm message (authentication transaction sequence number 2).

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12.4.8.4 Timers

The parent SAE process does not use timers. Each protocol instance can set timers that result in *fire()* events to be sent to itself. The following timers can be set:

— t0. A retransmission timer.
— t1. A PMK expiration timer.

Timers are set by the protocol instance issuing a *set()* for the particular timer.

12.4.8.5 Variables

12.4.8.5.1 Parent process variables

The parent SAE process maintains a counter, *Open*, which indicates the number of protocol instances in either *Committed* or *Confirmed* state. When the parent SAE process starts up, *Open* is set to 0.

The parent process maintains a database of protocol instances.

NOTE—Depending on how Anti-Clogging Token fields (see 12.4.6) are constructed, the parent SAE process might also maintain a random secret used for token creation.

12.4.8.5.2 Protocol instance variables

Each protocol instance maintains the following three variables:

— *Sync.* The number of state resynchronizations that have occurred.
— *Sc.* The number of SAE Confirm messages that have been sent. This is the send-confirm counter used in the construction of SAE Confirm messages (see 12.4.5.5).
— *Rc.* The received value of the *send-confirm* counter in the last received SAE Confirm message. In other words, this is the value of the peer's send-confirm counter.

Function *zero(X)* assigns the value 0 to the variable *X*, *inc(X)* increments the variable *X*, and *big(X)* indicates that the variable *X* has exceeded a maximum value.

In addition, protocol instances maintain the following six indicators that are not maintained as state variables but, instead, indicate the cause of certain behavior.

— *BadID.* The password identifier in an SAE Commit message is unknown or wrong.
— *BadGrp.* The group specified in an SAE Commit message is not supported.
— *DiffGrp.* The group specified in an SAE Commit message is supported but differs from the one offered.
— *BadAuth.* The contents of a confirm frame were incorrect. Authentication rejected due to verifier mismatch while processing SAE confirm message.
— *highmac*. The peer identity is numerically less than the local identity.
— *lowmac*. The peer identity is numerically greater than the local identity.
— *moregroups.* There are finite cyclic groups in the configuration that have not been offered to the peer.

A negative indication is shown with an exclamation point (!)—e.g., "the group specified in an SAE Commit message is supported" would be !BadGrp, which is read as "not BadGrp."

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12.4.8.6 Behavior of state machine

12.4.8.6.1 Parent process behavior

For any given peer identity, there shall be only one protocol instance in *Committed* or *Confirmed* state. Similarly, for any given peer identity, there shall be only one protocol instance in *Accepted* state.

The parent process creates protocol instances based upon different actions. Creating a protocol instance entails allocation of state necessary to maintain the protocol instance state machine, putting the protocol instance in *Nothing* state, incrementing the *Open* counter, and inserting the protocol instance into its database indexed by the MAC address of the peer with whom the protocol instance will communicate.

The parent process shall delete protocol instances irretrievably.

Upon receipt of an *Initiate* event, the parent process shall check whether there exists a protocol instance for the peer MAC address (from the *Init* event) in either *Committed* or *Confirmed* state. If there is, the *Initiate* event shall be ignored. Otherwise, a protocol instance shall be created, and an *Init* event shall be sent to the protocol instance.

Upon receipt of a *Kill* event, the parent process shall delete all protocol instances indexed by the peer MAC address (from the *Kill* event) in its database. For each protocol instance in *Committed* or *Confirmed* state, the *Open* counter shall be decremented.

Upon receipt of a *Sync, Del,* or *Fail* event from a protocol instance, the parent process shall decrement the *Open* counter and deletes the protocol instance.

Upon receipt of an *Auth* event from a protocol instance, the parent process shall decrement the *Open* counter. If another protocol instance exists in the database indexed by the same peer identity as the protocol instance that sent the *Auth* event, the other protocol instance shall be deleted.

Upon receipt of an SAE Commit message, the parent process checks whether a protocol instance for the peer MAC address exists in the database. If one does, and it is in either *Committed* state or *Confirmed* state the frame shall be passed to the protocol instance. If one does and it is in *Accepted* state, the scalar in the received frame is checked against the *peer-scalar* used in authentication of the existing protocol instance (in *Accepted* state). If it is identical, the frame shall be dropped. If not, the parent process checks the value of *Open*. If *Open* is greater than dot11RSNASAEAntiCloggingThreshold, the parent process shall check for the presence of an Anti-Clogging Token field. If an Anti-Clogging Token field exists and is correct, the parent process shall create a protocol instance. If the Anti-Clogging Token field is incorrect, the frame shall be silently discarded. If Open is greater than or equal to dot11RSNASAEAntiCloggingThreshold and there is no Anti-Clogging Token field in the received frame, the parent process shall construct a response as an Authentication frame with the Authentication Transaction Sequence Number field set to 1, the Status Code field set to ANTI_CLOGGING_TOKEN_REQUIRED, and the body of the frame consisting of an Anti-Clogging Token field (see 12.4.6). If *Open* is less than dot11RSNASAEAntiCloggingThreshold, the parent process shall create a protocol instance and the frame shall be sent to the protocol instance as a *Com* event.

Upon receipt of an SAE Confirm message, the parent process checks whether a protocol instance for the peer MAC address (as indicated by the SA in the received frame) exists in the database. If there is a single protocol instance, the frame shall be passed to it as a *Con* event. If there are two protocol instances indexed by that peer MAC address, the frame shall be passed, as a *Con* event, to the protocol instance that is not in *Accepted* state. If there are no protocol instances indexed by that peer MAC address, the frame shall be dropped.

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12.4.8.6.2 Protocol instance behavior—General

State machine behavior is illustrated in Figure 12-4. The protocol instance receives events from the parent process and from itself. It generates SAE messages that are transmitted to a peer and sends events to itself and the parent process.

The semantics of the state diagram are "occurrence/behavior" where "occurrence" is a comma-separated list of events and/or indicators, or the special symbol "—" indicating no occurrence; and, "behavior" is a comma-separated list of outputs and/or functions, or the special symbol "—" indicating no behavior.

When the state machine calls for the t0 (retransmission) timer to be set, it shall be set to dot11RSNASAERetransPeriod. When the state machine calls for the t1 (key expiration) timer to be set, it shall be set to dot11RSNAConfigPMKLifetime.

12.4.8.6.3 Protocol instance behavior—Nothing state

In *Nothing* state a protocol instance has just been allocated.

Upon receipt of an *Init* event, the protocol instance shall zero its *Sync* variable, *Rc*, and *Sc* variables, select a group from local configuration and generate the ***PWE*** and the secret values according to 12.4.5.2, generate an SAE Commit message (see 12.4.5.3), and set its t0 (retransmission) timer. The protocol instance transitions into *Committed* state.

Upon receipt of a *Com* event, the protocol instance shall check the Status of the Authentication frame. If the Status code is not SUCCESS, the frame shall be silently discarded and a *Del* event shall be sent to the parent process. Otherwise, the frame shall be processed by first checking whether a password identifier is present. If so and there is no password associated with that identifier, *BadID* shall be set and the protocol instance shall construct and transmit an Authentication frame with Status Code set to UNKNOWN_PASSWORD_IDENTIFIER. If there is no password identifier present or if a password is associated with that identifier, the frame shall be processed by next checking the finite cyclic group field to see if the requested group is supported. If not, *BadGrp* shall be set and the protocol instance shall construct and transmit an Authentication frame with Status code UNSUPPORTED_FINITE_CYCLIC_GROUP indicating rejection with the finite cyclic group field set to the rejected group, and shall send the parent process a *Del* event. If the group is supported, the protocol instance shall zero the *Sc* and *Rc* counters and it shall generate the ***PWE*** and the secret values according to 12.4.5.2. It shall then process the received SAE Commit message (see 12.4.5.4). If validation of the received SAE Commit message fails, the protocol instance shall send a Del event to the parent process; otherwise, it shall construct and transmit an SAE Commit message (see 12.4.5.3) followed by an SAE Confirm message (see 12.4.5.5). The *Sync* counter shall be set to 0 and the t0 (retransmission) timer shall be set. The protocol instance transitions to *Confirmed* state.

NOTE—A protocol instance in *Nothing* state will never receive an SAE Confirm message due to state machine behavior of the parent process.

12.4.8.6.4 Protocol instance behavior—Committed state

In *Committed* state, a protocol instance has sent its peer an SAE Commit message but has yet to receive (and accept) anything.

Upon receipt of a *Com* event, the t0 (retransmission) timer shall be canceled. Then the following is performed:

— The protocol instance shall check the Status code of the Authentication frame. If the Status code is ANTI_CLOGGING_TOKEN_REQUIRED, a new SAE Commit message shall be constructed with the Anti-Clogging Token field from the received Authentication frame, and the *commit-scalar* and ***COMMIT-ELEMENT*** previously sent. The new SAE Commit message shall be transmitted to the peer, *Sync* shall be zeroed, and the t0 (retransmission) timer shall be set.

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— If the Status code is UNKNOWN_PASSWORD_IDENTIFIER, the protocol instance shall send a Del event to the parent process and transition back to Nothing state.

— If the Status code is UNSUPPORTED_FINITE_CYCLIC_GROUP, the protocol instance shall check the finite cyclic group field being rejected. If the rejected group does not match the last offered group the protocol instance shall silently discard the message and set the t0 (retransmission) timer. If the rejected group matches the last offered group, the protocol instance shall choose a different group and generate the ***PWE*** and the secret values according to 12.4.5.2; it then generates and transmits a new SAE Commit message to the peer, zeros *Sync*, sets the t0 (retransmission) timer, and remains in *Committed* state. If there are no other groups to choose, the protocol instance shall send a *Del* event to the parent process and transitions back to *Nothing* state.

— If the Status is some other nonzero value, the frame shall be silently discarded and the t0 (retransmission) timer shall be set.

— If the Status is zero, the finite cyclic group field is checked. If the group is not supported, *BadGrp* shall be set and the value of *Sync* shall be checked.

  — If *Sync* is greater than dot11RSNASAESync, the protocol instance shall send a *Del* event to the parent process and transitions back to *Nothing* state.

  — If *Sync* is not greater than dot11RSNASAESync, *Sync* shall be incremented, an SAE Commit message with Status code equal to UNSUPPORTED_FINITE_CYCLIC_GROUP indicating rejection, and the Algorithm identifier set to the rejected algorithm shall be sent to the peer, the t0 (retransmission) timer shall be set and the protocol instance shall remain in *Committed* state.

— If there is a password identifier associated with the password when the protocol instance constructed its SAE Commit message and either there is no password identifier in the received frame or the password identifier in the received frame does not match the password identifier used to construct the protocol instance's SAE Commit message, *BadID* shall be set, the protocol instance shall send a Del event to the parent process and transition back to Nothing state.

— If the group is supported but does not match that used when the protocol instance constructed its SAE Commit message, *DiffGrp* shall be set and the local identity and peer identity shall be checked.

  — The mesh STA, with the numerically greater of the two MAC addresses, drops the received SAE Commit message, retransmits its last SAE Commit message, and shall set the t0 (retransmission) timer and remain in *Committed* state.

  — The mesh STA, with the numerically lesser of the two MAC addresses, zeros *Sync*, shall increment *Sc*, choose the group from the received SAE Commit message, generate new ***PWE*** and new secret values according to 12.4.5.2, process the received SAE Commit message according to 12.4.5.4, generate a new SAE Commit message and SAE Confirm message, and shall transmit the new Commit and Confirm to the peer. It shall then transition to *Confirmed* state.

— If the group is supported and matches that used when the protocol instance constructed its SAE Commit message, the protocol instance checks the *peer-commit-scalar* and ***PEER-COMMIT-ELEMENT*** from the message. If they match those sent as part of the protocol instance's own SAE Commit message, the frame shall be silently discarded (because it is evidence of a reflection attack) and the t0 (retransmission) timer shall be set. If the received element and scalar differ from the element and scalar offered, the received SAE Commit message shall be processed according to 12.4.5.4, the *Sc* counter shall be incremented (thereby setting its value to one), the protocol instance shall then construct an SAE Confirm message, transmit it to the peer, and set the t0 (retransmission) timer. It shall then transition to *Confirmed* state.

If the t0 (retransmission) timer fires, the value of the *Sync* counter is checked. If *Sync* is greater than dot11RSNASAESync, the protocol instance shall send a *Del* event to the parent process and transition back to *Nothing* state. If *Sync* is not greater than dot11RSNASAESync, the *Sync* counter shall be incremented, the last message sent shall be sent again, and the t0 (retransmission) timer shall be set.

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Upon receipt of a *Con* event, the protocol instance checks the value of *Sync*. If it is greater than dot11RSNASAESync, the protocol instance shall send a *Del* event to the parent process and transition back to *Nothing* state. If *Sync* is not greater than dot11RSNASAESync, the protocol instance shall transmit the last SAE Commit message sent to the peer.

12.4.8.6.5 Protocol instance behavior—Confirmed state

In *Confirmed* state, a protocol instance has sent its peer an SAE Commit message and SAE Confirm message. It has received an SAE Commit message from its peer.

Rejection frames received in Confirmed state shall be silently discarded.

Upon receipt of a *Com* event, the t0 (retransmission) timer shall be canceled. If the Status is nonzero, the frame shall be silently discarded, the t0 (retransmission) timer set, and the protocol instance shall remain in the *Confirmed* state. If *Sync* is greater than dot11RSNASAESync, the protocol instance shall send the parent process a *Del* event and transitions back to *Nothing* state. If *Sync* is not greater than dot11RSNASAESync, the protocol instance shall verify that the finite cyclic group is the same as the previously received SAE Commit message. If not, the frame shall be silently discarded. If so, the protocol instance shall increment *Sync*, increment *Sc*, and transmit its SAE Commit message and its SAE Confirm message with the new *Sc* value. It then shall set the t0 (retransmission) timer.

Upon receipt of a *Con* event, the SAE Confirm message shall be processed according to 12.4.5.6. If processing is unsuccessful and the SAE Confirm message is not verified, protocol instance shall remain in Confirmed state. If processing is successful and the SAE Confirm message has been verified, the *Rc* variable shall be set to the value of the Send-Confirm field, *Sc* shall be set to the value $2^{16} - 1$, the t1 (key expiration) timer shall be set, the t0 (retransmission) timer shall be canceled, and the protocol instance shall transition to *Accepted* state.

If the t0 (retransmission) timer fires, the value of the *Sync* counter shall be checked. If *Sync* is greater than dot11RSNASAESync, the protocol instance shall send a *Del* event to the parent process and transition back to *Nothing* state. If *Sync* is not greater than dot11RSNASAESync, the *Sync* counter shall be incremented, *Sc* shall be incremented, and the protocol instance shall create an SAE Confirm message with the new *Sc* value, transmit it to the peer, and set the t0 (retransmission) timer.

12.4.8.6.6 Protocol instance behavior—Accepted state

In *Accepted* state, a protocol instance has sent an SAE Commit message and an SAE Confirm message to its peer and received an SAE Commit message and SAE Confirm message from the peer. Unfortunately, there is no guarantee that the final SAE Confirm message sent by the STA was received by the peer.

Upon receipt of a *Con* event, the *Sync* counter shall be checked. If the value is greater than dot11RSNASAESync, the protocol instance shall send a *Del* event to the parent process and shall transition to *Nothing* state. If the value of *Sync* is not greater than dot11RSNASAESync, the Send-Confirm field shall be checked. If its value is not greater than *Rc* or is equal to $2^{16} - 1$, the received frame shall be silently discarded. Otherwise, the Confirm field shall be checked according to 12.4.5.6. If the verification fails, the received frame shall be silently discarded. If the verification succeeds, the *Rc* variable shall be set to the value of the Send-Confirm field, the *Sync* shall be incremented and a new SAE Confirm message shall be constructed (with *Sc* set to $2^{16} - 1$) and sent to the peer. The protocol instance shall remain in *Accepted* state.

If the t1 (key expiration) timer fires, the protocol instance shall send the parent process a *Del* event and transition to *Nothing* state.

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12.5 RSNA confidentiality and integrity protocols

12.5.1 Overview

This standard defines the following RSNA data confidentiality and integrity protocols: TKIP, CCMP, and GCMP. This standard defines one integrity protocol for Management frames: BIP.

Implementation of TKIP is optional for an RSNA and used only for the protection of Data frames. A design aim for TKIP was that the algorithm should be implementable within the capabilities of most devices supporting only WEP, so that many such devices would be field-upgradable by the supplier to support TKIP.

BIP is a mechanism that is used only when management frame protection is negotiated. BIP provides integrity protection for group addressed robust Management frames. BIP is used only to protect Management frames within the BSS.

12.5.2 Temporal key integrity protocol (TKIP)

12.5.2.1 TKIP overview

12.5.2.1.1 General

The TKIP is a cipher suite enhancing WEP on pre-RSNA hardware. TKIP modifies WEP as follows:

a) A transmitter calculates a keyed cryptographic message integrity code (MIC) over the MSDU SA and DA, the MSDU priority (see 12.5.2.3), and the MSDU plaintext data. TKIP appends the computed MIC to the MSDU data prior to fragmentation into MPDUs. The receiver verifies the MIC after decryption, ICV checking, and defragmentation of the MPDUs into an MSDU and discards any received MSDUs with invalid MICs. TKIP's MIC provides a defense against forgery attacks.

b) Because of the design constraints of the TKIP MIC, it is still possible for an adversary to compromise message integrity; therefore, TKIP also implements countermeasures. The countermeasures bound the probability of a successful forgery and the amount of information an attacker can learn about a key.

c) TKIP uses a per-MPDU TKIP sequence counter (TSC) to sequence the MPDUs it sends. The receiver drops MPDUs received out of order, i.e., not received with increasing sequence numbers. This provides replay protection. TKIP encodes the TSC value from the sender to the receiver as a WEP IV and extended IV.

d) TKIP uses a cryptographic mixing function to combine a temporal key, the TA, and the TSC into the WEP seed. The receiver recovers the TSC from a received MPDU and utilizes the mixing function to compute the same WEP seed needed to correctly decrypt the MPDU. The key mixing function is designed to defeat weak-key attacks against the WEP key.

TKIP defines additional MIB attributes; see Annex C.

12.5.2.1.2 TKIP cryptographic encapsulation

TKIP enhances the WEP cryptographic encapsulation with several additional functions, as depicted in Figure 12-5.

a) TKIP MIC computation protects the MSDU Data field and corresponding SA, DA, and Priority fields. The computation of the MIC is performed on the ordered concatenation of the SA, DA, Priority, and MSDU Data fields. The MIC is appended to the MSDU Data field. TKIP discards any MIC padding prior to appending the MIC.

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b) If needed, the MSDU with MIC is fragmented into one or more MPDUs. TKIP assigns a monotonically increasing TSC value to each MPDU, taking care that all of the MPDUs generated from the same MSDU have the same value of extended IV (see 12.5.2.2).

c) For each MPDU, TKIP uses the key mixing function to compute the WEP seed.

d) TKIP represents the WEP seed as a WEP IV and ARC4 key and passes these with each MPDU to WEP for generation of the ICV (see 9.2.4.7), and for encryption of the plaintext MPDU, including all or part of the MIC, if present. WEP uses the WEP seed as a WEP default key, identified by a key identifier associated with the temporal key.

NOTE—When the TSC space is exhausted, the choices available to an implementation are to replace the temporal key with a new one or to end communications. Reuse of any TSC value compromises already sent traffic. Note that retransmitted MPDUs reuse the TSC without any compromise of security. The TSC is large enough, however, that TSC space exhaustion is not expected to be an issue.

In Figure 12-5, the TKIP-mixed transmitter address and key (TTAK) denotes the intermediate key produced by Phase 1 of the TKIP mixing function (see 12.5.2.5).

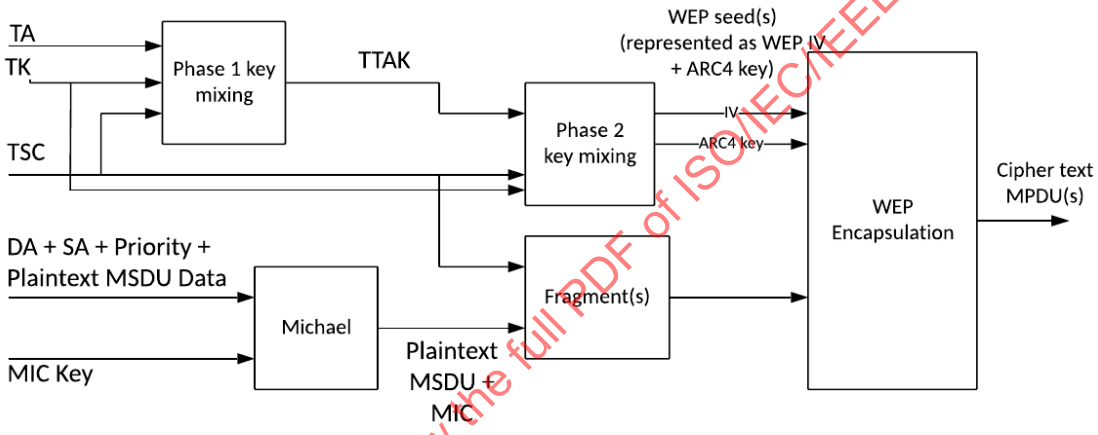

Figure 12-5—TKIP encapsulation block diagram

12.5.2.1.3 TKIP decapsulation

TKIP enhances the WEP decapsulation process with the following additional steps:

a) Before WEP decapsulates a received MPDU, TKIP extracts the TSC sequence number and key identifier from the WEP IV and the extended IV. TKIP discards a received MPDU that violates the sequencing rules (see 12.5.2.6) and otherwise uses the mixing function to construct the WEP seed.

b) TKIP represents the WEP seed as a WEP IV and ARC4 key and passes these with the MPDU to WEP for decapsulation.

c) If WEP indicates the ICV check succeeded, the implementation reassembles the MPDU into an MSDU. If the MSDU defragmentation succeeds, the receiver verifies the TKIP MIC. If MSDU defragmentation fails, then the MSDU is discarded.

d) The MIC verification step recomputes the MIC over the MSDU SA, DA, Priority, and MSDU Data fields (but not the TKIP MIC field). The calculated TKIP MIC result is then compared bitwise to the received MIC.

e) If the received and the locally computed MIC values are identical, the verification succeeds, and TKIP shall deliver the MSDU to the upper layer. If the two differ, then the verification fails; the receiver shall discard the MSDU and shall engage in appropriate countermeasures.

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Figure 12-6 depicts this process.

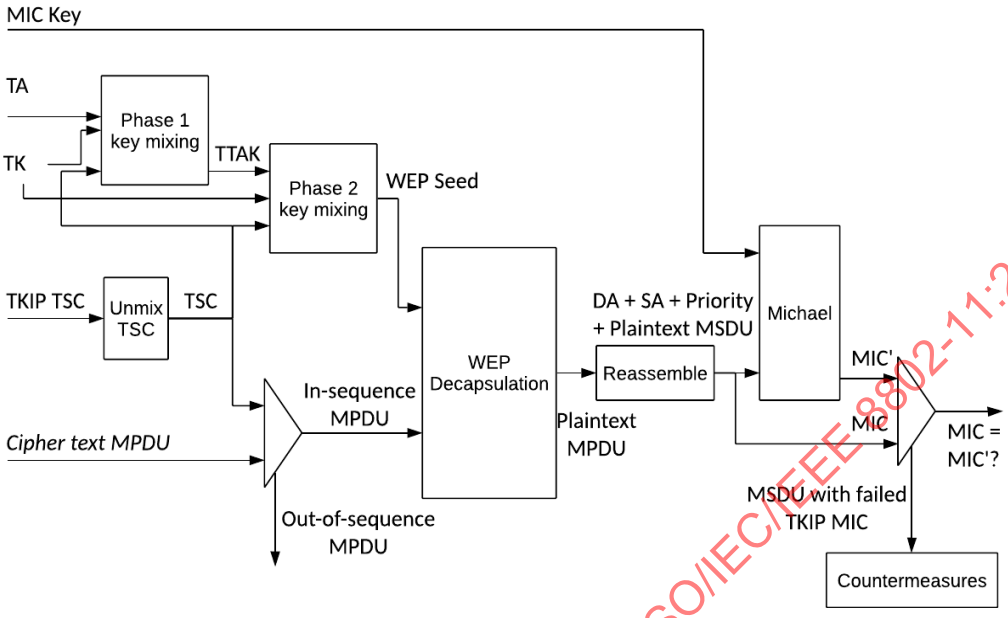

Figure 12-6—TKIP decapsulation block diagram

12.5.2.2 TKIP MPDU formats

TKIP reuses the pre-RSNA WEP MPDU format. It extends the MPDU by 4 octets to accommodate an extension to the WEP IV, denoted by the Extended IV field, and extends the MSDU format by 8 octets to accommodate the new MIC field. TKIP inserts the Extended IV field immediately after the WEP IV field and before the encrypted data. TKIP appends the MIC to the MSDU Data field; the MIC becomes part of the encrypted data.

Once the MIC is appended to the MSDU data, the added MIC octets are considered part of the MSDU for subsequent fragmentation.

Figure 12-7 depicts the layout of the encrypted MPDU when using TKIP. Note that the figure only depicts the case when the MSDU can be encapsulated in a single MPDU.

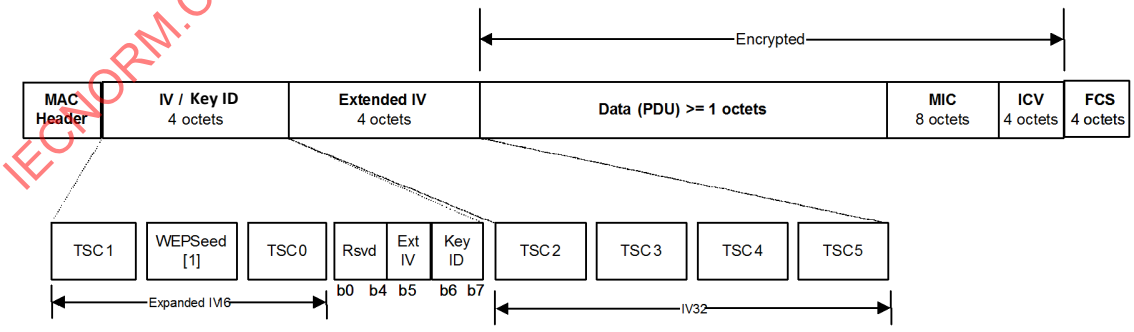

Figure 12-7—Construction of expanded TKIP MPDU

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The ExtIV bit in the Key ID octet indicates the presence or absence of an extended IV. If the ExtIV bit is 0, only the nonextended IV is transferred. If the ExtIV bit is 1, an extended IV of 4 octets follows the original IV. For TKIP the ExtIV bit shall be set to 1, and the Extended IV field shall be supplied. The ExtIV bit shall be 0 for WEP frames. The Key ID field shall be set to the key index supplied by the MLME-SETKEYS.request primitive for the key used in cryptographic encapsulation of the frame.

TSC5 is the most significant octet of the TSC, and TSC0 is the least significant. Octets TSC0 and TSC1 form the IV sequence number and are used with the TKIP Phase 2 key mixing. Octets TSC2–TSC5 are used in the TKIP Phase 1 key hashing and are in the Extended IV field. When the lower 16-bit sequence number rolls over (0xFFFF → 0x0000), the extended IV value, i.e., the upper 32 bits of the entire 48-bit TSC, shall be incremented by 1.

NOTE—The rationale for this construction is as follows:

a) Aligning on word boundaries eases implementation on legacy devices.
b) Adding 4 octets of extended IV eliminates TSC exhaustion as a reason to rekey.
c) Key ID octet changes. Bit 5 indicates that an extended IV is present. The receiver/transmitter interprets the 4 octets following the Key ID as the extended IV. The receiving/transmitting STA also uses the value of octets TSC0 and TSC1 to detect that the cached TTAK needs to be updated.

The Extended IV field shall not be encrypted.

WEPSeed[1] is not used to construct the TSC, but is set to (TSC1 | 0x20) & 0x7f.

TKIP shall encrypt all of the MPDUs generated from one MSDU under the same temporal key.

12.5.2.3 TKIP MIC

12.5.2.3.1 General

Flaws in the IEEE 802.11 WEP design cause it to fail to meet its goal of protecting data traffic content from casual eavesdroppers. Among the most significant WEP flaws is the lack of a mechanism to defeat message forgeries and other active attacks. To defend against active attacks, TKIP includes a MIC, called *michael*. This MIC offers only weak defenses against message forgeries, but it constitutes the best that can be achieved with the majority of legacy hardware. TKIP uses different MIC keys depending on the direction of the transfer as described in 12.8.1 and 12.8.2.

Annex J contains an implementation of the TKIP MIC. It also provides test vectors for the MIC.

12.5.2.3.2 Motivation for the TKIP MIC

Before defining the details of the MIC, it is useful to review the context in which this mechanism operates. Active attacks enabled by the original WEP design include the following:

— Bit-flipping attacks
— Data (payload) truncation, concatenation, and splicing
— Fragmentation attacks
— Iterative guessing attacks against the key
— Redirection by modifying the MPDU DA or RA field
— Impersonation attacks by modifying the MPDU SA or TA field

The MIC makes it more difficult for any of these attacks to succeed.

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All of these attacks remain at the MPDU level with the TKIP MIC. The MIC, however, applies to the MSDU, so it blocks successful MPDU-level attacks. TKIP applies the MIC to the MSDU at the transmitter and verifies it at the MSDU level at the receiver. If a MIC check fails at the MSDU level, the implementation shall discard the MSDU and invoke countermeasures (see 12.5.2.4).

Figure 12-8 depicts different peer layers communicating.

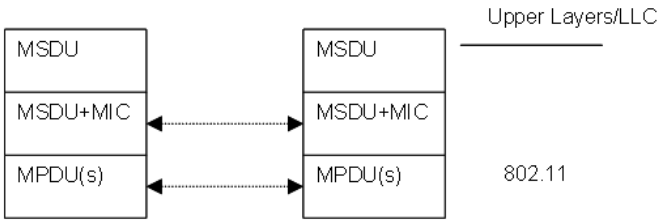

Figure 12-8—TKIP MIC relation to IEEE 802.11 processing

This figure depicts an architecture where the MIC is logically appended to the raw MSDU in response to the MA-UNITDATA.request primitive. The TKIP MIC is computed over

— The MSDU DA
— The MSDU SA
— The MSDU Priority
— The entire unencrypted MSDU data (payload)

The DA field, SA field, 3 reserved octets, and a 1-octet Priority field are used only for calculating the MIC. The Priority field refers to the priority parameter of the MA-UNITDATA.request primitive. The fields in Figure 12-9 are treated as an octet stream using the conventions described in 9.2.2.

6	6	1	3	M	1	1	1	1	1	1	1	1	octets
DA	SA	Priority	0	Data	M 0	M 1	M 2	M 3	M 4	M 5	M 6	M 7	

Figure 12-9—TKIP MIC processing format

TKIP appends the MIC at the end of the MSDU. The MIC is 8 octets in size for michael. The IEEE 802.11 MAC then applies its normal processing to transmit this MSDU-with-MIC as a sequence of one or more MPDUs. In other words, the MSDU-with-MIC can be partitioned into one or more MPDUs, the WEP ICV is calculated over each MPDU, and the MIC can even be partitioned to lie in two MPDUs after fragmentation. The TKIP MIC augments, but does not replace, the WEP ICV. Because the TKIP MIC is a weak construction, TKIP protects the MIC with encryption, which makes TKIP MIC forgeries more difficult. The WEP ICV helps to prevent false detection of MIC failures that would cause countermeasures to be invoked.

The receiver reverses this procedure to reassemble the MSDU; and, after the MSDU has been logically reassembled, the IEEE 802.11 MAC verifies the MIC prior to delivery of the MSDU to upper layers. If the MIC validation succeeds, the MAC delivers the MSDU. If the MIC validation fails, the MAC shall discard the MSDU and invoke countermeasures (see 12.5.2.4).

NOTE—TKIP calculates the MIC over the MSDU rather than the MPDU, because doing so increases the implementation flexibility with preexisting WEP hardware.

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Note that a MIC alone cannot provide complete forgery protection, as it cannot defend against replay attacks. Therefore, TKIP provides replay detection by TSC sequencing and ICV validation. Furthermore, if TKIP is utilized with a GTK, an insider STA can masquerade as any other STA belonging to the group.

12.5.2.3.3 Definition of the TKIP MIC

Michael generates a 64-bit MIC. The michael key consists of 64 bits, represented as an 8-octet sequence, $k_0 ... k_7$. This is converted to two 32-bit words, K_0 and K_1. Throughout this subclause, all conversions between octets and 32-bit words shall use the little endian conventions, given in 9.2.2.

Michael operates on each MSDU including the Priority field, 3 reserved octets, SA field, and DA field. An MSDU consists of octets $m_0 ... m_{n-1}$ where n is the number of MSDU octets, including SA, DA, Priority, and Data fields. The message is padded at the end with a single octet with value 0x5a, followed by between 4 and 7 zero octets. The number of zero octets is chosen so that the overall length of the padded MSDU is a multiple of four. The padding is not transmitted with the MSDU; it is used to simplify the computation over the final block. The MSDU is then converted to a sequence of 32-bit words $M_0 ... M_{N-1}$, where $N = \lceil (n+5)/4 \rceil$. By construction, $M_{N-1} = 0$ and $M_{N-2} \neq 0$.

The MIC value is computed iteratively starting with the key value (K_0 and K_1) and applying a block function b for every message word, as shown in Figure 12-10. The algorithm loop runs a total of N times (i takes on the values 0 to N–1), where N is as above, the number of 32-bit words composing the padded MSDU. The algorithm results in two words (l and r), which are converted to a sequence of 8 octets using the least-significant-octet-first convention:

- M0 = l & 0xff
- M1 = (l/0x100) & 0xff
- M2 = (l/0x10000) & 0xff
- M3 = (l/0x1000000) & 0xff
- M4 = r & 0xff
- M5 = (r/0x100) & 0xff
- M6 = (r/0x10000) & 0xff
- M7 = (r/0x1000000) & 0xff

This is the MIC value. The MIC value is appended to the MSDU as data to be sent.

Input: Key (K_0, K_1) and padded MSDU (represented as 32-bit words) M_0 ... M_{N-1}
Output: MIC value (V_0, V_1)

MICHAEL((K_0, K_1) , (M_0, ... , M_N))
(l,r) ← (K_0, K_1)
for i = 0 **to** N–1 **do**
    l ← l ⊕ M_i
    (l,r) ← b(l,r)
return (l,r)

Figure 12-10—Michael message processing

Figure 12-11 defines the michael block function b. It is a Feistel-type construction with alternating additions and XOR operations. It uses <<< to denote the rotate-left operator on 32-bit values, >>> for the rotate-right operator, and XSWAP for a function that swaps the position of the 2 least significant octets. It also uses the position of the two most significant octets in a word.

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```
Input: (l,r)
Output: (l,r)
b(L,R)
        r ← r ⊕ (l <<< 17)
        l ← (l + r) mod 2^32
        r ← r ⊕ XSWAP(l)
        l ← (l + r) mod 2^32
        r ← r ⊕ (l <<< 3)
        l ← (l + r) mod 2^32
        r ← r ⊕ (l >>> 2)
        l ← (l + r) mod 2^32
        return (l,r)
```

Figure 12-11—Michael block function

12.5.2.4 TKIP countermeasures procedures

12.5.2.4.1 General

The TKIP MIC trades off security in favor of implementability on pre-RSNA STAs. Michael provides only weak protection against active attacks. A failure of the MIC in a received MSDU indicates a probable active attack. A successful attack against the MIC would mean an attacker could inject forged Data frames and perform further effective attacks against the encryption key itself. If TKIP implementation detects a probable active attack, TKIP shall take countermeasures as specified in this subclause. These countermeasures accomplish the following goals:

— MIC failure events should be logged as a security-relevant matter. A MIC failure is an almost certain indication of an active attack and warrants a follow-up by the system administrator.

— The rate of MIC failures needs to be kept below two per minute. This implies that STAs and APs detecting two MIC failure events within 60 s need to disable all receptions using TKIP for a period of 60 s. The slowdown makes it difficult for an attacker to make a large number of forgery attempts in a short time.

— As an additional security feature, the PTK and, in the case of the Authenticator, the GTK should be changed.

Before verifying the MIC, the receiver shall check the FCS, ICV, and TSC for all related MPDUs. Any MPDU that has an invalid FCS, an incorrect ICV, or a TSC value that is less than or equal to the TSC replay counter shall be discarded before checking the MIC. This avoids unnecessary MIC failure events. Checking the TSC before the MIC makes countermeasure-based denial-of-service attacks harder to perform. While the FCS and ICV mechanisms are sufficient to detect noise, they are insufficient to detect active attacks. The FCS and ICV provide error detection, but not integrity protection.

A single counter or timer shall be used to log MIC failure events. These failure events are defined as follows:

— In an Authenticator:
  — Detection of a MIC failure on a received individually addressed frame.
  — Receipt of Michael MIC Failure Report frame.
— In a Supplicant:
  — Detection of a MIC failure on a received individually addressed or group addressed frame.
  — Attempt to transmit a Michael MIC Failure Report frame.

The number of MIC failures is accrued independent of the particular key context. Any single MIC failure, whether detected by the Supplicant or the Authenticator and whether resulting from a group MIC key failure or a pairwise MIC key failure, shall be treated as cause for a MIC failure event.

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The Supplicant uses a single Michael MIC Failure Report frame to report a MIC failure event to the Authenticator. A Michael MIC Failure Report is an EAPOL-Key frame with the following Key Information field bits set to 1: MIC bit, Error bit, Request bit, Secure bit. The Supplicant protects this message with the current PTK; the Supplicant uses the KCK portion of the PTK to compute the IEEE 802.1X EAPOL MIC.

The MLME-MICHAELMICFAILURE.indication primitive is used by the IEEE 802.11 MAC to attempt to indicate a MIC failure to the local IEEE 802.1X Supplicant or Authenticator. MLME-EAPOL.request primitive is used by the Supplicant to send the EAPOL-Key frame containing the Michael MIC Failure report. MLME-EAPOL.confirm primitive indicates to the Supplicant when the EAPOL-Key frame has been transmitted.

The first MIC failure shall be logged, and a timer initiated to enable enforcement of the countermeasures. If the MIC failure event is detected by the Supplicant, it shall also report the event to the AP by sending a Michael MIC Failure Report frame.

If a subsequent MIC failure occurs within 60 s of the most recent previous failure, then a STA whose IEEE 802.1X entity has acted as a Supplicant shall deauthenticate (as defined in 11.3.4.4) itself or deauthenticate all of the STAs with a security association if its IEEE 802.1X entity acted as an Authenticator. In an IBSS STA, both Supplicant and Authenticator actions shall be taken. Furthermore, the device shall not receive or transmit any TKIP-encrypted Data frames, and shall not receive or transmit any unencrypted Data frames other than IEEE 802.1X messages, to or from any peer for a period of at least 60 s after it detects the second failure. If the device is an AP, it shall disallow new associations using TKIP during this 60 s period; at the end of the 60 s period, the AP shall resume normal operations and allow STAs to (re)associate. If the device is an IBSS STA, it shall disallow any new security associations using TKIP during this 60 s period. If the device is a Supplicant, it shall first send a Michael MIC Failure Report frame prior to revoking its PTKSA and deauthenticating itself.

The `aMICFailTime` attribute shall contain the `sysUpTime` value at the time the MIC failure was logged.

12.5.2.4.2 TKIP countermeasures for an Authenticator

The countermeasures used by an Authenticator are depicted in Figure 12-12 and described as follows:

a) In an Authenticator's STA that receives a frame with a MIC error,
   1) Discard the frame.
   2) Increment the MIC failure counter, dot11RSNAStatsTKIPLocalMICFailures.
   3) Generate an MLME-MICHAELMICFAILURE.indication primitive.

b) In an Authenticator that receives an MLME-MICHAELMICFAILURE.indication primitive or a Michael MIC Failure Report frame,
   1) If it is a Michael MIC Failure Report frame, then increment dot11RSNAStatsTKIP-RemoteMICFailures.
   2) If this is the first MIC failure within the past 60 s, initialize the countermeasures timer.
   3) If less than 60 s have passed since the most recent previous MIC failure, the Authenticator shall deauthenticate and delete all PTKSAs for all STAs using TKIP. If the current GTKSA uses TKIP, that GTKSA shall be discarded, and a new GTKSA constructed, but not used for 60 s. The Authenticator shall refuse the construction of new PTKSAs using TKIP as one or more of the ciphers for 60 s. At the end of this period, the MIC failure counter and timer shall be reset, and creation of PTKSAs accepted as usual.
   4) If the Authenticator is using IEEE 802.1X authentication, the Authenticator shall transition the state of the IEEE 802.1X Authenticator state machine to the INITIALIZE state. This restarts the IEEE 802.1X state machine. If the Authenticator is instead using PSKs, this step is omitted.

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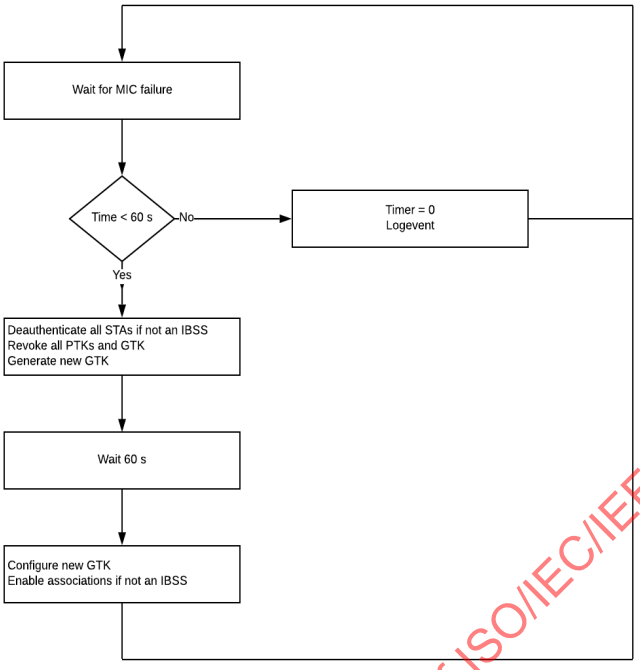

Figure 12-12—Authenticator MIC countermeasures

Note that a Supplicant's STA may deauthenticate with a reason code of MIC_FAILURE if it is an ESS STA. The Authenticator shall not log the deauthenticate as a MIC failure event to prevent denial-of-service attacks through deauthentications. The Supplicant's STA reports the MIC failure event through the Michael MIC Failure Report frame so that the AP can log the event.

The requirement to deauthenticate all STAs using TKIP includes those using other pairwise ciphers if they are using TKIP as the group cipher.

12.5.2.4.3 TKIP countermeasures for a Supplicant

The countermeasures used by a Supplicant are depicted in Figure 12-13 and described as follows:

a) In a Supplicant's STA that receives a frame with a MIC error,
   1) Increment the MIC failure counter, dot11RSNAStatsTKIPLocalMICFailures.
   2) Discard the offending frame.
   3) Generate an MLME-MICHAELMICFAILURE.indication primitive.

b) In a Supplicant that receives an MLME-MICHAELMICFAILURE.indication primitive from its STA,
   1) Send a Michael MIC Failure Report frame to the AP.
   2) If this is the first MIC failure within the past 60 s, initialize the countermeasures timer.
   3) If less than 60 s have passed since the most recent previous MIC failure, delete the PTKSA and GTKSA. Deauthenticate from the AP and wait for 60 s before (re)establishing a TKIP association with the same AP. A TKIP association is any IEEE 802.11 association that uses TKIP for its pairwise or group cipher suite.

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c) If a STA receives a Deauthentication frame with the reason code MIC_FAILURE it is unable to verify that the frame has not been forged, since the frame does not contain a MIC. The STA may attempt association with this, or another, AP. If the frame was genuine, then it is probable that attempts to associate with the same AP requesting the use of TKIP will fail because the AP is conducting countermeasures.

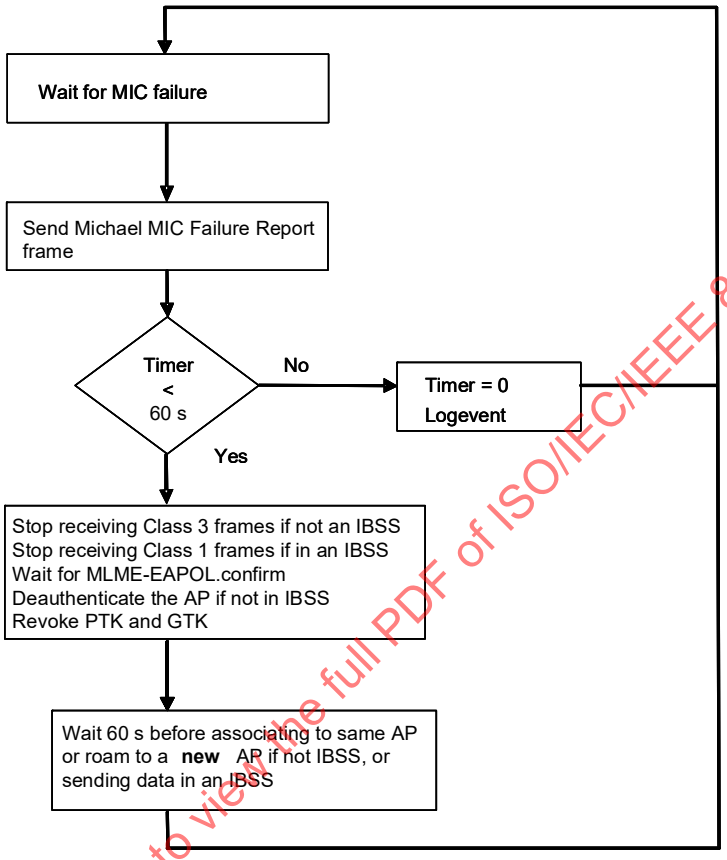

Figure 12-13—Supplicant MIC countermeasures

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12.5.2.5 TKIP mixing function

12.5.2.5.1 General

Annex J defines a C-language reference implementation of the TKIP mixing function. It also provides test vectors for the mixing function.

The mixing function has two phases. Phase 1 mixes the appropriate temporal key (pairwise or group) with the TA and TSC. A STA may cache the output of this phase to reuse with subsequent MPDUs associated with the same temporal key and TA. Phase 2 mixes the output of Phase 1 with the TSC and temporal key (TK) to produce the WEP seed, also called the *per-frame key*. The WEP seed may be precomputed before it is used. The two-phase process may be summarized as follows:

```
TTAK := Phase1 (TK, TA, TSC)
WEP seed := Phase2 (TTAK, TK, TSC)
```


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12.5.2.5.2 S-Box

Both Phase 1 and Phase 2 rely on an S-box, defined in this subclause. The S-box substitutes one 16-bit value with another 16-bit value. This function may be implemented as a table look up.

NOTE—The S-box is a nonlinear substitution. The table look-up is be organized as either a single table with 65 536 entries and a 16-bit index (128K octets of table) or two tables with 256 entries and an 8-bit index (1024 octets for both tables). When the two smaller tables are used, the high order octet is used to obtain a 16-bit value from one table, the low order octet is used to obtain a 16-bit value from the other table, and the S-box output is the XOR of the two 16-bit values. The second S-box table is an octet-swapped replica of the first.

```
#define _S_(v16)     (Sbox[0][Lo8(v16)] ^ Sbox[1][Hi8(v16)])

/* 2-byte by 2-byte subset of the full AES S-box table */
const u16b Sbox[2][256]=       /* Sbox for hash (can be in ROM)     */
{ {
   0xC6A5,0xF884,0xEE99,0xF68D,0xFF0D,0xD6BD,0xDEB1,0x9154,
   0x6050,0x0203,0xCEA9,0x567D,0xE719,0xB562,0x4DE6,0xEC9A,
   0x8F45,0x1F9D,0x8940,0xFA87,0xEF15,0xB2EB,0x8EC9,0xFB0B,
   0x41EC,0xB367,0x5FFD,0x45EA,0x23BF,0x53F7,0xE496,0x9B5B,
   0x75C2,0xE11C,0x3DAE,0x4C6A,0x6C5A,0x7E41,0xF502,0x834F,
   0x685C,0x51F4,0xD134,0xF908,0xE293,0xAB73,0x6253,0x2A3F,
   0x080C,0x9552,0x4665,0x9D5E,0x3028,0x37A1,0x0A0F,0x2FB5,
   0x0E09,0x2436,0x1B9B,0xDF3D,0xCD26,0x4E69,0x7FCD,0xEA9F,
   0x121B,0x1D9E,0x5874,0x342E,0x362D,0xDCB2,0xB4EE,0x5BFB,
   0xA4F6,0x764D,0xB761,0x7DCE,0x527B,0xDD3E,0x5E71,0x1397,
   0xA6F5,0xB968,0x0000,0xC12C,0x4060,0xE31F,0x79C8,0xB6ED,
   0xD4BE,0x8D46,0x67D9,0x724B,0x94DE,0x98D4,0xB0E8,0x854A,
   0xBB6B,0xC52A,0x4FE5,0xED16,0x86C5,0x9AD7,0x6655,0x1194,
   0x8ACF,0xE910,0x0406,0xFE81,0xA0F0,0x7844,0x25BA,0x4BE3,
   0xA2F3,0x5DFE,0x80C0,0x058A,0x3FAD,0x21BC,0x7048,0xF104,
   0x63DF,0x77C1,0xAF75,0x4263,0x2030,0xE51A,0xFD0E,0xBF6D,
   0x814C,0x1814,0x2635,0xC32F,0xBEE1,0x35A2,0x88CC,0x2E39,
   0x9357,0x55F2,0xFC82,0x7A47,0xC8AC,0xBAE7,0x322B,0xE695,
   0xC0A0,0x1998,0x9ED1,0xA37F,0x4466,0x547E,0x3BAB,0x0B83,
   0x8CCA,0xC729,0x6BD3,0x283C,0xA779,0xBCE2,0x161D,0xAD76,
   0xDB3B,0x6456,0x744E,0x141E,0x92DB,0x0C0A,0x486C,0xB8E4,
   0x9F5D,0xBD6E,0x43EF,0xC4A6,0x39A8,0x31A4,0xD337,0xF28B,
   0xD532,0x8B43,0x6E59,0xDAB7,0x018C,0xB164,0x9CD2,0x49E0,
   0xD8B4,0xACFA,0xF307,0xCF25,0xCAAF,0xF48E,0x47E9,0x1018,
   0x6FD5,0xF088,0x4A6F,0x5C72,0x3824,0x57F1,0x73C7,0x9751,
   0xCB23,0xA17C,0xE89C,0x3E21,0x96DD,0x61DC,0x0D86,0x0F85,
   0xE090,0x7C42,0x71C4,0xCCAA,0x90D8,0x0605,0xF701,0x1C12,
   0xC2A3,0x6A5F,0xAEF9,0x69D0,0x1791,0x9958,0x3A27,0x27B9,
   0xD938,0xEB13,0x2BB3,0x2233,0xD2BB,0xA970,0x0789,0x33A7,
   0x2DB6,0x3C22,0x1592,0xC920,0x8749,0xAAFF,0x5078,0xA57A,
   0x038F,0x59F8,0x0980,0x1A17,0x65DA,0xD731,0x84C6,0xD0B8,
   0x82C3,0x29B0,0x5A77,0x1E11,0x7BCB,0xA8FC,0x6DD6,0x2C3A,
  },
  {  /* second half of table is byte-reversed version of first! */
   0xA5C6,0x84F8,0x99EE,0x8DF6,0x0DFF,0xBDD6,0xB1DE,0x5491,
   0x5060,0x0302,0xA9CE,0x7D56,0x19E7,0x62B5,0xE64D,0x9AEC,
   0x458F,0x9D1F,0x4089,0x87FA,0x15EF,0xEBB2,0xC98E,0x0BFB,
   0xEC41,0x67B3,0xFD5F,0xEA45,0xBF23,0xF753,0x96E4,0x5B9B,
   0xC275,0x1CE1,0xAE3D,0x6A4C,0x5A6C,0x417E,0x02F5,0x4F83,
   0x5C68,0xF451,0x34D1,0x08F9,0x93E2,0x73AB,0x5362,0x3F2A,
   0x0C08,0x5295,0x6546,0x5E9D,0x2830,0xA137,0x0F0A,0xB52F,
   0x090E,0x3624,0x9B1B,0x3DDF,0x26CD,0x694E,0xCD7F,0x9FEA,
   0x1B12,0x9E1D,0x7458,0x2E34,0x2D36,0xB2DC,0xEEB4,0xFB5B,
```

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```
        0xF6A4,0x4D76,0x61B7,0xCE7D,0x7B52,0x3EDD,0x715E,0x9713,
        0xF5A6,0x68B9,0x0000,0x2CC1,0x6040,0x1FE3,0xC879,0xEDB6,
        0xBED4,0x468D,0xD967,0x4B72,0xDE94,0xD498,0xE8B0,0x4A85,
        0x6BBB,0x2AC5,0xE54F,0x16ED,0xC586,0xD79A,0x5566,0x9411,
        0xCF8A,0x10E9,0x0604,0x81FE,0xF0A0,0x4478,0xBA25,0xE34B,
        0xF3A2,0xFE5D,0xC080,0x8A05,0xAD3F,0xBC21,0x4870,0x04F1,
        0xDF63,0xC177,0x75AF,0x6342,0x3020,0x1AE5,0x0EFD,0x6DBF,
        0x4C81,0x1418,0x3526,0x2FC3,0xE1BE,0xA235,0xCC88,0x392E,
        0x5793,0xF255,0x82FC,0x477A,0xACC8,0xE7BA,0x2B32,0x95E6,
        0xA0C0,0x9819,0xD19E,0x7FA3,0x6644,0x7E54,0xAB3B,0x830B,
        0xCA8C,0x29C7,0xD36B,0x3C28,0x79A7,0xE2BC,0x1D16,0x76AD,
        0x3BDB,0x5664,0x4E74,0x1E14,0xDB92,0x0A0C,0x6C48,0xE4B8,
        0x5D9F,0x6EBD,0xEF43,0xA6C4,0xA839,0xA431,0x37D3,0x8BF2,
        0x32D5,0x438B,0x596E,0xB7DA,0x8C01,0x64B1,0xD29C,0xE049,
        0xB4D8,0xFAAC,0x07F3,0x25CF,0xAFCA,0x8EF4,0xE947,0x1810,
        0xD56F,0x88F0,0x6F4A,0x725C,0x2438,0xF157,0xC773,0x5197,
        0x23CB,0x7CA1,0x9CE8,0x213E,0xDD96,0xDC61,0x860D,0x850F,
        0x90E0,0x427C,0xC471,0xAACC,0xD890,0x0506,0x01F7,0x121C,
        0xA3C2,0x5F6A,0xF9AE,0xD069,0x9117,0x5899,0x273A,0xB927,
        0x38D9,0x13EB,0xB32B,0x3322,0xBBD2,0x70A9,0x8907,0xA733,
        0xB62D,0x223C,0x9215,0x20C9,0x4987,0xFFAA,0x7850,0x7AA5,
        0x8F03,0xF859,0x8009,0x171A,0xDA65,0x31D7,0xC684,0xB8D0,
        0xC382,0xB029,0x775A,0x111E,0xCB7B,0xFCA8,0xD66D,0x3A2C,
    }
};
```

12.5.2.5.3 Phase 1 Definition

The inputs to Phase 1 of the temporal key mixing function shall be a temporal key (*TK*), the TA, and the TSC. The temporal key shall be 128 bits in length. Only the 32 MSBs of the TSC and all of the temporal key are used in Phase 1. The output, *TTAK*, shall be 80 bits in length and is represented by an array of 16-bit values: $TTAK_0$ $TTAK_1$ $TTAK_2$ $TTAK_3$ $TTAK_4$.

The description of the Phase 1 algorithm treats all of the following values as arrays of 8-bit values: $TA_0..TA_5$, $TK_0..TK_{15}$. The *TA* octet order is represented according to the conventions from 9.2.2, and the first 3 octets represent the OUI.

The XOR operation, the bitwise-and (&) operation, and the addition (+) operation are used in the Phase 1 specification. A loop counter, *i*, and an array index temporary variable, *j*, are also employed.

One function, *Mk*16, is used in the definition of Phase 1. The function *Mk*16 constructs a 16-bit value from two 8-bit inputs as $Mk16(X,Y) = (256 \cdot X)+Y$.

Two steps make up the Phase 1 algorithm. The first step initializes *TTAK* from *TSC* and *TA*. The second step uses an S-box to iteratively mix the keying material into the 80-bit *TTAK*. The second step sets the PHASE1_LOOP_COUNT to 8. See Figure 12-14.

NOTE 1—The TA is mixed into the temporal key in Phase 1 of the hash algorithm. Implementations might achieve a significant performance improvement by caching the output of Phase 1. The Phase 1 output is the same for $2^{16} = 65\,536$ consecutive frames from the same temporal key and TA. Consider the simple case where a STA communicates only with an AP. The STA performs Phase 1 using its own address, and the *TTAK* is used to protect traffic sent to the AP. The STA performs Phase 1 using the AP address, and it is used to unwrap traffic received from the AP.

NOTE 2—The cached *TTAK* from Phase 1 needs to be updated when the lower 16 bits of the TSC wrap and the upper 32 bits need to be updated.

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```
Input: transmitter address TA0 ... TA5, Temporal Key TK0...TK15, and TSC0...TSC5
Output: intermediate key TTAK0... TTAK4
PHASE1-KEY-MIXING(TA0 ... TA5, TK0...TK15, TSC0...TSC5)
    PHASE1_STEP1:
    TTAK0 ← MK16(TSC3, TSC2)
    TTAK1 ← MK16(TSC5, TSC4)
    TTAK2 ← Mk16(TA1, TA0)
    TTAK3 ← Mk16(TA3, TA2)
    TTAK4 ← Mk16(TA5, TA4)
    PHASE1_STEP2:
    for i = 0 to PHASE1_LOOP_COUNT-1
        j ← 2·(i & 1)
        TTAK0 ← TTAK0 + S[TTAK4 ⊕ Mk16(TK1+j, TK0+j)]
        TTAK1 ← TTAK1 + S[TTAK0 ⊕ Mk16(TK5+j, TK4+j)]
        TTAK2 ← TTAK2 + S[TTAK1 ⊕ Mk16(TK9+j, TK8+j)]
        TTAK3 ← TTAK3 + S[TTAK2 ⊕ Mk16(TK13+j, TK12+j)]
        TTAK4 ← TTAK4 + S[TTAK3 ⊕ Mk16(TK1+j, TK0+j )] + i
```

Figure 12-14—Phase 1 key mixing

12.5.2.5.4 Phase 2 definition

The inputs to Phase 2 of the temporal key mixing function shall be the output of Phase 1 (*TTAK*) together with the temporal key and the TSC. The *TTAK* is 80 bits in length. Only the 16 LSBs of the TSC are used in Phase 2. The temporal key is 128 bits. The output is the WEP seed, which is a per-frame key, and is 128 bits in length. The constructed WEP seed has an internal structure compliant with the WEP specification. In other words, the first 24 bits of the WEP seed shall be transmitted in plaintext as the WEP IV. As such, these 24 bits are used to convey lower 16 bits of the TSC from the sender (encryptor) to the receiver (decryptor). The rest of the TSC shall be conveyed in the Extended IV field. The temporal key and *TTAK* values are represented as in Phase 1. The WEP seed is treated as an array of 8-bit values: $WEPSeed_0 \ldots WEPSeed_{15}$. The TSC shall be treated as an array of 8-bit values: $TSC_0\ TSC_1\ TSC_2\ TSC_3\ TSC_4\ TSC_5$.

The pseudocode specifying the Phase 2 mixing function employs one variable: *PPK*, which is 96 bits long. The *PPK* is represented as an array of 16-bit values: $PPK_0..PPK_5$. The pseudocode also employs a loop counter, *i*. As detailed in this subclause, the mapping from the 16-bit *PPK* values to the 8-bit *WEPseed* values is explicitly little endian to match the endian architecture of the most common processors used for this application.

The XOR (⊕) operation, the addition (+) operation, the AND (&) operation, the OR (|) operation, and the right bit shift (>>) operation are used in the specification of Phase 2. See Figure 12-15.

The algorithm specification relies on four functions:

— The first function, *Lo*8, references the 8 LSBs of the 16-bit input value.
— The second function, *Hi*8, references the 8 MSBs of the 16-bit value.
— The third function, *RotR*1, rotates its 16-bit argument 1 bit to the right.
— The fourth function, *Mk*16, is already used in Phase 1, defined by $Mk16(X,Y) = (256 \cdot X)+Y$, and constructs a 16-bit output from two 8-bit inputs.

NOTE—The rotate and addition operations in STEP2 make Phase 2 particularly sensitive to the endian architecture of the processor, although the performance degradation due to running this algorithm on a big endian processor is expected to be minor.

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Input: intermediate key *TTAK*0…*TTAK*4, *TK*, and TKIP sequence counter *TSC*
Output: WEP Seed *WEPSeed*0…*WEPSeed*15
PHASE2-KEY-MIXING(*TTAK*0…*TTAK*4, *TK*0…*TK*15, *TSC*0…*TSC*5)
PHASE2_STEP1:
*PPK*0 ← *TTAK*0
*PPK*1 ← *TTAK*1
*PPK*2 ← *TTAK*2
*PPK*3 ← *TTAK*3
*PPK*4 ← *TTAK*4
*PPK*5 ← *TTAK*4 + Mk16(TSC1, TSC0)
PHASE2_STEP2:
*PPK*0 ← *PPK*0 + S[*PPK*5 ⊕ *Mk*16(*TK*1,*TK*0)]
*PPK*1 ← *PPK*1 + S[*PPK*0 ⊕ *Mk*16(*TK*3,*TK*2)]
*PPK*2 ← *PPK*2 + S[*PPK*1 ⊕ *Mk*16(*TK*5,*TK*4)]
*PPK*3 ← *PPK*3 + S[*PPK*2 ⊕ *Mk*16(*TK*7,*TK*6)]
*PPK*4 ← *PPK*4 + S[*PPK*3 ⊕ *Mk*16(*TK*9,*TK*8)]
*PPK*5 ← *PPK*5 + S[*PPK*4 ⊕ *Mk*16(*TK*11,*TK*10)]
*PPK*0 ← *PPK*0 + *RotR*1(*PPK*5 ⊕ *Mk*16(*TK*13,*TK*12))
*PPK*1 ← *PPK*1 + *RotR*1(*PPK*0 ⊕ *Mk*16(*TK*15,*TK*14))
*PPK*2 ← *PPK*2 + *RotR*1(*PPK*1)
*PPK*3 ← *PPK*3 + *RotR*1(*PPK*2)
*PPK*4 ← *PPK*4 + *RotR*1(*PPK*3)
*PPK*5 ← *PPK*5 + *RotR*1(*PPK*4)
PHASE2_STEP3:
*WEPSeed*0 ← *TSC*1
*WEPSeed*1 ← (TSC1 | 0x20) & 0x7F
*WEPSeed*2 ← TSC0
*WEPSeed*3 ← *Lo*8((*PPK*5 ⊕ *Mk*16(*TK*1,*TK*0)) >> 1)
for *i* = 0 to 5
*WEPSeed*4+(2·*i*) ← *Lo*8(*PPKi*)
*WEPSeed*5+(2·*i*) ← *Hi*8(*PPKi*)
end
return *WEPSeed*0…*WEPSeed*15

Figure 12-15—Phase 2 key mixing

Phase 2 comprises three steps:

— STEP1 makes a copy of *TTAK* and brings in the TSC.
— STEP2 is a 96-bit bijective mixing, employing an S-box.
— STEP3 brings in the last of the temporal key *TK* bits and assigns the 24-bit WEP IV value.

The WEP IV format carries 3 octets. STEP3 of Phase 2 determines the value of each of these three octets. The construction was selected to preclude the use of known ARC4 weak keys. The recipient can reconstruct the 16 LSBs of the TSC used by the originator by concatenating the third and first octets, ignoring the second octet. The remaining 32 bits of the TSC are obtained from the Extended IV field.

12.5.2.6 TKIP replay protection procedures

TKIP implementations shall use the TSC field to defend against replay attacks by implementing the following rules:

a) Each MPDU shall have a unique TKIP TSC value.
b) Each transmitter shall maintain a single TSC (48-bit counter) for each PTKSA and GTKSA.
c) The TSC shall be implemented as a 48-bit strictly increasing counter, initialized to 1 when the corresponding TKIP temporal key is initialized or refreshed.
d) The WEP IV format carries the 16 LSBs of the 48-bit TSC, as defined by the TKIP mixing function (Phase 2, STEP3). The remainder of the TSC is carried in the Extended IV field.

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e) A receiver shall maintain a separate set of TKIP TSC replay counters for each PTKSA and GTKSA.

f) TKIP replay detection takes place after the MIC verification and any reordering required by ack processing. Thus, a receiver shall delay advancing a TKIP TSC replay counter until an MSDU passes the MIC check, to prevent attackers from injecting MPDUs with valid ICVs and TSCs, but invalid MICs.

NOTE—This works because if an attacker modifies the TSC, then the encryption key is modified and hence both the ICV and MIC decrypt incorrectly, causing the received MPDU to be dropped.

g) For each PTKSA and GTKSA, the receiver shall maintain a separate replay counter for each frame priority and shall use the TSC in a received frame to detect replayed frames, subject to the limitations on the number of supported replay counters indicated in the RSN Capabilities field, as described in 9.4.2.24. A replayed frame occurs when the TSC in a received frame is less than or equal to the current replay counter value for the frame's priority. A transmitter shall not reorder TKIP protected frames with different priorities without ensuring that the receiver supports the required number of replay counters. The transmitter shall not reorder TKIP protected frames within a replay counter, but may reorder TKIP protected frames across replay counters. One possible reason for reordering frames is the IEEE 802.11 MSDU priority.

h) A receiver shall discard any MPDU that is received out of order and shall increment dot11RSNAStatsTKIPReplays for this key.

i) For MSDUs sent using the block ack feature, reordering of received MSDUs according to the block ack receiver operation is performed prior to replay detection.

12.5.3 CTR with CBC-MAC protocol (CCMP)

12.5.3.1 General

Subclause 12.5.3 specifies all variants of CCMP, which provides data confidentiality, authentication, integrity, and replay protection. A non-DMG RSNA STA shall support CCMP-128.

CCMP is based on the CCM of the AES encryption algorithm. CCM combines CTR for data confidentiality and CBC-MAC for authentication and integrity. CCM protects the integrity of both the MPDU Data field and selected portions of the IEEE 802.11 MPDU header.

The AES algorithm is defined in FIPS 197. AES processing used within CCMP uses AES with either a 128-bit key (CCMP-128) or a 256-bit key (CCMP-256).

CCM is defined in IETF RFC 3610. CCM is a generic mode that can be used with any block-oriented encryption algorithm. CCM has two parameters (M and L).

CCMP-128 uses the following values for the CCM parameters:

— $M = 8$; indicating that the MIC is 8 octets.

— $L = 2$; indicating that the Length field is 2 octets, which is sufficient to hold the length of the largest possible IEEE 802.11 MPDU, expressed in octets.

CCMP-256 uses the following values for the CCM parameters:

— $M = 16$; indicating that the MIC is 16 octets.

— $L = 2$; indicating that the Length field is 2 octets, which is sufficient to hold the length of the largest possible IEEE 802.11 MPDU, expressed in octets.

CCM requires a fresh temporal key for every session. CCM also requires a unique nonce value for each frame protected by a given temporal key. Reuse of a nonce value with the same temporal key voids all security guarantees.

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Annex J provides a test vector for CCM.

When CCMP is selected as the RSN pairwise cipher and management frame protection is negotiated, individually addressed robust Management frames and the group addressed Management frames that receive "Group Addressed Privacy" as indicated in Table 9-51 shall be protected with CCMP.

12.5.3.2 CCMP MPDU format

Figure 12-16 depicts the MPDU when using CCMP.

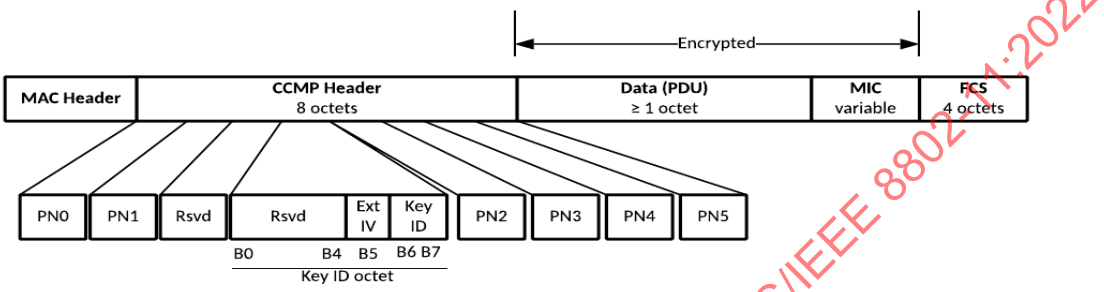

Figure 12-16—Expanded CCMP MPDU

For secure PV0 MPDUs, CCMP-128 processing expands the original MPDU size by 16 octets, 8 octets for the CCMP Header field and 8 octets for the MIC field. CCMP-256 processing expands the original MPDU size by 24 octets, 8 octets for the CCMP Header field, and 16 octets for the MIC field. The CCMP Header field is constructed from the PN, ExtIV, and Key ID subfields. PN is a 48-bit PN represented as an array of 6 octets. PN5 is the most significant octet of the PN, and PN0 is the least significant.

The ExtIV subfield (bit 5) of the Key ID octet signals that the CCMP Header field extends the MPDU header by a total of 8 octets, compared to the 4 octets added to the MPDU header when WEP is used. The ExtIV bit (bit 5) is always set to 1 for CCMP.

Bits 6–7 of the Key ID octet are for the Key ID subfield.

The CCMP header is not included in secure PV1 MPDUs, but constructed locally at the STA as defined in 12.5.3.3.6. For secure PV1 MPDUs, CCMP-128 processing expands the original MPDU size by 8 octets for the MIC field. CCMP-256 processing expands the original MPDU size by 16 octets for the MIC field. Figure 12-17 depicts the PV1 MPDU when using CCMP.

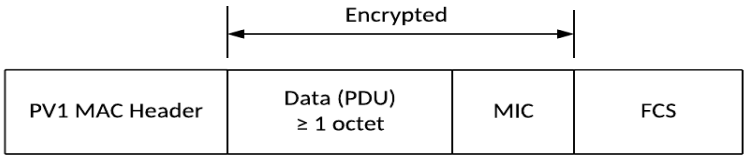

Figure 12-17—Expanded PV1 CCMP MPDU

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12.5.3.3 CCMP cryptographic encapsulation

12.5.3.3.1 General

The CCMP cryptographic encapsulation process is depicted in Figure 12-18 and described as follows:

a) For secure PV0 MPDUs, CCMP encrypts the Frame Body field of a plaintext MPDU and encapsulates the resulting cipher text using the following steps:

1) Increment the PN, to obtain a fresh PN for each MPDU, so that the PN never repeats for the same temporal key.

NOTE 1—Retransmitted MPDUs are not modified on retransmission.

2) Use the fields in the MPDU header to construct the additional authentication data (AAD) for CCM. The CCM algorithm provides integrity protection for the fields included in the AAD. MPDU header fields that may change when retransmitted are muted by being masked to 0 when calculating the AAD.

3) Construct the CCM nonce block as defined in 12.5.3.3.4 from the PN, A2, and the priority value of the MPDU where A2 is MPDU Address 2. If the Type field of the Frame Control field is 10 (Data frame) and there is a QoS Control field present in the MPDU header, the priority value of the MPDU is equal to the value of the TID subfield of the QoS Control field (bits 0 to 3 of the QoS Control field). If the Type field of the Frame Control field is 00 (Management frame) and the frame is a QMF, the priority value of the MPDU is equal to the value in the ACI subfield of the Sequence Number field. Otherwise, the priority value of the MPDU is equal to the fixed value 0.

4) Construct the CCMP header as defined in 12.5.3.3.5.

5) Use the temporal key, AAD, nonce, and MPDU data to form the cipher text and the encrypted MIC. This step is known as CCM originator processing.

6) Form the encrypted MPDU by combining the original MPDU header, the CCMP header, the encrypted data and the encrypted MIC, as described in 12.5.3.2.

b) For secure PV1 MPDUs, CCMP encrypts the Frame Body field of a plaintext MPDU and encapsulates the resulting cipher text using the following steps:

1) When the sequence number of the MPDU is less than the previous sequence number and satisfies the BPN update conditions in 12.5.3.3.6 for that TID/ACI, increment the base PN so that the PN never repeats for the same temporal key and TID/ACI.

NOTE 2—Retransmitted MPDUs are not modified on retransmission.

2) Use the fields in the MPDU header to construct the AAD for CCM. The CCM algorithm provides integrity protection for the fields included in the AAD. MPDU header fields that might change when retransmitted are muted by being masked to 0 when calculating the AAD.

3) Construct the CCM nonce block as defined in 12.5.3.3.4 from the PN, A2, and the priority value of the MPDU, where A2 is the STA MAC address identified by the A2 field of the MPDU. If the MPDU is a QoS Data MPDU, the priority value of the MPDU is equal to the value of the PTID subfield of the Frame Control field. If the Type field of the Frame Control field is 001 (Management frame) and the frame is a QMF, the priority value of the MPDU is equal to the value in the ACI subfield of the Sequence Number field. Otherwise, the priority value of the MPDU is equal to the fixed value 0.

4) Construct the CCMP header as defined in 12.5.3.3.6.

5) Use the temporal key, AAD, nonce, and MPDU data to form the cipher text and the encrypted MIC. This step is known as CCM originator processing.

6) Form the encrypted MPDU by combining the original MPDU header, the encrypted data, and the encrypted MIC, as described in 12.5.3.2.

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The CCM reference describes the processing of the key, nonce, AAD, and data to produce the encrypted output. See 12.5.3.3.2 to 12.5.3.3.7 for details of the creation of the AAD and nonce from the MPDU and the associated MPDU-specific processing.

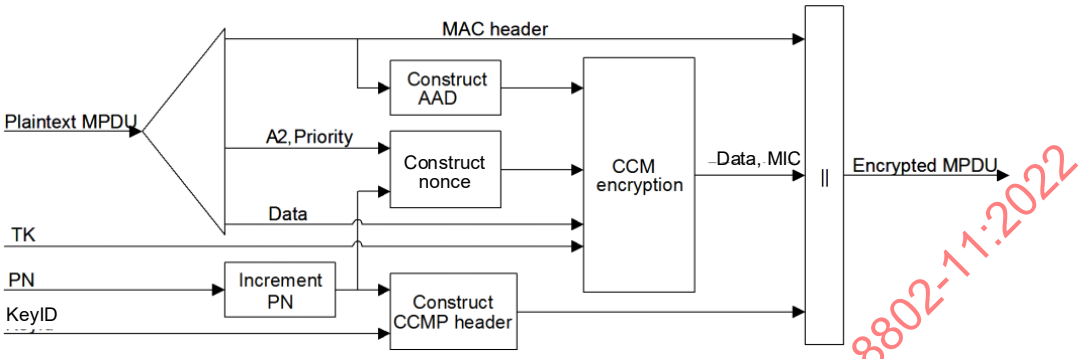

Figure 12-18—CCMP encapsulation block diagram

12.5.3.3.2 PN processing

The PN is incremented by a positive number for each MPDU. The PN shall be incremented in steps of 1 for constituent MPDUs of fragmented MSDUs and MMPDUs. For PV0 MPDUs, the PN shall never repeat for a series of encrypted MPDUs using the same temporal key. For PV1 MPDUs, the PN shall never repeat for a series of encrypted MPDUs using the same temporal key and TID/ACI.

If the PN exceeds the threshold that is defined in dot11PNExhaustionThresholdLow and dot11PNExhaustionThresholdHigh, an MLME-PN-EXHAUSTION.indication primitive shall be generated.

NOTE 1—When PN space is exhausted, the choices available to an implementation are to replace the corresponding key or to end communications.

NOTE 2—When a group addressed MSDU is retransmitted using GCR, it is concealed from non-GCR capable STAs using the procedures described in 11.21.16.3.5. The MPDU containing this concealed A-MSDU has a different PN from the MPDU that contained the original transmission of the group addressed MSDU.

12.5.3.3.3 Construct AAD

a) For PV0 MPDUs, the format of the AAD is shown in Figure 12-19. The length of the AAD for PV0 varies depending on the presence or absence of the QC and A4 fields and is shown in Table 12-3.

	FC	A1	A2	A3	SC	A4	QC
Octets:	2	6	6	6	2	6	2

Figure 12-19—AAD construction for PV0 MPDUs

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Table 12-3—AAD length for PV0 MPDUs

QC field	A4 field	AAD length (octets)
Absent	Absent	22
Present	Absent	24
Absent	Present	28
Present	Present	30

The AAD is constructed from the MPDU header. The AAD includes neither the Duration/ID field nor the HT Control field because the contents of these fields might change during normal operation (e.g., due to a rate change preceding retransmission). The HT Control field might also be inserted or removed during normal operation (e.g., retransmission of an A-MPDU where the original A-MPDU included an MRQ that has already generated a response). For similar reasons, several subfields in the Frame Control field are masked to 0. For PV0 MPDUs, AAD construction is performed as follows:

1) FC – MPDU Frame Control field, with
   i) Subtype subfield (bits 4 5 6) in a Data frame masked to 0
   ii) Retry subfield (bit 11) masked to 0
   iii) Power Management subfield (bit 12) masked to 0
   iv) More Data subfield (bit 13) masked to 0
   v) Protected Frame subfield (bit 14) always set to 1
   vi) +HTC subfield (bit 15) as follows:
      — Masked to 0 in all Data frames containing a QoS Control field
      — Unmasked otherwise
   vii) Other subfields are not modified
2) A1 – MPDU Address 1 field.
3) A2 – MPDU Address 2 field.
4) A3 – MPDU Address 3 field.
5) SC – MPDU Sequence Control field, with the Sequence Number subfield (bits 4–15 of the Sequence Control field) masked to 0. The Fragment Number subfield is not modified.
6) A4 – MPDU Address field, if present.
7) QC – QoS Control field contains the MSDU priority, if present. The QC TID is used in the construction of the AAD. When in a non-DMG BSS and both the STA and its peer have their SPP A-MSDU Capable fields equal to 1, bit 7 (the A-MSDU Present field) is used in the construction of the AAD. The remaining QC fields are masked to 0 for the AAD calculation (bits 4 to 6, bits 8 to 15, and bit 7 when either the STA or its peer has the SPP A-MSDU Capable field equal to 0). When in a DMG BSS, the A-MSDU Present bit 7 and A-MSDU Type bit 8 are used in the construction of the AAD, and the remaining QC fields are masked to 0 for the AAD calculation (bits 4 to 6, bits 9 to 15).

b) For PV1 MPDUs, the format of the AAD is shown in Figure 12-20.

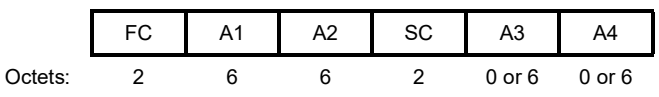

Figure 12-20—AAD construction for PV1 MPDUs

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For PV1 MPDUs, the length of the AAD varies depending on the presence or absence of the A3 and A4 fields and is shown in Table 12-4.

Table 12-4—AAD length for PV1 MPDUs

Type subfield in the Frame Control	A3 field in uncompressed header	A4 field in uncompressed header	AAD length (octets)
0, 1 or 3	Absent	Absent	16
0, 1 or 3	Present	Absent	22
0 or 3	Absent	Present	22
0 or 3	Present	Present	28

For PV1 MPDUs, AAD construction is performed as follows:

1) FC – MPDU Frame Control field, with
   i) Power Management subfield (bit 10) masked to 0
   ii) More Data subfield (bit 11) masked to 0
   iii) Protected Frame subfield (bit 12) always set to 1
   iv) EOSP subfield (bit 13) masked to 0
   v) Relayed Frame subfield (bit 14) masked to 0
   vi) Ack Policy Indicator subfield (bit 15) masked to 0
   vii) Other subfields are not modified.
2) A1 – MPDU A1 field if it contains a MAC address; otherwise, the MAC address that corresponds to the AID value contained in the SID field of the A1 field.
3) A2 – MPDU A2 field if it contains a MAC address; otherwise, the MAC address corresponding to the AID value contained in the SID field of the A2 field.
4) SC – MPDU Sequence Control field, with the Sequence Number subfield (bits 4–15 of the Sequence Control field) masked to 0. The Fragment Number subfield is not modified.
5) A3 – MPDU A3 field if present in the MPDU, the value of A3 stored at the receiver if A3 is stored at the receiver and is not present in the MPDU (see 10.58); otherwise, not present.
6) A4 – MPDU A4 field if present in the MPDU, the value of A4 stored at the receiver if A4 is stored at the receiver and is not present in the MPDU (see 10.58); otherwise, not present.

12.5.3.3.4 Construct CCM nonce

The Nonce field occupies 13 octets, and its structure is shown in Figure 12-21. The structure of the Nonce Flags subfield of the Nonce field is shown in Figure 12-22.

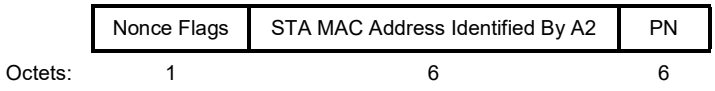

Figure 12-21—Nonce field

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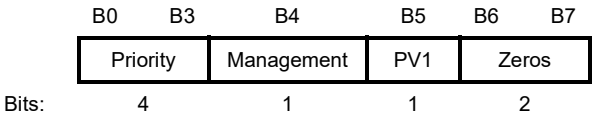

Figure 12-22—Nonce Flags subfield

The Priority subfield shall be set to the priority value of the MPDU.

The Management subfield shall be set to 1 if the MPDU is a Management frame and management frame protection is negotiated; otherwise, it shall be set to 0.

The PV1 subfield shall be set to 1 for a PV1 frame; otherwise, it shall be set to 0.

The Zeros subfield shall be set to 0.

The STA MAC Address Identified By A2 subfield shall contain the Address 2 field from the MAC header for PV0 MPDUs and the MAC address identified by the A2 field in the MAC header for PV1 MPDUs (see 9.8.3.2).

The PN subfield shall contain the packet number, with PN0 in the last octet of the subfield.

12.5.3.3.5 Construct CCMP header for PV0 MPDUs

The format of the 8-octet CCMP header is given in 12.5.3.2. The header encodes the PN, Key ID, and ExtIV field values used to encrypt the MPDU.

12.5.3.3.6 Construct CCMP header for PV1 MPDUs

The CCMP header is not present in secure PV1 MPDUs, but constructed locally at the STA as follows:

- The PN is composed of the Sequence Control field and the base PN (BPN), where
  - The Sequence Control field is present in the MPDU header
    - PN0||PN1 = Sequence Control field with the Fragment Number subfield masked to 0 when the PV1 MPDU is carried in an A-MPDU that is not an S-MPDU
  - The base PN is retrieved from the local storage at the receiver
    - PN2||PN3||PN4||PN5 = BPN
  - PN = PN0||PN1|| PN2||PN3||PN4||PN5 (= Sequence Control ||BPN)
- The Key ID is retrieved from the local storage at the receiver

The locally stored BPN and Key ID are initialized at 0 when PTKSA is established.

The locally stored BPN shall be incremented by 1 when the sequence number of the MPDU is less than the previous sequence number for that TID/ACI if any of the following two conditions is satisfied:

- Block Ack is not used
- Block Ack is used but decryption occurs after Block Ack reordering

When Block Ack is used and decryption occurs before Block Ack reordering, the BPN may be updated as follows. The receiver maintains a sequence number window of size w, which is equal to twice the Block Ack reorder window. The sequence number window has a lower edge *a* and an upper edge *b*. For a received sequence number SN (as part of the received Sequence Control field), the associated packet number (PN) is determined as follows (where *b* is initialized as $b = 0$):

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if ($b \geq$ w) then
    $a = b -$ w
    if (SN < a) then BPN = BPN + 1
    PN = Sequence Control ||BPN
    if not (a < SN < b) then b = SN
else (i.e., $b <$ w) then
    $a = b -$ w + 2^{12}
    if (SN < a) then PN = Sequence Control ||BPN
    if (SN $\geq a$) then PN = Sequence Control ||(BPN − 1)
    if (b < SN < a) then b = SN

The BPN can also be updated explicitly through a header compression request/response exchange, as defined in 10.58.

12.5.3.3.7 CCM originator processing

CCM is a generic authenticate-and-encrypt block cipher mode, and in this standard, CCM is used with the AES block cipher.

There are four inputs to CCM originator processing (see Figure 12-18):

a) *Key:* the temporal key.
b) *Nonce:* the nonce constructed as described in 12.5.3.3.3.
c) *Plaintext data:* the plaintext frame body of the MPDU to be encrypted and transmitted.
d) *AAD:* the AAD that is the canonical MPDU header as described in 12.5.3.3.3.

CCM originator processing provides authentication and integrity of the frame body and the AAD as well as data confidentiality of the frame body. The output from CCM originator processing consists of the encrypted data and an encrypted MIC (see Figure 12-16).

The CCM encryption algorithm is described in IETF RFC 3610. The key, nonce, plaintext data and AAD described above are passed to the CCM encryption algorithm as K, N, m and a respectively. The CCM encryption algorithm yields a final result c containing the encrypted message and an encrypted authentication value U; from this the encrypted frame body is taken as the encrypted message and the MIC is taken as U.

The PN values sequentially number each MPDU. Each transmitter shall maintain a single PN (48-bit counter) for each PTKSA and GTKSA. The PN shall be implemented as a 48-bit strictly increasing integer, initialized to 1 when the corresponding temporal key is initialized or refreshed.

A transmitter shall not use an IEEE 802.11 MSDU or A-MSDU priority if this would cause the total number of priorities used during the lifetime of the SA to exceed the number of replay counters supported by the receiver (for a pairwise SA) or all the receivers (for a group SA) for that SA. The transmitter shall not reorder CCMP protected frames that are transmitted to the same RA within a replay counter, but may reorder frames across replay counters. One possible reason for reordering frames is the IEEE 802.11 MSDU or A-MSDU priority.

The transmitter shall preserve the order of protected robust Management frames that are transmitted to the same DA without the QMF service. When the QMF service is used, the transmitter shall not reorder robust IQMFs within an AC when the frames are transmitted to the same RA.

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A CCMP protected individually addressed robust Management frame shall be protected using the same TK as a Data frame.

12.5.3.4 CCMP decapsulation

12.5.3.4.1 General

Figure 12-23 depicts the CCMP decapsulation process and is described as follows.

a) For secure PV0 MPDUs, CCMP decrypts the Frame Body field of a cipher text MPDU and decapsulates a plaintext MPDU using the following steps:
   1) The encrypted MPDU is parsed to construct the AAD (see 12.5.3.3.3) and nonce (see 12.5.3.3.4) values.
   2) The MIC is extracted for use in CCM integrity checking.
   3) CCM recipient processing uses the temporal key, AAD, nonce, encrypted MIC, and MPDU cipher text data to recover the MPDU plaintext data as well as to check the integrity of the AAD and MPDU plaintext data.
   4) The received MPDU header and the MPDU plaintext data from CCM recipient processing are concatenated to form a plaintext MPDU.
   5) The decryption processing prevents replay of MPDUs by validating that the PN in the MPDU is greater than the replay counter maintained for the session.

b) For secure PV1 MPDUs, CCMP decrypts the Frame Body field of a cipher text MPDU and decapsulates a plaintext MPDU using the following steps:
   1) The encrypted MPDU is parsed to construct the AAD (see 12.5.3.3.3) and nonce (see 12.5.3.3.4) values.
   2) The CCMP header is constructed as defined in 12.5.3.3.6.
   3) The MIC is extracted for use in CCM integrity checking.
   4) CCM recipient processing uses the temporal key, AAD, nonce, encrypted MIC, and MPDU cipher text data to recover the MPDU plaintext data as well as to check the integrity of the AAD and MPDU plaintext data.
   5) The received MPDU header and the MPDU plaintext data from CCM recipient processing are concatenated to form a plaintext MPDU.
   6) The decryption processing prevents replay of MPDUs by validating that the PN in the CCMP header is greater than the replay counter maintained for the session and TID/ACI.

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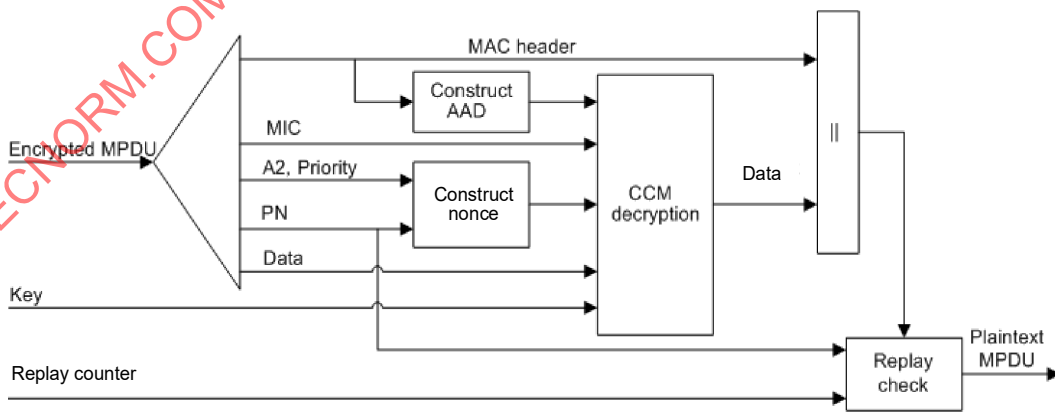

Figure 12-23—CCMP decapsulation block diagram

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See 12.5.3.4.2 to 12.5.3.4.4 for details of this processing.

When the received frame is a CCMP protected individually addressed robust Management frame or PV1 Management frame, contents of the MMPDU body after protection is removed shall be delivered to the SME via the MLME primitive designated for that MMPDU or PV1 Management frame rather than through the MA-UNITDATA.indication primitive.

12.5.3.4.2 CCM recipient processing

CCM recipient processing uses the same parameters as CCM originator processing. A CCMP protected individually addressed robust Management frame or PV1 Management frame shall use the same TK as a Data frame or PV1 Data frame.

There are five inputs to CCM recipient processing (see Figure 12-23):

— *Key:* the temporal key.
— *Nonce:* the nonce constructed as described in 12.5.3.3.3.
— *Encrypted data:* the encrypted portion of the frame body from the received MPDU, excluding the MIC (see Figure 12-16 and Figure 12-17).
— *MIC:* the encrypted MIC from the received MPDU.
— *AAD:* the AAD that is the canonical MPDU header as described in 12.5.3.3.3.

CCM recipient processing checks the authentication and integrity of the frame body and the AAD as well as decrypting the frame body. A MIC check is performed by comparing the received MIC with a MIC calculated as described in 12.5.3.3. The plaintext is returned only if the MIC check is successful.

The CCM decryption algorithm is described in IETF RFC 3610. The key, nonce, AAD and encrypted data described above are passed to the CCM decryption algorithm as K, N, a and c respectively. The CCM decryption algorithm yields a decrypted message m and a value T; from this the plaintext frame body described below is taken as m, if the MIC described above matches T.

There is one output from error-free CCM recipient processing:

— *Frame body:* the plaintext frame body, which is 8 octets (CCMP-128) or 16 octets (CCMP-256) smaller than the encrypted portion of the frame body.

12.5.3.4.3 Decrypted CCMP MPDU

The decapsulation process succeeds when the calculated MIC (as described in 12.5.3.3) matches the MIC value obtained from decrypting the received encrypted MPDU. The original MPDU header is concatenated with the plaintext data resulting from the successful CCM recipient processing to create the plaintext MPDU.

12.5.3.4.4 PN and replay detection

To effect replay detection, the receiver extracts the PN from the CCMP header.

NOTE—The CCMP header is not present in secure PV1 MPDUs, but constructed locally at the STA as defined in 12.5.3.3.6.

See 12.5.3.2 for a description of how the PN is encoded in the CCMP header. The following processing rules are used to detect replay:

a) The receiver shall maintain a separate set of replay counters for each PTKSA, GTKSA, and protocol version value. The receiver initializes these replay counters to 0 when it resets the temporal key for a peer. The replay counter is set to the PN value of accepted CCMP MPDUs.

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b) For each PTKSA, GTKSA, and protocol version value, the recipient shall maintain a separate replay counter for each TID, subject to the limitation of the number of supported replay counters indicated in the RSN Capabilities field (see 9.4.2.24), and shall use the PN from a received frame to detect replayed frames. A replayed frame occurs when the PN from a received frame is less than or equal to the current replay counter value for the frame's MSDU or A-MSDU priority and frame type.

c) If dot11RSNAProtectedManagementFramesActivated is true, the recipient shall maintain a single replay counter for received individually addressed robust Management frames that are received with the To DS subfield equal to 0, and a single replay counter for received individually addressed robust PV1 Management frames and shall use the PN from the received frame to detect replays. If dot11QMFActivated is also true, the recipient shall maintain an additional replay counter for each ACI for received individually addressed robust Management frames and robust PV1 Management frames that are received with the To DS subfield equal to 1. The QMF receiver shall use the ACI encoded in the Sequence Number field of the received frame to select the replay counter to use for the received frame, and shall use the PN from the received frame to detect replays. A replayed frame occurs when the PN from the frame is less than or equal to the current value of the management frame replay counter that corresponds to the ACI of the frame.

d) The receiver shall discard any Data frame that is received with its PN less than or equal to the value of the replay counter that is associated with the TA and priority value of the received MPDU. The receiver shall discard MSDUs and MMPDUs whose constituent MPDU PN values are not incrementing in steps of 1. If dot11RSNAProtectedManagementFramesActivated is true, the receiver shall discard any individually addressed robust Management frame that is received with its PN less than or equal to the value of the replay counter associated with the TA of that individually addressed Management frame.

e) When discarding a frame, the receiver shall increment by 1 dot11RSNAStatsCCMPReplays for Data frames or dot11RSNAStatsRobustMgmtCCMPReplays for robust Management frames.

f) For MSDUs or A-MSDUs sent using the block ack feature, reordering of received MSDUs or A-MSDUs according to the block ack receiver operation is performed prior to replay detection.

12.5.4 Broadcast/multicast integrity protocol (BIP)

12.5.4.1 BIP overview

BIP provides data integrity and replay protection for group addressed robust Management frames after establishment of an IGTKSA (see 12.6.1.1.9) and for Beacon frames after establishment of a BIGTKSA (see 12.6.1.1.11).

BIP-CMAC-128 provides data integrity and replay protection, using AES-128 in CMAC Mode with a 128-bit integrity key and a CMAC TLen value of 128 (16 octets). BIP-CMAC-256 provides data integrity and replay protection, using AES-256 in CMAC Mode with a 256-bit integrity key and a CMAC TLen value of 128 (16 octets). NIST Special Publication 800-38B defines the CMAC algorithm, and NIST SP 800-38D defines the GMAC algorithm. BIP processing uses AES with a 128-bit or 256-bit integrity key and a CMAC TLen value of 128 (16 octets). The CMAC output for BIP-CMAC-256 is not truncated and shall be 128 bits (16 octets). The CMAC output for BIP-CMAC-128 is truncated to 64 bits:

MIC = Truncate-64(CMAC Output).

BIP-GMAC-128 uses AES with a 128-bit integrity key, and BIP-GMAC-256 uses AES with a 256-bit integrity key. The authentication tag for both BIP-GMAC-128 and BIP-GMAC-256 is not truncated and shall be 128 bits (16 octets).

BIP uses the IGTK or BIGTK to compute the MMPDU MIC. The authenticator shall distribute one new IGTK and IGTK PN (IPN) whenever it distributes a new GTK. The IGTK is identified by the MAC address of the transmitting STA plus an IGTK identifier that is encoded in the MME Key ID field. If beacon protection is

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enabled, the authenticator may distribute one new BIGTK and BIPN when it distributes a new GTK. The BIGTK is identified by the MAC address of the transmitting STA plus a BIGTK identifier that is encoded in the MME Key ID field.

12.5.4.2 BIP MMPDU format

The Management MIC element shall follow all of the other elements in the management frame body but precede the FCS. See 9.4.2.54 for the format of the Management MIC element. Figure 12-24 shows the BIP MMPDU.

Figure 12-24—BIP encapsulation

12.5.4.3 BIP AAD construction

The BIP Additional Authentication Data (AAD) is constructed from the MPDU header. AAD construction is performed as follows:

a) FC—MPDU Frame Control field, with the following modifications:
   1) Retry subfield (bit 11) masked to 0
   2) Power Management subfield (bit 12) masked to 0
   3) More Data subfield (bit 13) masked to 0
   4) Other subfields are not modified
b) A1—MPDU Address 1 field.
c) A2—MPDU Address 2 field.
d) A3—MPDU Address 3 field.

Figure 12-25 depicts the format of the AAD. The length of the AAD is 20 octets.

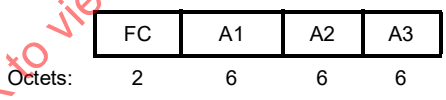

Figure 12-25—BIP AAD construction

12.5.4.4 BIP replay protection

When management frame protection is negotiated, the receiver shall maintain a 48-bit replay counter for each IGTK. The receiver shall set the receive replay counter to the value of the IPN in the IGTK KDE (see 12.7.2) provided by the Authenticator in the 4-way handshake, FT 4-way handshake, FT handshake, group key handshake, or FILS authentication. The transmitter shall maintain a single IPN for each IGTK. The IPN shall be implemented as a 48-bit strictly increasing integer, initialized to 1 when the corresponding IGTK is initialized. The transmitter may reinitialize the sequence counter when the IGTK is refreshed.

When beacon protection is enabled, the receiver shall maintain a 48-bit replay counter for each BIGTK. The receiver shall set the receive replay counter to the value of the BIPN in the BIGTK key data encapsulation (KDE) (see 12.7.2) provided by the Authenticator in the 4-way handshake, FT 4-way handshake, FT handshake, group key handshake, or FILS authentication. The transmitter shall maintain a single BIPN for each BIGTK. The BIPN shall be implemented as a 48-bit strictly increasing integer, initialized to 1 when the corresponding BIGTK is initialized. The transmitter may reinitialize the sequence counter when the BIGTK is refreshed.

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See 12.5.4.5 and 12.5.4.6 for per frame BIP processing.

If the PN is larger than dot11PNExhaustionThreshold, an MLME-PN-EXHAUSTION.indication primitive shall be generated.

NOTE—When the IPN or BIPN space is exhausted, the choices available to an implementation are to replace the corresponding key or to end communications.

When dot11QMFActivated is true, the receiver shall maintain an additional replay counter for each ACI for received group addressed robust Management frames that use QMF. The receiver shall use the ACI encoded in the Sequence Number field of received GQMFs protected by BIP to select the replay counter to use for the received frame, and shall use the IPN from the received frame to detect replays.

If dot11RSNAProtectedManagementFramesActivated is true and dot11MeshSecurityActivated is true, the recipient shall maintain a single replay counter for received group addressed robust Management frames that do not use the QMF service and shall use the PN from the received frame to detect replays. If dot11QMFActivated is also true, the recipient shall maintain an additional replay counter for each ACI for received group addressed robust Management frames that use the QMF service. The QMF receiver shall use the ACI encoded in the Sequence Number field of the received frame to select the replay counter to use for the received frame, and shall use the PN from the received frame to detect replays. A replayed frame occurs when the PN from the frame is less than or equal to the value of the management frame replay counter that corresponds to the ACI of the frame. The transmitter shall preserve the order of protected robust Management frames transmitted to the same DA without the QMF service. When the QMF service is used, the transmitter shall not reorder robust GQMFs within an AC when the frames are transmitted to the same RA.

12.5.4.5 BIP transmission

When a STA transmits a protected group addressed robust Management frame, it shall

a) Select the IGTK or BIGTK currently active for transmission of frames to the intended group of recipients and construct the MME (see 9.4.2.54) with the MIC field masked to 0 and the Key ID field set to the corresponding IGTK Key ID value. If the frame is not a GQMF, the transmitting STA shall insert a strictly increasing integer into the MME IPN/BIPN field. If the frame is a GQMF, then the transmitting STA shall maintain a 48-bit counter for use as the IPN, the counter shall be incremented for each GQMF until the two least significant bits of the counter match the ACI of the AC that is used to transmit the frame, and the counter value shall be inserted into the MME IPN/BIPN field of the frame. For BIP-GMAC-128 and BIP-GMAC-256, the initialization vector passed to GMAC shall be a concatenation of Address 2 from the MAC header of the MPDU and the non-negative integer inserted into the MME IPN/BIPN field.
b) Compute AAD as specified in 12.5.4.3.
c) Compute an integrity value over the concatenation of AAD and the management frame body including MME, and the Timestamp field masked to 0 if it is a protected Beacon frame, and insert the output into the MME MIC field. For BIP-CMAC-128, the integrity value is 64 bits and is computed using AES-128-CMAC; for BIP-CMAC-256, the integrity value is 128 bits and is computed using AES-256-CMAC; for BIP-GMAC-128, the integrity value is 128 bits and is computed using AES-128-GMAC; and, for BIP-GMAC-256, the integrity value is 128 bits and is computed using AES-256-GMAC.
d) Compose the frame as the IEEE 802.11 header, management frame body, including MME, and FCS. The MME shall appear last in the frame body.
e) Transmit the frame.

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Once a STA transmits a protected Beacon frame using a new BIGTK, the STA shall not transmit protected Beacon frames using the previously BIGTK. Once a STA transmits a protected group addressed robust Management frame using a new IGTK, the STA should not transmit protected group addressed robust Management frames using the previously used IGTK.

12.5.4.6 BIP reception

When a STA with management frame protection negotiated receives a group addressed robust Management frame or protected Beacon frame protected by BIP-CMAC-128, BIP-CMAC-256, BIP-GMAC-128, or BIP-GMAC-256, it shall

a) Identify the appropriate IGTK or BIGTK and associated state based on the MME Key ID field. If no such IGTK exists, silently drop the frame and terminate BIP processing for this reception. If the frame is a protected Beacon frame and no such BIGTK exists, terminate BIP processing for this reception, and
   1) If beacon protection is enabled, silently drop the frame and optionally transmit to the AP a WNM Notification Request frame to report beacon protection failure.
   2) Otherwise, process the frame.

b) Perform replay protection on the received frame. The receiver shall interpret the MME IPN/BIPN field as a 48-bit unsigned integer.
   1) If the frame is a robust Management frame but not a GQMF, the receiver shall compare this MME IPN value to the value of the receive replay counter for the IGTK identified by the MME Key ID field. If the value from the received MME IPN/BIPN field is less than or equal to the replay counter value for this IGTK, the receiver shall discard the frame and increment the dot11RSNAStatsCMACReplays counter by 1.
   2) If the frame is a robust Management frame and also a GQMF, the receiver shall compare this MME IPN value to the value of the receive replay counter for the IGTK identified by the MME Key ID field and the AC represented by the value of the ACI subfield of the received frame. If the value from the received MME IPN/BIPN field is less than or equal to the replay counter value for this IGTK and AC, the receiver shall discard the frame and increment the dot11RSNAStatsCMACReplays counter by 1.
   3) If the frame is a protected Beacon frame, the receiver shall compare this MME IPN/BIPN value to the value of the receive replay counter for the BIGTK identified by the MME Key ID field. If the integer value from the received MME IPN/BIPN field is less than or equal to the replay counter value for this BIGTK, the receiver shall discard the frame and increment the dot11RSNAStatsCMACReplays counter by 1.

c) Compute AAD for this Management frame, as specified in 12.5.4.3. For BIP-GMAC-128 and BIP-GMAC-256, an initialization vector for GMAC is constructed as the concatenation of Address 2 from the MAC header of the MPDU and the 48-bit unsigned integer from the MME IPN/BIPN field.

d) Extract and save the received MIC value, and compute a verifier over the concatenation of AAD, the management frame body, with the Timestamp field masked to 0 if it is a protected Beacon frame, and MME, with the MIC field masked to 0 in the MME. For BIP-CMAC-128, the integrity value is 64 bits and is computed using AES-128-CMAC; for BIP-CMAC-256, the integrity value is 128 bits and is computed using AES-256-CMAC; for BIP-GMAC-128, the integrity value is 128 bits and is computed using AES-128-GMAC; and, for BIP-GMAC-256, the integrity value is 128 bits and is computed using AES-256-GMAC. If the result does not match the received MIC value, then the receiver shall discard the frame, increment the dot11RSNAStatsBIPMICErrors counter by 1, and terminate BIP processing for this reception.

e) If the frame is a robust Management frame but not a GQMF, update the replay counter for the IGTK identified by the MME Key ID field with the value of the MME IPN/BIPN field.

f) If the frame is a robust Management frame and also a GQMF, update the replay counter for the IGTK identified by the MME Key ID field and the AC represented by the value of the ACI subfield of the received frame with the value of the MME IPN/BIPN field.

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g) If the frame is a protected Beacon frame, update the replay counter for the BIGTK identified by the MME Key ID field with the value of the MME IPN/BIPN field.

If management frame protection is negotiated, group addressed robust Management frames that are received without BIP protection shall be discarded.

If beacon protection is enabled, Beacon frames that are received without BIP protection shall be discarded. A WNM Notification Request frame may be used to report beacon protection failure.

12.5.5 GCM protocol (GCMP)

12.5.5.1 GCMP overview

Subclause 12.5.5 specifies the GCMP, which provides data confidentiality, authentication, integrity, and replay protection. A DMG RSNA STA shall support GCMP-128.

GCMP is based on the GCM of the AES encryption algorithm. GCM protects the integrity of both the MPDU Data field and selected portions of the MPDU header.

The AES algorithm is defined in FIPS 197. All AES processing used within GCMP uses AES with a 128-bit key (GCMP-128) or a 256-bit key (GCMP-256).

GCM is defined in NIST Special Publication 800-38D. GCM is a generic mode that can be used with any block-oriented encryption algorithm.

GCM requires a fresh temporal key for every session. GCM also requires a unique nonce value for each frame protected by a given temporal key. Reuse of a nonce value with the same temporal key voids all security guarantees. GCMP uses a 128-bit MIC.

Annex J provides test vectors for GCM.

When GCMP is selected as the RSN pairwise cipher and management frame protection is negotiated, individually addressed robust Management frames and the group addressed Management frames that receive "Group Addressed Privacy" as indicated in Table 9-51 shall be protected with GCMP.

An S1G STA shall use PV0 frames when using GCMP encapsulation.

12.5.5.2 GCMP MPDU format

Figure 12-26 shows the MPDU format when using GCMP.

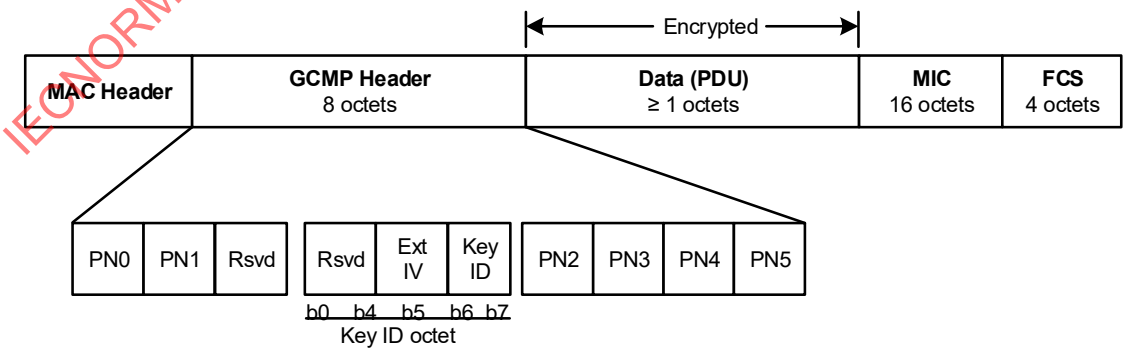

Figure 12-26—Expanded GCMP MPDU

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GCMP processing expands the original MPDU size by 24 octets, 8 octets for the GCMP Header field and 16 octets for the MIC field. The GCMP Header field is constructed from the PN and Key ID subfields. The 48-bit PN is represented as an array of 6 octets. PN5 is the most significant octet of the PN, and PN0 is the least significant.

The ExtIV subfield (bit 5) of the Key ID octet is always set to 1 for GCMP.

Bits 6–7 of the Key ID octet are for the Key ID subfield. The remaining bits of the Key ID octet are reserved.

12.5.5.3 GCMP cryptographic encapsulation

12.5.5.3.1 General

The GCMP cryptographic encapsulation process is depicted in Figure 12-27.

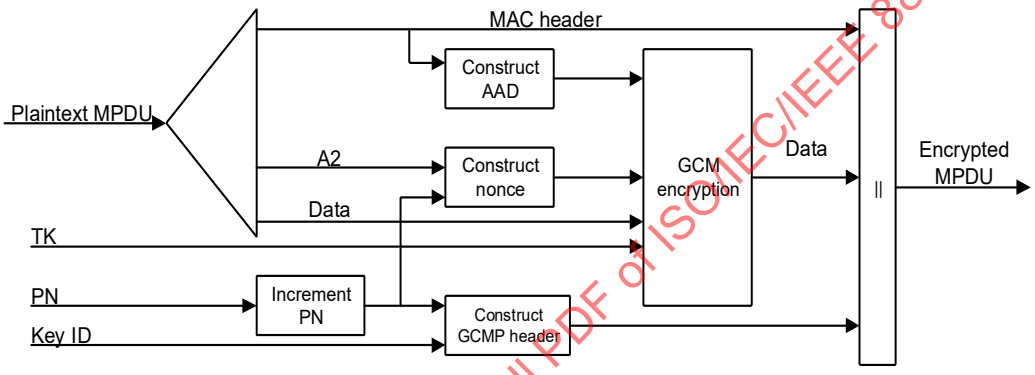

Figure 12-27—GCMP encapsulation block diagram

GCMP encrypts the Frame Body field of a plaintext MPDU and encapsulates the resulting cipher text using the following steps:

a) Increment the PN, to obtain a fresh PN for each MPDU, so that the PN never repeats for the same temporal key.

NOTE—Retransmitted MPDUs are not modified on retransmission.

b) Use the fields in the MPDU header to construct the additional authentication data (AAD) for GCM. The GCM algorithm provides integrity protection for the fields included in the AAD. MPDU header fields that may change when retransmitted are muted by being masked to 0 when calculating the AAD.

c) Construct the GCM nonce block as defined in 12.5.3.3.4 from the PN and A2, where A2 is MPDU Address 2.

d) Construct the GCMP header as defined in 12.5.5.3.5.

e) Use the temporal key, AAD, nonce, and MPDU data to form the cipher text and the MIC. This step is known as GCM originator processing.

f) Form the encrypted MPDU by combining the original MPDU header, the GCMP header, the encrypted data and the MIC, as described in 12.5.5.2.

The GCM reference describes the processing of the key, nonce, AAD, and data to produce the encrypted output. See 12.5.5.3.2 to 12.5.5.3.6 for details of the creation of the AAD and nonce from the MPDU and the associated MPDU-specific processing.

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12.5.5.3.2 PN processing

The PN is incremented by a positive number for each MPDU. The PN shall be incremented in steps of 1 for constituent MPDUs of fragmented MSDUs and MMPDUs. The PN shall never repeat for a series of encrypted MPDUs using the same temporal key.

If the PN exceeds the threshold defined in dot11PNExhaustionThresholdLow and dot11PNExhaustionThresholdHigh, an MLME-PN-EXHAUSTION.indication primitive shall be generated.

NOTE 1—When PN space is exhausted, the choices available to an implementation are to replace the corresponding key or to end communications.

NOTE 2—When a group addressed MSDU is retransmitted using GCR, it is concealed from non-GCR capable STAs using the procedures described in 11.21.16.3.5. The MPDU containing this concealed A-MSDU has a different PN from the MPDU that contained the original transmission of the group addressed MSDU.

12.5.5.3.3 Construct AAD

The AAD construction is defined in 12.5.3.3.3.

12.5.5.3.4 Construct GCM nonce

The Nonce field occupies 12 octets, and its structure is shown in Figure 12-28.

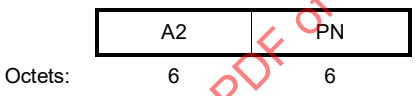

Figure 12-28—Nonce field format

The A2 subfield shall contain the Address 2 field from the MAC header.

The PN subfield shall contain the packet number, with PN0 in the last octet of the subfield.

12.5.5.3.5 Construct GCMP header

The format of the 8-octet GCMP header is given in 12.5.5.2. The header encodes the PN and Key ID field values used to encrypt the MPDU.

12.5.5.3.6 GCM originator processing

GCM is a generic authenticate-and-encrypt block cipher mode, and in this standard, GCM is used with the AES block cipher.

There are four inputs to GCM originator processing (see Figure 12-27):

a) *Key:* the temporal key.
b) *Nonce:* the nonce constructed as described in 12.5.5.3.4.
c) *Plaintext data:* the plaintext frame body of the MPDU to be encrypted and transmitted.
d) *AAD:* the AAD that is the canonical MPDU header as described in 12.5.5.3.3.

GCM originator processing provides authentication and integrity of the frame body and the AAD as well as data confidentiality of the frame body. The output from GCM originator processing consists of the encrypted data and 16 additional octets of MIC (see Figure 12-26).

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NOTE—In GCM originator processing, the MIC obtained is not encrypted, unlike in CCM originator processing. Refer to NIST Special Publication 800-38D for details.

The GCM encryption algorithm is described in NIST Special Publication 800-38D. The key, nonce, plaintext data and AAD described above are passed to the GCM encryption algorithm as *K*, *IV*, *P*, and *A*, respectively. The GCM encryption algorithm yields a cipher text *C* and an authentication tag *T*; from this the encrypted frame body is taken as *C* and the MIC is taken as *T*.

The PN values sequentially number each MPDU. Each transmitter shall maintain a single PN (48-bit counter) for each PTKSA and GTKSA. The PN shall be implemented as a 48-bit strictly increasing integer, initialized to 1 when the corresponding temporal key is initialized or refreshed.

A transmitter shall not use IEEE 802.11 MSDU or A-MSDU priorities without ensuring that the receiver supports the required number of replay counters. The transmitter shall not reorder GCMP protected frames that are transmitted to the same RA within a replay counter, but may reorder frames across replay counters. One possible reason for reordering frames is the IEEE 802.11 MSDU or A-MSDU priority.

The transmitter shall preserve the order of protected robust Management frames that are transmitted to the same DA without the QMF service. When the QMF service is used, the transmitter shall not reorder robust IQMFs within an AC when the frames are transmitted to the same RA.

A GCMP protected individually addressed robust Management frame shall be protected using the same TK as a Data frame.

12.5.5.4 GCMP decapsulation

12.5.5.4.1 General

Figure 12-29 shows the GCMP decapsulation process.

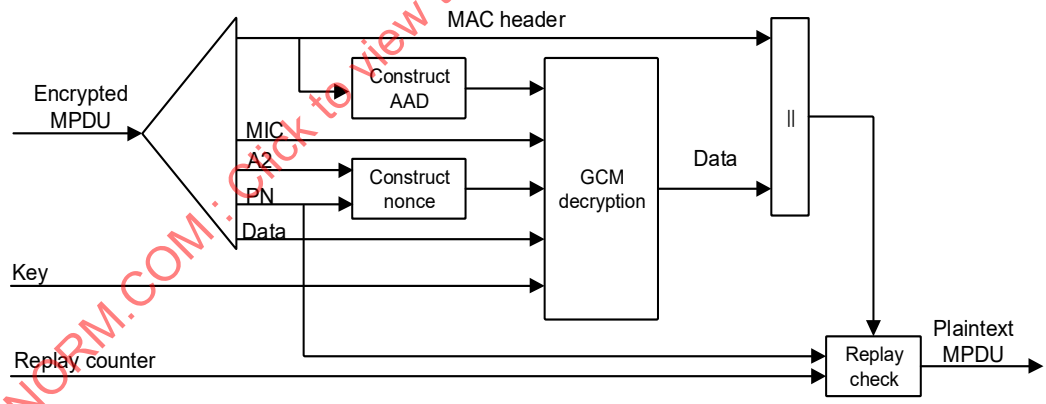

Figure 12-29—GCMP decapsulation block diagram

GCMP decrypts the Frame Body field of a cipher text MPDU and decapsulates a plaintext MPDU using the following steps:

a) The encrypted MPDU is parsed to construct the AAD (see 12.5.5.3.3) and nonce (see 12.5.5.3.4) values.

b) The MIC is extracted for use in GCM integrity checking.

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c) GCM recipient processing uses the temporal key, AAD, nonce, MIC, and MPDU cipher text data to recover the MPDU plaintext data as well as to check the integrity of the AAD and MPDU plaintext data.

d) The received MPDU header and the MPDU plaintext data from GCM recipient processing are concatenated to form a plaintext MPDU.

e) The decryption processing prevents replay of MPDUs by validating that the PN in the MPDU is greater than the replay counter maintained for the session.

See 12.5.5.4.2 to 12.5.5.4.4 for details of this processing.

When the received frame is a GCMP protected individually addressed robust Management frame, the contents of the MMPDU body after protection is removed and shall be delivered to the SME via the MLME primitive designated for that MMPDU rather than through the MA-UNITDATA.indication primitive.

12.5.5.4.2 GCM recipient processing

GCM recipient processing uses the same parameters as GCM originator processing. A GCMP protected individually addressed robust Management frame shall use the same TK as a Data frame.

There are five inputs to GCM recipient processing (see Figure 12-29):

— *Key:* the temporal key.
— *Nonce:* the nonce constructed as described in 12.5.5.3.4.
— *Encrypted data:* the encrypted portion of the frame body from the received MPDU (see Figure 12-26).
— *MIC:* the MIC from the received MPDU.
— *AAD:* the AAD that is the canonical MPDU header as described in 12.5.5.3.3.

GCM recipient processing checks the authentication and integrity of the frame body and the AAD as well as decrypting the frame body. A MIC check is performed by comparing the received MIC with a MIC calculated as described in 12.5.5.3. The plaintext is returned only if the MIC check is successful.

The GCM decryption algorithm is described in NIST Special Publication 800-38D. The key, nonce, encrypted data, AAD and MIC described above are passed to the GCM decryption algorithm as K, IV, C, A and T respectively. The GCM decryption algorithm yields a plaintext P or an indication of inauthenticity $FAIL$; from this the plaintext frame body is taken as P, if there was no indication of inauthenticity.

There is one output from error-free GCM recipient processing:

— *Frame body:* the plaintext frame body, which is the same size as the encrypted portion of the frame body.

12.5.5.4.3 Decrypted GCMP MPDU

The decapsulation process succeeds when the calculated MIC (as described in 12.5.5.3 matches the MIC value obtained from decrypting the received encrypted MPDU. The original MPDU header is concatenated with the plaintext data resulting from the successful GCM recipient processing to create the plaintext MPDU.

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12.5.5.4.4 PN and replay detection

To effect replay detection, the receiver extracts the PN from the GCMP header. See 12.5.5.2 for a description of how the PN is encoded in the GCMP header. The following processing rules are used to detect replay:

a) The receiver shall maintain a separate set of replay counters for each PTKSA and GTKSA. The receiver initializes these replay counters to 0 when it resets the temporal key for a peer. The replay counter is set to the PN value of accepted GCMP MPDUs.

b) For each PTKSA and GTKSA, the recipient shall maintain a separate replay counter for each TID, subject to the limitation of the number of supported replay counters indicated in the RSN Capabilities field (see 9.4.2.24), and shall use the PN from a received frame to detect replayed frames. A replayed frame occurs when the PN from a received frame is less than or equal to the current replay counter value for the frame's MSDU or A-MSDU priority and frame type.

c) If dot11RSNAProtectedManagementFramesActivated is true, the recipient shall maintain a single replay counter for received individually addressed robust Management frames that are received with the To DS subfield equal to 0 and shall use the PN from the received frame to detect replays. If dot11QMFActivated is also true, the recipient shall maintain an additional replay counter for each ACI for received individually addressed robust Management frames that are received with the To DS subfield equal to 1. The QMF receiver shall use the ACI encoded in the Sequence Number field of the received frame to select the replay counter to use for the received frame, and shall use the PN from the received frame to detect replays. A replayed frame occurs when the PN from the frame is less than or equal to the current value of the management frame replay counter that corresponds to the ACI of the frame.

d) The receiver shall discard any Data frame that is received with its PN less than or equal to the value of the replay counter that is associated with the TA and priority value of the received MPDU. The receiver shall discard MSDUs and MMPDUs whose constituent MPDU PN values are not incrementing in steps of 1. If dot11RSNAProtectedManagementFramesActivated is true, the receiver shall discard any individually addressed robust Management frame that is received with its PN less than or equal to the value of the replay counter associated with the TA of that individually addressed Management frame.

e) When discarding a frame, the receiver shall increment by 1 dot11RSNAStatsGCMPReplays for Data frames or dot11RSNAStatsRobustMgmtGCMPReplays for robust Management frames.

f) For MSDUs or A-MSDUs sent using the block ack feature, reordering of received MSDUs or A-MSDUs according to the block ack receiver operation is performed prior to replay detection.

12.6 RSNA security association management

12.6.1 Security associations

12.6.1.1 Security association definitions

12.6.1.1.1 General

IEEE Std 802.11 uses the notion of a security association to describe secure operation. Secure communications are possible only within the context of a security association, as this is the context providing the state (e.g., cryptographic keys, counters, sequence spaces) needed for correct operation of the IEEE 802.11 cipher suites.

A security association is a set of policy(ies) and key(s) used to protect information. The information in the security association is stored by each party of the security association, needs to be consistent among all parties, and needs to have an identity. The identity is a compact name of the key and other bits of security association

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information to fit into a table index or an MPDU. The following types of security associations are supported by an RSNA STA:

- PMKSA: A result of a successful IEEE 802.1X exchange, SAE authentication, FILS authentication, or preshared PMK information. A PMKSA can be cached.
- PMK-R0 security association: A result of a successful FT initial mobility domain association.
- PMK-R1 security association: A result of a successful FT initial mobility domain association or FT authentication sequence.
- Mesh PMKSA: A result of successful completion of the active authentication protocol.
- PTKSA: A result of a successful 4-way handshake, FT 4-way handshake, FT authentication sequence, or FILS authentication.
- Mesh TKSA: A result of a successful authenticated mesh peering exchange (AMPE).
- GTKSA: A result of a successful group key handshake, 4-way handshake, FT 4-way handshake, FT authentication sequence, or FILS authentication.
- IGTKSA: A result of a successful group key handshake, successful 4-way handshake, successful FT 4-way handshake, the Reassociation Response frame of the fast BSS transition protocol, or successful FILS authentication.
- Mesh GTKSA: A result of a successful AMPE or mesh group key handshake.
- BIGTKSA: A result of a successful group key handshake, successful 4-way handshake, successful FT 4-way handshake, the Reassociation Response frame of the fast BSS transition protocol, or successful FILS authentication.

In order to set up a security association to a peer STA, an SME that does not know the security policy of the peer should send a Probe Request frame to the peer STA to find its security policy before setting up a security association to the peer STA.

In order to set up a security association to a peer STA, a STA that received a 4-way handshake but does not know the security policy of the peer should send a Probe Request frame to the peer STA to find its security policy before setting up a security association to the peer STA.

12.6.1.1.2 PMKSA

The PMKSA is created by the Authenticator's SME and Supplicant's SME when EAP authentication, SAE authentication, or FILS authentication completes successfully, or when the PSK is configured.

When the negotiated AKM uses PMKID derivation with KCK as a parameter as defined in 12.7.1.3, the PMKID derived from the KCK during the initial 4-way handshake is not changed during the lifetime of this PMKSA.

A PMKSA association is bidirectional. In other words, both parties use the information in the security association for both sending and receiving. The PMKSA is used to create the PTKSA. PMKSAs have a certain lifetime. The PMKSA consists of the following:

- PMKID, as defined in 12.7.1.3 or 12.7.1.6.3. The PMKID identifies the security association.
- Authenticator's or peer's MAC address. For multi-band RSNA, the MAC address is associated with the operating band in use when the PMKSA is established.
- PMK; or if the PMKSA was established with an AKM suite type for which the Authentication type column includes FT authentication (see Table 9-151), MPMK (see 12.7.1.6.3).
- Lifetime, as defined in 12.7.1.3 or 12.7.1.6.
- AKMP.

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— All authorization parameters specified by the AS or local configuration. This might include parameters such as the STA's authorized SSID.
— Cache Identifier, if advertised by the AP in FILS Indication element.

12.6.1.1.3 PMK-R0 security association

The PMK-R0 security association is the result of a successful completion of the IEEE 802.1X authentication, SAE authentication, or use of PSK during the FT initial mobility domain association. This security association is bidirectional. It has a certain lifetime. It consists of the following:

— SSID
— Mobility domain identifier (MDID)
— PMK-R0
— R0KH-ID
— PMKR0Name
— S0KH-ID
— PMK-R0 lifetime
— Pairwise cipher suite selector
— All authorization parameters specified by the AS or local configuration

12.6.1.1.4 PMK-R1 security association

The PMK-R1 security association is the result of

— A successful completion of the IEEE 802.1X authentication, SAE authentication, or use of PSK during the FT initial mobility domain association or
— A successful completion of the authentication phase in the fast BSS transition to the target AP

This security association is bidirectional. It has a certain lifetime. It consists of the following:

— SSID
— MDID
— PMK-R1
— PMK-R1 lifetime
— PMKR1Name
— R1KH-ID
— R0KH-ID
— PMKR0Name
— S0KH-ID
— S1KH-ID
— Pairwise cipher suite selector
— All authorization parameters specified by the AS or local configuration

12.6.1.1.5 Mesh PMKSA

The mesh PMKSA is the result of successful completion of the active authentication protocol. This security association is bidirectional. The two authenticated parties use the information in the security association for both sending and receiving. The mesh PMKSA is created by the Mesh STA's SME when the active authentication protocol completes successfully with the peer mesh STA. The mesh PMKSA is used to create

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the mesh TKSA. Mesh PMKSAs have a certain lifetime. Mesh PMKSAs contain the following, and are identified by their PMKID.

- PMKID, as defined in 12.4.5.4
- Mesh STA's MAC address
- Peer mesh STA's MAC address
- PMK
- AEK, as defined in 14.5.7
- Lifetime, as defined in 12.7.1.3
- Selected AKM suite (see 9.4.2.24.3)

12.6.1.1.6 PTKSA

The PTKSA results from a successful 4-way handshake, FT 4-way handshake, FT protocol, FT resource request protocol, or FILS authentication. This security association is also bidirectional. PTKSAs have the same lifetime as the PMKSA or PMK-R1 security Association, whichever comes first. Because the PTKSA is tied to the PMKSA or to a PMK-R1 security association, it only has the additional information from the 4-way handshake, or FT Protocol authentication, or FILS authentication. For the PTKSA derived as a result of the 4-way handshake, there shall be only one PTKSA per band (see 12.6.19) with the same Supplicant and Authenticator MAC addresses. For the PTKSA derived as a result of an initial mobility domain association or fast BSS transition, there shall be only one PTKSA with the same STA's MAC address and BSSID.

During the 4-way handshake defined in 12.7.6.5 and the FT 4-way handshake defined in 13.4.2, there is state created between message 1 and message 3 of the handshake. This does not create a PTKSA until message 3 is validated by the Supplicant and message 4 is validated by the Authenticator.

During the FT authentication sequence defined in 13.8, the PTKSA is validated when message 3 is validated by the R1KH and message 4 is validated by the S1KH.

During the FILS authentication sequence defined in 12.11.2, the PTKSA is validated by key confirmation using (Re)Association Request and (Re)Association Response frames.

The PTKSA consists of the following:

- PTK
- Pairwise cipher suite selector
- Supplicant MAC address or STA's MAC address
- Authenticator MAC address or BSSID
- Key ID
- If FT key hierarchy is used,
  - R1KH-ID
  - S1KH-ID
  - PTKName

12.6.1.1.7 Mesh TKSA

The mesh TKSA is a result of the AMPE. This security association is also bidirectional. It has a certain lifetime. The mesh TKSA contains the following:

- MTK, as defined in 14.5.7
- PMKID
- Local mesh STA MAC address

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— Peer mesh STA MAC address
— Local Link ID
— Peer Link ID
— Local nonce
— Peer nonce
— Lifetime as defined in 12.6.16
— Pairwise cipher suite selector

12.6.1.1.8 GTKSA

The GTKSA results from a successful 4-way handshake, FT 4-way handshake, FT protocol, FT resource request protocol, group key handshake, or FILS authentication, and is unidirectional. In an infrastructure BSS, there is one GTKSA, used exclusively for encrypting group addressed MPDUs that are transmitted by the AP and for decrypting group addressed transmissions that are received by the STAs. In an IBSS or in a PBSS, each STA defines its own GTKSA, which is used to encrypt its group addressed transmissions, and stores a separate GTKSA for each peer STA so that encrypted group addressed traffic received from other STAs may be decrypted. A GTKSA is created by the Supplicant's SME when message 3 of the 4-way handshake is received, when message 1 of the group key handshake is received, when the Reassociation Response frame of the FT handshake is received, or when the FILS authentication with a status code indicating success is received. The GTKSA is created by the Authenticator's SME when the SME changes the GTK and has sent the GTK to all STAs with which it has a PTKSA. It has the same lifetime as the BSS, unless superseded. A GTKSA consists of the following:

— Direction vector (whether the GTK is used for transmit or receive).
— Group cipher suite selector.
— GTK.
— Authenticator MAC address.
— Key ID.
— All authorization parameters specified by local configuration. This might include parameters such as the STA's authorized SSID.

When the GTK is used to encrypt individually addressed traffic (the selectable cipher suite is "Use group cipher suite"), the GTKSA is bidirectional.

12.6.1.1.9 IGTKSA

When management frame protection is enabled, a non-AP STA's SME creates an IGTKSA when it receives a valid message 3 of the 4-way handshake or FT 4-way handshake, the Reassociation Response frame of the fast BSS transition protocol with a status code indicating success, a Mesh Peering Open Message of the Authenticated Mesh Peering Exchange (AMPE) protocol, a valid message 1 of the group key handshake, or the (Re)Association Response frame of FILS authentication with a status code indicating success. The Authenticator's SME creates an IGTKSA when it establishes or changes the IGTK with all STAs to which it has a valid PTKSA or mesh TKSA. An IGTKSA has the same lifetime as the BSS, unless superseded.

An IGTKSA consists of the following:

— Direction vector (whether the IGTK is used for transmit or receive)
— Key ID
— IGTK
— Authenticator MAC address

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12.6.1.1.10 Mesh GTKSA

The mesh GTKSA results from a successful AMPE or mesh group key handshake and is unidirectional. In an MBSS, each mesh STA defines its own "transmit mesh GTKSA," which is used to encrypt its group addressed transmissions. Also, each mesh STA stores a separate "receive mesh GTKSA" for each peer mesh STA so that encrypted group addressed traffic received from the peer mesh STAs may be decrypted.

A transmit mesh GTKSA is created by a mesh STA after the SME has changed the mesh GTK (MGTK) and the new MGTK has been sent to all peer mesh STAs. A receive mesh GTKSA is created by a mesh STA after successfully completing the AMPE in which a wrapped MGTK has been received, or after receiving a valid message 1 of the mesh group key handshake. The receive mesh GTKSA shall be deleted when the lifetime expires or a new receive mesh GTKSA is created with the same Key ID for the same MGTK source mesh STA. See 14.6.1.

The MGTK and the GTK shall be independently selected from a uniform distribution. The MGTK source mesh STA MAC address in the mesh GTKSA shall not be the same as the Authenticator MAC address in the GTKSA.

NOTE—The use of a distinct Transmit MGTK and ESS GTK with identical transmit MAC addresses is precluded by limitations on key rollover and reception by STAs in an infrastructure BSS (see 14.11.5 for collocated mesh STA rules). If the distinct MGTKs were to use different Key IDs, then rollover would be impossible. Since Key ID 0 is reserved for individually addressed frame transmission, there are at most three available Key IDs (only two if extended Key IDs for individually addressed frames are in use), and the different MGTKs would contend for the single remaining Key ID upon rollover. If the distinct MGTKs were to use the same Key IDs, then STAs would incorrectly attempt to decrypt mesh broadcast traffic using the ESS GTK, causing error counters (such as dot11RSNAStatsCCMPDecryptErrors) to continuously increment.

The mesh GTKSA contains the following:

— MGTK
— MGTK source mesh STA MAC address (mesh STA that uses this GTK to encrypt transmissions)
— Group cipher suite selector
— Direction vector (whether this is a receive mesh GTKSA or transmit mesh GTKSA)
— Key Index

12.6.1.1.11 BIGTKSA

An Authenticator's SME creates a BIGTKSA when dot11BeaconProtectionEnabled is true. A BIGTKSA has the same lifetime as the BSS, unless superseded.

A Supplicant's SME creates a BIGTKSA when dot11BeaconProtectionEnabled is true, upon receiving a BIGTK from its Authenticator.

A BIGTKSA consists of the following:

— Direction vector (whether the BIGTK is used for transmit or receive)
— Key ID
— BIGTK
— Authenticator MAC address

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12.6.1.2 TPKSA

The TPKSA results from a successful completion of the TPK handshake. This security association is bidirectional between the TDLS initiator STA and the TDLS responder STA. The TPKSA is used to create session keys to protect this TDLS session. The TPKSA has the lifetime indicated in the TPK handshake or the lifetime of the TDLS direct link, whichever comes first.

The TPKSA consists of the following:

— MAC addresses of the TDLS initiator STA and the TDLS responder STA
— Pairwise cipher suite selector
— TPK Lifetime
— TPK
— Link Identifier

12.6.1.3 Security association life cycle

12.6.1.3.1 General

A STA can operate in an ESS, an IBSS, an MBSS, or a PBSS, and a security association has a distinct life cycle for each. A STA that operates OCB does not have a security association life cycle.

12.6.1.3.2 Security association in an ESS

In an ESS there are two cases:

— Initial contact between the STA and the ESS
— Roaming by the STA within the ESS

A STA and AP establish an initial security association via the following steps:

a) The STA selects an authorized ESS by selecting among APs that advertise an appropriate SSID.
b) The STA then performs IEEE 802.11 authentication followed by association to the chosen AP. Confirmation of security parameters takes place during association. A STA performing IEEE 802.1X authentication uses Open System authentication. A STA performing password-based authentication can use SAE authentication. A STA performing FILS uses FILS authentication.

NOTE 1—It is possible for more than one PMKSA to exist. As an example, a second PMKSA might come into existence through PMKSA caching. A STA might leave the ESS and flush its cache. Before its PMKSA expires in the AP's cache, the STA returns to the ESS and establishes a second PMKSA from the AP's perspective.

NOTE 2—An attack altering the security parameters is detected by the key derivation procedure.

NOTE 3—IEEE 802.11 Open System authentication provides no security, but is included to maintain backward compatibility with the IEEE 802.11 state machine (see 11.3).

c) SAE authentication and FILS authentication provides mutual authentication and derivation of a PMK. If Open System authentication is chosen instead, the Authenticator or the Supplicant initiates IEEE 802.1X authentication. The EAP method used by IEEE Std 802.1X-2010 needs to support mutual authentication, as the STA needs assurance that the AP is a legitimate AP.

NOTE 4—Prior to the completion of IEEE 802.1X authentication and the installation of keys, the IEEE 802.1X Controlled Port in the AP blocks all Data frames. The IEEE 802.1X Controlled Port returns to the unauthorized state and blocks all Data frames before invocation of an MLME-DELETEKEYS.request primitive. The IEEE 802.1X Uncontrolled Port allows IEEE 802.1X frames to pass between the Supplicant and Authenticator. Although IEEE Std 802.1X-2010 does not require a Supplicant Controlled Port, this standard assumes that the Supplicant has a Controlled Port in order to provide the needed level of security. Supplicants without a Controlled Port compromise RSN security and are not used.

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NOTE 5—Any secure network cannot support promiscuous association, e.g., an unsecured operation of IEEE Std 802.11. A trust relationship is needed between the STA and the AS of the targeted SSID prior to association and secure operation, in order for the association to be trustworthy. The reason is that an attacker can deploy a rogue AP just as easily as a legitimate network provider can deploy a legitimate AP, so some sort of prior relationship is necessary to establish credentials between the ESS and the STA.

d) The last step is key management. The authentication process, whether SAE authentication or FILS authentication utilizing Authentication frames or IEEE 802.1X authentication utilizing Data frames post association, creates cryptographic keys shared between the cryptographic endpoints—the AP and STA, or the IEEE 802.1X AS and the STA, when using SAE/FILS or IEEE Std 802.1X, respectively. When using IEEE Std 802.1X, the AS transfers these keys to the AP, and the AP and STA uses one of the key confirmation handshakes, e.g., the 4-way handshake or FT 4-way handshake, to complete security association establishment. When using SAE authentication there is no AS and therefore no key transfer; the 4-way handshake is performed directly between the AP and STA. The key confirmation handshake indicates when the link has been secured by the keys and is ready to allow normal data traffic and protected robust Management frames. When FILS authentication is performed, the key confirmation is performed using association frames. Hence, no additional handshake is necessary.

When FT is not enabled, a STA roaming within an ESS establishes a new PMKSA by one of the five schemes:

— In the case of (re)association followed by IEEE 802.1X or PSK authentication, the STA repeats the same actions as for an initial contact association, but its Supplicant also deletes the PTKSA when it roams from the old AP. The Supplicant also deletes the PTKSA when it disassociates/deauthenticates from all BSSIDs in the ESS.

— In the case of SAE authentication followed by (re)association, the STA repeats the same actions as for initial contact association, but the non-AP STA also deletes the PTKSA when it roams from the old AP. Note that a STA can take advantage of the fact that it can perform SAE authentication to multiple APs while maintaining a single association with one AP, and then use any of the PMKSAs created during authentication to effect a fast BSS transition.

— A STA (AP) can cache PMKSAs for APs (STAs) in the ESS to which it has previously performed a full IEEE 802.1X authentication or SAE authentication. If a STA wishes to roam to an AP for which it has cached one or more PMKSAs, it can include one or more PMKIDs in the RSNE of its (Re)Association Request frame. An AP that has retained the PMK for one or more of the PMKIDs can proceed with the 4-way handshake (see 12.6.10.3). If the STA fails to send a PMKID when the negotiated AKM uses IEEE 802.1X authentication, the STA and AP need to perform a full IEEE 802.1X authentication.

— A STA already associated with the ESS can request its IEEE 802.1X Supplicant to authenticate with a new AP before associating to that new AP. The normal operation of the DS via the old AP provides the communication between the STA and the new AP. The SME delays reassociation with the new AP until IEEE 802.1X authentication completes via the DS. If IEEE 802.1X authentication completes successfully, then PMKSAs shared between the new AP and the STA are cached, thereby enabling the possible usage of reassociation without requiring a subsequent full IEEE 802.1X authentication procedure.

— In the case of FILS, the STA may repeat the same actions as an initial contact and authentication, The STA may also use a cached PMKSA to authenticate (see 12.6.10.3 and 12.11.2). A STA already associated with the ESS can initiate FILS authentication to multiple other APs while associated.

The MLME-DELETEKEYS.request primitive deletes the temporal key(s) established for the security association so that they cannot be used to protect subsequent IEEE 802.11 traffic. An SME uses this primitive when it deletes a PTKSA, GTKSA, IGTKSA, or BIGTKSA.

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12.6.1.3.3 Security association in an IBSS

In an IBSS utilizing IEEE 802.11 Open System authentication and IEEE Std 802.1X, when a STA's SME establishes a security association with a peer STA, it creates both an IEEE 802.1X Supplicant and Authenticator for the peer. A STA in such an IBSS might also receive IEEE 802.1X messages from a previously unknown MAC address.

In an IBSS utilizing IEEE 802.11 SAE authentication, a STA creates a security association for a peer upon successful SAE authentication.

Any IBSS STA may decline to form a security association with a STA joining the IBSS. An attempt to form a security association may also fail because, for example, the peer uses a different PSK or password from what the STA expects.

In an IBSS each STA defines its own group key, i.e., GTK, to secure its group addressed transmissions. Each STA shall use either the 4-way handshake or the group key handshake to distribute its transmit GTK to its new peer STA. When the STA generates a new GTK, it also uses the group key handshake to distribute the new GTK to each established peer.

12.6.1.3.4 Security association in an MBSS

In order to create a secure peering, mesh STAs first authenticate each other and create a mesh PMKSA. This can be done using either SAE or IEEE Std 802.1X. A mesh STA shall support SAE authentication (see 12.4). A mesh STA may support IEEE 802.1X authentication (see 4.10).

When dot11MeshActiveAuthenticationProtocol is sae (1), the scanning mesh STA shall initiate SAE to the candidate mesh STA. If SAE terminates unsuccessfully, the scanning mesh STA shall terminate the peering establishment procedure. Otherwise, the PMK that results from successful SAE authentication shall be used to create a mesh PMKSA.

When dot11MeshActiveAuthenticationProtocol is ieee8021x (2), then the scanning mesh STA shall initiate the MPM protocol to establish a peering. If the MPM protocol fails then the scanning mesh STA shall terminate the peering establishment procedure. Otherwise, IEEE 802.1X authentication shall be performed between the two peers according to the following:

a) If only one mesh STA has the Connected to AS field set to 1, that STA shall act as the IEEE 802.1X Authenticator and the other STA shall act as the IEEE 802.1X Supplicant;

b) If both mesh STAs have the Connected to AS field set to 1, then the mesh STA with the higher MAC address shall act as the IEEE 802.1X Authenticator and the other mesh STA shall act as the IEEE 802.1X Supplicant (see 12.7.1 for MAC address comparison).

If IEEE 802.1X authentication fails, the peering establishment procedure shall be terminated and the peering established between the two mesh STAs shall be closed. Otherwise, the peering established between the two mesh STAs shall be closed and a mesh PMKSA shall be created using the PMK that resulted from the successful IEEE 802.1X authentication.

12.6.1.3.5 Security association in a PBSS

A STA and a peer establish an initial security association via the following steps:

a) The STA selects an authorized PBSS by identifying a peer from a DMG Beacon, Announce, Probe Response, or Information Response frames.

b) A STA may associate with a peer if the peer is a PCP.

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c) If authentication is required, the STA or the peer initiates IEEE 802.1X authentication. The EAP method used by IEEE Std 802.1X-2010 shall support mutual authentication.

d) The last step is key management. The authentication process creates cryptographic keys shared between the IEEE 802.1X AS and the STA. The AS transfers these keys to the peer and the peer and the STA use one of the key confirmation handshakes, e.g., the 4-way handshake or FT 4-way handshake, to complete security association establishment. The key confirmation handshake indicates when the link has been secured by the keys and is ready to allow data traffic and protected robust Management frames.

12.6.2 RSNA selection

A STA prepared to establish RSNAs shall advertise its capabilities by including the RSNE in Beacon, Information Response, and Probe Response frames and may also include the RSNE in DMG Beacon and Announce frames. The included RSNE shall specify all of the authentication and cipher suites enabled by the STA's policy. A STA shall not advertise any authentication or cipher suite that is not enabled.

The SME shall utilize the MLME-SCAN.request primitive to identify neighboring STAs that assert robust security and advertise an SSID identifying an authorized ESS, PBSS, or IBSS. A STA may decline to communicate with STAs that fail to advertise an RSNE in their Beacon, Information Response, and Probe Response frames or that do not advertise an authorized SSID. A STA may also decline to communicate with other STAs that do not advertise authorized authentication and cipher suites within their RSNEs.

A STA shall advertise the same RSNE in its Beacon, DMG Beacon, Announce, Information Response, and Probe Response frames.

NOTE—Whether a STA with robust security enabled attempts to communicate with a STA that does not include the RSNE is a matter of policy.

A STA shall observe the following rules when processing an RSNE:

— A STA shall advertise the highest version it supports.
— A STA shall request the highest Version field value it supports that is less than or equal to the version advertised by the peer STA.
— Two peer STAs without overlapping supported Version field values shall not use RSNA methods to secure their communication.
— A STA shall ignore suite selectors that it does not recognize.

12.6.3 RSNA policy selection in an infrastructure BSS

The requirements in this subclause apply to a STA when dot11RSNAActivated is true.

RSNA policy selection in an infrastructure BSS utilizes the normal IEEE 802.11 association procedure. RSNA policy selection is performed by the associating STA. The STA does this by including an RSNE in its (Re)Association Requests.

In an RSN, an AP shall not associate with pre-RSNA STAs, i.e., with STAs that fail to include the RSNE in the (Re)Association Request frame.

An SME initiating an association shall insert an RSNE into its (Re)Association Request via the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive, when the targeted AP indicates RSNA support. The initiating STA's RSNE shall include one authentication and pairwise cipher suite from among those advertised by the targeted AP in its Beacon and Probe Response frames. It shall also specify the group cipher suite specified by the targeted AP. If at least one RSNE field from the AP's RSNE fails to overlap with any value the STA supports, the STA shall decline to associate with that AP. An HT STA shall eliminate TKIP

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as a choice for the pairwise cipher suite if CCMP-128 or CCMP-256 is advertised by the AP or if the AP included an HT Capabilities element in its Beacon and Probe Response frames. The elimination of TKIP as a choice for the pairwise cipher suite may result in a lack of overlap of the remaining pairwise cipher suite choices, in which case the STA shall decline to create an RSN association with that AP.

If an AP receives a (Re)Association Request frame that includes an RSNE and if it chooses to accept the association as a secure association, then it shall use the authentication and pairwise cipher suites in the (Re)Association Request frame, unless the AP includes an optional second RSNE in message 3 of the 4-way handshake. If the second RSNE is supplied in message 3, then the pairwise cipher suite used by the security association, if established, shall be the pairwise cipher from the second RSNE.

In order to accommodate local security policy, a STA may choose not to associate with an AP that does not support any pairwise cipher suites. An AP may indicate that it does not support any pairwise keys by advertising 00-0F-AC:0 (Use group cipher suite) as the pairwise cipher suite selector.

NOTE—When an ESS uses PSKs, STAs negotiate a pairwise cipher. However, any STA in the ESS can derive the pairwise keys of any other that uses the same PSK by capturing the first two messages of the 4-way handshake. This provides malicious insiders with the ability to eavesdrop as well as the ability to establish a man-in-the-middle attack.

An AP shall use Table 12-5 and the values of the MFPC and MFPR bits advertised in the RSNEs to determine if it may associate with a non-AP STA. An non-AP STA shall use Table 12-5 and the values of the MFPC and MFPR bits advertised in the RSNEs to determine if it may associate with an AP. Management frame protection is enabled when dot11RSNAProtectedManagementFramesActivated is set to 1. Management frame protection is negotiated when an AP and non-AP STA set the Management Frame Protection Capable field to 1 in their respective RSNEs in the (re)association procedure, and both parties confirm the Management Frame Protection Capable bit set to 1 in the 4-way handshake, FT 4-way handshake, FT fast BSS transition protocol, or the (Re)Association Request and (Re)Association Response frames of FILS authentication.

Table 12-5—Robust management frame selection in an infrastructure BSS

AP MFPC	AP MFPR	STA MFPC	STA MFPR	AP action	STA action
0	0	0	0	The AP may accept associations from the STA	The STA may associate with the AP
1	0	0	0	The AP may accept associations from the STA	The STA may associate with the AP
1	0 or 1	1	0 or 1	The AP may accept associations from the STA	The STA may associate with the AP
1	1	0	0	The AP shall reject associations from the STA with the Status Code ROBUST_MANAGEMENT_POLICY_VIOLATION	The STA shall not associate with the AP
0	0	1	1	No action	The STA shall not try to associate with the AP
0	0	1	0	The AP may accept associations from the STA	The STA may associate with the AP

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Table 12-5—Robust management frame selection in an infrastructure BSS *(continued)*

AP MFPC	AP MFPR	STA MFPC	STA MFPR	AP action	STA action
1	0 or 1	0	1	The STA advertises an invalid setting. The AP shall reject associations from the STA with the Status Code ROBUST_MANAGEMENT_POLICY_VIOLATION	The STA shall not try to associate with the AP
0	1	1	0 or 1	No action	The AP advertises an invalid setting. The STA shall not try to associate with the AP

12.6.4 TSN policy selection in an infrastructure BSS

In a TSN, an RSNA STA shall include the RSNE in its (Re)Association Requests.

An RSNA AP configured to operate in a TSN shall include the RSNE and may associate with both RSNA and pre-RSNA STAs. In other words, an RSNA AP shall respond to an associating STA that includes the RSNE just as in an RSN.

If an AP operating within a TSN receives a (Re)Association Request frame without an RSNE, its IEEE 802.1X Controlled Port shall initially be blocked. The SME shall unblock the IEEE 802.1X Controlled Port when WEP has been enabled.

12.6.5 RSNA policy selection in an IBSS

In an IBSS all STAs use a single group cipher suite, and all STAs support a common subset of pairwise cipher suites. However, the SMEs of any pair of non-HT STAs may negotiate to use any common pairwise cipher suite they both support. Each STA shall include the group cipher suite and its list of pairwise cipher suites in its Beacon and Probe Response frames. Two STAs shall not establish a PMKSA unless they have advertised the same group cipher suite. Similarly, the two STAs shall not establish a PMKSA if the STAs have advertised disjoint sets of pairwise cipher suites.

An HT STA that is in an IBSS or that is transmitting frames through a direct link shall eliminate TKIP as a choice for the pairwise cipher suite if CCMP-128 or CCMP-256 is advertised by the other STA or if the other STA included an HT Capabilities element in any of its Beacon or Probe Response frames.

NOTE 1—The elimination of TKIP as a choice for the pairwise cipher suite might result in a lack of overlap of the remaining pairwise cipher suite choices, in which case the STAs do not exchange encrypted frames.

In order to set up a security association with a peer STA, the SME of an IBSS STA that does not know the peer's policy needs first to obtain the peer's security policy using a Probe Request frame. The SME entities of the two STAs select the pairwise cipher suites using one of the 4-way handshakes. The SMEs of each pair of STAs within an IBSS may use the EAPOL-Key 4-way handshake to select a pairwise cipher suite. As specified in 12.7.2, message 2 and message 3 of the 4-way handshake convey an RSNE. The message 2 RSNE includes the selected pairwise cipher suite, and message 3 includes the RSNE that the STA would send in a Probe Response frame.

If the 4-way handshake is successfully completed, then the pair of STAs shall use the pairwise cipher suite specified in message 2 of the 4-way handshake initiated by the Authenticator STA with the higher MAC address (see 12.7.1).

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The SME shall check that the group cipher suite and AKMP match those in the Beacon and Probe Response frames for the IBSS.

NOTE 2—The RSNEs in message 2 and message 3 are not the same as in the Beacon frame. The group cipher and AKMP are the same, but the pairwise ciphers might differ because Beacon frames from different STAs might advertise different pairwise ciphers. Thus, IBSS STAs use the same AKM suite and group cipher, while different pairwise ciphers might be used between STA pairs.

NOTE 3—When an IBSS uses PSKs, STAs can negotiate a pairwise cipher. However, any STA in the IBSS can derive the PTKs of any other that uses the same PSK by capturing the first two messages of the 4-way handshake. This provides malicious insiders with the ability to eavesdrop as well as the ability to establish a man-in-the-middle attack.

To establish a connection with a peer STA, an RSNA enabled STA that implements management frame protection shall use Table 12-6 and the MFPC and MFPR values advertised in the RSNEs exchanged in the 4-way handshake initiated by the Authenticator of the STA with the larger MAC address to determine if the communication is allowed. Management frame protection is enabled when dot11RSNAProtectedManagementFramesActivated is set to 1. The STAs negotiate protection of Management frames when the both STAs set the Management Frame Protection Capable subfield to 1 during the 4-way handshake.

Table 12-6—Robust management frame selection in an IBSS

MFPC	MFPR	Peer STA MFPC	Peer STA MFPR	STA action
0	0	0	0	The STA may exchange data with the peer STA.
1	0	0	0	The STA may exchange data with the peer STA.
1	0 or 1	1	0 or 1	The STA may exchange data with the peer STA.
1	1	0	0	The STA shall not exchange data with the peer STA and shall reject security association attempts from the peer STA with the Status Code ROBUST_MANAGEMENT_POLICY_VIOLATION.
0	0	1	1	The STA shall not exchange data with the peer STA and shall reject security association attempts from the peer STA with the Status Code ROBUST_MANAGEMENT_POLICY_VIOLATION.
0	0	1	0	The STA may establish a security association with the peer STA.
1	0 or 1	0	1	The STA shall not establish a security association with the peer STA and shall reject security association attempts from the peer STA with the Status Code ROBUST_MANAGEMENT_POLICY_VIOLATION because the peer STA is advertising an invalid setting. The STA shall not exchange data with the peer STA.
0	1	1	0 or 1	The peer STA shall not establish a security association with the peer STA and shall reject security association attempts from the STA with the Status Code ROBUST_MANAGEMENT_POLICY_VIOLATION because the STA is advertising an invalid setting.

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12.6.6 TSN policy selection in an IBSS

Pre-RSNA STAs generate Beacon and Probe Response frames without an RSNE and ignore the RSNE because it is unknown to them. This allows an RSNA STA to identify the pre-RSNA STAs from which it has received Beacon and Probe Response frames.

If an RSNA STA's SME instead identifies a possible IBSS member on the basis of a received group addressed message, via MLME-PROTECTEDFRAMEDROPPED.indication primitive, it cannot identify the peer's security policy directly. The SME might attempt to obtain the peer STA's security policy via a Probe Request frame.

12.6.7 RSNA policy selection in an MBSS

RSNA policy is advertised in Beacon frames and Probe Response frames. A mesh STA identifies a candidate peer by parsing its neighbor STA's Beacon frames and Probe Response frames (see 14.2). An HT mesh STA shall eliminate TKIP as a choice for the pairwise cipher suite if CCMP-128 or CCMP-256 is advertised by the peer or if the peer included an HT Capabilities element in any of its Beacon or Probe Response frames.

All mesh STAs in an MBSS use the same group cipher suite. Mesh STAs establish authenticated peerings with each other using the AMPE protocol (see 14.5). In AMPE, mesh STAs negotiate a pairwise cipher suite, and establish a mesh TKSA, to protect individually addressed frames and state a group cipher suite and establish a mesh GTKSA to process incoming group addressed frames from a peer.

The AMPE performs key confirmation of a secret, authenticated, and shared PMK derived by an authenticated key management protocol (see 12.4) and derives pairwise symmetric keys.

12.6.8 RSNA policy selection in a PBSS

RSNA policy selection in a PBSS utilizes the association procedure (11.3.1) if the initiating STA chooses to associate with a PCP. RSNA policy selection is performed by the associating STA. The STA does this by including an RSNE in its (Re)Association Requests.

The STA follows the procedures in 12.5.3 to select RSNA policy with the PCP, with the PCP taking the role of the AP. If the initiating STA chooses not to associate with a peer in a PBSS, it follows the procedures in 12.5.5 to select RSNA policy with the peer.

12.6.9 RSN management of the IEEE 802.1X Controlled Port

When the policy selection process chooses IEEE 802.1X authentication, this standard assumes that IEEE 802.1X Supplicants and Authenticators exchange protocol information via the IEEE 802.1X Uncontrolled Port. The IEEE 802.1X Controlled Port is blocked from passing general data traffic between the STAs until an IEEE 802.1X authentication procedure completes successfully over the IEEE 802.1X Uncontrolled Port. The security of an RSNA depends on this assumption being true.

In an infrastructure BSS or PBSS, if the STA associates with the AP or PCP, the STA indicates the IEEE 802.11 link is available by invoking the MLME-ASSOCIATE.confirm or MLME-REASSOCIATE.confirm primitive. This signals the Supplicant that the MAC has transitioned from the disabled to enabled state. At this point, the Supplicant's Controlled Port is blocked, and communication of all non-IEEE-802.1X MSDUs sent or received via the port is not authorized.

In an infrastructure BSS or PBSS, if the AP or PCP associates with a STA, the AP or PCP indicates that the IEEE 802.11 link is available by invoking the MLME-ASSOCIATE.indication or MLME-REASSOCIATE.indication primitive. At this point the Authenticator's Controlled Port corresponding to the

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STA's association is blocked, and communication of all non-IEEE-802.1X MSDUs sent or received via the Controlled Port is not authorized.

In an IBSS the STA shall block all IEEE 802.1X ports at initialization. Communication of all non-IEEE 802.1X MSDUs sent or received via the Controlled Port is not authorized.

In a PBSS, if a STA chooses not to associate with the PCP, the STA shall block all IEEE 802.1X ports at initialization. Communication of all non-IEEE-802.1X MSDUs sent or received via the Controlled Port is not authorized.

This standard assumes each Controlled Port remains blocked until the IEEE 802.1X state variables portValid and keyDone both become true. This assumption means that the IEEE 802.1X Controlled Port discards MSDUs sent across the IEEE 802.11 channel prior to the installation of cryptographic keys into the MAC. This protects the STA's host from forged MSDUs written to the channel while it is still being initialized.

The MAC does not distinguish between MSDUs for the Controlled Port, and MSDUs for the Uncontrolled Port. In other words, EAPOL-Start frames and EAPOL-Key frames are encrypted only after invocation of the MLME-SETPROTECTION.request primitive.

This standard assumes that IEEE Std 802.1X-2010 does not block the Controlled Port when authentication is triggered through reauthentication. During IEEE 802.1X reauthentication, an existing RSNA can protect all MSDUs exchanged between the STAs. Blocking MSDUs is not required during reauthentication over an RSNA.

12.6.10 RSNA authentication in an infrastructure BSS

12.6.10.1 General

When establishing an RSNA in a non-FT environment or during an FT initial mobility domain association, a STA shall use IEEE 802.11 SAE authentication, FILS authentication, or Open System authentication prior to (re)association.

SAE authentication is initiated when a STA's MLME-SCAN.confirm primitive finds another AP within the ESS of which the STA is a member that advertises support for SAE in its RSNE.

FILS authentication is initiated when a STA's MLME-SCAN.confirm primitive finds an AP that advertises support for FILS authentication in its RSNE.

IEEE 802.1X authentication is initiated by any one of the following mechanisms:

— If a STA negotiates to use IEEE 802.1X authentication during (re)association, the STA's management entity may respond to the MLME-ASSOCIATE.confirm (or indication) or MLME-REASSOCIATE.confirm (or indication) primitive by requesting the Supplicant (or Authenticator) to initiate IEEE 802.1X authentication. Thus, in this case, authentication is driven by the STA's decision to associate and the AP's decision to accept the association.

— If a STA's MLME-SCAN.confirm primitive finds another AP within the ESS of which the STA is a member, a STA may signal its Supplicant to use IEEE Std 802.1X-2010 to preauthenticate with that AP.

NOTE—A roaming STA's IEEE 802.1X Supplicant can initiate preauthentication by sending an EAPOL-Start frame via its old AP, through the DS, to a new AP.

— If a STA receives an IEEE 802.1X message, it delivers this to its Supplicant or Authenticator, which may initiate a new IEEE 802.1X authentication.

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12.6.10.2 Preauthentication and RSNA key management

Preauthentication allows a STA to perform RSNA authentication with an AP prior to attempting (re)association. This might reduce the time that the IEEE 802.1X port is not valid.

A STA shall not use preauthentication except when pairwise keys are employed. A STA shall not use preauthentication within the same mobility domain if an AKM suite type for which the Authentication type column indicates FT authentication (see Table 9-151) is used in the current association. Preauthentication shall not be used unless the new AP advertises the preauthentication capability in the RSNE.

When preauthentication is used, then:

a) Authentication is independent of roaming.
b) The Supplicant may authenticate with multiple APs at a time.

NOTE—Preauthentication might be useful as a performance enhancement, as reassociation does not include the protocol overhead of a full reauthentication when it is used.

Preauthentication uses the IEEE 802.1X protocol and state machines with Ethertype 88-C7, rather than the Ethertype 88-8E. Only IEEE 802.1X packet types EAPOL-EAP and EAPOL-Start are valid for preauthentication.

A Supplicant may initiate preauthentication when it has completed the 4-way handshake and configured the required temporal key(s). To effect preauthentication, the Supplicant sends an EAPOL-Start frame with the DA being the BSSID of a targeted AP's BSS and the RA being the BSSID of the BSS of which it is a member. The target AP shall use a BSSID equal to the MAC address of its Authenticator. As preauthentication frames do not use the IEEE 802.1X EAPOL Ethertype field, the AP with which the STA is currently associated need not apply any special handling. The AP and the MAC in the STA shall handle these frames in the same way as other frames with arbitrary Ethertype field values that require distribution via the DS.

An AP's Authenticator that receives an EAPOL-Start frame via the DS may initiate IEEE 802.1X authentication to the STA via the DS. The DS forwards this message to the AP with which the STA is associated.

The result of preauthentication may be a PMKSA, if the IEEE 802.1X authentication completes successfully. The AKM shall be set to 00-0F-AC:1 in the PMKSA that results from preauthentication. If preauthentication produces a PMKSA, then, when the Supplicant's STA associates with the preauthenticated AP, the Supplicant may use the PMKSA with the 4-way handshake.

Successful completion of EAP authentication over IEEE Std 802.1X establishes a PMKSA at the Supplicant. The Authenticator has the PMKSA when the AS completes the authentication, passes the keying information (the master session key (MSK), a portion of which is the PMK) to the Authenticator, and the Authenticator creates a PMKSA using the PMK. The PMKSA is inserted into the PMKSA cache. Therefore, if the Supplicant and Authenticator lose synchronization with respect to the PMKSA, the 4-way handshake fails. In such circumstances, dot11RSNA4WayHandshakeFailures shall be incremented.

A Supplicant may initiate preauthentication with any AP within its present ESS with preauthentication enabled regardless of whether the targeted AP is within radio range.

Even if a STA has preauthenticated, it is still possible that it may have to undergo a full IEEE 802.1X authentication, as the AP's Authenticator may have purged its PMKSA due to, for example, unavailability of resources, delay in the STA associating, etc.

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12.6.10.3 Cached PMKSAs and RSNA key management

A STA might cache PMKSAs it establishes as a result of previous authentication. The PMKSA shall not be changed while cached. The PMK in the PMKSA is used with the 4-way handshake or FILS authentication to establish fresh PTKs.

If a STA in an infrastructure BSS has determined it has a valid PMKSA with an AP to which it is about to (re)associate, it performs Open System authentication to the AP, or performs FILS Authentication to the AP, or (only in the case of a DMG STA) does not perform IEEE 802.11 authentication. When Open System authentication is used or IEEE 802.11 authentication is not performed, it includes the PMKID for the PMKSA in the RSNE in the (re)association request. When FILS Authentication is performed, it includes the PMKID for the PMKSA in the FILS Authentication frame (see 12.11.2). When the PMKSA was not created using preauthentication, the AKM indicated in the RSNE by the STA in the (re)association request shall be identical to the AKM used to establish the cached PMKSA in the first place.

A cached PMKSA established using an AKM suite type for which the Authentication type column indicates FT authentication (see Table 9-151) may be used in a subsequent FT Initial Mobility Domain Association using an identical AKM suite. A cached PMKSA is not used in an FT authentication sequence.

If a cached PMKSA is used in FT Initial Mobility Domain Association, the cached MPMK is used to derive the PMK-R0 of a new FT key hierarchy (see 12.7.1.6). The PMKID indicated by the STA in the (Re)Association Request frame and message 1 of the FT 4-way handshake (when FILS authentication is not used) or FILS Authentication frame (when FILS authentication is used) is the PMKID of the cached PMKSA as defined in 12.7.1.6.3 (i.e., not the PMKR0Name or PMKR1Name of the FT key hierarchy that was derived when the PMKSA was originally established). The PMKR1Name indicated in RSNE in messages 2 and 3 of the FT 4-way handshake (when FILS authentication is not used) or in (Re)Association Request and Response frames (when FILS authentication is used) is the PMKR1Name of the newly derived FT key hierarchy (see 13.4).

Upon receipt of a (Re)Association Request frame with one or more PMKIDs following Open System authentication or (only in the case of a DMG AP) if IEEE 802.11 authentication was not performed, an AP checks whether its Authenticator has cached a PMKSA for the PMKIDs and whether the AKM in the cached PMKSA matches the AKM in the (Re)Association Request; and if so, it shall assert possession of that PMKSA by beginning the 4-way handshake after association has completed and shall include the PMKID in message 1 (see 12.7.6.2). If the Authenticator does not have a PMKSA for the PMKIDs in the (re)association request or the AKM does not match, its behavior depends on how the PMKSA was established. If SAE authentication was used to establish the PMKSA, then the AP shall reject (re)association by sending a (Re)Association Response frame with status code STATUS_INVALID_PMKID. Note that this allows the non-AP STA to fall back to full SAE authentication to establish another PMKSA. If IEEE 802.1X authentication was used to establish the PMKSA, the AP begins a full IEEE 802.1X authentication after association has completed.

Upon receipt of a FILS Authentication frame with one or more PMKIDs, an AP checks whether its Authenticator has cached a PMKSA for the PMKIDs, whether the AKM in the cached PMKSA matches the AKM in the FILS Authentication frame, and whether the PMK is still valid; and if so, it shall assert possession of that PMK by including the PMKID in the FILS Authentication frame sent in response (see 12.11.2.3.4). If the Authenticator does not have a PMK for the PMKIDs in the FILS Authentication frame or the AKM does not match, the AP may either reply with EAP-Finish/Reauth to continue FILS Shared Key authentication option if the non-AP STA included sufficient information for that, or the AP rejects the authentication.

If both sides assert possession of a cached PMKSA, but the 4-way handshake or FILS authentication fails, both sides may delete the cached PMKSA for the selected PMKID.

If the lifetime of a cached PMKSA expires, the STA shall delete the expired PMKSA.

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If a STA roams to an AP with which it is preauthenticating and the STA does not have a PMKSA for that AP, the STA needs to initiate a full IEEE 802.1X EAP authentication.

12.6.11 RSNA authentication in an IBSS

When authentication is used in an IBSS, it is driven by each STA wishing to establish communications. The management entity of this STA chooses a set of STAs with which it might need to authenticate and then may cause the MAC to send an IEEE 802.11 Open System authentication message to each targeted STA. Candidate STAs can be identified from Beacon frames, Probe Response frames, and Data frames from the same BSSID. Before communicating with STAs identified from Data frames, the security policy of the STAs may be obtained, e.g., by sending a Probe Request frame to the STA and obtaining a Probe Response frame. Targeted STAs that wish to respond may return an IEEE 802.11 Open System authentication message to the initiating STA.

When IEEE 802.1X authentication is used, the STA management entity requests its local IEEE 802.1X entity to create a Supplicant PAE for the peer STA. The Supplicant PAE initiates the authentication to the peer STA by sending an EAPOL-Start frame to the peer. The STA management entity also requests its local IEEE 802.1X entity to create an Authenticator PAE for the peer STA on receipt of the EAPOL-Start frame. The Authenticator initiates authentication to the peer STA by sending an EAP-Request message or, if PSK mode is in effect, message 1 of the 4-way handshake.

Upon initial authentication between any pair of STAs, Data frames, other than IEEE 802.1X messages, are not allowed to flow between the pair of STAs until both STAs in each pair of STAs have successfully completed AKM and have provided the supplied encryption keys.

Upon the initiation of an IEEE 802.1X reauthentication by any STA of a pair of STAs, Data frames continue to flow between the STAs while authentication completes. Upon a timeout or failure in the authentication process, the Authenticator of the STA initiating the reauthentication shall cause a Deauthentication message to be sent to the Supplicant of the STA targeted for reauthentication. The Deauthentication message causes both STAs in the pair of STAs to follow the deauthentication procedure defined in 11.3.4.4 and 11.3.4.5.

The IEEE 802.1X reauthentication timers in each STA are independent. If the reauthentication timer of the STA with the higher MAC address (see 12.7.1 for MAC comparison) triggers the reauthentication via its Authenticator, its Supplicant shall send an EAPOL-Start frame to the authenticator of the STA with the lower MAC address (see 12.7.1 for MAC comparison) to trigger reauthentication on the other STA. This process keeps the pair of STAs in a consistent state with respect to derivation of one or more fresh temporal keys upon an IEEE 802.1X reauthentication.

When it receives an MLME-AUTHENTICATE.indication primitive due to an Open System authentication request, the IEEE 802.11 management entity on a targeted STA shall, if it intends to set up a security association with the peer STA, request its Authenticator to begin IEEE 802.1X authentication, i.e., to send an EAP-Request/Identity message or message 1 of the 4-way handshake to the Supplicant.

The EAPOL-Key frame is used to exchange information between the Supplicant and the Authenticator to negotiate a fresh PTK. The 4-way handshake produces a single PTK from the PMK. The 4-way handshake and group key handshake use the PTK to protect the GTK as it is transferred to the receiving STA.

Password or PSK authentication may also be used in an IBSS. When a single password or PSK is shared among the IBSS STAs, an SAE capable STA wishing to establish communication with a STA that advertises support for SAE in Beacon and Probe Response frames invokes SAE authentication, and upon successful conclusion of SAE, sends 4-way handshake message 1 to the target STA. If the STA does not support SAE authentication or the target STA does not advertise support for SAE in Beacon and Probe Response frames, the STA may use the PSK as a PMK and initiate the 4-way handshake by sending a 4-way handshake message 1 to the target STA. In either case, the targeted STA responds to message 1 with message 2 of the 4-way handshake

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and begins its 4-way handshake by sending message 1 to the initiating STA. The two 4-way handshakes establish PTKSAs and GTKSAs to be used between the initiating STA and the targeted STA. PSK PMKIDs have security vulnerabilities if used with low-entropy keys and should be used only after taking this into account.

The model for security in an IBSS is not general. In particular, it assumes the following:

a) The sets of use cases for which the authentication procedures described in this subclause are valid are as follows:
   1) Password or PSK-based authentication using SAE to perform mutual authentication and generation of a shared PMK.
   2) An alternate form of PSK-based authentication, typically managed by the pass-phrase hash method as described in J.4. This method has security vulnerabilities and should only be used when SAE authentication is not possible.
   3) EAP-based authentication, using credentials that have been issued and preinstalled on the STAs within a common administrative domain, such as a single organization
b) All of the STAs are in direct radio communication. In particular, there is no routing, bridging, or forwarding of traffic by a third STA to effect communication. This assumption is made, because the model makes no provision to protect IBSS topology information from tampering by one of the members.

12.6.12 RSNA authentication in an MBSS

When establishing an RSNA in an MBSS, a mesh STA shall use IEEE 802.11 SAE authentication (see 12.4), or optionally IEEE 802.1X authentication, prior to establishment of an authenticated peering. An RSNA security association, called a *mesh PMKSA*, is created upon successful completion of authentication. The mesh PMKSA is used with the AMPE to create a mesh TKSA.

A mesh PMKSA may be cached and used with the AMPE to establish a fresh mesh TKSA. A STA includes the PMKID for the PMKSA in the Mesh Peering Open frame. If the PMKID in a received Mesh Peering Open frame is unknown, the AMPE handshake fails. If both sides assert possession of a cached mesh PMKSA but the AMPE handshake fails, a STA may delete the cached mesh PMKSA for the selected PMKID. A mesh PMKSA shall not be changed while cached.

Authentication using IEEE 802.11 SAE authentication is based on a password. A password is required to be shared between two mesh STAs in order to successfully complete authentication. This password can be pairwise—each pair of mesh STAs in an MBSS has a unique password—or it can be shared-all mesh STAs in the MBSS share the same password.

Due to the security properties of IEEE 802.11 SAE authentication, an adversary has no greater possibility in determining a shared password than in determining a pairwise password. The potential for misuse, though, is greater if a shared password becomes known to an adversary because an unlimited number of mesh STAs under the control of the adversary can be added to the MBSS.

12.6.13 RSNA authentication in a PBSS

IEEE 802.11 Open System authentication is not used in a PBSS.

When establishing an RSNA with a PCP, a STA may associate to the PCP and initiate RSNA authentication with the PCP following the procedures of 12.6.10, with the PCP taking the role of the AP. When a STA chooses not to associate to a peer, it initiates RSNA authentication with the peer following the procedures of 12.6.11 with the following caveat: if both peers simultaneously initiate RSNA authentication, the peer with

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the lower MAC address shall abandon the authentication it initiated in favor of the authentication initiated by the peer with the higher MAC address.

12.6.14 RSNA key management in an infrastructure BSS

When the IEEE 802.1X authentication completes successfully, this standard assumes that the STA's IEEE 802.1X Supplicant and the IEEE 802.1X AS share a secret, called a *PMK*. In a non-FT environment, the AS transfers the PMK, within the MSK, to the AP, using a technique that is outside the scope of this standard; the derivation of the PMK from the MSK is EAP-method-specific. With the PMK in place, the AP initiates a key confirmation handshake with the STA. The key confirmation handshake sets the IEEE 802.1X state variable portValid (as described in IEEE Std 802.1X-2010) to true.

When SAE authentication completes, both STAs share a PMK. With this PMK in place, the AP initiates the key confirmation handshake with the STA.

Key confirmation is part of the FILS authentication exchange and no further handshakes are needed to satisfy key management requirements.

In a non-FT environment or during an FT initial mobility domain association, when FILS authentication is not used, the key confirmation handshake is implemented by the 4-way handshake. The purposes of the 4-way handshake are as follows:

a) Confirm the existence of the PMK at the peer.
b) Ensure that the security association keys are fresh.
c) Synchronize the installation of one or more temporal keys into the MAC.
d) Transfer the GTK from the Authenticator to the Supplicant.
e) Confirm the selection of cipher suites.

NOTE 1—It is possible to forge message 1 of the 4-way handshake. However, the forgery attempt is detected in the failure of the 4-way handshake.

NOTE 2—Neither the AP nor the STA can use the PMK for any purpose but the one specified herein without compromising the key. If the AP uses it for another purpose, then the STA can masquerade as the AP; similarly if the STA reuses the PMK in another context, then the AP can masquerade as the STA.

The Supplicant and Authenticator signal the completion of key management by utilizing the MLME-SETKEYS.request primitive to configure the agreed-upon temporal pairwise key into the IEEE 802.11 MAC and by calling the MLME-SETPROTECTION.request primitive to enable its use.

A second key exchange, the group key handshake, is also defined. It distributes a subsequent GTK. The AP's Authenticator can use the group key handshake to update the GTK at the Supplicant. The group key handshake uses the EAPOL-Key frames for this exchange. When it completes, the Supplicant can use the MLME-SETKEYS.request primitive to configure the GTK into the IEEE 802.11 MAC.

12.6.15 RSNA key management in an IBSS

To establish a security association between two IBSS STAs, each STA's SME has an accompanying IEEE 802.1X Authenticator and Supplicant. Each SME initiates the 4-way handshake from the Authenticator to the peer STA's Supplicant (see 12.6.11). Two separate 4-way handshakes are conducted.

The 4-way handshake is used to negotiate the pairwise cipher suites, as described in 12.6.5. The IEEE 802.11 SME configures the temporal key portion of the PTK into the IEEE 802.11 MAC. Each Authenticator uses the KCK and KEK portions of the PTK negotiated by the exchange it initiates to distribute its own GTK and if management frame protection is enabled, its own IGTK. Each Authenticator generates its own GTK and

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if management frame protection is enabled, its own IGTK, and uses either the 4-way handshake or the group key handshake to transfer the GTK and if management frame protection is negotiated, the IGTK, to other STAs with whom it has completed a 4-way handshake. The pairwise key used between any two STAs shall be the pairwise key from the 4-way handshake initiated by the STA with the highest MAC address.

A STA joining an IBSS is required to adopt the security configuration of the IBSS, which includes the group cipher suite, pairwise cipher suite, AKMP, and if management frame protection is enabled, group management cipher suite (see 12.6.5). The STA shall not set up a security association with any STA having a different security configuration. The Beacon and Probe Response frames of the various STAs within an IBSS need to reflect a consistent security policy, as the beacon initiation rotates among the STAs.

A STA joining an IBSS shall support and advertise in the Beacon frame the security configuration of the IBSS, which includes the group cipher suite, advertised pairwise cipher suite, AKMP, and if management frame protection is enabled, group management cipher suite (see 12.6.5). The STA may use the Probe Request frame to discover the security policy of a STA, including additional individual cipher suites the STA supports. If enabled, management frame protection shall only be used as a required feature (MFPR) in an IBSS.

NOTE—Because of the requirement for a STA joining an IBSS to support the security configuration of the IBSS, all Beacon frames transmitted in an IBSS have the same security policy.

12.6.16 RSNA key management in an MBSS

Upon successful completion of the AMPE, a secure mesh peering is established between two mesh STAs. This secure mesh peering includes a mesh PMKSA and a mesh TKSA. Multiple mesh TKSAs may be created using a single mesh PMKSA (a limit to that number is a policy decision outside the scope of this standard).

A mesh TKSA is logically a child of the mesh PMKSA. A mesh TKSA shall be deleted if the corresponding mesh PMKSA, which was used by the AMPE to create it, is deleted. Mesh PMKSAs are limited by their lifetime (see 12.7.1.3).

12.6.17 RSNA key management in a PBSS

Upon successful association and authentication in a PBSS, a STA performs a key confirmation handshake with the PCP, following the procedures in 12.6.14 with the PCP taking the role of the AP. If a STA chooses not to associate to a peer, after successful authentication, it performs a key confirmation handshake with the peer following the procedures in 12.6.15 with the following caveat: if both peers simultaneously initiate the key confirmation handshake, the peer with the lower MAC address shall abandon the handshake it initiated in favor of the handshake initiated by the peer with the higher MAC address.

12.6.18 RSNA security association termination

When a non-AP STA's SME receives a successful MLME-ASSOCIATE.confirm or MLME-REASSOCIATE.confirm primitive that is not part of a fast BSS transition or receives or invokes an MLME Disassociation or Deauthentication primitive, it deletes some security associations. Similarly, when an AP's SME

— Receives an MLME-ASSOCIATE.indication or MLME-REASSOCIATE.indication primitive from a STA that has not negotiated management frame protection, or

— Receives an MLME-ASSOCIATE.indication or MLME-REASSOCIATE.indication primitive from a STA that has negotiated management frame protection that a) has resulted in an MLME (re)association response that is successful, and b) is not part of a fast BSS transition, or receives an MLME-DEAUTHENTICATE.indication or MLME-DISASSOCIATE.indication primitive or issues an MLME-DEAUTHENTICATE.request or MLME-DISASSOCIATE.request primitive,

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it deletes some security associations. In the case of an ESS, the non-AP STA's SME shall delete the PTKSA, GTKSA, any IGTKSA, any BIGTKSA and any TPKSA, and the AP's SME shall delete the PTKSA. In the case of an IBSS, the SME shall delete the PTKSA and the receive GTKSA and any IGTKSA. Once the security associations have been deleted, the SME then invokes MLME-DELETEKEYS.request primitive to delete all temporal keys associated with the deleted security associations.

If a STA loses key state synchronization, it can apply the following rules to recover:

a) Any protected frame(s) received shall be discarded, and an MLME-PROTECTEDFRAMEDROPPED.indication primitive shall be invoked.
b) If the STA is RSNA-enabled and has joined an IBSS, the SME shall execute the authentication procedure as described in 11.3.4.2.
c) If the STA is RSNA-enabled and has joined an ESS, the SME shall execute the deauthentication procedures as described in 11.3.4.4. However, if the STA has initiated the RSN security association, but has not yet invoked the MLME-SETPROTECTION.request primitive, then no additional action is required.

NOTE 1—There is a race condition between when MLME-SETPROTECTION.request primitive is invoked on the Supplicant and when it is invoked on the Authenticator. During this time, the STA might receive an MPDU that it is unable to decrypt; and the MPDU is discarded without a deauthentication occurring.

NOTE 2—Null and QoS (+)Null frames are not protected.

If the selected AKMP fails between a STA and an AP that are associated, then both the STA and the AP shall invoke the MAC deauthentication procedure described in 11.3.4.4.

When a STA's SME receives an MLME-PN-EXHAUSTION.indication primitive and the PN is associated with a PTKSA, the STA's SME shall invoke an MLME-DISASSOCIATE.request primitive and delete the PTKSA.

When a STA's SME receives an MLME-PN-EXHAUSTION.indication primitive and the PN is associated with a GTKSA, the STA's SME shall delete the GTKSA.

When a STA's SME receives an MLME-PN-EXHAUSTION.indication primitive and the PN is associated with an IGTKSA, the STA's SME shall delete the IGTKSA.

Once the security associations have been deleted, the SME then invokes MLME-DELETEKEYS.request primitive to delete all temporal keys associated with the deleted security associations.

12.6.19 Protection of robust Management frames

This subclause defines rules that shall be followed by STAs that implement Management Frame protection and have dot11RSNAActivated equal to true.

A STA with dot11RSNAProtectedManagementFramesActivated equal to false shall transmit and receive unprotected individually addressed robust Management frames to and from any associated STA and shall discard protected individually addressed robust Management frames received from any associated STA.

A STA with dot11RSNAProtectedManagementFramesActivated equal to true and dot11RSNAUnprotectedManagementFramesAllowed equal to true shall transmit and receive unprotected individually addressed robust Management frames to and from any associated STA that advertised MFPC = 0 and shall discard protected individually addressed robust Management frames received from any associated STA that advertised MFPC = 0.

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A STA with dot11RSNAProtectedManagementFramesActivated equal to true and dot11RSNAUnprotectedManagementFramesAllowed equal to true shall transmit and receive protected individually addressed robust Management frames to and from any associated STA that advertised MFPC = 1, shall discard unprotected individually addressed robust Action frames received from any STA that advertised MFPC = 1, and shall discard unprotected individually addressed Disassociation and Deauthentication frames received from a STA that advertised MFPC = 1 after the PTK and IGTK have been installed. The receiver shall process unprotected individually addressed Disassociation and Deauthentication frames before the PTK and IGTK are installed.

A STA with dot11RSNAProtectedManagementFramesActivated equal to true and dot11RSNAUnprotectedManagementFramesAllowed equal to false shall transmit and receive protected individually addressed robust Action frames to and from any STA, shall not transmit unprotected individually addressed robust Action frames to any STA, and shall discard unprotected individually addressed robust Action frames received from a STA after the PTK and IGTK have been installed. The receiver shall process unprotected individually addressed Disassociation and Deauthentication frames before the PTK and IGTK are installed.

A STA with dot11RSNAProtectedManagementFramesActivated equal to true shall protect transmitted group addressed robust Management frames using the group management cipher suite.

A STA with dot11RSNAProtectedManagementFramesActivated equal to true shall discard group addressed robust Management frames received from any associated STA that advertised MFPC = 1 if the frames are unprotected or if a matching IGTK is not available.

A STA with dot11RSNAProtectedManagementFramesActivated equal to true and dot11RSNAUnprotectedManagementFramesAllowed equal to false shall discard received group addressed robust Management frames that are unprotected or for which a matching IGTK is not available.

A STA with dot11RSNAProtectedManagementFramesActivated equal to false shall transmit group addressed robust Management frames unprotected and shall ignore the protection on received group addressed robust Management frames.

NOTE—BIP does not provide protection against forgery by associated and authenticated STAs. A STA that has left the group can successfully forge Management frames until the IGTK is updated.

Protection of group addressed robust Management frames shall be provided by a service in the MLME as described in 11.12.

Management frame protection cannot be applied until the PTK and IGTK has been established with the STA. A STA shall not transmit robust Action frames until it has installed the PTK for the peer STA, or in the case of group addressed frames, has installed the IGTK. The STA shall discard any robust Action frames received before the PTK and IGTK are installed.

12.6.20 Robust management frame selection procedure

A STA with dot11RSNAProtectedManagementFramesActivated equal to true shall negotiate management frame protection with a STA that advertised MFPC = 1.

The Protected Dual of Public Action frame is defined to allow robust STA-STA communications of the same information that is conveyed in Action frames that are not robust (see 9.6.10). A Public Action field, in the octet immediately after the Category field, differentiates the Protected Dual of Public Action frame formats. The defined Protected Dual of Public Action frames are listed in Table 9-404. When a Public Action frame is transmitted for which a Protected Dual of Public Action frame is defined (see 9.4.1.11), which variant (i.e., protected or not protected) is used depends on the setting of the “Protected” parameter of the corresponding

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MLME.request or MLME.confirm primitive. Where there is no such parameter, the protected variant is used when management frame protection has been negotiated.

12.6.21 RSNA rekeying

When a PTKSA is deleted, a non-AP and non-PCP STA may reassociate with the same AP or PCP and/or establish a new RSNA with the AP or PCP. If the non-AP and non-PCP STA has cached one or more PMKSAs, it may skip the PMKSA establishment and proceed with the creation of a new PTKSA by using 4-way handshake, FT 4-way handshake, or FILS authentication using the procedures defined in 12.6.10.3. When a GTKSA is deleted, an originating STA may create a new GTKSA by using 4-way handshake or group key handshake.

An Authenticator may initiate a 4-way handshake for the purpose of renewing the key associated with a PTKSA. A supplicant may send an EAPOL request message to the authenticator to request rekeying. In addition, if both the Authenticator and the Supplicant support multiple keys for individually addressed traffic, a smooth switchover to the new key is possible using the following procedure.

The IEEE 802.11 MAC shall issue an MLME-PN-WARNING.indication primitive when the packet number assignment for a particular PTKSA, IGTKSA, GTKSA or BIGTKSA reaches or exceeds the threshold that is defined in dot11PNWarningThresholdLow and dot11PNWarningThresholdHigh for the first time. The indication shall be issued only once for a given PTKSA, IGTKSA, GTKSA or BIGTKSA. The SME may use the indication as a trigger to establish a new PTKSA, IGTKSA, GTKSA or BIGTKSA before the Packet Number space is exhausted.

A PTKSA has a limited lifetime, either in absolute time or due to exhausting the PN space. To maintain an uninterrupted security association, a STA should establish a new PTKSA prior to the expiration of the old PTKSA.

When both ends of the link support extended Key IDs for individually addressed frames, it is possible to install the new PTKSA without data loss, provided the new PTKSA uses a different Key ID from the old PTKSA. Data loss might occur if the same Key ID is used because it is not possible to precisely coordinate (due to software processing delays) when the new key is used for transmit at one end and when it is applied to receive at the other end. If a different Key ID is used for the new PTKSA, then provided the new key is installed at the receive side prior to its first use at the transmit side there is no need for precise coordination. During the transition, received packets are unambiguously identified using the Key ID as belonging to either the old or new PTKSA.

12.6.22 Multi-band RSNA

12.6.22.1 General

A STA is multi-band capable and an RSNA STA if the values of both dot11MultibandImplemented and dot11RSNAActivated are true.

A STA that is multi-band capable and an RSNA STA shall set the Pairwise Cipher Suite Present field of the Multi-band element to 1 and shall include the Pairwise Cipher Suite Count field and the Pairwise Cipher Suite List field in the Multi-band element. The STA may include the RSNE and the Multi-band element in the DMG Beacon and Announce frames and shall include the RSNE and the Multi-band element in Beacon, Probe Response, and Information Response frames. The included RSNE shall specify all of the authentication and cipher suites enabled by the STA's policy for the band where this element is transmitted, and the included Multi-band element shall specify all of the pairwise cipher suites enabled by the STA's policy for the band specified within the Multi-band element. A STA shall not advertise any cipher suite that is not enabled.

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A multi-band capable and RSNA STA shall include the Multi-band element in the (Re)Association Request frame and in message 2 and message 3 of the 4-way handshake.

In order to set up an RSNA with a peer STA for a supported band/channel, a STA that does not know the peer's policy for the band/channel shall first obtain the peer STA's policy for the supported band/channel by using a Probe Request frame or Information Request frame. The STA initiating RSNA establishment for a supported band/channel is called *RSNA initiator*, and the targeted STA of the RSNA establishment is called *RSNA responder*.

A multi-band capable device can create its own group key(s) for one or more supported bands/channels. If the STA uses different MAC addresses in different bands/channels, different GTKSAs shall be created for different bands. If the STA uses a same MAC address in all supported bands/channels, a single GTKSA shall be created for all supported bands/channels.

If the pairwise and group cipher suites used by a pair of multi-band capable devices to communicate with each other in the current operating band/channel is also supported after the transfer to another band/channel that was performed using transparent FST, the devices shall continue using the same cipher suites to communicate with each other after the transfer. In all other cases, a separate RSNA has to be established for the other band/channel (see 12.6.22.2 and 12.6.22.4).

12.6.22.2 Nontransparent multi-band RSNA

An RSNA initiator can establish a nontransparent (11.31) multi-band RSNA with an RSNA responder for a supported band/channel other than the current operating band/channel. The two STAs use the same PMKSA for both the supported band/channel and the current operating band/channel and create different PTKSAs for different bands/channels.

If the RSNA initiator does not have an existing PMKSA with the RSNA responder, the RSNA initiator shall first establish a PMKSA with the RSNA responder in the current operating band/channel and then use the PMKSA to create a PTKSA with the RSNA responder for the supported band/channel. If the RSNA initiator has already established a PMKSA with the RSNA responder, the PMKSA shall be used to create a PTKSA between the two STAs for the supported band/channel.

With the PMK in place, the RSNA initiator and RSNA responder can proceed in two ways depending on the setting of the Joint Multi-band RSNA subfield within the RSN Capabilities field in the RSNE of both STAs.

If the Joint Multi-band RSNA subfield within the RSN Capabilities field of either the RSNA initiator or RSNA responder is 0, the STA pair uses a 4-way handshake to establish a PTKSA for the current band/channel and may start a separate 4-way handshake in the current operating band/channel to negotiate a pairwise cipher suite for the supported band/channel and establish a PTKSA for the supported band/channel. As specified in 12.7.6, message 2 and message 3 of the 4-way handshake convey the Multi-band element associated with the supported band/channel. The Multi-band element in message 2 includes the selected pairwise cipher suite for the supported band/channel. message 3 includes the Multi-band element that the STA would send in a Beacon, DMG Beacon, Announce, Probe Response, or Information Response frame. message 3 may include a second Multi-band element that indicates the STA's pairwise cipher suite assignment for the supported band/channel.

If the Joint Multi-band RSNA subfield within the RSN Capabilities field is 1 for both the RSNA initiator and the RSNA responder and at least one of the STAs uses different MAC addresses for different bands/channels, the STAs shall use a single 4-way handshake to negotiate pairwise cipher suites and establish PTKSAs for both the current operating band/channel and the other supported band(s)/channel(s). As specified in 12.7.6, message 2 and message 3 of the 4-way handshake convey the RSNE and the Multi-band element(s). The RSNE in message 2 includes the selected pairwise cipher suite for the current operating band/channel, and the Multi-band element(s) in message 2 includes the selected pairwise cipher suite(s) for the other supported band(s)/channel(s). message 3 includes the RSNE and the Multi-band element(s) that the STA would send in a

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Beacon, DMG Beacon, Announce, Probe Response, or Information Response frame. message 3 may include a second RSNE and Multi-band element(s) that indicate the STA's pairwise cipher suite assignments for the current operating band/channel and the other supported band(s)/channel(s). KCK and KEK associated with the current operating band/channel shall be used in the 4-way handshake.

12.6.22.3 Transparent multi-band RSNA

An RSNA initiator can establish a transparent (11.31) multi-band RSNA with an RSNA responder for both the current operating band/channel and the other supported band(s)/channel(s) if

a) Both STAs use the same MAC address in the current operating band/channel and the other supported band(s)/channel(s); and
b) At least one common pairwise cipher suite is supported by both STAs in the current operating band/channel and the other supported band(s)/channel(s).

Two STAs that establish a transparent multi-band RSNA create one PMKSA and one PTKSA for both the current operating band/channel and other supported band(s)/channel.

A STA shall use a single PN counter (12.5.3.3 and 12.5.5.3) for transmission in both the current operating band and the other supported band(s) when transparent multi-band RSNA is used.

If the RSNA initiator does not have an existing PMKSA with the RSNA responder, the RSNA initiator shall first establish a PMKSA with the RSNA responder in the current operating band/channel and then use the PMKSA to create a PTKSA with the RSNA responder for all involved bands/channels. If the RSNA initiator has already established a PMKSA with the RSNA responder, the PMKSA shall be used to create a PTKSA between the two STAs for all involved bands/channels.

With the PMK in place, the STA pair shall use a single 4-way handshake in the current operating band/channel to negotiate a pairwise cipher suite for all involved bands/channels and also establish a single PTKSA for all involved bands/channels. As specified in 12.7.6, message 2 and message 3 of the 4-way handshake convey the RSNE and the Multi-band element(s). The RSNE and the Multi-band element(s) in message 2 include one selected pairwise cipher suite for all involved bands/channels. message 3 includes the RSNE and the Multi-band element(s) that the STA would send in a Beacon, DMG Beacon, Announce, Probe Response, or Information Response frame. message 3 may include a second RSNE and Multi-band element(s) that indicate the STA's pairwise cipher suite assignment for all involved bands/channels.

12.6.22.4 Multi-band RSNA with TDLS in a non-DMG BSS

When two multi-band capable devices operate in a non-DMG BSS and set up a TDLS direct link in the BSS, the TPK handshake protocol can be used to create a PTKSA for use in another supported band/channel that is supported by both STAs and that was indicated in the Multi-band element in each of the STAs. Only TK in PTKSA is required for the supported band/channel and it shall be equal to the TPK-TK of the TPK.

If at least one of the peer STAs has a different MAC address in the supported band/channel from that of the current operating band/channel, the TPK handshake protocol may be used to establish a PTKSA for the supported band/channel. In this case, the TPK creation method shall be used to calculate a different PTKSA in the supported band/channel: the TDLS peer MAC addresses and cipher suite shall be replaced by the MAC addresses and cipher suite indicated within the corresponding Multi-band elements contained in the TDLS Setup Request and TDLS Setup Response frames used to establish the PTKSA for the supported band/channel.

If two TDLS peer STAs use the same MAC addresses and pairwise cipher suites in the operating band/channel and in the supported band/channel, the TPKSA that is acquired by the successful completion of the TPK handshake protocol may be used as the PTKSA for the supported band/channel.

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12.6.23 Protection of Beacon frames

An AP shall transmit protected Beacon frames if beacon protection is enabled. Protected Beacon frames cannot be validated until a BIGTKSA has been established. If a BIGTKSA exists, the non-AP STA shall validate the MME in received Beacon frames.

For Multiple BSSIDs, each of Authenticators shall maintain and transmit the BIGTK and BIPN which are common to all of the co-located transmitted and nontransmitted BSSs, and the Supplicant uses the received BIGTK and BIPN to maintain a BIGTKSA. If a Supplicant that has a BIGTKSA with an Authenticator that is using a nontransmitted BSSID receives a protected Beacon frame from the AP with the transmitted BSSID, it shall execute the BIP procedures (see 12.5.4) to validate the Beacon frame.

The group management cipher suite of the AP transmitting a Beacon frame is used to protect Beacon frames.

Beacon protection is not applicable to IBSS and MBSS.

12.7 Keys and key distribution

12.7.1 Key hierarchy

12.7.1.1 General

RSNA defines the following key hierarchies:

a) Pairwise key hierarchy, to protect individually addressed traffic
b) GTK, a hierarchy consisting of a single key to protect group addressed traffic

NOTE 1—Pairwise key support with enhanced data cryptographic encapsulation mechanisms allows a receiving STA to detect MAC address spoofing and data forgery. The RSNA architecture binds the transmitter and receiver addresses to the pairwise key. If an attacker creates an MPDU with the spoofed TA, then the decapsulation procedure at the receiver generates an error. GTKs do not have this property.

c) Integrity GTK (IGTK), a hierarchy consisting of a single key to provide integrity protection for group addressed robust Management frames
d) BIGTK, a hierarchy consisting of a single key to provide for integrity protection for Beacon frames
e) FT key hierarchy, to protect individually addressed traffic in an FT environment

The description of the key hierarchies uses the pseudorandom function producing *n* bits of output, PRF-*n*, defined in 12.7.1.2.

In an infrastructure BSS, the IEEE 802.1X Authenticator MAC address (AA) and the AP's MAC address are the same, and the Supplicant's MAC address (SPA) and the STA's MAC address are equal. For the purposes of comparison in this standard, the MAC address is encoded as 6 octets, taken to represent an unsigned integer. The first octet of the MAC address shall be used as the most significant octet. The bit numbering conventions in 9.2.2 shall be used within each octet. This results in a sequence of 48 bits represented such that bit 0 is the first transmitted bit (Individual/Group bit) and bit 47 is the last transmitted bit.

An RSNA STA shall support at least one pairwise key for any <TA,RA> pair for use with enhanced data cryptographic encapsulation mechanisms. The <TA,RA> identifies the pairwise key, which does not correspond to any WEP key identifier.

In a a mixed environment, an AP may simultaneously communicate with some STAs using WEP with shared WEP keys and to STAs using enhanced data cryptographic encapsulation mechanisms with pairwise keys. The STAs running WEP use default keys 0–3 for shared WEP keys; the important point here is that WEP can still use WEP default key 0. The AP might be configured to use the WEP key in WEP default key 0 for WEP; if the

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AP is configured in this way, STAs that cannot support WEP default key 0 simultaneously with a TKIP pairwise key shall specify the No Pairwise subfield in the RSN Capabilities field. If an AP is configured to use WEP default key 0 as a WEP key and a "No Pairwise" STA associates, the AP shall not set the Install bit in the 4-way handshake. In other words, the STA does not install a pairwise temporal key and instead uses WEP default key 0 for all traffic.

NOTE 2—The behavior of "No Pairwise" STAs is intended only to support the migration of WEP to RSNA.

TKIP STAs in a mixed environment are expected to support a single pairwise key either by using a key mapping key or by mapping to default key 0. The AP uses a pairwise key for individually addressed traffic between the AP and the STA. If a key mapping key is available, the <RA,TA> pair identifies the key; if there is no key mapping key, then the default key 0 is used because the key index in the message is 0.

A STA that cannot support TKIP keys and WEP default key 0 simultaneously advertises this deficiency by setting the No Pairwise subfield in the RSNE it sends in the (Re)Association Request frame to the AP. In response, the AP sets the Install bit to 0 in message 3 of the 4-way handshake to notify the STA not to install the pairwise key. The AP instead sends the WEP shared key to the STA to be plumbed as the WEP default key 0; this key is then used with WEP to send and receive individually addressed traffic between the AP and the STA.

The TKIP STA that has this limitation might not know that it will be forced to use WEP for all transmissions until it has associated with the AP and been given the keys to use. (The STA cannot know that the AP has been configured to use WEP default key 0 for WEP communication.) If this does not satisfy the security policy configured at the STA, the STA's only recourse is to disassociate and try a different AP.

STAs using enhanced data cryptographic encapsulation mechanisms in a TSN shall support pairwise keys and WEP default key 0 simultaneously. It is invalid for the STA to negotiate the No Pairwise subfield when an enhanced data cryptographic encapsulation mechanism other than TKIP is one of the configured ciphers.

12.7.1.2 PRF

A PRF is used in a number of places in this standard. Depending on its use, it may need to output 128, 192, 256, 384, 512, or 704 bits. This subclause defines six functions:

- PRF-128, which outputs 128 bits
- PRF-192, which outputs 192 bits
- PRF-256, which outputs 256 bits
- PRF-384, which outputs 384 bits
- PRF-512, which outputs 512 bits
- PRF-704, which outputs 704 bits

In the following, K is a key; A is a unique label for each different purpose of the PRF, treated as an ASCII string; B is a variable length string; Y is a single octet containing 0; X is a single octet containing the loop parameter i:

H-SHA-1(K, A, B, X) ← HMAC-SHA-1(K, A || Y || B || X)

PRF(K, A, B, Len)
for i ← 0 **to** $\left\lceil \frac{Len}{160} \right\rceil$ **do**
R ← R || H-SHA-1(K, A, B, i)
return L(R, 0, Len)

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PRF-128(K, A, B) = PRF(K, A, B, 128)
PRF-192(K, A, B) = PRF(K, A, B, 192)
PRF-256(K, A, B) = PRF(K, A, B, 256)
PRF-384(K, A, B) = PRF(K, A, B, 384)
PRF-512(K, A, B) = PRF(K, A, B, 512)

When the negotiated AKM is 00-0F-AC:5, 00-0F-AC:6, or 00-0F-AC:11, the KDF specified in 12.7.1.6.2 shall be used instead of the PRF construction defined here. In this case, A is used as the KDF label and B as the KDF Context, and the PRF functions are defined as follows:

PRF-128(K, A, B) = KDF-SHA-256-128(K, A, B)
PRF-192(K, A, B) = KDF-SHA-256-192(K, A, B)
PRF-256(K, A, B) = KDF-SHA-256-256(K, A, B)
PRF-384(K, A, B) = KDF-SHA-256-384(K, A, B)
PRF-512(K, A, B) = KDF-SHA-256-512(K, A, B)

When the negotiated AKM is 00-0F-AC:12, the KDF specified in 12.7.1.6.2 shall be used instead of the PRF construction defined here. In this case, A is used as the KDF label and B as the KDF Context, and the PRF function is defined as follows:

PRF-704(K, A, B) = KDF-SHA-384-704(K, A, B)

When the negotiated AKM is 00-0F-AC:13, the KDF specified in 12.7.1.6.2 shall be used instead of the PRF construction defined here. In this case, A is used as the KDF label and B as the KDF Context, and the PRF functions are defined as follows:

PRF-384(K, A, B) = KDF-SHA-384-384(K, A, B)
PRF-512(K, A, B) = KDF-SHA-384-512(K, A, B)
PRF-704(K, A, B) = KDF-SHA-384-704(K, A, B)

When the negotiated AKM is 00-0F-AC:14 or 00-0F-AC:16, the KDF specified in 12.7.1.6.2 shall be used instead of the PRF construction defined here. In this case, A is used as the KDF label and B as the KDF Context, and the PRF functions are defined as follows:

PRF-384(K, A, B) = KDF-SHA-256-384(K, A, B)
PRF-512(K, A, B) = KDF-SHA-256-512(K, A, B)
PRF-640(K, A, B) = KDF-SHA-256-640(K, A, B)
PRF-768(K, A, B) = KDF-SHA-256-768(K, A, B)
PRF-896(K, A, B) = KDF-SHA-256-896(K, A, B)
PRF-1024(K, A, B) = KDF-SHA-256-1024(K, A, B)

When the negotiated AKM is 00-0F-AC:15 or 00-0F-AC:17, the KDF specified in 12.7.1.6.2 shall be used instead of the PRF construction defined here. In this case, A is used as the KDF label and B as the KDF Context, and the PRF functions are defined as follows:

PRF-640(K, A, B) = KDF-SHA-384-640(K, A, B)
PRF-768(K, A, B) = KDF-SHA-384-768(K, A, B)
PRF-1024(K, A, B) = KDF-SHA-384-1024(K, A, B)
PRF-1152(K, A, B) = KDF-SHA-384-1152(K, A, B)
PRF-1408(K, A, B) = KDF-SHA-384-1408(K, A, B)
PRF-1536(K, A, B) = KDF-SHA-384-1536(K, A, B)

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12.7.1.3 Pairwise key hierarchy

Except when preauthentication or FILS authentication is used, the pairwise key hierarchy utilizes PRF-384, PRF-512, or PRF-704 to derive session specific keys from a PMK, as depicted in Figure 12-30. When using AKM suite selector 00-0F-AC:12 or 00-0F-AC:15, the length of the PMK, PMK_bits, shall be 384 bits. When using AKM suite selectors for which the Authentication type column indicates FT authentication (see Table 9-151), the FT key hierarchy is used to derive session specific keys from an MPMK as defined in 12.7.1.6. With all other AKM suite selectors, the length of the PMK, PMK_bits, shall be 256 bits. The pairwise key hierarchy takes a PMK and generates a PTK. The PTK is partitioned into KCK, KEK, and a temporal key, which is used by the MAC to protect individually addressed communication between the Authenticator's and Supplicant's respective STAs. PTKs are used between a single Supplicant and a single Authenticator.

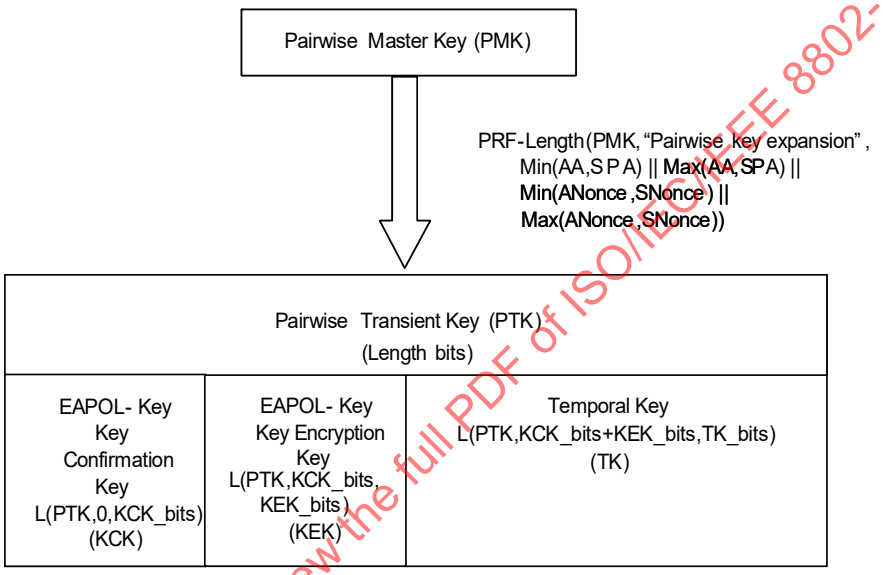

Figure 12-30—Pairwise key hierarchy

When using IEEE 802.1X authentication, the PMK is derived from the MSK. The PMK shall be computed as the first PMK_bits bits (bits 0 to PMK_bits–1) of the MSK: PMK = L(MSK, 0, PMK_bits). When using SAE or FILS authentication, the PMK is derived per 12.4.5.4 or 12.11.2.5.2, respectively.

The PTK shall not be used longer than the PMK lifetime as determined by the minimum of the PMK lifetime indicated by the AS, e.g., Session-Timeout + dot1xAuthTxPeriod or from dot11RSNAConfigPMK-Lifetime. When RADIUS is used and the Session-Timeout attribute is not in the RADIUS Accept message, and if the key lifetime is not otherwise specified, then the PMK lifetime is infinite.

NOTE 1—If the protocol between the Authenticator (or AP) and AS is RADIUS, then the MS-MPPE-Recv-Key attribute (vendor-id = 17; see section 2.4.3 in IETF RFC 2548 [B31]) is available to be used to transport the first 32 octets of the MSK to the AP, and the MS-MPPE-Send-Key attribute (vendor-id = 16; see section 2.4.2 in IETF RFC 2548 [B31]) is available to be used to transport the remaining 32 octets of the MSK.

NOTE 2—When reauthenticating and changing the pairwise key, a race condition might occur when using TKIP. If a frame is received while MLME-SETKEYS.request primitive is being processed, the received frame might be decrypted with one key and the MIC checked with a different key. Two possible options to avoid this race condition are as follows: the frame might be checked against the old MIC key, and the received frames might be queued while the keys are changed.

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NOTE 3—If the AKMP is RSNA-PSK, then a 256-bit PSK might be configured into the STA and AP or a pass-phrase might be configured into the Supplicant or Authenticator. The method used to configure the PSK is outside this standard, but one method is via user interaction. If a pass-phrase is configured, then a 256-bit key is derived and used as the PSK. In any RSNA-PSK method, the PSK is used directly as the PMK. Implementations might support different PSKs for each pair of communicating STAs.

The following apply when not using FILS authentication:

— SNonce is a random or pseudorandom value contributed by the Supplicant; its value is taken when a PTK is instantiated and is sent to the PTK Authenticator.

— ANonce is a random or pseudorandom value contributed by the Authenticator.

— The PTK shall be derived from the PMK by

PTK = PRF-Length(PMK, “Pairwise key expansion”, Min(AA,SPA) || Max(AA,SPA) || Min(ANonce,SNonce) || Max(ANonce,SNonce))

where Length = KCK_bits + KEK_bits + TK_bits. The values of KCK_bits and KEK_bits are AKM suite dependent and are listed in Table 12-10. The value of TK_bits is cipher-suite dependent and is defined in Table 12-7. The Min and Max operations for IEEE 802 addresses are with the address converted to a positive integer treating the first transmitted octet as the most significant octet of the integer. The nonces are encoded as specified in 9.2.2.

NOTE 4—The Authenticator and Supplicant normally derive a PTK only once per association. A Supplicant or an Authenticator use the 4-way handshake or FILS authentication to derive a new PTK. Both the Authenticator and Supplicant create a new nonce value for each 4-way handshake or FILS authentication instance.

— The KCK shall be computed as the first KCK_bits bits (bits 0 to KCK_bits–1) of the PTK:

KCK= L(PTK, 0, KCK_bits)

The KCK is used by IEEE Std 802.1X-2010 to provided data origin authenticity in the 4-way handshake and group key handshake messages.

— The KEK shall be computed as the next KEK_bits bits of the PTK:

KEK = L(PTK, KCK_bits, KEK_bits)

The KEK is used by the EAPOL-Key frames to provide data confidentiality in the 4-way handshake and group key handshake messages.

— The temporal key (TK) shall be computed as the next TK_bits bits of the PTK:

TK = L(PTK, KCK_bits+KEK_bits, TK_bits)

When using FILS authentication, the PTK is derived as defined in 12.11.2.5.3.

The EAPOL-Key state machines (see 12.7.9 and 12.7.10) use the MLME-SETKEYS.request primitive to configure the temporal key into the STA. The STA uses the temporal key with the pairwise cipher suite; interpretation of this value is cipher-suite dependent.

When the negotiated AKM is 00-0F-AC:5 or 00-0F-AC:6, the PMK identifier is defined as

PMKID = Truncate-128(HMAC-SHA-256(PMK, “PMK Name” || AA || SPA))

When the negotiated AKM is 00-0F-AC:11, the PMK identifier is defined as

PMKID = Truncate-128(HMAC-SHA-256(KCK, “PMK Name” || AA || SPA))

When the negotiated AKM is 00-0F-AC:12, and the PMK identifier is defined as

PMKID = Truncate-128(HMAC-SHA-384(KCK, “PMK Name” || AA || SPA))

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When the negotiated AKM is 00-0F-AC:14:

— When IEEE 802.1X authentication is used, the PMK identifier is defined as:

PMKID = Truncate-128(HMAC-SHA-256(PMK, “PMK Name” || AA || SPA))

— When FILS authentication is used, the PMK identifier is derived as defined in 12.11.2.5.

When the negotiated AKM is 00-0F-AC:15:

— When IEEE 802.1X authentication is used, the PMK identifier is defined as:

PMKID = Truncate-128(HMAC-SHA-384(PMK, “PMK Name” || AA || SPA))

— When FILS authentication is used, the PMK identifier is derived as defined in 12.11.2.5.

When the negotiated AKM is 00-0F-AC:20, the PMK identifier is defined as

PMKID = Truncate-128(HMAC-SHA-384(PMK, “PMK Name” || AA || SPA))

When the negotiated AKM is 00-0F-AC:8, the PMK identifier is derived as defined in 12.4.5.4.

When the negotiated AKM is a suite type for which the Authentication type column indicates FT authentication (see Table 9-151), the PMKID (used for PMKSA caching in FT Initial Mobility Domain Association, see 12.6.10.3) and PMKR0Name are derived as defined in 12.7.1.6.3 and PMKR1Name is derived as defined in 12.7.1.6.4.

Otherwise, the PMK identifier is defined as

PMKID = Truncate-128(HMAC-SHA-1(PMK, “PMK Name” || AA || SPA))

In all these cases, “PMK Name” is treated as an ASCII string.

When the PMKID is calculated for the PMKSA as part of preauthentication, the AKM has not yet been negotiated. In this case, the HMAC-SHA-1 based derivation is used for the PMKID calculation.

12.7.1.4 Group key hierarchy

The group temporal key (GTK) shall be a random number. The following is an example method for deriving a random GTK. Any other pseudorandom function, such as that specified in 12.7.1.2, could also be used.

A group master key (GMK) is an auxiliary key that may be used to derive a GTK at a time interval configured into the AP to reduce the exposure of data if the GMK is ever compromised.

The Authenticator might update the GTK for a number of reasons:

— The Authenticator might change the GTK on disassociation or deauthentication of a STA.

— An event within the SME might trigger a group key handshake.

Figure 12-31 depicts an example of a relationship among the keys of the group key hierarchy. In this model, the group key hierarchy takes a GMK and generates a GTK. The GTK is a temporal key, which is used to protect group addressed communication. GTKs are used between a single Authenticator and all Supplicants authenticated to that Authenticator. The Authenticator derives new GTKs when it needs to update the GTKs.

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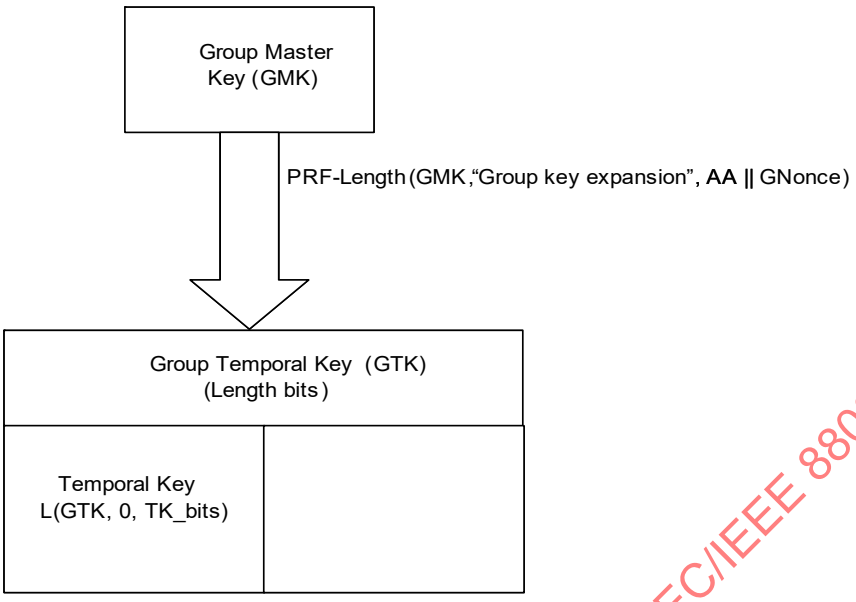

Figure 12-31—Group key hierarchy

In this example, the following apply:

a) Group nonce (GNonce) is a random or pseudorandom value contributed by the IEEE 802.1X Authenticator.

b) The GTK is derived from the GMK by GTK =PRF-Length(GMK, "Group key expansion", AA || GNonce)

c) Length = TK_bits. The value of TK_bits is cipher-suite dependent and is defined in Table 12-7. AA is represented as an IEEE 802 address and GNonce as a bit string as defined in 9.2.2.

d) The temporal key (TK) is bits 0 to (TK_bits – 1) of the GTK:
TK =L(GTK, 0, TK_bits)

e) The EAPOL-Key state machines (see 12.7.9 and 12.7.10) configure the temporal key into a STA via the MLME-SETKEYS.request primitive. Its interpretation is cipher-suite dependent.

12.7.1.5 Integrity group key hierarchy

The Authenticator shall select the IGTK as a random value each time it is generated.

The Authenticator may update the IGTK for any reason, including:

a) The disassociation or deauthentication of a STA.

b) An event within the SME that triggers a group key handshake.

The IGTK is configured via the MLME-SETKEYS.request primitive; see 6.3.19. IGTK configuration is described in the EAPOL-Key state machines; see 12.7.9 and 12.7.10.

The IPN is used to provide replay protection.

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12.7.1.6 FT key hierarchy

12.7.1.6.1 Overview

This subclause describes the FT key hierarchy and its supporting architecture. The FT key hierarchy is designed to allow a STA to make fast BSS transitions between APs without the need to perform an SAE or IEEE 802.1X authentication at every AP within the mobility domain.

The FT key hierarchy can be used with SAE, IEEE 802.1X authentication, PSK authentication, or FILS authentication.

A three-level key hierarchy provides key separation between the key holders. The FT key hierarchy for the Authenticator is shown in Figure 12-32. An identical key hierarchy exists for the Supplicant, and identical functions are performed by the corresponding S0KH and S1KH.

The FT key hierarchy shown in Figure 12-32 consists of three levels whose keys are derived using the key derivation function (KDF) described in 12.7.1.6.2 as follows:

a) PMK-R0. The first-level key of the FT key hierarchy. This key is derived as a function of the master session key (MSK), PMK, or PSK. It is stored by the PMK-R0 key holders, R0KH and S0KH.
b) PMK-R1. The second-level key of the FT key hierarchy. This key is mutually derived by the S0KH and R0KH.
c) PTK. The third-level key of the FT key hierarchy that defines the IEEE 802.11 and IEEE 802.1X protection keys. The PTK is mutually derived by the PMK-R1 key holders, R1KH and S1KH.

As shown in Figure 12-32, the Master PMK (MPMK) is obtained from the PMK obtained from SAE authentication, from the PSK, or from the MSK resulting (per IETF RFC 3748) from a successful IEEE 802.1X authentication between the AS and the Supplicant, or from the PMK (see 12.11.2.5.2) resulting from a successful FILS authentication. The R0KH computes the PMK-R0 from the MPMK.

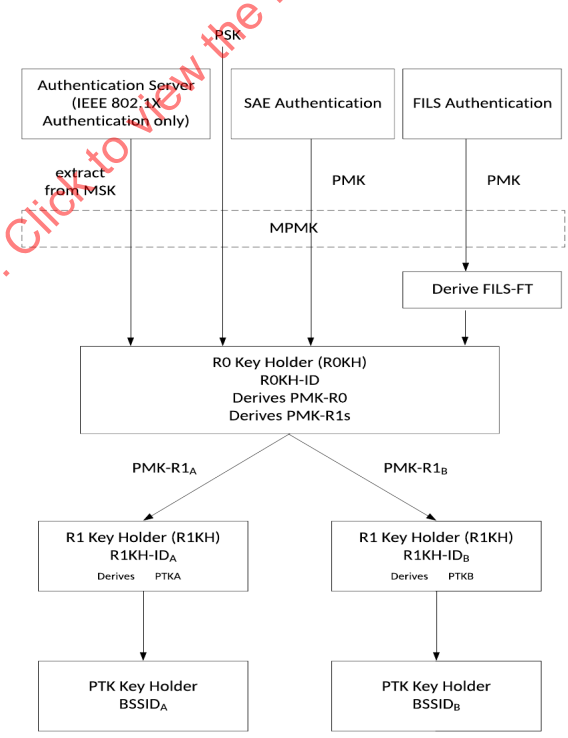

Figure 12-32—FT key hierarchy at an Authenticator

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NOTE—The MPMK is a constituent of a PMKSA that may be cached (see 12.6.1.1.2 and 12.6.10.3).

Upon a successful authentication, the R0KH shall delete any prior PMK-R0 security association for this mobility domain pertaining to this S0KH. The R0KH shall also delete all PMK-R1 security associations derived from that prior PMK-R0 security association. The PMK-R1s are generated by the R0KH and are assumed to be delivered from the R0KH to the R1KHs within the same mobility domain. The PMK-R1s are used for PTK generation. Upon receiving a new PMK-R1 for an S0KH, an R1KH deletes the prior PMK-R1 security association and PTKSAs derived from the prior PMK-R1.

It is assumed by this standard that the PSK is specific to a single S0KH and a single R0KH.

The lifetime of the MPMK, PMK-R0, PMK-R1, and PTK are bound to the lifetime of the PMK, PSK, or MSK from which it was derived. For example, the AS may communicate the MSK lifetime with the MSK. If such an attribute is provided, the lifetime of the MPMK shall be not more than the lifetime of the MSK. The lifetime of the PTK, PMK-R1, and PMK-R0 is the same as that of the MPM. When the key lifetime expires, each key holder shall delete its respective MPMK, PMK-R0, PMK-R1 or PTKSA.

The FT key hierarchy derives its keys using the KDF defined in 12.7.1.6.2 with separate labels to further distinguish derivations.

During a fast BSS transition, a STA shall negotiate the same pairwise cipher suite with target APs as was negotiated in the FT initial mobility domain association. Using the pairwise cipher suite selector value in the PMK-R1 security association received from the R0KH, the target AP shall verify that the same pairwise cipher suite selector is being used.

The distribution of keys from the R0KH to the R1KHs is outside the scope of this standard. It is assumed that the PMK-R1s are distributed from the R0KH to the R1KHs following the requirements specified in 13.2.2.

The PMK-R0 may be deleted by the R0KH after PMK-R1s have been derived. When the PMK-R0 is deleted, the R0KH needs only to maintain the PMK-R1 security associations.

12.7.1.6.2 Key derivation function (KDF)

The KDF is a variant of the pseudorandom function (PRF) defined in 12.7.1.2 and is defined as follows:

Output ← KDF-Hash-Length (K, Label, Context) where
Input: *K*, a derivation key whose length equals the block size of the hash algorithm
Hash, a cryptographically strong hash algorithm
Label, a string identifying the purpose of the keys derived using this KDF, treated as an ASCII string
Context, a bit string that provides context to identify the derived key
Length, the length of the derived key in bits
Output: a *Length*-bit derived key

result ← “”
iterations ← $\lceil Length/Hashlen \rceil$
do *i* = 1 **to** *iterations*
result ← *result* || HMAC-*Hash*(*K*, *i* || *Label* || *Context* || *Length*)
od
return first *Length* bits of *result,* and irretrievably delete the other bits

where
i and *Length* are encoded as 16-bit unsigned integers, represented using the bit ordering conventions of 9.2.2

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K, *Label*, and *Context*	are bit strings and are represented using the ordering conventions of 9.2.2
Hashlen	is the length, in bits, of the digest produced by Hash

12.7.1.6.3 PMK-R0

The first-level key in the FT key hierarchy, PMK-R0, is derived using the KDF defined in 12.7.1.6.2. The PMK-R0 is the first level keying material used to derive the next level keys (PMK-R1s).

The PMK-R0 is derived from the MPMK, which is obtained when a PMKSA is established using a negotiated AKM for which the Authentication type column indicates FT authentication (see Table 9-151).

If the negotiated AKM is 00-0F-AC:3, then Q = 256 and

- MPMK = L(MSK, 256, 256), i.e., the second 256 bits of the MSK (which is derived from the IEEE 802.1X authentication)
- PMKID = Truncate-128(HMAC-SHA-256(MPMK, “PMK Name” || AA || SPA))

If the negotiated AKM is 00-0F-AC:4, then Q = 256 and

- MPMK = PSK
- PMKID = Truncate-128(HMAC-SHA-256(MPMK, “PMK Name” || AA || SPA))

If the negotiated AKM is 00-0F-AC:9, then Q = 256 and

- MPMK = PMK generated as the result of SAE authentication per 12.4.5.4
- PMKID is derived as defined in 12.4.5.4

If the negotiated AKM is 00-0F-AC:13, then Q = 384 and

- MPMK = L(MSK, 0, 384), i.e., the first 384 bits of the MSK (which is derived from the IEEE 802.1X authentication)
- PMKID = Truncate-128(HMAC-SHA-384(MPMK, “PMK Name” || AA || SPA))

If the negotiated AKM is 00-0F-AC:16, then Q = 256 and

- When FILS authentication is used:
  - MPMK = PMK generated as the result of FILS authentication per 12.11.2.5.2
  - PMKID is defined in 12.11.2.5.2
- When IEEE 802.1X authentication is used, then
  - MPMK = L(MSK, 256, 256), i.e., the second 256 bits of the MSK (which is derived from the IEEE 802.1X authentication)
  - PMKID = Truncate-128(HMAC-SHA-256(MPMK, “PMK Name” || AA || SPA))

If the negotiated AKM is 00-0F-AC:17, then Q = 384 and

- When FILS authentication is used,
  - MPMK = PMK generated as the result of FILS authentication per 12.11.2.5.2
  - PMKID is defined in 12.11.2.5.2
- When IEEE 802.1X authentication is used, then
  - MPMK = L(MSK, 0, 384), i.e., the first 384 bits of the MSK (which is derived from the IEEE 802.1X authentication)
  - PMKID = Truncate-128(HMAC-SHA-384(MPMK, “PMK Name” || AA || SPA))

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If the negotiated AKM is 00-0F-AC:19, then Q = 384 and

— MPMK = PSK
— PMKID = Truncate-128(HMAC-SHA-384(MPMK, “PMK Name” || AA || SPA))

In all these cases, "PMK Name" is treated as an ASCII string.

The PMK-R0 is then derived as follows:

R0-Key-Data = KDF-Hash-Length(XXKey, “FT-R0”, SSIDlength || SSID || MDID || R0KHlength || R0KH-ID || S0KH-ID)
PMK-R0 = L(R0-Key-Data, 0, Q)
PMK-R0Name-Salt = L(R0-Key-Data, Q, 128)
Length = Q + 128

where

KDF-Hash-Length	is the key derivation function as defined in 12.7.1.6.2 using the hash algorithm identified by the AKM suite selector (see Table 9-151)
If the negotiated AKM	is 00-0F-AC:16 or 00-0F-AC:17 and FILS authentication is used, then XXKey shall be the FILS-FT derived from MPMK as described in 12.11.2.5.3. Otherwise, XXKey is equal to MPMK.
SSIDlength	is a single octet whose value is the number of octets in the SSID
SSID	is the service set identifier, a variable length sequence of octets, as it appears in the Beacon and Probe Response frames
MDID	is the Mobility Domain Identifier field from the Mobile Domain element (MDE) that was used during FT initial mobility domain association
R0KHlength	is a single octet whose value is the number of octets in the R0KH-ID
R0KH-ID	is the identifier of the holder of PMK-R0 in the Authenticator
S0KH-ID	is the Supplicant’s MAC address (SPA)

The PMK-R0 is referenced and named as follows:

PMKR0Name = Truncate-128(Hash(“FT-R0N” || PMK-R0Name-Salt))

where

Hash is the hash algorithm specific to the negotiated AKM (see Table 9-151)
“FT-R0N” is treated as an ASCII string

The PMKR0Name is used to identify the PMK-R0.

12.7.1.6.4 PMK-R1

The second-level key in the FT key hierarchy, PMK-R1, is a key used to derive the PTK. The PMK-R1 is derived using the KDF defined in 12.7.1.6.2:

PMK-R1 = KDF-Hash-Length(PMK-R0, “FT-R1”, R1KH-ID || S1KH-ID)

where

KDF-Hash-Length	is the key derivation function as defined in 12.7.1.6.2
Hash	is the hash algorithm specific to the negotiated AKM (see Table 9-151)
Length	is the length of the hash algorithm’s digest
PMK-R0	is the first level key in the FT key hierarchy
R1KH-ID	is a MAC address of the holder of the PMK-R1 in the Authenticator of the AP
S1KH-ID	is the SPA

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The PMK-R1 is referenced and named as follows:

PMKR1Name = Truncate-128(Hash("FT-R1N" || PMKR0Name || R1KH-ID || S1KH-ID))

where
Hash is the hash algorithm specific to the negotiated AKM (see Table 9-151)
"FT-R1N" is treated as an ASCII string

PMKR1Name is used to identify the PMK-R1.

12.7.1.6.5 PTK

The third-level key in the FT key hierarchy is the PTK. When FILS authentication is used to establish the FT key hierarchy, PTK for the initial mobility domain association is derived as part of the FILS authentication as defined in 12.11.2.5.3. Otherwise, this key is mutually derived by the S1KH and the R1KH used by the target AP, with the key length being a function of the negotiated cipher suite as defined by Table 12-7 in 12.7.2.

Using the KDF defined in 12.7.1.6.2, the PTK derivation is as follows:

PTK = KDF-Hash-Length(PMK-R1, "FT-PTK", SNonce || ANonce || BSSID || STA-ADDR)

where

KDF-Hash-Length	is the key derivation function as defined in 12.7.1.6.2 using the hash algorithm identified by the AKM suite selector (see Table 9-151)
PMK-R1	is the key that is shared between the S1KH and the R1KH
SNonce	is a 256-bit random bit string contributed by the S1KH
ANonce	is a 256-bit random bit string contributed by the R1KH
STA-ADDR	is the non-AP STA's MAC address
BSSID	is the BSSID of the target AP's BSS
Length	is the total number of bits to derive, i.e., number of bits of the PTK. The length is dependent on the negotiated cipher suites and AKM suites as defined by Table 12-7 in 12.7.2 and Table 12-10 in 12.7.3.

Each PTK has five component keys, KCK, KEK, a temporal key, KCK2, and KEK2 derived as follows:

The KCK shall be computed as the first KCK_bits bits (bits 0 to KCK_bits–1) of the PTK:

KCK = L(PTK, 0, KCK_bits)

The KCK is used to provide data origin authenticity in EAPOL-Key frames, as defined in 12.7.2, and in the FT authentication sequence, as defined in 13.8.

The KEK shall be computed as the next KEK_bits of the PTK:

KEK = L(PTK, KCK_bits, KEK_bits)

The KEK is used to provide data confidentiality for certain fields (KeyData) in EAPOL-Key frames, as defined in 12.7.2, and in the FT authentication sequence, as defined in 13.8.

The temporal key (TK) shall be computed as the next TK_bits (see Table 12-7) bits of the PTK:

TK = L(PTK, KCK_bits+KEK_bits, TK_bits)

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The KCK2 shall be computed as the next KCK2_bits of the PTK:

KCK2 = L(PTK, KCK_bits+KEK_bits+TK_bits, KCK2_bits)

The KCK2 is used to provide data origin authenticity in the FT authentication sequence, as defined in 13.8.

The KEK2 shall be computed as the next KEK2_bits of the PTK:

KEK2 = L(PTK, KCK_bits+KEK_bits+TK_bits+KCK2_bits, KEK2_bits)

The KEK2 is used to provide data confidentiality for certain fields in the FT authentication sequence, as defined in 13.8.

For vendor-specific cipher suites, the length of the temporal key (and the value of Length) depend on the vendor-specific algorithm.

The temporal key is configured into the STA by the SME through the use of the MLME-SETKEYS.request primitive. The STA uses the temporal key with the pairwise cipher suite; interpretation of this value is specific to the cipher suite.

The PTK is referenced and named as follows:

PTKName = Truncate-128(SHA-256(PMKR1Name || "FT-PTKN" || SNonce || ANonce || BSSID || STA-ADDR))

where
"FT-PTKN" is treated as an ASCII string

The PTKName is used to identify the PTK.

12.7.1.7 Beacon protection key hierarchy

The Authenticator shall select the BIGTK as a random value each time it is generated.

The Authenticator may update the BIGTK for any reason, including:

a) The disassociation or deauthentication of a STA.
b) An event within the SME that triggers a group key handshake.
c) The reception of a WNM Notification Request frame indicating beacon protection failure.

The BIGTK is configured via the MLME-SETKEYS.request primitive; see 6.3.19. The BIGTK configuration is described in the EAPOL-Key state machines; see 12.7.9 and 12.7.10.

The BIPN is used to provide replay protection.

12.7.2 EAPOL-Key frames

IEEE Std 802.11 uses EAPOL-Key frames to exchange information between STAs' Supplicants and Authenticators. These exchanges result in cryptographic keys and synchronization of security association state. EAPOL-Key frames are used to implement three different exchanges:

— 4-way handshake, to confirm that the PMK between associated STAs is the same and live and to transfer the GTK to the STA.
— Group key handshake, to update the GTK at the STA.

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When priority processing of Data frames is supported, an SME should send EAPOL-Key frames at the highest priority.

The IEEE 802.11 Key Descriptor maps to the IEEE 802.1X Key Descriptor as described in this subclause.

The bit and octet convention for fields in the EAPOL-Key frame are defined in 11.2 of IEEE Std 802.1X-2010. EAPOL-Key frames containing invalid field values shall be silently discarded. Figure 12-33 depicts the format of an EAPOL-Key frame.

Protocol Version – 1 octet	Packet Type – 1 octet	Packet Body Length – 2 octets
Descriptor Type – 1 octet		
Key Information – 2 octets		Key Length – 2 octets
Key Replay Counter – 8 octets		
Key Nonce – 32 octets		
EAPOL - Key IV – 16 octets		
Key RSC – 8 octets		
Reserved - 8 octets		
Key MIC – variable		
Key Data Length – 2 octets		Key Data – n octets

Figure 12-33—EAPOL-Key frame format

The fields of an EAPOL-Key frame body are as follows:

a) **Descriptor Type.** This field has a value defined by IEEE Std 802.1X-2010, identifying an IEEE 802.11 Key Descriptor.

b) **Key Information**. This field specifies characteristics of the key. See Figure 12-34.

B0 B2	B3	B4 B5	B6	B7	B8	B9	B10	B11	B12	B13 B15
Key Descriptor Version	Key Type	Reserved	Install	Key Ack	Key MIC	Se-cure	Error	Request	Encrypted Key Data	Reserved

Figure 12-34—Key Information bit format

The bit convention used is as in 11.2 of IEEE Std 802.1X-2010. The subfields of the Key Information field are as follows:

1) Key Descriptor Version (bits 0–2) shall be set to 0 on all transmitted EAPOL-Key frames indicating that the EAPOL-Key frame is constructed and processed according to the negotiated AKM as described in Table 12-10 except under the following circumstances:

   i) The value 1 shall be used for all EAPOL-Key frames to a STA when the negotiated AKM is 00-0F-AC:1 or 00-0F-AC:2 and the pairwise cipher is TKIP or “Use group cipher suite”. In this case, the “Deprecated” row in Table 12-10 is used.

   ii) The value 2 shall be used for all EAPOL-Key frames to a STA when the negotiated AKM is 00-0F-AC:1 or 00-0F-AC:2 and either the pairwise or the group cipher is an enhanced data cryptographic encapsulation mechanism other than TKIP. In this case, the matching row in Table 12-10 is used.

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iii) The value 3 shall be used for all EAPOL-Key frames to a STA when the negotiated AKM is 00-0F-AC:3, 00-0F-AC:4, 00-0F-AC:5, or 00-0F-AC:6. In this case, the matching row in Table 12-10 is used.

2) Key Type (bit 3) specifies whether this EAPOL-Key frame is part of a 4-way handshake deriving a PTK.
   i) The value 0 (Group) indicates the message is not part of a PTK derivation.
   ii) The value 1 (Pairwise) indicates the message is part of a PTK derivation.
3) Reserved (bits 4–5).
4) Install (bit 6).
   i) If the value of Key Type (bit 3) is 1, then for the Install bit,
      — The value 1 means the IEEE 802.1X component shall configure the temporal key derived from this message into its IEEE 802.11 MAC.
      — The value 0 means the IEEE 802.1X component shall not configure the temporal key into the IEEE 802.11 MAC.
   ii) If the value of Key Type (bit 3) is 0, then this bit is reserved.
5) Key Ack (bit 7) is set to 1 in messages from the Authenticator if an EAPOL-Key frame is required in response to this message and is 0 otherwise. The Supplicant's response to this message shall use the same replay counter as this message.
6) Key MIC (bit 8) is set to 1 if not using an AEAD cipher and a MIC is in this EAPOL-Key frame and is set to 0 otherwise.
7) Secure (bit 9) is set to 1 once the initial key exchange is complete.

   The Authenticator shall set the Secure bit to 0 in all EAPOL-Key frames sent before the Supplicant has the PTK and the GTK. The Authenticator shall set the Secure bit to 1 in all EAPOL-Key frames it sends to the Supplicant containing the last key needed to complete the Supplicant's initialization.

   The Supplicant shall set the Secure bit to 0 in all EAPOL-Key frames it sends before it has the PTK and the GTK and before it has received an EAPOL-Key frame from the Authenticator with the Secure bit equal to 1 (this should be before receiving message 3 of the 4-way handshake). The Supplicant shall set the Secure bit to 1 in all EAPOL-Key frames sent after this until it loses the security association it shares with the Authenticator.
8) Error (bit 10) is set by a Supplicant to report that a MIC failure occurred in a TKIP MSDU. In case of a MIC failure, a Supplicant shall set this bit to 1 only when the Request (bit 11) is 1.
9) Request (bit 11) is set to 1 by a Supplicant to request that the Authenticator initiate either a 4-way handshake or group key handshake, and is set to 1 by a Supplicant in a Michael MIC Failure Report. The Supplicant shall not set this bit to 1 in on-going 4-way handshakes, i.e., the Key Ack bit (bit 7) shall not be set to 1 in any message in which the Request bit is 1. The Authenticator shall never set this bit to 1.

   In a Michael MIC Failure Report, setting the bit is not a request to initiate a new handshake. However, the recipient may initiate a new handshake on receiving such a message.

   If an EAPOL-Key frame in which the Request bit is 1 has a key type of Pairwise, the Authenticator shall initiate a 4-way handshake. If the EAPOL-Key frame in which the Request bit is 1 has a key type of Group, the Authenticator shall change the GTK, initiate a 4-way handshake with the Supplicant, and then execute the group key handshake to all Supplicants.
10) Encrypted Key Data (bit 12) is set to 1 if the Key Data field is encrypted and is set to 0 if the Key Data field is not encrypted. This subfield shall be set to 1, and the Key Data field shall be encrypted, if any key material (e.g., GTK) is included in the frame.
11) Reserved (bits 13–15).

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c) **Key Length**. This field is represented as an unsigned integer. The value defines the length in octets of the pairwise temporal key. See Table 12-7.

Table 12-7—Cipher suite key lengths

Cipher suite	Key length (octets)	TK_bits (bits)
WEP-40	5	40
WEP-104	13	104
TKIP	32	256
CCMP-128	16	128
BIP-CMAC-128	16	128
GCMP-128	16	128
GCMP-256	32	256
CCMP-256	32	256
BIP-GMAC-128	16	128
BIP-GMAC-256	32	256
BIP-CMAC-256	32	256

d) **Key Replay Counter**. This field is represented as an unsigned integer, and is initialized to 0 when the PMK is established. The Supplicant shall use the key replay counter in the received EAPOL-Key frame when responding to an EAPOL-Key frame. It carries a sequence number that the protocol uses to detect replayed EAPOL-Key frames.

The Supplicant and Authenticator shall track the key replay counter per security association. The key replay counter shall be initialized to 0 on (re)association. The Authenticator shall increment the key replay counter on each successive EAPOL-Key frame.

When replying to a message from the Authenticator, the Supplicant shall use the Key Replay Counter field value from the last valid EAPOL-Key frames received from the Authenticator. The Authenticator should use the key replay counter to identify invalid messages to silently discard. The Supplicant should also use the key replay counter and ignore EAPOL-Key frames with a Key Replay Counter field value smaller than or equal to any received in a valid message. The local Key Replay Counter field should not be updated until after the EAPOL-Key MIC is checked and is found to be valid. In other words, the Supplicant never updates the Key Replay Counter field for message 1 in the 4-way handshake, as it includes no MIC. This implies the Supplicant needs to allow for retransmission of message 1 when checking for the key replay counter of message 3.

The Supplicant shall maintain a separate key replay counter for sending EAPOL-Key request frames to the Authenticator; the Authenticator also shall maintain a separate replay counter to filter received EAPOL-Key request frames.

NOTE 1—The key replay counter does not play any role beyond a performance optimization in the 4-way handshake. In particular, replay protection is provided by selecting a never-before-used nonce value to incorporate into the PTK. It does, however, play a useful role in the group key handshake.

e) **Key Nonce**. This field conveys the ANonce from the Authenticator and the SNonce from the Supplicant. It may contain 0 if a nonce is not required to be sent.

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f) **EAPOL-Key IV**. This field contains the IV used with the KEK. It shall contain 0 when an IV is not required. It should be initialized by taking the current value of the global key counter (see 12.7.10) and then incrementing the counter. Note that only the lower 16 octets of the counter value are used.

g) **Key RSC**. This field contains the current receive sequence counter (RSC) for the GTK being installed. It is used in message 3 of the 4-way handshake and message 1 of the group key handshake, where it is used to synchronize the IEEE 802.11 replay state. It may also be used in the Michael MIC Failure Report frame, to report the TSC field value of the frame experiencing a MIC failure. It shall contain 0 in other messages. If the RSC is less than 8 octets in length, it is stored in the first octets and the remaining octets are set to 0. The least significant octet of the RSC is in the first octet of the Key RSC field. The RSC for TKIP is the TKIP sequence number (TSC); for CCMP and GCMP it is the packet number (PN); see Table 12-8.

Table 12-8—Key RSC field

KeyRSC 0	KeyRSC 1	KeyRSC 2	KeyRSC 3	KeyRSC 4	KeyRSC 5	KeyRSC 6	KeyRSC 7
TSC0	TSC1	TSC2	TSC3	TSC4	TSC5	0	0
PN0	PN1	PN2	PN3	PN4	PN5	0	0

For WEP, the Key RSC field is reserved.

h) **Key MIC**. When the negotiated AKM is not 00-0F-AC:14, 00-0F-AC:15, 00-0F-AC:16, or 00-0F-AC:17, the EAPOL Key MIC is a MIC of the EAPOL-Key frames, from and including the EAPOL protocol version field to and including the Key Data field, calculated with the Key MIC field set to 0. If the Encrypted Key Data subfield (of the Key Information field) is 1, the Key Data field is encrypted prior to computing the MIC. When using an AEAD cipher, the EAPOL Key MIC is not present. The length of this field depends on the negotiated AKM as defined in 12.7.3.

i) **Key Data Length**. This field is an unsigned integer. This represents the length of the Key Data field in octets. If the Encrypted Key Data subfield (of the Key Information field) is 1, the length is the length of the Key Data field after encryption, including any padding.

j) **Key Data**. This field is a variable length field that is used to include any additional data required for the key exchange that is not included in the fields of the EAPOL-Key frame. The additional data may be zero or more element(s) (such as the RSNE and RSNXE) and zero or more key data encapsulation(s) (KDEs) (such as GTK KDE or PMKID KDE(s)). KDEs shall be encapsulated using the format shown in Figure 12-35.

	Type (0xdd)	Length	OUI	Data Type	Data
Octets:	1	1	3	1	(Length – 4)

Figure 12-35—KDE format

The Type field shall be set to 0xdd. The Length field specifies the number of octets in the OUI, Data Type, and Data fields. The OUI field contains either an OUI or CID. The order of the OUI field is described in 9.2.2.

NOTE 2—The KDE format is a subset of the Vendor Specific element format (see 9.4.2.25). It is generally not possible to distinguish, from the format, a Vendor Specific element and a vendor specific KDE.

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Table 12-9 lists the KDE selectors defined by this standard.

Table 12-9—KDE selectors

OUI	Data type	Meaning
00-0F-AC	0	Reserved
00-0F-AC	1	GTK KDE
00-0F-AC	2	Reserved
00-0F-AC	3	MAC address KDE
00-0F-AC	4	PMKID KDE
00-0F-AC	5	Reserved
00-0F-AC	6	Nonce KDE
00-0F-AC	7	Lifetime KDE
00-0F-AC	8	Error KDE
00-0F-AC	9	IGTK KDE
00-0F-AC	10	Key ID KDE
00-0F-AC	11	Multi-band GTK KDE
00-0F-AC	12	Multi-band Key ID KDE
00-0F-AC	13	OCI KDE
00-0F-AC	14	BIGTK KDE
00-0F-AC	15–255	Reserved
Other OUI or CID	Any	Vendor specific

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A STA shall ignore any elements and KDEs it does not understand.

If the Encrypted Key Data subfield (of the Key Information field) is 1, the entire Key Data field shall be encrypted. If the Key Data field uses the NIST AES key wrap, then the Key Data field shall be padded before encrypting if the key data length is less than 16 octets or if it is not a multiple of 8. The padding consists of appending a single octet 0xdd followed by zero or more 0x00 octets. When processing a received EAPOL-Key frame, the receiver shall ignore this trailing padding. If the Key Data field uses an AEAD cipher, then the Key Data field shall not be padded and the AAD for the encipherment operation shall be the data of the EAPOL-Key frame from the EAPOL protocol version field (inclusive) to the Key Data field (exclusive). Key Data fields that are encrypted, but do not contain the GroupKey, shall be accepted.

If the GroupKey is included in the Key Data field, but the Key Data field is not encrypted, the EAPOL-Key frames shall be ignored.

The format of the GTK KDE is shown in Figure 12-36.

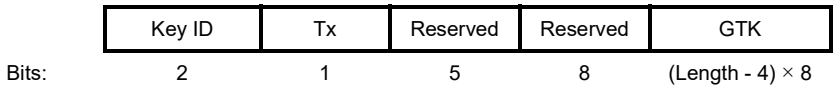

Figure 12-36—GTK KDE format

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If the value of the Tx field is 1, then the IEEE 802.1X component shall configure the temporal key derived from this KDE into its IEEE 802.11 MAC for both transmission and reception.

If the value of the Tx field is 0, then the IEEE 802.1X component shall configure the temporal key derived from this KDE into its IEEE 802.11 MAC for reception only.

The format of the MAC address KDE is shown in Figure 12-37.

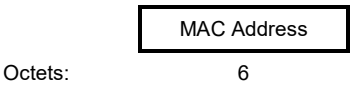

Figure 12-37—MAC address KDE format

The format of the PMKID KDE is shown in Figure 12-38.

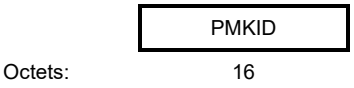

Figure 12-38—PMKID KDE format

The format of the Nonce KDE is shown in Figure 12-39.

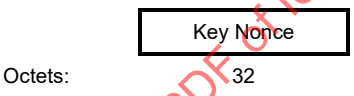

Figure 12-39—Nonce KDE format

The format of the Lifetime KDE is shown in Figure 12-40. The Key Lifetime value is expressed in seconds and uses big endian octet order.

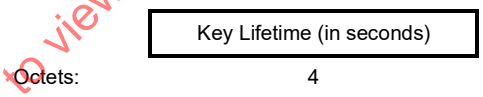

Figure 12-40—Lifetime KDE format

The format of the Error KDE is shown in Figure 12-41. The Error Type field is in big endian octet order.

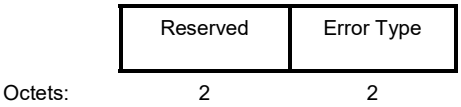

Figure 12-41—Error KDE format

The format of the IGTK KDE is shown in Figure 12-42. The IPN corresponds to the last packet number used by the broadcast/multicast transmitter, and it is used by the receiver as the initial value for the BIP replay counter.

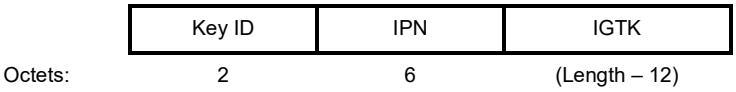

Figure 12-42—IGTK KDE format

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The following EAPOL-Key frames are used to implement the three different exchanges:

— **4-way handshake message 1** is an EAPOL-Key frame with the Key Type subfield equal to 1. Use of the Key Data field to indicate a PMKID when a cached PMKSA is being used in this key derivation is defined in 12.6.10.3. When a cached PMKSA is not being used, inclusion of the PMKID (if derived) is optional. The Key Data field need not be encrypted.

— **4-way handshake message 2** is an EAPOL-Key frame with the Key Type subfield equal to 1. The Key Data field shall contain an RSNE, may contain an RSNXE, and need not be encrypted.

An ESS Supplicant's SME shall insert the RSNE it sent in its (Re)Association Request frame, and shall insert the RSNXE it sent in its (Re)Association Request frame if the RSNXE is present in the (Re)Association Request frame it sent. The RSNE and the RSNXE are included as transmitted in the Management frame. On receipt of message 2, the Authenticator's SME shall validate the selected security configuration against the RSNE received in the (Re)Association Request frame, and shall validate the RSNXE included in message 2 against the RSNXE received in the (Re)Association Request frame from the Supplicant.

An IBSS Supplicant's SME shall insert an RSNE containing a selected pairwise cipher suite. The Authenticator's SME shall validate that the pairwise cipher suite selected is one of its configured cipher suites and that the group cipher suite and AKM are consistent.

— **4-way handshake message 3** is an EAPOL-Key frame with the Key Type subfield equal to 1. The Key Data field shall contain one or two RSNEs, and may contain an RSNXE. If a group cipher has been negotiated, this field shall also include a GTK. This field shall be encrypted if a GTK is included.

An Authenticator's SME shall insert the RSNE it sent in its Beacon or Probe Response frame, and shall insert the RSNXE it sent in its Beacon or Probe Response frame if the RSNXE is present in the Beacon or Probe Response frame it sent. When this message 3 is part of a fast BSS transition initial mobility domain association or an association started through the FT protocol, the PMKR1Name is added in the PMKID List field of the RSNE. The Supplicant's SME shall validate the selected security configuration against the RSNE received in message 3, and shall validate the RSNXE included in message 3 against the RSNXE received in the Beacon or Probe Response frame from the Authenticator. If the second optional RSNE is present, the STA shall either use that cipher suite with its pairwise key or deauthenticate. In any of these cases, if the values do not match, then the receiver shall consider the RSNE or the RSNXE modified and shall use the MLME-DEAUTHENTICATE.request primitive to break the association. A security error should be logged at this time.

It may happen, for example, that a Supplicant selects a pairwise cipher suite which is advertised by an AP, but which policy disallows for this particular STA. An Authenticator may, therefore, insert a second RSNE to overrule the STA's selection. An Authenticator's SME shall insert the second RSNE, after the first RSNE, only for this purpose. The pairwise cipher suite in the second RSNE included shall be one of the ciphers advertised by the Authenticator. All other fields in the second RSNE shall be identical to the first RSNE.

A GTK shall be included and the unencrypted length of the GTK is six less than the length of the GTK KDE in octets. The entire Key Data field shall be encrypted as specified by the Key Descriptor Version.

— **4-way handshake message 4** is an EAPOL-Key frame with the Key Type subfield equal to 1. The Key Data field can be empty.

— **Group key handshake message 1** is an EAPOL-Key frame with the Key Type subfield equal to 0. The Key Data field shall contain a GTK KDE and shall be encrypted.

— **Group key handshake message 2** is an EAPOL-Key frame with the Key Type subfield equal to 0. The Key Data field can be empty.

The key wrap algorithm selected depends on the negotiated AKM as defined in 12.7.3.

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The format of the Key ID KDE is shown in Figure 12-43.

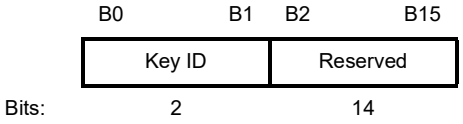

Figure 12-43—Key ID KDE format

The Key ID field contains the Authenticator selected Key ID.

The format of the Multi-band GTK KDE is shown in Figure 12-44.

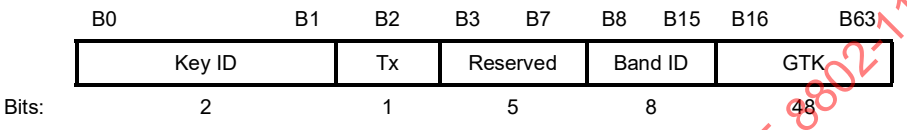

Figure 12-44—Multi-band GTK KDE format

The definitions of the Key ID, Tx, and GTK fields are the same as in the GTK KDE described above.

The Band ID field contains the identification of the frequency band (see 9.4.1.45).

The format of the Multi-band Key ID KDE is shown in Figure 12-45.

Figure 12-45—Multi-band Key ID KDE format

The definitions of the Key ID and Band ID fields are the same as in the Multi-band GTK KDE described above.

The format of the OCI KDE is shown in Figure 12-46.

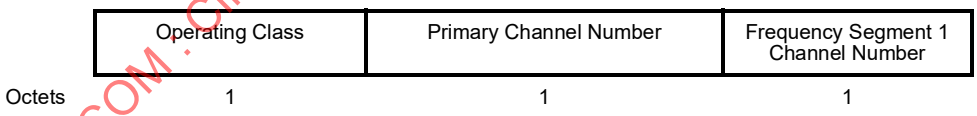

Figure 12-46—OCI KDE format

The definitions of Operating Class, Primary Channel Number, and Frequency Segment 1 Channel Number are the same as those described in 9.4.2.236.

The format of the BIGTK KDE is shown in Figure 12-47.

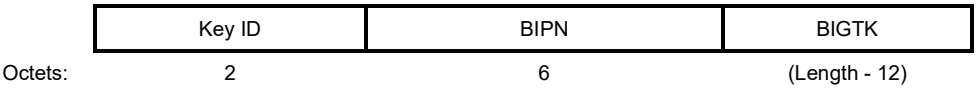

Figure 12-47—BIGTK KDE format

The BIPN corresponds to the BIPN value that was carried in the MME of the last protected Beacon frame and it is used by the receiver as the initial value for the BIP replay counter for the BIGTK.

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12.7.3 EAPOL-Key frame construction and processing

EAPOL-Key frames are constructed and processed according to the negotiated AKM at association time. The negotiated AKM determines what algorithm is used to construct and verify a MIC, the size of the MIC, and the algorithm used to wrap and unwrap the Key Data field.

Table 12-10 indicates the particular algorithms to use when constructing and processing EAPOL-Key frames and FT authentication sequence. The AKM of "Deprecated" indicates an AKM of 00-0F-AC:1 or 00-0F-AC:2 when either TKIP or "Use group cipher suite" is the negotiated pairwise cipher. For all other AKMs the negotiated pairwise cipher suite does not influence the algorithms used to process EAPOL-Key frames. For the 00-0F-AC:16 and 00-0F-AC:17 AKMs (FILS with FT), different keys and algorithms are used in EAPOL-Key frames and FT authentication sequence. These different cases are indicated in the table in <EAPOL-Key> / <FT authentication> format.

HMAC is defined in IETF RFC 2104. MD5 is defined in IETF RFC 1321. SHA-1 is defined by FIPS 180-4. The NIST AES key wrap algorithm is defined in IETF RFC 3394. AES-128-CMAC is defined by NIST Special Publication 800-38B and also found in IETF RFC 4493 [B42].

Table 12-10—Integrity and key wrap algorithms

AKM	Integrity algorithm	KCK_bits	Size of MIC	Key wrap algorithm	KEK_bits	KCK2_bits	KEK2_bits
Deprecated	HMAC-MD5	128	16	ARC4	128	0	0
00-0F-AC:1	HMAC-SHA-1-128	128	16	NIST AES Key Wrap	128	0	0
00-0F-AC:2	HMAC-SHA-1-128	128	16	NIST AES Key Wrap	128	0	0
00-0F-AC:3	AES-128-CMAC	128	16	NIST AES Key Wrap	128	0	0
00-0F-AC:4	AES-128-CMAC	128	16	NIST AES Key Wrap	128	0	0
00-0F-AC:5	AES-128-CMAC	128	16	NIST AES Key Wrap	128	0	0
00-0F-AC:6	AES-128-CMAC	128	16	NIST AES Key Wrap	128	0	0
00-0F-AC:8	AES-128-CMAC	128	16	NIST AES Key Wrap	128	0	0
00-0F-AC:9	AES-128-CMAC	128	16	NIST AES Key Wrap	128	0	0
00-0F-AC:11	HMAC-SHA-256	128	16	NIST AES Key Wrap	128	0	0
00-0F-AC:12	HMAC-SHA-384	192	24	NIST AES Key Wrap	256	0	0
00-0F-AC:13	HMAC-SHA-384	192	24	NIST AES Key Wrap	256	0	0

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Table 12-10—Integrity and key wrap algorithms *(continued)*

AKM	Integrity algorithm	KCK_bits	Size of MIC	Key wrap algorithm	KEK_bits	KCK2_bits	KEK2_bits
00-0F-AC:14	AES-SIV-256	0	0	AES-SIV-256	256	0	0
00-0F-AC:15	AES-SIV-512	0	0	AES-SIV-512	512	0	0
00-0F-AC:16	AES-SIV-256/ AES-128-CMAC	0	0/16	AES-SIV-256/ NIST AES Key Wrap	256	128	128
00-0F-AC:17	AES-SIV-512/ HMAC-SHA-384	0	0/24	AES-SIV-512/ NIST AES Key Wrap	512	192	256

12.7.4 EAPOL-Key frame notation

The following notation is used throughout the remainder of 12.7 and 13.4 to represent EAPOL-Key frames:

EAPOL-Key(S, M, A, I, K, Reserved, KeyRSC, ANonce/SNonce, MIC, {Key Data})

where

S means the initial key exchange is complete; this is the Secure bit of the Key Information field

M means the MIC is available in message [This should be set in all messages except message 1 of a 4-way handshake. This is the Key MIC bit of the Key Information field. When the negotiated AKM is 00-0F-AC:14, 00-0F-AC:15, 00-0F-AC:16, or 00-0F-AC:17, this Key MIC bit is set to 0 regardless of the M parameter value.

A means a response is required to this message. This is used when the receiver should respond to this message. This is the Key Ack bit of the Key Information field.

I is the Install bit: indicates whether to install (1) or not install (0) for the pairwise key. This is the Install bit of the Key Information field.]

K is the key type: P (Pairwise), G (Group); this is the Key Type bit of the Key Information field

Reserved is reserved

KeyRSC is the key RSC; this is the Key RSC field

ANonce/SNonce is the Authenticator or Supplicant nonce, respectively (This is the Key Nonce field.

MIC is the integrity check, which is generated using the KCK. This is the Key MIC field. When the negotiated AKM is 00-0F-AC:14, 00-0F-AC:15, 00-0F-AC:16, or 00-0F-AC:17, this Key MIC field is not included regardless of the MIC parameter value.)

{Key Data} is a sequence of zero or more elements and KDEs, concatenated and contained in the Key Data field, where

- RSNE is described in 9.4.2.24
- RSNE[KeyName] is the RSNE, with the PMKID List field set to KeyName
- GTK[N] is the GTK, with the key identifier field set to N (The key identifier specifies which index is used for this GTK. Index 0 shall not be used for GTKs, except in mixed environments, as described in 12.7.1.)
- FTE is the Fast BSS Transition element, described in 9.4.2.47
- MDE is the Mobility Domain element, described in 9.4.2.46
- TIE[IntervalType] is a Timeout Interval element of type IntervalType, as described in 9.4.2.48, containing e.g., for type KeyLifetime, the lifetime of the FT key hierarchy
- IGTK[M] is the IGTK, with key identifier field set to M

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IPN	is the current IGTK replay counter value provided by the IGTK KDE
BIGTK[Q]	is the BIGTK, with key identifier field set to Q
BIPN	is the current BIGTK replay counter value provided by the BIGTK KDE
PMKID	is of type PMKID KDE and is the key identifier used during 4-way PTK handshake for PMK identification
OCI KDE	is a KDE containing operating channel information
RSNXE	is described in 9.4.2.241
PMKID	identifies the PMKSA selected by the Authenticator
"{a} or {b}"	means that exactly one of either {a} or {b} is present as the {Key Data}

12.7.5 Nonce generation

The following is a description of nonce generation.

All STAs contain a global key counter, which is 256 bits in size. It should be initialized at system boot-up time to a fresh cryptographic-quality random number. Refer to J.5 on random number generation. It is recommended that the counter value is initialized to the following:

PRF-256(Random number, "Init Counter", Local MAC Address || Time)

The local MAC address should be AA on the Authenticator and SPA on the Supplicant.

The random number is 256 bits in size. Time should be the current time from Network Time Protocol (NTP) or another time in NTP format whenever possible. This initialization causes different initial key counter values to occur across system restarts regardless of whether a real-time clock is available. The key counter can be used as additional input data for nonce generation. A STA derives a random nonce for each new use.

12.7.6 4-way handshake

12.7.6.1 General

RSNA defines a protocol using EAPOL-Key frames called the *4-way handshake*. The handshake completes the IEEE 802.1X authentication process. The information flow of the 4-way handshake is as follows:

Message 1: Authenticator→Supplicant: EAPOL-Key(0,0,1,0,P,0,0,ANonce,0,{} or {PMKID})

Message 2: Supplicant→Authenticator: EAPOL-Key(0,1,0,0,P,0,0,SNonce,MIC,{RSNE} or {RSNE, OCI KDE} or {RSNE, RSNXE} or {RSNE, OCI KDE, RSNXE})

Message 3: Authenticator→Supplicant: EAPOL-Key(1,1,1,1,P,0,KeyRSC,ANonce,MIC,{RSNE,GTK[N]} or {RSNE, GTK[N], OCI KDE} or {RSNE, GTK[N], RSNXE} or {RSNE, GTK[N], OCI KDE, RSNXE})

Message 4: Supplicant → Authenticator: EAPOL-Key(1,1,0,0,P,0,0,0,MIC,{}).

The FT initial mobility domain association uses the FT 4-way handshake to establish an initial PTKSA, GTKSA, if management frame protection is enabled, an IGTKSA, and if beacon protection is enabled, a BIGTKSA, that is based on this protocol. The FT 4-way handshake protocol is described in 13.4.

The following apply:

— EAPOL-Key(·) denotes an EAPOL-Key frame conveying the specified argument list, using the notation introduced in 12.7.4.

— ANonce is a nonce that the Authenticator contributes for PTK generation. ANonce has the same value in message 1 and message 3.

— SNonce is a nonce from the Supplicant for PTK generation.

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— P means the pairwise bit is set.
— The MIC is computed over the body of the EAPOL-Key frame (with the Key MIC field first zeroed before the computation) using the KCK defined in 12.7.1.3 for PTK generation.
— RSNE represents the appropriate RSNEs.
— GTK[N] represents the GTK with its key identifier.
— OCI KDE contains the current operating channel information for the operating channel in which the EAPOL-Key frame is sent. OCI KDE is present when dot11RSNAOperatingChannelValidationActivated is true on the Supplicant in Message 2 and Authenticator in Message 3. Otherwise it is absent.
— RSNXE, when included in message 2, contains the RSNXE that the Supplicant sent in its (Re)Association Request frame, and when included in message 3, contains the RSNXE that the Authenticator sent in its Beacon or Probe Response frame. RSNXE is present in message 2 if this element is present in the (Re)Association Request frame that the Supplicant sent, and is present in message 3 if this element is present in the Beacon or Probe Response frame that the Authenticator sent.

NOTE—While the MIC calculation is the same in each direction, the Key Ack bit is different in each direction. It is set in EAPOL-Key frames from the Authenticator and 0 in EAPOL-Key frames from the Supplicant. 4-way handshake requests from the Supplicant have the Request bit equal to 1. The Authenticator and Supplicant need to check these bits to stop reflection attacks. It is important that message 1 contents not be used to update state, in particular the keys in use, until the data are validated with message 3.

If dot11RSNAOperatingChannelValidationActivated is true and a channel switch is requested while the handshake is in progress, the handshake should be aborted.

12.7.6.2 4-way handshake message 1

Message 1 uses the following values for each of the EAPOL-Key frame fields:

Descriptor Type = N – see 12.7.2
Key Information:
Key Descriptor Version = 1 (ARC4 encryption with HMAC-MD5) or 2 (NIST AES key wrap with HMAC-SHA-1-128) or 3 (NIST AES key wrap with AES-128-CMAC), in all other cases 0
Key Type = 1 (Pairwise)
Reserved = 0
Install = 0
Key Ack = 1
Key MIC = 0
Secure = 0
Error = 0
Request = 0
Encrypted Key Data = 0
Reserved = 0 – unused by this protocol version
Key Length = Cipher-suite dependent; see Table 12-7
Key Replay Counter = *n* – to allow Authenticator or initiator STA to match the right message 2 from Supplicant or peer STA
Key Nonce = ANonce
EAPOL-Key IV = 0
Key RSC = 0

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Key MIC = 0

Key Data Length = length of Key Data field in octets

Key Data = PMKID for the PMK being used during PTK generation

Processing for PTK generation is as follows:

The Authenticator sends message 1 to the Supplicant at the end of a successful IEEE 802.1X authentication, after (re)association completes for a STA that has authenticated with SAE or PSK authentication is negotiated, when a cached PMKSA is used, or after a STA requests a new key. On reception of message 1, the Supplicant determines whether the Key Replay Counter field value has been used before with the current PMKSA. If the Key Replay Counter field value is less than or equal to the current local value, the Supplicant discards the message. Otherwise, the Supplicant:

a) Generates a new nonce SNonce.
b) Derives PTK.
c) Constructs message 2.

12.7.6.3 4-way handshake message 2

Message 2 uses the following values for each of the EAPOL-Key frame fields:

Descriptor Type = N – see 12.7.2

Key Information:

Key Descriptor Version = 1 (ARC4 encryption with HMAC-MD5) or 2 (NIST AES key wrap with HMAC-SHA-1-128) or 3 (NIST AES key wrap with AES-128-CMAC), in all other cases 0 – same as message 1

Key Type = 1 (Pairwise) – same as message 1

Reserved = 0

Install = 0

Key Ack = 0

Key MIC = 0 when using an AEAD cipher or 1 otherwise

Secure = 0 – same as message 1

Error = 0 – same as message 1

Request = 0 – same as message 1

Encrypted Key Data = 1 when using an AEAD cipher or 0 otherwise

Reserved = 0 – unused by this protocol version

Key Length = 0

Key Replay Counter = *n* – to let the Authenticator or initiator STA know to which message 1 this corresponds

Key Nonce = SNonce

EAPOL-Key IV = 0

Key RSC = 0

Key MIC = Not present when using an AEAD cipher; otherwise, MIC(KCK, EAPOL) – MIC computed over the body of this EAPOL-Key frame with the Key MIC field first initialized to 0

Key Data Length = length of Key Data field in octets

Key Data =

— included RSNE – the sending STA's RSNE for PTK generation or peer RSNE for the current operating band, and when this message 2 is part of a fast BSS transition initial mobility domain association or an association started through the FT protocol, the

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PMKR1Name calculated by the S1KH according to the procedures of 12.7.1.6.4 is included in the PMKID List field of the RSNE and the FTE and MDE are also included, or

- The sending STA's Multi-band element for PTK generation for a supported band other than the current operating band if dot11MultibandImplemented is true, or
- The sending STA's RSNE and Multi-band element(s) for generating a single PTK for all involved bands, if dot11MultibandImplemented is true and both the Authenticator and the Supplicant use the same MAC address in the current operating band and the other supported band(s); or
- The sending STA's RSNE and Multi-band element(s) for generating a different PTK for each involved band, if dot11MultibandImplemented is true and the Joint Multi-band RSNA subfield of the RSN capabilities field is 1 for both the Authenticator and the Supplicant, and either the Authenticator or the Supplicant uses different MAC addresses for different bands.
- Additionally, contains an OCI KDE when dot11RSNAOperatingChannelValidationActivated is true on the Supplicant.
- The RSNXE that the Supplicant sent in its (Re)Association Request frame, if this element is present in the (Re)Association Request frame that the Supplicant sent.

Processing for PTK generation is as follows:

The Supplicant sends message 2 to the Authenticator.

On reception of message 2, the Authenticator checks that the key replay counter corresponds to the outstanding message 1. If not, it silently discards the message.

If dot11RSNAOperatingChannelValidationActivated is true and Supplicant RSNE indicates OCVC capability, the Authenticator silently discards message 2 if any of the following are true:

- OCI KDE or FTE OCI subelement is missing in the message
- Channel information in the OCI does not match current operating channel parameters (see 12.2.9)

Otherwise, the Authenticator:

a) Derives PTK.

b) Verifies the message 2 MIC or AEAD decryption operation result.

   1) If the calculated MIC does not match the MIC that the Supplicant included in the EAPOL-Key frame or the AEAD decryption operation returns failure, the Authenticator silently discards message 2.

   2) If the MIC or AEAD decryption is valid and this message 2 is part of a fast BSS transition initial mobility domain association or an association started through the FT protocol, the Authenticator checks that all fields of the RSNE other than the PMKID List field and, if present, the RSNXE bitwise matches the fields from the (Re)Association Request frame and that the FTE and MDE are the same as those provided in the AP's (Re)Association Response frame. If the MIC or AEAD decryption is valid and this message 2 is not part of a fast BSS transition initial mobility domain association and this message 2 is not part of an association started through the FT protocol, the Authenticator checks that the RSNE and, if present, the RSNXE bitwise matches that from the (Re)Association Request frame.

      i) If these are not exactly the same, the Authenticator uses MLME-DEAUTHENTICATE.request primitive to terminate the association.

      ii) If they do match bitwise, the Authenticator constructs message 3.

c) If management frame protection is being negotiated, the AP initializes the SA Query Transaction Identifier to an implementation-specific non-negative integer value, valid for the current pairwise security association.

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12.7.6.4 4-way handshake message 3

Message 3 uses the following values for each of the EAPOL-Key frame fields:

Descriptor Type = N – see 12.7.2

Key Information:

Key Descriptor Version = 1 (ARC4 encryption with HMAC-MD5) or 2 (NIST AES key wrap with HMAC-SHA-1-128) or 3 (NIST AES key wrap with AES-128-CMAC), in all other cases 0 – same as message 1

Key Type = 1 (Pairwise) – same as message 1

Reserved = 0

Install = 0/1 – For PTK generation, 0 only if the AP does not support key mapping keys, or if the STA has the No Pairwise bit (in the RSN Capabilities field) equal to 1and only the group key is used.

Key Ack = 1

Key MIC = 0 when using an AEAD cipher or 1 otherwise

Secure = 1 (keys installed)

Error = 0 – same as message 1

Request = 0 – same as message 1

Encrypted Key Data = 1

Reserved = 0 – unused by this protocol version

Key Length = Cipher-suite dependent; see Table 12-7

Key Replay Counter = $n+1$

Key Nonce = ANonce – same as message 1

EAPOL-Key IV = 0 (Version 2) or random (Version 1)

Key RSC = For PTK generation, starting TSC or PN that the Authenticator's STA uses in MPDUs protected by GTK.

Key MIC = Not present when using an AEAD cipher; or otherwise, MIC(KCK, EAPOL) or MIC(SKCK, EAPOL) – MIC computed over the body of this EAPOL-Key frame with the Key MIC field first initialized to 0

Key Data Length = length of Key Data field in octets

Key Data =

— For PTK generation for the current operating band, the AP's Beacon/Probe Response frame's RSNE for the current operating band, and, optionally, a second RSNE that is the Authenticator's pairwise cipher suite assignment for the current operating band, and, if a group cipher has been negotiated, the GTK and the GTK's key identifier (see 12.7.2) for the current operating band, and if management frame protection is negotiated, the IGTK KDE, and if beacon protection is enabled, the BIGTK KDE, and when this message 3 is part of a fast BSS transition initial mobility domain association or an association started through the FT protocol, the PMKR1Name calculated according to the procedures of 12.7.1.6.4 in the PMKID List field of the RSNE and the FTE with the same contents as in the (Re)Association Response frame, the MDE with the same contents as in the (Re)Association Response frame, the reassociation deadline timeout set to the minimum of dot11FTReassociationDeadline and the key lifetime in the TIE[ReassociationDeadline], and the PTK lifetime in the TIE[KeyLifetime]; or

— For PTK generation for a supported band other than the current operating band, the Authenticator's Beacon/DMG Beacon/Announce/Probe Response/Information Response frame's Multi-band element associated with the supported band, and optionally a second Multi-band element that indicates the Authenticator's pairwise cipher suite assignment for

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the supported band, and, if group cipher for the supported band is negotiated, the Multi-band GTK KDE for the supported band if dot11MultibandImplemented is true, or

— For generating a single PTK for all involved bands, the Authenticator's Beacon/DMG Beacon/Announce/Probe Response/Information Response frame's RSNE and Multi-band element(s), and optionally, additional RSNE and Multi-band element(s) that indicate the Authenticator's assignment of one pairwise cipher suite for all involved bands; if a group cipher for all involved bands is negotiated, the GTK and the GTK's key identifier for all involved bands, if dot11MultibandImplemented is true and both the Authenticator and the Supplicant use the same MAC address in the current operating band and the other supported band(s), or

— For generating different PTKs for the current operating band and other supported band(s), the Authenticator's Beacon/DMG Beacon/Announce/Probe Response/Information Response frame's RSNE and Multi-band element(s), and optionally, additional RSNE and Multi-band elements that are the Authenticator's pairwise cipher suite assignments for one or more involved bands; if group ciphers for the involved bands are negotiated, the Multi-band GTK KDEs for the involved bands, if dot11MultibandImplemented is true and the Joint Multi-band RSNA subfield is 1 for both the Authenticator and Supplicant, and either the Authenticator or the Supplicant uses different MAC addresses for different bands.

— Additionally, contains an OCI KDE when dot11RSNAOperatingChannelValidationActivated is true on the Authenticator.

— The RSNXE that the Authenticator sent in its Beacon or Probe Response frame, if this element is present in the Beacon or Probe Response frame that the Authenticator sent.

Processing for PTK generation is as follows:

If the Extended Key ID for Individually Addressed Frames subfield of the RSN Capabilities field is 1 for both the Authenticator and the Supplicant, then the Authenticator assigns a new Key ID for the PTKSA in the range of 0 to 1 that is different from the Key ID assigned in the previous handshake and uses the MLME-SETKEYS.request primitive to install the new key to receive individually addressed MPDUs protected by the PTK with the assigned Key ID. Otherwise Key ID 0 is used and installation of the key is deferred until after message 4 has been received. The Authenticator sends message 3 to the Supplicant.

NOTE—If an existing PTK is still in effect, the Authenticator IEEE 802.11 MAC continues to transmit protected, individually addressed MPDUs (if any) using the existing key. With the installation of the new key for receive, the Authenticator is able to receive protected, individually addressed MPDUs using either the old key (if present) or the new key.

On reception of message 3, the Supplicant silently discards the message if the Key Replay Counter field value has already been used or if the ANonce value in message 3 differs from the ANonce value in message 1.

If dot11RSNAOperatingChannelValidationActivated is true and Authenticator RSNE indicates OCVC capability, the Supplicant silently discards message 3 if any of the following are true:

— OCI KDE or FTE OCI subelement is missing in the message

— Channel information in the OCI does not match current operating channel parameters (see 12.2.9)

The Supplicant also:

a) Verifies the RSNE and, if present, the RSNXE. If this message 3 is part of a fast BSS transition initial mobility domain association or an association started through the FT protocol, the Supplicant verifies that the PMKR1Name in the PMKID List field of the RSNE is identical to the value it sent in message 2 and verifies that all other fields of the RSNE are identical to the fields in the RSNE present in the Beacon or Probe Response frames and verifies that the FTE and MDE are the same as in the (Re)Association Response frame. Otherwise, the Supplicant verifies that the RSNE is identical to that the STA received in the Beacon or Probe Response frame. If the RSNXE is present,

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the Supplicant verifies that the RSNXE is identical to that the STA received in the Beacon or Probe Response frame. If any of these verification steps indicates a mismatch, the STA shall disassociate or deauthenticate. If a second RSNE is provided in the message, the Supplicant uses the pairwise cipher suite specified in the second RSNE or deauthenticates.

b) Verifies the message 3 MIC or AEAD decryption operation result. If the calculated MIC does not match the MIC that the Authenticator included in the EAPOL-Key frame or AEAD decryption operation returns failure, the Supplicant silently discards message 3.

c) Updates the last-seen value of the Key Replay Counter field.

d) If the Extended Key ID for Individually Addressed Frames subfield of the RSN Capabilities field is 1 for both the Authenticator and Supplicant: Uses the MLME-SETKEYS.request primitive to configure the IEEE 802.11 MAC to receive individually addressed MPDUs protected by the PTK with the assigned Key ID.

e) Constructs message 4.

f) Sends message 4 to the Authenticator.

g) Uses the MLME-SETKEYS.request primitive to configure the IEEE 802.11 MAC to send and, if the receive key has not yet been installed, to receive individually addressed MPDUs protected by the PTK. The GTK is also configured by MLME-SETKEYS primitive.

12.7.6.5 4-way handshake message 4

Message 4 uses the following values for each of the EAPOL-Key frame fields:

Descriptor Type = N – see 12.7.2

Key Information:

Key Descriptor Version = 1 (ARC4 encryption with HMAC-MD5) or 2 (NIST AES key wrap with HMAC-SHA-1-128) or 3 (NIST AES key wrap with AES-128-CMAC), in all other cases 0 – same as message 1

Key Type = 1 (Pairwise) – same as message 1

Reserved = 0

Install = 0

Key Ack = 0 – this is the last message

Key MIC = 0 when using an AEAD cipher or 1 otherwise

Secure = 1

Error = 0

Request = 0

Encrypted Key Data = 1 when using an AEAD cipher or 0 otherwise

Reserved = 0 – unused by this protocol version

Key Length = 0

Key Replay Counter = $n+1$

Key Nonce = 0

EAPOL-Key IV = 0

Key RSC = 0

Key MIC = Not present when using an AEAD cipher; or otherwise, MIC(KCK, EAPOL) – MIC computed over the body of this EAPOL-Key frame with the Key MIC field first initialized to 0

Key Data Length = length of Key Data field in octets

Key Data = none required

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Processing for PTK generation is as follows:

The Supplicant sends message 4 to the Authenticator. Note that when the 4-way handshake is first used, message 4 is sent in the clear.

On reception of message 4, the Authenticator verifies that the Key Replay Counter field value is one that it used on this 4-way handshake and is strictly larger than that in any other EAPOL-Key frame that has the Request bit in the Key Information field set to 0 and that has been received during this session; if it is not, it silently discards the message. Otherwise:

a) The Authenticator checks the MIC or AEAD decryption operation result. If the calculated MIC does not match the MIC that the Supplicant included in the EAPOL-Key frame or AEAD decryption operation returns failure, the Authenticator silently discards message 4.
b) If the MIC is valid, the Authenticator uses the MLME-SETKEYS.request primitive to configure the IEEE 802.11 MAC to send and, if the receive key has not yet been installed, to receive protected, individually addressed MPDUs using for the new PTK.
c) The Authenticator updates the Key Replay Counter field so that it uses a fresh value if a rekey becomes necessary.

12.7.6.6 4-way handshake implementation considerations

If the Authenticator does not receive a reply to its messages, it shall attempt dot11RSNAConfigPairwiseUpdateCount transmits of the message, plus a final timeout. The retransmit timeout value shall be 100 ms for the first timeout, half the listen interval for the second timeout, and the listen interval for subsequent timeouts. If there is no listen interval or the listen interval is zero, then 100 ms shall be used for all timeout values. If it still has not received a response after these retries, then for PTK generation the Authenticator should deauthenticate the STA.

For PTK generation, if the Supplicant does not receive message 1 within the expected time interval (prior to IEEE 802.1X timeout), it should disassociate, deauthenticate, and try another AP or peer STA.

The Authenticator should ignore EAPOL-Key frames it is not expecting in reply to messages it has sent or EAPOL-Key frames in which the Ack bit is 1. This stops an attacker from sending the first message to the Supplicant who responds to the Authenticator.

An implementation should save the KCK and KEK beyond the 4-way handshake, as they are needed for group key handshakes, and recovery from TKIP MIC failures.

The Supplicant uses the MLME-SETKEYS.request primitive to configure the temporal key from 12.7.1 into its STA after sending message 4 to the Authenticator.

If the RSNE check for message 2 or message 3 fails, the SME should log an error and deauthenticate the peer.

12.7.6.7 Sample 4-way handshake

The following is a sample of a 4-way handshake for illustration.

After IEEE 802.1X authentication completes by the AP sending an EAP-Success, the AP initiates the 4-way handshake. See Figure 12-48.

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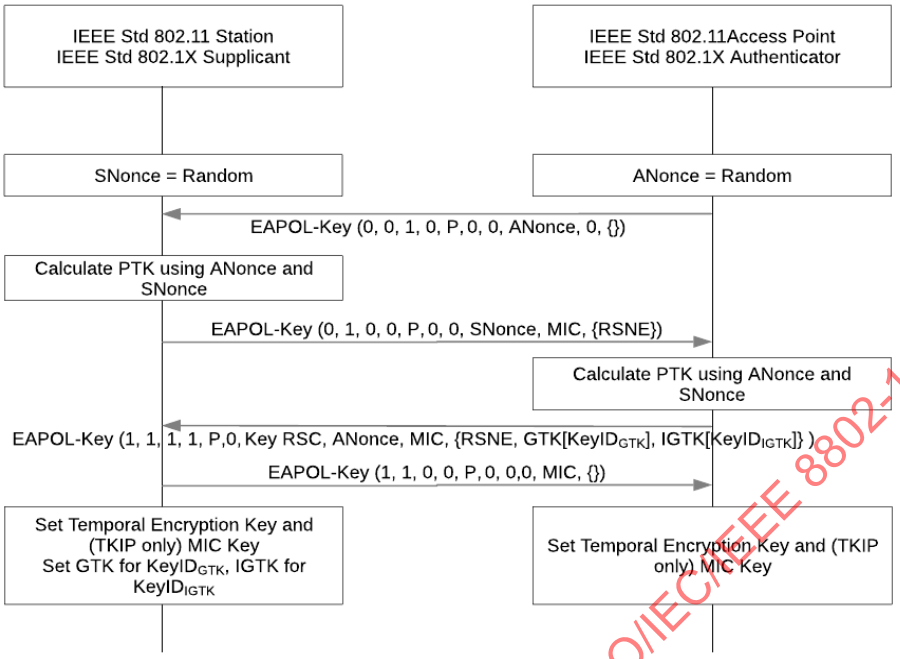

Figure 12-48—Sample 4-way handshake

The 4-way handshake consists of the following steps:

a) The Authenticator sends an EAPOL-Key frame containing an ANonce.

b) The Supplicant derives a PTK from ANonce and SNonce.

c) The Supplicant sends an EAPOL-Key frame containing SNonce, the RSNE from the (Re)Association Request frame, and a MIC.

d) The Authenticator derives PTK from ANonce and SNonce and validates the MIC in the EAPOL-Key frame.

e) The Authenticator sends an EAPOL-Key frame containing ANonce, the RSNE from its Beacon or Probe Response frames, the MIC, the GTK, an indication of whether to install the temporal keys, and if management frame protection is negotiated, the IGTK, and if beacon protection is enabled, the BIGTK.

f) The Supplicant sends an EAPOL-Key frame to confirm whether the temporal keys were installed.

12.7.6.8 4-way handshake analysis

The following is an analysis of the 4-way handshake.

This subclause makes the trust assumptions used in this protocol explicit. The protocol assumes the following:

— The PMK is known only by the Supplicant's STA and the Authenticator's STA.

— The Supplicant's STA uses IEEE 802 address SPA.

— The Authenticator's STA uses IEEE 802 address AA.

In many instantiations the RSNA architecture immediately breaks the first assumption because the IEEE 802.1X AS also knows the PMK. Therefore, additional assumptions are required:

— The AS does not expose the PMK to other parties.

— The AS does not masquerade as the Supplicant to the Authenticator.

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— The AS does not masquerade as the Authenticator to the Supplicant.
— The AS does not masquerade as the Supplicant's STA.
— The AS does not masquerade as the Authenticator's STA.

The protocol also assumes this particular Supplicant-Authenticator pair is authorized to know this PMK and to use it in the 4-way handshake. If any of these assumptions are broken, then the protocol fails to provide any security guarantees.

The protocol also assumes that the AS delivers the correct PMK to the AP with IEEE 802 address AA and that the STA with IEEE 802 address SPA hosts the Supplicant that negotiated the PMK with the AS. None of the protocols defined by this standard and IEEE Std 802.1X-2010 permit the AS, the Authenticator, the Supplicant, or either STA to verify these assumptions.

The PTK derivation step

PTK =PRF-Length(PMK, "Pairwise key expansion", Min(AA,SPA) || Max(AA,SPA) ||
Min(ANonce,SNonce) || Max(ANonce,SNonce))

performs a number of functions:

— Including the AA and SPA in the computation
  — Binds the PTK to the communicating STAs and
  — Prevents undetected man-in-the-middle attacks against 4-way handshake messages between the STAs with these two IEEE 802 addresses.
— If ANonce is randomly selected, including ANonce
  — Guarantees the STA at IEEE 802 address AA that PTK is fresh,
  — Guarantees that message 2 and message 4 are live, and
  — Uniquely identifies PTK as <AA, ANonce>.
— If SNonce is randomly selected, including SNonce
  — Guarantees the STA at IEEE 802 address SPA that PTK is fresh,
  — Guarantees that message 3 is live, and
  — Uniquely identifies PTK as <SPA, SNonce>.

Choosing the nonces randomly helps prevent precomputation attacks. With unpredictable nonces, a man-in-the-middle attack that uses the Supplicant to precompute messages to attack the Authenticator cannot progress beyond message 2, and a similar attack against the Supplicant cannot progress beyond message 3. The protocol might execute further before an error if predictable nonces are used.

Message 1 delivers ANonce to the Supplicant and initiates negotiation for a new PTK. It identifies AA as the peer STA to the Supplicant's STA. If an adversary modifies either of the addresses or ANonce, the Authenticator detects the result when validating the MIC in message 2. Message 1 does not carry a MIC, as it is impossible for the Supplicant to distinguish this message from a replay without maintaining state of all security associations through all time (PMK might be a static key).

Message 2 delivers SNonce to the Authenticator so it can derive the PTK. If the Authenticator selected ANonce randomly, message 2 also demonstrates to the Authenticator that the Supplicant is live, that the PTK is fresh, and that there is no man-in-the-middle attack, as the PTK includes the IEEE 802 MAC addresses of both. Inclusion of ANonce in the PTK derivation also protects against replay. The MIC prevents undetected modification of message 2 contents.

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Message 3 confirms to the Supplicant that there is no man-in-the-middle attack. If the Supplicant selected SNonce randomly, it also demonstrates that the PTK is fresh and that the Authenticator is live. The MIC again prevents undetected modification of message 3.

While message 4 serves no cryptographic purpose, it serves as an acknowledgment to message 3. It is required to inform the Authenticator that the Supplicant has installed the PTK and GTK and hence can receive encrypted frames.

The PTK and GTK are installed by using MLME-SETKEYS.request primitive after message 4 is sent. The PTK is installed before the GTK.

Then the 4-way handshake uses a correct, but unusual, mechanism to guard against replay. As noted earlier in this subclause, ANonce provides replay protection to the Authenticator, and SNonce to the Supplicant. In most session initiation protocols, replay protection is accomplished explicitly by selecting a nonce randomly and requiring the peer to reflect the received nonce in a response message. The 4-way handshake instead mixes ANonce and SNonce into the PTK, and replays are detected implicitly by MIC failures. In particular, the Key Replay Counter field serves no cryptographic purpose in the 4-way handshake. Its presence is not detrimental, however, and it plays a useful role as a minor performance optimization for processing stale instances of message 2. This replay mechanism is correct, but its implicit nature makes the protocol harder to understand than an explicit approach.

It is critical to the correctness of the 4-way handshake that at least one bit differs in each message. Within the 4-way handshake, message 1 can be recognized as the only one in which the Key MIC bit is 0, meaning message 1 does not include the MIC, while message 2 to message 4 do. Message 3 differs from message 2 by not asserting the Ack bit and from message 4 by asserting the Ack Bit. Message 2 differs from message 4 by including the RSNE.

Request messages are distinct from 4-way handshake messages because the former asserts the Request bit and 4-way handshake messages do not. Group key handshake messages are distinct from 4-way handshake messages because they assert a different key type.

12.7.7 Group key handshake

12.7.7.1 General

The Authenticator uses the Group key handshake to send a new GTK and, if management frame protection is negotiated, a new IGTK, and if beacon protection is enabled, a new BIGTK to the Supplicant.

The Authenticator may initiate the exchange when a Supplicant is disassociated or deauthenticated.

Message 1: Authenticator → Supplicant:

EAPOL-Key(1,1,1,0,G,0,Key RSC,0, MIC, {GTK[N], IGTK[M], BIGTK[Q]})

Message 2: Supplicant → Authenticator: EAPOL-Key(1,1,0,0,G,0,0,0,MIC,{})

The following apply:

— Key RSC denotes the last TSC or PN sent using the GTK.

— GTK[N] denotes the GTK with its key identifier as defined in 12.7.2 using the KEK defined in 12.7.1.3 and associated IV.

— IGTK[M], when present, denotes the IGTK with its key identifier as defined in 12.7.2 using the KEK defined in 12.7.1.3 and associated IV.

— BIGTK[Q], when present, denotes the BIGTK with its key identifier as defined in 12.7.2 using the KEK defined in 12.7.1.3 and associated IV.

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— The MIC is computed over the body of the EAPOL-Key frame (with the MIC field zeroed for the computation) using the KCK defined in 12.7.1.3.
— OCI KDE represents the current operating channel information using which the EAPOL-Key frame is sent. OCI KDE is included when dot11RSNAOperatingChannelValidationActivated is true on the STA sending the message.

The Supplicant may trigger a group key handshake by sending an EAPOL-Key frame with the Request bit set to 1 and the type of the Group Key bit.

An Authenticator shall do a 4-way handshake before a group key handshake if both are required to be done.

NOTE—The Authenticator cannot initiate the group key handshake until the 4-way handshake completes successfully.

If dot11RSNAOperatingChannelValidationActivated is true and a channel switch is requested while the handshake is in progress, the handshake should be aborted.

12.7.7.2 Group key handshake message 1

Message 1 uses the following values for each of the EAPOL-Key frame fields:

Descriptor Type = N – see 12.7.2
Key Information:
Key Descriptor Version = 1 (ARC4 encryption with HMAC-MD5) or 2 (NIST AES key wrap with HMAC-SHA-1-128) or 3 (NIST AES key wrap with AES-128-CMAC), in all other cases 0
Key Type = 0 (Group)
Install = 0
Key Ack = 1
Key MIC = 0 when using an AEAD cipher or 1 otherwise
Secure = 1
Error = 0
Request = 0
Encrypted Key Data = 1
Reserved = 0
Key Length = 0
Key Replay Counter = n+2
Key Nonce = 0
EAPOL-Key IV = 0 (Version 2) or random (Version 1)
Key RSC = last TSC or PN for the GTK
Key MIC = Not present when using an AEAD cipher; otherwise, MIC(KCK, EAPOL)
Key Data Length = length of Key Data field in octets
Key Data = encrypted, encapsulated
— GTK and the GTK's key identifier (see 12.7.2)
— When present, IGTK, IGTK's key identifier, and IPN (see 12.7.2)
— When present, BIGTK, BIGTK's key identifier, and BIPN (see 12.7.2)
— OCI KDE when dot11RSNAOperatingChannelValidationActivated is true on the Authenticator

The Authenticator sends message 1 to the Supplicant.

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On reception of message 1, the Supplicant:

a) Verifies that the Key Replay Counter field value has not yet been seen before, i.e., its value is strictly larger than that in any other EAPOL-Key frame received thus far during this session.

b) If dot11RSNAOperatingChannelValidationActivated is true and Authenticator RSNE indicates OCVC capability, the Supplicant silently discards message 1 if any of the following are true:

— OCI KDE is missing in the message

— Channel information in the OCI KDE does not match current operating channel parameters (see 12.2.9)

c) Verifies that the MIC is valid, i.e., it uses the KCK that is part of the PTK to verify that there is no data integrity error, or that the AEAD decryption steps succeed.

d) Uses the MLME-SETKEYS.request primitive to configure the temporal GTK and, the IGTK when present, and the BIGTK if beacon protection is enabled, into the MAC.

e) Responds by creating and sending message 2 of the group key handshake to the Authenticator and incrementing the replay counter.

NOTE—The Authenticator increments and uses a new Key Replay Counter field value on every message 1 instance, even retries, because the message 2 responding to an earlier message 1 might have been lost. If the Authenticator did not increment the replay counter, the Supplicant discards the retry, and no responding message 2 ever arrives.

12.7.7.3 Group key handshake message 2

Message 2 uses the following values for each of the EAPOL-Key frame fields:

Descriptor Type = N – see 12.7.2

Key Information:

Key Descriptor Version = 1 (ARC4 encryption with HMAC-MD5) or 2 (NIST AES key wrap with HMAC-SHA-1-128) or 3 (NIST AES key wrap with AES-128-CMAC), in all other cases 0 – same as message 1

Key Type = 0 (Group) – same as message 1

Install = 0

Key Ack = 0

Key MIC = 0 when using an AEAD cipher or 1 otherwise

Secure = 1

Error = 0

Request = 0

Encrypted Key Data = 1 when using an AEAD cipher or 0 otherwise

Reserved = 0

Key Length = 0

Key Replay Counter = n+2 – same as message 1

Key Nonce = 0

EAPOL-Key IV = 0

Key RSC = 0

Key MIC = Not present when using an AEAD cipher; otherwise, MIC(KCK, EAPOL)

Key Data Length = length of Key Data field in octets

Key Data = OCI KDE when dot11RSNAOperatingChannelValidationActivated on the Authenticator

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On reception of message 2, the Authenticator:

a) Verifies that the Key Replay Counter field value matches one it has used in the group key handshake.

b) If dot11RSNAOperatingChannelValidationActivated is true and Supplicant RSNE indicates OCVC capability, the Authenticator silently discards message 2 if any of the following are true:
   — OCI KDE is missing in the message
   — Channel information in the OCI KDE does not match current operating channel parameters (see 12.2.9)

c) Verifies that the MIC is valid, i.e., it uses the KCK that is part of the PTK to verify that there is no data integrity error, or that the AEAD decryption steps succeed.

12.7.7.4 Group key handshake implementation considerations

If the Authenticator does not receive a reply to its messages, its shall attempt dot11RSNAConfigGroupUpdateCount transmits of the message, plus a final timeout. The retransmit timeout value shall be 100 ms for the first timeout, half the listen interval for the second timeout, and the listen interval for subsequent timeouts. If there is no listen interval or the listen interval is zero, then 100 ms shall be used for all timeout values. If it still has not received a response after this, then the Authenticator's STA should use the MLME-DEAUTHENTICATE.request primitive to deauthenticate the STA.

To prevent key reinstallation attacks, the Supplicant shall maintain a copy of the most recent GTK, most recent IGTK, and most recent BIGTK, installed as a result of receipt of EAPOL-Key frames. The Supplicant shall not install a GTK, an IGTK or a BIGTK when the key to be set matches either of these two keys (see 6.3.19).

12.7.7.5 Sample group key handshake

The following is a sample of a group key handshake for illustration.

The state machines in 12.7.9 and 12.7.10 change the GTK and, when present, IGTK in use by the network. See Figure 12-49.

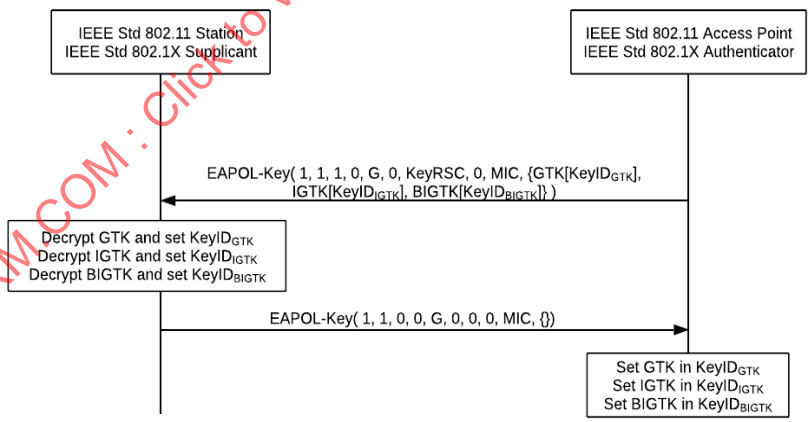

Figure 12-49—Sample group key handshake

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The following steps occur:

a) The Authenticator generates a new GTK, a new IGTK and when management frame protection has been negotiated, and a new BIGTK when beacon protection is enabled. It encapsulates the GTK, as necessary, the IGTK, and the BIGTK. It sends an EAPOL-Key frame containing the GTK, IGTK and BIGTK (message 1), along with the last TSC or PN used with the GTK (RSC), the last IPN used with the IGTK and the last BIPN used with the BIGTK.

b) On receiving the EAPOL-Key frame, the Supplicant validates the MIC, decapsulates the GTK, the IGTK when present and the BIGTK when present, and uses the MLME-SETKEYS.request primitive to configure the GTK, PN, IGTK, RSC, IPN, BIGTK and BIPN in its STA.

c) The Supplicant then constructs and sends an EAPOL-Key frame in acknowledgment to the Authenticator.

d) On receiving the EAPOL-Key frame, the Authenticator validates the MIC. If the GTK, the IGTK, if present, and the BIGTK, if present, have not yet been configured using the MLME-SETKEYS.request primitive, after the Authenticator has delivered the GTK, IGTK and BIGTK to all associated STAs, it uses the MLME-SETKEYS.request primitive to configure them.

12.7.8 TDLS PeerKey (TPK) security protocol

12.7.8.1 General

The TPK security protocol is executed between the two non-AP STAs that intend to establish an RSNA for direct-link communication. If any security method (pre-RSNA or RSNA) is enabled on the connection between a STA and the AP, the STA shall require that the TPK security protocol complete successfully before using a direct link. If no security method is enabled on the connection between a STA and the AP, the STA shall not use the TPK security protocol on the direct link. A STA may refuse to set up a TDLS link when the protection on the STA link to the AP is secured with a weak algorithm or when the link between the STA and the AP is not using any security.

12.7.8.2 TPK handshake

The TPK handshake occurs as part of the TDLS direct-link setup procedure. The TPKSA is the result of the successful completion of the TPK handshake protocol, which derives keys for providing confidentiality and data origin authentication.

In order to maintain TPK confidentiality, both the TDLS initiator STA and the TDLS responder STAs establish an RSNA with their common AP prior to executing the TPK handshake. To meet this criterion, a STA may refuse to initiate the TDLS direct link if:

a) The AP does not include an RSNE in its Beacon and Probe Response frames to advertise the availability of security;

b) The AP's RSNE indicates that WEP-40 (OUI 00-0F-AC:1) or WEP-104 (OUI 00-0F-AC:5) are enabled as either pairwise or group cipher suites; or

c) The AP's RSNE indicates that Use group cipher suite (00-0F-AC:0) is used as the pairwise cipher suite.

Violation of any of these cases would cause the TPK handshake to leak the TPK.

The TDLS initiator STA and the TDLS responder STA perform the following exchange to set up a TPK:

TDLS PMK handshake message 1: TDLS initiator STA → TDLS responder STA:

Link Identifier element, RSNE, Timeout Interval element, FTE

TDLS PMK handshake message 2: TDLS responder STA → TDLS initiator STA:

Link Identifier element, RSNE, Timeout Interval element, FTE

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TDLS PMK handshake message 3: TDLS initiator STA → TDLS responder STA:
Link Identifier element, RSNE, Timeout Interval element, FTE

where

TDLS initiator STA Address field of the Link Identifier element	is the MAC address of the TDLS initiator STA
TDLS responder STA Address field of the Link Identifier element	is the MAC address of the TDLS responder STA
TimeoutIntervalType field of the Timeout Interval element	is the key lifetime
PairwiseCipherSuite field of the RSNE	identifies the cipher suite used to protect the Data frames sent over the direct link
AKM suite list of the RSNE	identifies which Authentication Method was used
SNonce field of the FTE	is a 256 bit value randomly generated by the TDLS initiator STA
ANonce field of the FTE	is a 256 bit value randomly generated by the TDLS responder STA (set to 0 in message 1)
MIC field of the FTE	is 0 for message 1 and computed as described in 12.7.8.4.3 and 12.7.8.4.4 for messages 2 and 3, respectively

The TDLS PMK handshake message 1 shall be transmitted in the TDLS Setup Request frame.

TDLS PMK handshake message 2 shall be transmitted in the TDLS Setup Response frame.

TDLS PMK handshake message 3 shall be transmitted in the TDLS Setup Confirm frame.

The TPK shall be derived as follows:

TPK-Key-Input = Hash(min (SNonce, ANonce) || max (SNonce, ANonce))
TPK = KDF-Hash-Length(TPK-Key-Input, "TDLS PMK", min (MAC_I, MAC_R)
|| max (MAC_I, MAC_R) || BSSID)

where

Hash	is the hash algorithm specific to the negotiated AKM (see Table 9-151)
KDF-Hash-Length	is the key derivation function defined in 12.7.1.6.2
Length	is TK_bits + 128
TK_bits	is cipher-suite dependent and specified in Table 12-7
MAC_I and MAC_R	are the MAC addresses of the TDLS initiator STA and the TDLS responder STA, respectively
SNonce and ANonce	are the nonces generated by the TDLS initiator STA and TDLS responder STA, respectively, for this instance of the TPK handshake. The BSSID is set to the BSSID of the BSS of which the TDLS initiator STA is a member.

Each TPK has two component keys—TPK-KCK and TPK-TK, defined as follows:

The Key Confirmation Key (KCK) shall be computed as the first 128 bits (i.e., bits 0–127) of the TPK.

TPK-KCK = L(TPK, 0, 128)

The KCK is used to provide data origin authenticity in TDLS Setup Response and TDLS Setup Confirm frames.

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The temporal key (TK) shall be computed as the remaining bits (for CCMP-128, the second 128 bits, i.e., bits 128–255) of the TPK

TPK-TK = L(TPK, 128, Length – 128)

The TPK-TK is used to provide confidentiality for direct-link data.

The temporal key is configured into the STA by the SME through the use of the MLME-SETKEYS.request primitive.

12.7.8.3 TPK handshake security assumptions

The security of the TDLS PMK handshake depends on the following:

a) The TDLS initiator STA and the TDLS peer STA each have an RSNA established with the AP that is being used for TDLS Setup.
b) The AP does not expose the nonces exchanged by the TDLS initiator STA and the TDLS responder STA to any external party.
c) The AP does not use these nonces to derive the TPK and attack the TDLS direct-link instance.
d) TDLS message security (encryption and integrity computations) processing at the AP is protected from illegal eavesdropping, alterations, insertions and substitutions.
e) The TDLS initiator STA and TDLS responder STAs do not expose SNonce, ANonce, or the derived key to a third party.
f) The TDLS initiator STA and the TDLS peer STA are associated to the same AP.

12.7.8.4 TPK Security Protocol handshake messages

12.7.8.4.1 Overview

The TPK handshake consists of three messages. Each message comprises a number of elements and is included in the TDLS Setup Request, TDLS Setup Response, and TDLS Setup Confirm.

In an RSN, these handshake messages serve to provide a session identifier, are identified by the nonces, and are used as association instance identifiers. These nonces are chosen randomly or pseudorandomly, and are used to generate the TPK.

12.7.8.4.2 TPK handshake message 1

If security is required on the TDLS direct link (see 12.7.8.1), the TDLS initiator STA shall add an RSNE, FTE, and Timeout Interval element to its TDLS Setup Request frame. The elements shall be formatted as follows:

The RSNE, if present, shall be set as follows:

Version shall be set to 1.

The pairwise cipher suite list field indicating the pairwise cipher suites the TDLS initiator STA is willing to use with the TPKSA. WEP-40, WEP-104, and TKIP shall not be included in this list.

The group cipher suite shall be set to 00-0F-AC:7.

The AKM suite count field shall be set to 1.

The AKM suite list field shall be set to indicate TPK handshake (00-0F-AC:7).

In the RSN Capabilities field, the No Pairwise subfield shall be set to 0 and the PeerKey Enabled subfield shall be set to 1.

PMKID Count subfield, if present, shall be set to 0.

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PMKID list shall not be present.

The Group Management Cipher Suite subfield, if present, shall be set to 00-0F-AC:7.

The Timeout Interval element indicates the lifetime of the TPKSA. The Lifetime Interval Type shall be set to 2 (Key Lifetime Interval). The minimum lifetime shall be 300 seconds.

The FTE shall be set as follows:

SNonce shall be set to a value chosen randomly by the TDLS initiator STA, see 12.7.5 for a recommended procedure.

All other fields shall be set to 0.

The TDLS initiator STA sends message 1 to the TDLS responder STA.

On reception of message 1, the TDLS responder STA checks whether the RSNE is present.

If security is not required on the TDLS direct link (see 12.7.8.1), it shall reject the request with status code SECURITY_DISABLED.

If security is required on the TDLS direct link (see 12.7.8.1), it checks whether the request includes an RSNE and FTE. If not, the TDLS responder STA shall reject the request with status code INVALID_PARAMETERS.

If the version field of the RSNE is 0, then the TDLS responder STA shall reject the request with status code UNSUPPORTED_RSNE_VERSION.

Otherwise, the TDLS responder STA processes the message as follows:

If the contents of the RSNE do not indicate AKM of TPK handshake (suite type 00-0F-AC:7), the TDLS responder STA shall reject the request with status code STATUS_INVALID_AKMP.

If none of the pairwise cipher suites are acceptable, or pairwise ciphers include WEP-40, WEP-104, or TKIP, then the TDLS responder STA shall reject the TDLS Setup Request frame with status code STATUS_INVALID_PAIRWISE_CIPHER.

If the RSN Capabilities field has not set the subfields according to the described rules for this message, then the TDLS responder STA rejects with status code INVALID_RSNE_CAPABILITIES.

If the suggested lifetime is unacceptable or below the default value, the TDLS responder STA shall reject the TDLS Setup Request frame with status code UNACCEPTABLE_LIFETIME.

If the contents of the FTE are not as per specified for this message, then the TDLS responder STA shall reject the TDLS Setup Request frame with status code STATUS_INVALID_FTE.

The TDLS responder STA shall ignore the remaining fields in the RSNE, FTE, and Timeout Interval element.

Otherwise, the TDLS responder STA shall respond as specified in 11.20.4.

12.7.8.4.3 TPK handshake message 2

If the TDLS responder STA validates the TPK handshake message 1 for this TDLS instance, the TDLS responder STA may respond with TPK handshake message 2. To do so, the TDLS responder STA shall add an RSNE, FTE, and Timeout Interval element to its TDLS Setup Response frame. The elements shall be formatted as follows:

The RSNE shall include the following:

Include a pairwise cipher suite from one of those presented in RSNE of message 1 of this sequence in the pairwise cipher suite list, and set the pairwise cipher suite count to 1.

The version number shall be the minimum of the maximum version supported by the TDLS responder STA and the version number received in the RSNE of message 1.

All other RSNE fields shall be same as those received in message 1.

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The Timeout Interval element shall be the same as that received in the TPK handshake message 1.

The FTE shall include the following:

ANonce shall be set to a value chosen randomly by the TDLS responder STA, see 12.7.5 for a recommended procedure.

SNonce shall be same as that received in message 1 of this sequence

The MIC shall be calculated on the concatenation, in the following order, of:

TDLS initiator STA MAC address (6 octets)

TDLS responder STA MAC address (6 octets)

Transaction Sequence number (1 octet) which shall be set to the value 2

Link Identifier element

RSNE

Timeout Interval element

FTE, with the MIC field of the FTE set to 0.

The MIC shall be calculated using the TPK-KCK and the AES-128-CMAC algorithm. The output of the AES-128-CMAC shall be 128 bits.

All other fields shall be set to 0.

The TDLS responder STA shall use the MLME-SETKEYS.request primitive to configure the Temporal Key into its STA prior to sending message 2.

The TDLS responder STA sends message 2 to the TDLS initiator STA. The TDLS initiator STA shall process message 2 as follows:

If the TDLS initiator STA Address and TDLS responder STA Address of the Link Identifier element do not match those for an outstanding TDLS Setup Request, the TDLS initiator STA shall silently discard the received TDLS Setup Response frame.

If the SNonce field of the FTE does not match that of an outstanding request to the TDLS responder STA, then the TDLS initiator STA shall silently discard the received TDLS Setup Response frame.

Otherwise, the TDLS initiator STA shall compute the TPK and then validate the MIC in the FTE as specified in MIC calculation procedure for TPK handshake message 2. If invalid, the TDLS initiator STA shall discard the message.

If the version of the RSNE is 0 or is greater than the version of the RSNE sent in message 1, then the TDLS initiator STA shall reject the response with status code UNSUPPORTED_RSNE_VERSION. Otherwise,

If the contents of the RSNE, with the exception of the pairwise cipher suite count and pairwise cipher suite list are not the same as those sent by the TDLS initiator STA in message 1 of this sequence, then the TDLS initiator STA shall reject the response with status code INVALID_RSNE.

If the pairwise cipher suite count is other than 1, then the TDLS initiator STA shall reject the response with status code STATUS_INVALID_PAIRWISE_CIPHER.

If the selected pairwise cipher suite was not included in the Initiator's request, then the TDLS initiator STA shall reject the TDLS Setup Response frame with status code STATUS_INVALID_PAIRWISE_CIPHER.

If the Timeout Interval element is not the same as that sent in message 1, the TDLS initiator STA shall reject the TDLS Setup Response frame with status code UNACCEPTABLE_LIFETIME.

If the BSSID in the Link Identifier element is different from the one sent in message 1, then the TDLS initiator STA shall reject the response with status code NOT_IN_SAME_BSS.

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If the TDLS initiator STA validates TDLS message 2, the TDLS initiator STA shall create a TPKSA and respond with message 3 as defined in 11.20.4. The TDLS initiator STA shall use the MLME-SETKEYS.request primitive to configure the Temporal Key into its STA prior to sending message 3.

12.7.8.4.4 TPK handshake message 3

If the TDLS initiator STA responds to message 2 for this TDLS instance, the TDLS initiator STA shall add an RSNE, FTE, and Timeout Interval element to its TDLS Setup Confirm frame. The elements shall be formatted as follows:

The RSNE shall be the same as the RSNE received in message 2.

The Timeout Interval element shall be the same as that received in the TPK handshake message 2.

With the exception of the MIC field, the contents of the FTE shall be the same as the FTE received in message 2.

The MIC shall be calculated on the concatenation, in the following order, of:

TDLS initiator STA MAC address (6 octets)

TDLS responder STA MAC address (6 octets)

Transaction Sequence number (1 octet), which shall be set to the value 3

Link Identifier element

RSNE

Timeout Interval element

FTE, with the MIC field of the FTE set to 0.

The MIC shall be calculated using the TPK-KCK and the AES-128-CMAC algorithm. The output of the AES-128-CMAC shall be 128 bits.

All other fields shall be set to 0.

The TDLS initiator STA sends message 3 to the TDLS responder STA. The TDLS responder STA shall process message 3 as follows:

Confirm that the Source and Destination Address of the Link Identifier element match those for an outstanding TDLS Setup Request;

Confirm that the ANonce and SNonce fields of the FTE match that of an outstanding request to the TDLS initiator STA;

Validate the MIC in the FTE as specified in the MIC calculation procedure for TPK handshake message 3.

If any of the above conditions are not met, the TDLS responder STA shall discard the message. If the above conditions are met, the TDLS responder STA shall:

Validate that the contents of the RSNE received in message 3 are the same as the RSNE sent by the TDLS responder STA in message 2;

Confirm that the Timeout Interval element is the same as that sent in message 2;

Confirm that the BSSID from the Link Identifier element is the same as that sent in message 2.

If any one of the above conditions are not met, the TDLS responder STA shall discard the message and abandon the TPK handshake identified by <ANonce, SNonce> combination, and delete any state resulting from the existing TPK handshake for this sequence.

On successful processing of message 3, the TPK handshake is considered successful.

If the TDLS responder STA does not receive a valid TPK handshake message 3 from the TDLS initiator STA within dot11TDLSResponseTimeout, the TDLS responder STA shall abandon the TPK handshake and delete any state resulting from the TPK handshake.

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12.7.9 RSNA Supplicant key management state machine

12.7.9.1 General

The Supplicant shall reinitialize the Supplicant state machine whenever its system initializes. A Supplicant enters the AUTHENTICATION state on an event from the MAC that requests another STA to be authenticated. A Supplicant enters the STAKEYSTART state on receiving an EAPOL-Key frame from the Authenticator. If the MIC or any of the EAPOL-Key frames fails, the Supplicant silently discards the frame. Figure 12-50 depicts the RSNA Supplicant state machine.

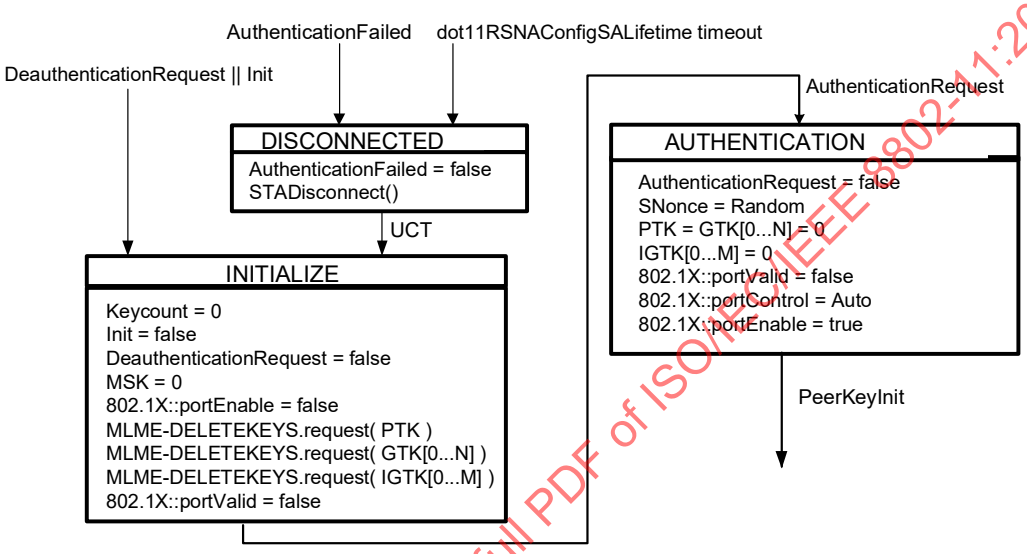

Figure 12-50—RSNA Supplicant key management state machine

Unconditional transfer (UCT) means the event triggers an immediate transition.

This state machine does not use timeouts or retries. The IEEE 802.1X state machine has timeouts that recover from authentication failures, etc.

In order to authenticate an Authenticator, the management entity sends an authentication request event. This might be before or after the STA associates to the AP. In an IBSS environment, the event is generated when a Probe Response frame is received.

12.7.9.2 Supplicant state machine states

The following list summarizes the states of the Supplicant state machine:

— **AUTHENTICATION**: A Supplicant enters this state when it sends an IEEE 802.1X AuthenticationRequest to authenticate to an SSID.

— **DISCONNECTED**: A Supplicant enters this state when IEEE 802.1X authentication fails. The Supplicant executes StaDisconnect and enters the INITIALIZE state.

— **INITIALIZE**: A Supplicant enters this state from the DISCONNECTED state, when it receives Disassociation or Deauthentication messages or when the STA initializes, causing the Supplicant to initialize the key state variables.

— **STAKEYSTART:** A Supplicant enters this state when it receives an EAPOL-Key frame. All the information to process the EAPOL-Key frame is in the message and is described in the StaProcessEAPOL-Key procedure.

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12.7.9.3 Supplicant state machine variables

The following list summarizes the variables used by the Supplicant state machine:

— *DeauthenticationRequest.* The Supplicant sets this variable to true if the Supplicant's STA reports it has received Disassociation or Deauthentication messages.

— *AuthenticationRequest.* The Supplicant sets this variable to true if its STA's IEEE 802.11 management entity reports that an SSID is to be authenticated. This might be on association or at other times.

— *AuthenticationFailed*. The Supplicant sets this variable to true if the IEEE 802.1X authentication failed. The Supplicant uses the MLME-DISASSOCIATE.request primitive to cause its STA to disassociate from the Authenticator's STA.

— *EAPOLKeyReceived.* The Supplicant sets this variable to true when it receives an EAPOL-Key frame.

— *IntegrityFailed.* The Supplicant sets this variable to true when its STA reports that a fatal data integrity error (e.g., michael failure) has occurred.

NOTE—A michael failure is not the same as MICVerified because IntegrityFailed is generated if the michael integrity check fails; MICVerified is generated from validating the EAPOL-Key integrity check. Note also the STA does not generate this event for ciphers other than TKIP because countermeasures are not required.

— *MICVerified*. The Supplicant sets this variable to true if the MIC on the received EAPOL-Key frame verifies as correct or if the AEAD cipher is used and the AEAD decryption steps succeed. The Supplicant silently discards any EAPOL-Key frame received with an invalid MIC.

— *SNonce.* This variable represents the Supplicant's nonce.

— *PTK.* This variable represents the current PTK.

— *TPTK.* This variable represents the current PTK until message 3 of the 4-way handshake arrives and is verified.

— *GTK[].* This variable represents the current GTKs for each group key index.

— *IGTK[].* This variable represents the current IGTKs for each group management key index.

— *PMK.* This variable represents the current PMK.

— *keycount*. This variable is used in an IBSS to decide when all of the keys have been delivered and an IBSS link is secure.

— *802.1X::XXX.* This variable denotes another IEEE 802.1X state variable *XXX* not specified in this standard.

12.7.9.4 Supplicant state machine procedures

The following list summarizes the procedures used by the Supplicant state machine:

— **STADisconnect.** The Supplicant invokes this procedure to disassociate and deauthenticate its STA from the AP.

— **MIC**(*x*). The Supplicant invokes this procedure to compute a MIC of the data *x*.

— **CheckMIC**(). he Supplicant invokes this procedure to verify a MIC computed by the MIC() function.

— **StaProcessEAPOL-Key.** The Supplicant invokes this procedure to process a received EAPOL-Key frame. The pseudocode for this procedure is as follows:

StaProcessEAPOL-Key (*S*, *M*, *A*, *I*, *K*, *RSC*, *ANonce*, RSC, *MIC*, {RSNE, *GTK*[*N*], *IGTK*[*M*], IPN})

TPTK ← PTK
TSNonce ← 0
PRSC ← 0

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```
UpdatePTK ← 0
State ← UNKNOWN
if M = 1 then
    if Check MIC(PTK, EAPOL-Key frame) fails then
        State ← FAILED
    else
        State ← MICOK
    endif
endif
if K = P then
    if State ≠ FAILED then
        if PSK exists then – PSK is a preshared key
            PMK ← PSK
        else
            PMK ← L(MSK, 0, PMK_bits)
        endif
        TSNonce ← SNonce
        if ANonce ≠ PreANonce then
            TPTK ← Calc PTK(PMK, ANonce, TSNonce)
            PreANonce ← ANonce
        endif
        if State = MICOK then
            PTK ← TPTK
            UpdatePTK ← I
            if UpdatePTK = 1 then
                if no GTK then
                    PRSC ← RSC
                endif
                if MLME-SETKEYS.request(0, true, PRSC, PTK) fails then
                    invoke MLME-
                    DEAUTHENTICATE.request
                endif
                MLME-SETPROTECTION.request(TA, Rx)
            endif
            if GTK then
                if (GTK[N] ← Decrypt GTK) succeeds then
                    if MLME-SETKEYS.request(N, 0, RSC, GTK[N]) fails then
                        invoke MLME-DEAUTHENTICATE.request
                    endif
                else
                    State ← FAILED
                endif
            endif
            if IGTK then
                if (IGTK[M] ← Decrypt IGTK) succeeds then
                    if MLME-SETKEYS.request(M, 0, IPN, IGTK[M]) fails then
                        invoke MLME-DEAUTHENTICATE.request
                    endif
                else
                    State ← FAILED
                endif
            endif
        endif
    endif
```

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```
else if KeyData = GTK then
    if State = MICOK then
        if (GTK[N] ← Decrypt GTK) succeeds then
            if MLME-SETKEYS.request(N, T, RSC, GTK[N]) fails then
                invoke MLME-DEAUTHENTICATE.request
            endif
        else
            State ← FAILED
        endif
        if (IGTK[M] ← Decrypt IGTK) succeeds then
            if MLME-SETKEYS.request(M, T, IPN, IGTK[M]) fails then
                invoke MLME-DEAUTHENTICATE request
            endif
        else
            State ← FAILED
        endif
    else
        State ← FAILED
    endif
endif
if A = 1 && State ≠ Failed then
    Send EAPOL-Key(0,1,0,0,K,0,0,TSNonce,MIC(TPTK),{RSNE})
endif
if UpdatePTK = 1 then
    MLME-SETPROTECTION.request(TA, Rx_Tx)
endif
if State = MICOK && S = 1 then
    MLME-SETPROTECTION.request(TA, Rx_Tx)
    if IBSS then
        keycount++
        if keycount = 2 then
            802.1X::portValid← true
        endif
    else
        802.1X::portValid← true
    endif
endif
```

Here UNKNOWN, MICOK, and FAILED are values of the variable State used in the Supplicant pseudocode. State is used to decide how to do the key processing. MICOK is set to 1 when the MIC of the EAPOL-Key has been checked and is valid. FAILED is used when a failure has occurred in processing the EAPOL-Key frame. UNKNOWN is the initial value of the variable State.

When processing 4-way handshake message 3, the GTK, IGTK and BIGTK if present are decrypted from the EAPOL-Key frame and installed. The PTK shall be installed before the GTK and IGTK.

The Key Replay Counter field used by the Supplicant for EAPOL-Key frames that are sent in response to an EAPOL-Key frame shall be the received Key Replay Counter field. Invalid EAPOL-Key frames such as invalid MIC, GTK without a MIC, etc., shall be ignored.

NOTE 1—TPTK is used to stop attackers changing the PTK on the Supplicant by sending the first message of the 4-way handshake. An attacker can still affect the 4-way handshake while the 4-way handshake is being carried out.

NOTE 2—The PMK is supplied by the authentication method used with IEEE Std 802.1X-2010 if preshared mode is not used.

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NOTE 3—A PTK is configured into the encryption/integrity engine depending on the Tx/Rx bit, but if configured, is always a transmit key. A GTK is configured into the encryption/integrity engine independent of the state of the Tx/Rx bit, but whether the GTK is used as a transmit key is dependent on the state of the Tx/Rx bit.

— **CalcGTK**(x). Generates the GTK.
— **DecryptGTK**(x). Decrypt the GTK from the EAPOL-Key frame.
— **DecryptIGTK**(x). Decrypt the IGTK from the EAPOL-Key frame.

12.7.10 RSNA Authenticator key management state machine

12.7.10.1 General

There is one state diagram for the Authenticator. In an infrastructure BSS, the Authenticator is always on the AP; and in an IBSS environment, the Authenticator is on every STA.

The state diagram shown in parts in Figure 12-51 to Figure 12-54 consists of the following states:

a) The AUTHENTICATION, AUTHENTICATION2, INITPMK, INITPSK, PTKSTART, PTKCALCNEGOTIATING, PTKCALCNEGOTIATING2, PTKINITNEGOTIATING, PTKINITDONE, DISCONNECT, DISCONNECTED, and INITIALIZE states. These states handle the initialization, 4-way handshake, teardown, and general clean-up. These states are per associated STA.
b) The IDLE, REKEYNEGOTIATING, KEYERROR, and REKEYESTABLISHED states. These states handle the transfer of the GTK to the associated client. These states are per associated STA.
c) The GTK_INIT, SETKEYS, and SETKEYSDONE states. These states change the GTK when required, trigger all of the PTK group key state machines, and update the IEEE 802.11 MAC in the Authenticator's AP when all STAs have the updated GTK. These states are global to the Authenticator.

Because there are two GTKs, responsibility for updating these keys is given to the group key state machine (see Figure 12-53). In other words, this state machine determines which GTK is in use at any time.

When a second STA associates, the group key state machine is already initialized, and a GTK is already available and in use.

When the GTK is to be updated the variable GTKReKey is set to 1. The SETKEYS state updates the GTK and triggers all of the PTK group key state machines that currently exist—one per associated STA. Each PTK group key state machine sends the GTK to its STA. When all of the STAs have received the GTK (or failed to receive the key), the SETKEYSDONE state is executed which updates the APs encryption/integrity engine with the new key.

Both the PTK state machine and the PTK group key state machine use received EAPOL-Key frames as an event to change states. The PTK state machine only uses EAPOL-Key frames with the Key Type field equal to Pairwise, and the PTK group key state machine only uses EAPOL-Key frames with the Key Type field equal to Group.

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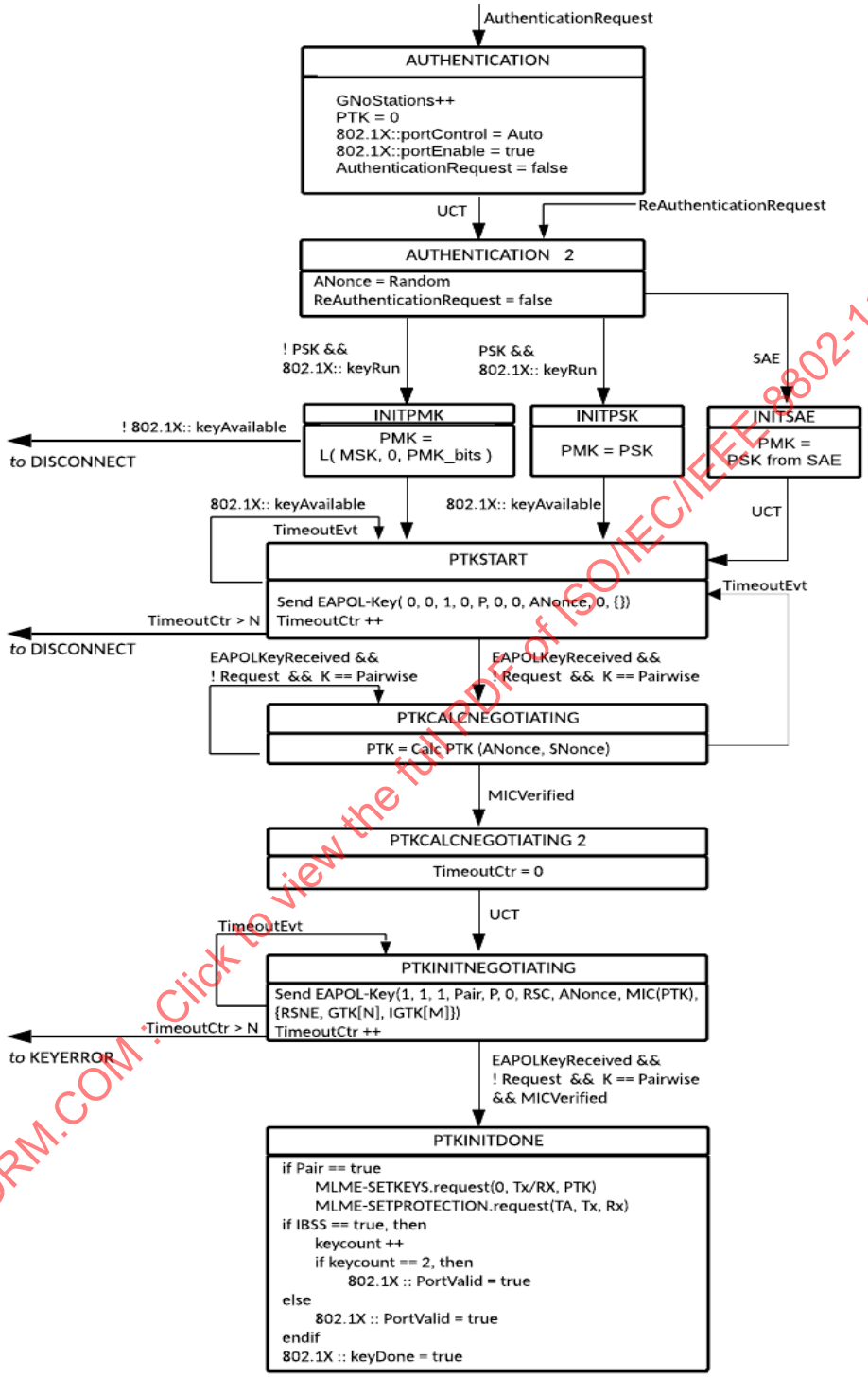

Figure 12-51—Authenticator state machines, part 1

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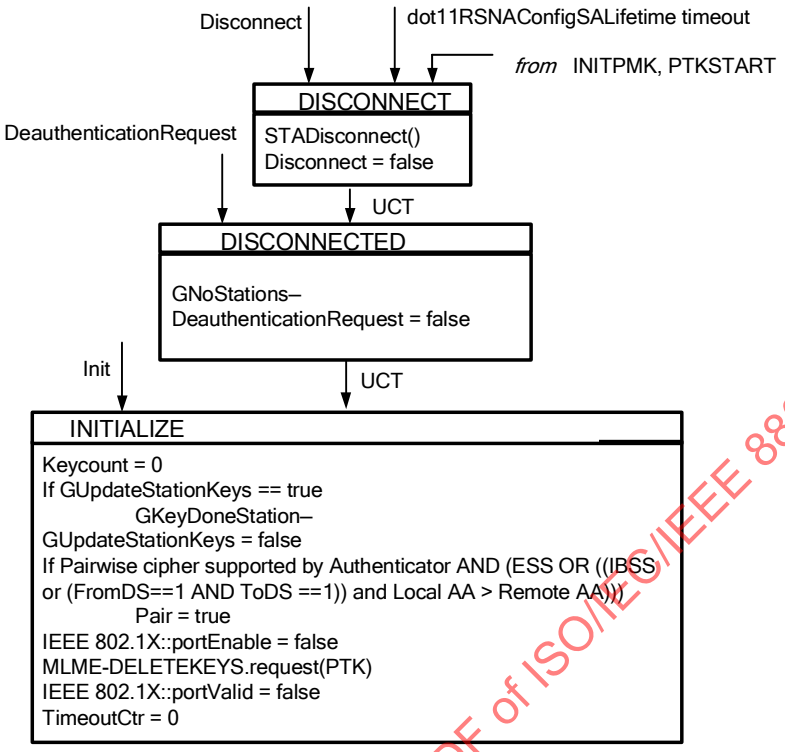

Figure 12-52—Authenticator state machines, part 2

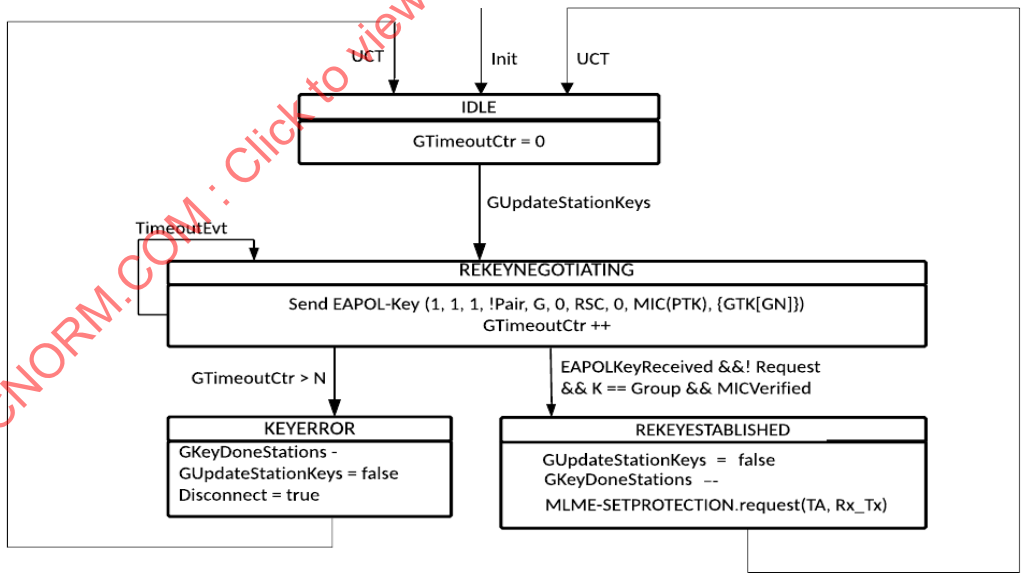

Figure 12-53—Authenticator state machines, part 3

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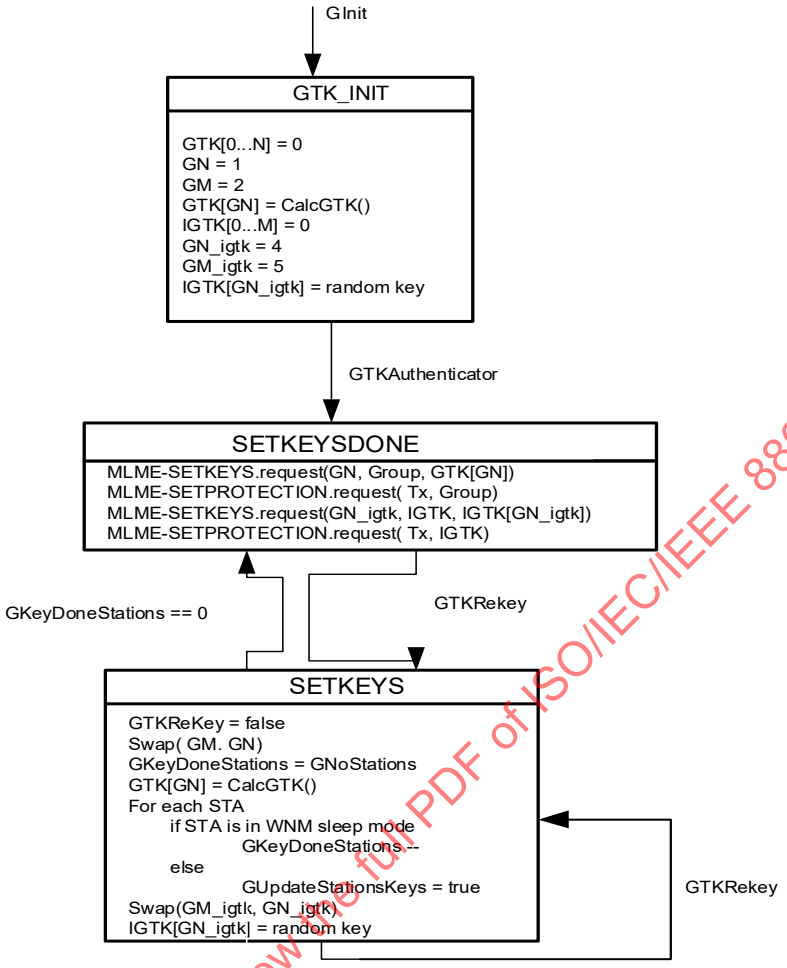

Figure 12-54—Authenticator state machines, part 4

12.7.10.2 Authenticator state machine states

12.7.10.2.1 Authenticator state machine: 4-way handshake (per STA)

The following list summarizes the states the Authenticator state machine uses to support the 4-way handshake:

— **AUTHENTICATION**: This state is entered when an AuthenticationRequest is sent from the management entity to authenticate a BSSID.

— **AUTHENTICATION2**: This state is entered from the AUTHENTICATION state or from the PTKINITDONE state.

— **DISCONNECT**: This state is entered if an EAPOL-Key frame is received and fails its MIC check. It sends a Deauthentication message to the STA and enters the INITIALIZE state.

— **DISCONNECTED**: This state is entered when Disassociation or Deauthentication messages are received.

— **INITIALIZE**: This state is entered from the DISCONNECTED state, when a deauthentication request event occurs, or when the STA initializes. The state initializes the key state variables.

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— **INITPMK**: This state is entered when the IEEE 802.1X backend AS completes successfully. If a PMK is supplied, it goes to the PTKSTART state; otherwise, it goes to the DISCONNECTED state.
— **INITPSK:** This state is entered when a PSK is configured.
— **INITSAE:** This state is entered when SAE authentication is completed successfully.
— **PTKCALCNEGOTIATING:** This state is entered when the second EAPOL-Key frame for the 4-way handshake is received with the key type of Pairwise.
— **PTKCALNEGOTIATING2:** This state is entered when the MIC for the second EAPOL-Key frame of the 4-way handshake is verified.
— **PTKINITNEGOTIATING:** This state is entered when the MIC for the second EAPOL-Key frame for the 4-way handshake is verified. When message 3 of the 4-way handshake is sent in state PTKINITNEGOTIATING, the wrapped GTK shall be sent at the end of the data field, and the GTK length is put in the GTK Length field.
— **PTKINITDONE:** This state is entered when the last EAPOL-Key frame for the 4-way handshake is received with the key type of Pairwise. This state may call SetPTK; if this call fails, the AP should detect and recover from the situation, for example, by doing a disconnect event for this association.
— **PTKSTART:** This state is entered from INITPMK, INITPSK, or INITSAE to start the 4-way handshake or if no response to the 4-way handshake occurs.

12.7.10.2.2 Authenticator state machine: group key handshake (per STA)

The following list summarizes the states the Authenticator state machine uses to support the group key handshake:

— **IDLE:** This state is entered when no group key handshake is occurring.
— **KEYERROR:** This state is entered if the EAPOL-Key acknowledgment for the group key handshake is not received.
— **REKEYESTABLISHED:** This state is entered when an EAPOL-Key frame is received from the Supplicant with the Key Type subfield equal to Group.
— **REKEYNEGOTIATING:** This state is entered when the GTK is to be sent to the Supplicant.

NOTE—The Rx_Tx flag for sending a GTK is always the opposite of whether the pairwise key is used for data encryption/integrity or not. If a pairwise key is used for encryption/integrity, then the STA never transmits with the GTK; otherwise, the STA uses the GTK for transmit.

12.7.10.2.3 Authenticator state machine: group key handshake (global)

The following list summarizes the states the Authenticator state machine uses to coordinate a group key update of all STAs:

— **GTK_INIT:** This state is entered on system initialization.
— **SETKEYS:** This state is entered if the GTK is to be updated on all Supplicants.
— **SETKEYSDONE:** This state is entered if the GTK has been updated on all Supplicants.

NOTE—SETKEYSDONE calls SetGTK to set the GTK for all associated STAs that are not in WNM sleep mode. If this fails, all communication via this key fails, and the AP needs to detect and recover from this situation. A STA that is in WNM sleep mode will not have the current GTK installed when it wakes up and will need to get new GTK as described in the WNM sleep mode procedures in 11.2.3.16.

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12.7.10.3 Authenticator state machine variables

The following list summarizes the variables used by the Authenticator state machine:

— *AuthenticationRequest.* This variable is set to true by the STA's IEEE 802.11 management entity in order to authenticate an association. This can be set to true when the STA associates or at other times.

— *ReAuthenticationRequest.* This variable is set to true if the IEEE 802.1X Authenticator received an eapStart or 802.1X::reAuthenticate is 1.

— *DeauthenticationRequest*. This variable is set to true if a Disassociation or Deauthentication message is received.

— *Disconnect***.** This variable is set to true when the STA should initiate a deauthentication.

— *EAPOLKeyReceived.* This variable is set to true when an EAPOL-Key frame is received. EAPOL-Key frames that are received in response to an EAPOL-Key frame sent by the Authenticator shall contain the same Key Replay Counter field value as the Key Replay Counter field in the transmitted message. EAPOL-Key frames that contain different Key Replay Counter field values should be discarded. An EAPOL-Key frame that is sent by the Supplicant in response to an EAPOL-Key frame from the Authenticator shall not have the Ack bit set to 1. EAPOL-Key frames sent by the Supplicant not in response to an EAPOL-Key frame from the Authenticator shall have the Request bit set to 1.

  EAPOL-Key frames with a key type of Pairwise and a nonzero key index should be ignored.

  EAPOL-Key frames with a key type of Group and an invalid key index should be ignored.

NOTE—When an EAPOL-Key frame in which the Ack bit is 0 is received, then it is expected as a reply to a message that the Authenticator sent, and the replay counter is checked against the replay counter used in the sent EAPOL-Key frame. When an EAPOL-Key frame in which the Request bit is 1 is received, then a replay counter for these messages is used that is a different replay counter than the replay counter used for sending messages to the Supplicant.

— *GTimeoutCtr*. This variable maintains the count of EAPOL-Key receive timeouts for the group key handshake. It is incremented each time a timeout occurs on EAPOL-Key receive event and is initialized to 0. Annex C details the timeout values. The Key Replay Counter field value for the EAPOL-Key frame shall be incremented on each transmission of the EAPOL-Key frame.

— *GInit*. This variable is used to initialize the group key state machine. This is a group variable.

— *Init*. This variable is used to initialize per-STA state machine

— *TimeoutEvt.* This variable is set to true if the EAPOL-Key frame sent out fails to obtain a response from the Supplicant. The variable may be set to 1 by management action or set to 1 by the operation of a timeout while in the PTKSTART and REKEYNEGOTIATING states.

— *TimeoutCtr*. This variable maintains the count of EAPOL-Key receive timeouts. It is incremented each time a timeout occurs on EAPOL-Key receive event and is initialized to 0. Annex C contains details of the timeout values. The Key Replay Counter field value for the EAPOL-Key frame shall be incremented on each transmission of the EAPOL-Key frame.

— *MICVerified.* This variable is set to true if the MIC on the received EAPOL-Key frame is verified and is correct or if the AEAD cipher is used and the AEAD decryption steps succeed. Any EAPOL-Key frames with an invalid MIC are dropped and ignored.

— *GTKAuthenticator.* This variable is set to true if the Authenticator is on an AP or it is the designated Authenticator for an IBSS.

— *GKeyDoneStations.* Count of number of STAs left to have their GTK updated. This is a global variable.

— *GTKRekey.* This variable is set to true when a group key handshake is required. This is a global variable.

— *GUpdateStationKeys.* This variable is set to true when a new GTK is available to be sent to Supplicants.

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— *GNoStations.* This variable counts the number of Authenticators so it is known how many Supplicants need to be sent the GTK. This is a global variable.
— *ANonce.* This variable holds the current nonce to be used if the STA is an Authenticator.
— *GN*, *GM.* These are the current key indices for GTKs. Swap(GM, GN) means that the global key index in GN is swapped with the global key index in GM, so now GM and GN are reversed.
— *PTK.* This variable is the current PTK.
— *GTK[].* This variable is the current GTKs for each GTK index.
— *PMK.* This variable is the buffer holding the current PMK.
— *802.1X::XXX.* This variable is the IEEE 802.1X state variable *XXX.*
— *keycount*. This variable is used in an IBSS to decide when all of the keys have been delivered and an IBSS link is secure.
— *WNM sleep mode.* This variable is true when the non-AP STA is in the WNM sleep mode, as described in 11.2.3.16. Otherwise, it is false.

12.7.10.4 Authenticator state machine procedures

The following list summarizes the procedures used by the Authenticator state machine:

— **STADisconnect**(). Execution of this procedure deauthenticates the STA.
— **CalcGTK**(x). Generates the GTK.
— **MIC**(x). Computes a MIC over the plaintext data. When an AEAD cipher is used, returns an empty string.

12.8 Mapping EAPOL keys to IEEE 802.11 keys

12.8.1 Mapping PTK to TKIP keys

See 12.7.1.3 for the definition of the EAPOL temporal key derived from PTK.

A STA shall use bits 0–127 of the temporal key as its input to the TKIP Phase 1 and Phase 2 mixing functions.

A STA shall use bits 128–191 of the temporal key as the michael key for MSDUs from the Authenticator's STA to the Supplicant's STA.

A STA shall use bits 192–255 of the temporal key as the michael key for MSDUs from the Supplicant's STA to the Authenticator's STA.

12.8.2 Mapping GTK to TKIP keys

See 12.7.1.4 for the definition of the EAPOL temporal key derived from GTK.

A STA shall use bits 0–127 of the temporal key as the input to the TKIP Phase 1 and Phase 2 mixing functions.

A STA shall use bits 128–191 of the temporal key as the michael key for MSDUs from the Authenticator's STA to the Supplicant's STA.

A STA shall use bits 192–255 of the temporal key as the michael key for MSDUs from the Supplicant's STA to the Authenticator's STA.

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12.8.3 Mapping PTK to CCMP keys

See 12.7.1.3 for the definition of the EAPOL temporal key derived from PTK.

A STA shall use the temporal key as the CCMP key for MPDUs between the two communicating STAs.

12.8.4 Mapping GTK to CCMP keys

See 12.7.1.4 for the definition of the EAPOL temporal key derived from GTK.

A STA shall use the temporal key as the CCMP key.

12.8.5 Mapping GTK to WEP-40 keys

See 12.7.1.4 for the definition of the EAPOL temporal key derived from GTK.

A STA shall use bits 0–39 of the temporal key as the WEP-40 key.

12.8.6 Mapping GTK to WEP-104 keys

See 12.7.1.4 for the definition of the EAPOL temporal key derived from GTK.

A STA shall use bits 0–103 of the temporal key as the WEP-104 key.

12.8.7 Mapping IGTK to BIP keys

See 12.7.1.5 for the definition of the IGTK. A STA shall use bits 0-127 of the IGTK as the AES-128-CMAC key, bits 0-127 of the IGTK as the AES-128-GMAC key, bits 0-255 of the IGTK as the AES-256-GMAC key, and bits 0-255 of the IGTK as the AES-256-CMAC key.

12.8.8 Mapping PTK to GCMP keys

See 12.7.1.3 for the definition of the EAPOL temporal key derived from PTK.

A STA shall use the temporal key as the GCMP key for MPDUs between the two communicating STAs.

12.8.9 Mapping GTK to GCMP keys

See 12.7.1.4 for the definition of the EAPOL temporal key derived from GTK.

A STA shall use the temporal key as the GCMP key.

12.8.10 Mapping BIGTK to BIP keys

See 12.7.1.7 for the definition of the BIGTK. A STA shall use bits 0-127 of the BIGTK as the AES-128-CMAC key, bits 0-127 of the BIGTK as the AES-128-GMAC key, bits 0-255 of the BIGTK as the AES-256-GMAC key, and bits 0-255 of the BIGTK as the AES-256-CMAC key.

12.9 Authenticated mesh peering exchange (AMPE)

The authenticated mesh peering exchange is defined in 14.5.

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12.10 AP PeerKey support

12.10.1 AP PeerKey overview

The AP PeerKey protocol provides session identification and creation of an AP PeerKey association to provide for security of OBSS management communication between two APs. The result of a successful run of the AP PeerKey protocol is an AP PeerKey association. An AP PeerKey association is composed of a mesh PMKSA and a mesh TKSA.

Two APs perform the AP PeerKey protocol in order to protect HCCA TXOP Advertisement frames in an OBSS. The AP PeerKey protocol is unauthenticated (neither peer has a verified identity of the other peer) but an AP knows that only the peer AP that completed the AP PeerKey protocol is able to send protected HCCA TXOP Advertisement frames protected by the resulting AP PeerKey association. This allows an AP to determine whether a peer AP honors the HCCA TXOP avoidance schedule that is negotiated. In this manner, an AP is able to honor the negotiated schedule of trusted peer APs and ignore peer APs that are not trustworthy. This allows trustworthy APs to negotiate mutually beneficial schedules while allowing an AP to not disadvantage itself in an OBSS in the presence of untrustworthy APs.

AP PeerKey uses various functions and data to accomplish its task and assumes certain properties about each function as follows:

— H is an “extractor” function (see IETF RFC 5869) that concentrates potentially dispersed entropy from an input to create an output that is a cryptographically strong, pseudorandom key. This function takes as input a nonsecret “salt” and a secret input and produces a fixed-length output.

— A finite cyclic group is negotiated for which solving the discrete logarithm problem is computationally infeasible.

When using AKM suite selector 00-0F-AC:10 to indicate AP PeerKey, H shall be instantiated as HMAC-SHA-256, taking as input a nonsecret “salt” and a secret input keying material “ikm”:

H(salt, ikm) = HMAC-SHA-256(salt, ikm)

Other instantiations of function H require creation of a new AKM identifier.

12.10.2 AP PeerKey protocol

AP PeerKey uses the same discrete logarithm cryptography as SAE (as described in 12.4) to achieve key agreement. Each party to the exchange has a public and private key with respect to a particular set of domain parameters that define a finite cyclic group. Groups may be based on elliptic curve cryptography (ECC) or finite field cryptography (FFC). Each component of a group is referred to as an *element*. Groups are negotiated using an identifying number from a repository maintained by IANA as “Group Description” attributes for IETF RFC 2409 (IKE) [B14][B30]. The repository maps an identifying number to a complete set of domain parameters for the particular group. For the purpose of interoperability, APs that have dot11ProtectedHCCATXOPNegotiationImplemented true or dot11ProtectedQLoadReportImplemented true shall implement support for group 19, an ECC group defined over a 256-bit prime order field.

AP PeerKey uses one arithmetic operator that takes one element and one scalar value to produce another element (called the *scalar operation*). The convention used here is to represent group elements in uppercase bold italic and scalar values in lowercase italic.

The private key d shall be chosen randomly so that $1 < d < r$, where r is the order of the group. The public key $\boldsymbol{Q}$ shall be produced using Equation (12-1).

$$\boldsymbol{Q} = \text{scalar-op}(d, \boldsymbol{G}) \tag{12-1}$$

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where

G is the generator (also known as the base point) of the group

An AP for which dot11ProtectedTXOPNegotiationActivated is true or dot11ProtectedQLoadReportActivated is true shall support at least one public key from cyclic group nineteen and may support multiple public keys from multiple cyclic groups. An AP that supports the Multiple BSSID capability and has dot11ProtectedTXOPNegotiationActivated true or dot11ProtectedQLoadReportActivated true may use one public key across multiple BSSIDs, or it may choose to generate a public key for each supported BSSID.

The AP PeerKey protocol consists of an exchange of public keys from an AP and a peer AP. An AP requests the public key of a peer AP by sending a Public Key frame with the Public Key Frame Usage field set to "Request." This frame contains the public key of the initiating AP. The initiating AP awaits a response to its request. The peer AP responds to the "Request" from the initiating AP with a Public Key frame with the Public Key Frame Usage field set to "Response", indicating an acceptable group was sent by the initiating AP, or set to "NAK" indicating that the group sent by the initiating AP was unacceptable.

It is possible for multiple runs of the AP PeerKey protocol to be performed by an AP but there shall be only one instance at a time of the AP PeerKey protocol to a peer AP for a particular group. The state associated with each run of the AP PeerKey protocol is the group and the two public keys of the participating APs.

An AP for which dot11ProtectedTXOPNegotiationActivated is true or dot11ProtectedQLoadReportActivated is true shall reply to a Public Key frame. An AP that has both dot11ProtectedTXOPNegotiationActivated is false and dot11ProtectedQLoadReportActivated is false shall drop all received Public Key frames. If the responding AP refuses to perform the AP PeerKey protocol with the initiating AP it shall respond with a Public Key frame, setting the Public Key Frame Usage field to "Refused". Otherwise, if the Finite Cyclic Group field in the public key request is a group that is supported by the responding AP, the AP shall reply with a public key of the same group as the request, generating such a key pair if required, and setting the Public Key Frame Usage field to "Response". The receiving AP shall generate a PMK and a mesh PMKSA, see below, and terminate the AP PeerKey protocol. If the Finite Cyclic Group field in the public key request is not supported by the responding AP, the responding AP shall respond with a Public Key frame, setting the Public Key Frame Usage field to "NAK" and the group set to a group acceptable by the receiving AP.

If the initiating AP does not receive a response to its request after five seconds, it should retransmit its request. The initiating AP should attempt such retransmission a minimum of five times.

If the initiating AP receives a Public Key frame from a peer AP with the Public Key Frame Usage field set to "NAK", the initiating AP inspects the Finite Cyclic Group field in the received "NAK". If the group is supported, the initiating AP should initiate to the peer AP using the indicated group. If the group is not supported, the AP may choose to initiate to the peer AP using a different group from the dot11RSNAConfigDLCGroupTable. Receipt of a Public Key frame from a peer AP with the Public Key Frame Usage field set to "NAK" terminates the AP PeerKey protocol.

If the initiating AP receives a Public Key frame from a peer AP with the Public Key Frame Usage field set to "Refused", the initiating AP shall terminate the AP PeerKey protocol.

An initiating AP that receives a refusal should delay sending another request for at least 5 seconds, and should perform exponential backoff on all subsequent requests by doubling the delay with each subsequent refusal.

NOTE 1—This standard does not specify a limit on the number of attempts an initiating AP makes to communicate with another AP.

If the initiating AP receives a Public Key frame from a peer AP with the Public Key Frame Usage field set to "Response" and the group set to the value in the initiating AP's "Request", the initiating AP shall generate a PMK and a mesh PMKSA. This terminates the AP PeerKey protocol.

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If the initiating AP receives a Public Key frame from a peer AP with the Public Key Frame Usage field set to "Request" prior to receiving a "Response", it checks the Finite Cyclic Group field in the request. If the Group in the received "Request" is the same as the Group the initiating AP sent it its request, the AP shall construct a Public Key frame with the Public Key Frame Usage field set to "Response" containing the public key it sent in its "Request" and transmit it to the peer. The AP shall then generate a PMK and a mesh PMKSA, see below, and terminate the PeerKey protocol. If the Finite Cyclic Group field differs and the group indicated is supported, the AP shall respond to the peer AP by replying with a public key from that group, generating a key pair if required, and setting the Public Key Frame Usage field to "Response". The AP shall generate a PMK and a mesh PMKSA, see below, and terminate this run of the AP PeerKey protocol.

Once the AP and peer AP have exchanged public keys from the same finite cyclic group they can compute the Diffie-Hellman shared secret using scalar-op() and function F from 12.4.4:

$$k = \text{F}(\text{scalor-op}(d, \boldsymbol{Q}_p)) \quad (12\text{-}2)$$

where

d	is the private key of the AP that is calculating k
$\boldsymbol{Q}_p$	is the public key of the peer AP

Entropy of the shared secret shall then be extracted using function H to produce *keyseed* using Equation (12-3).

$$keyseed = \text{H}(<0>32, k) \quad (12\text{-}3)$$

where

<0>32 denotes 32 octets of the value zero

The PMK shall be derived according to Equation (12-4), and the PMKID shall be derived according to Equation (12-5).

$$\text{PMK} = \text{KDF-Hash-256}(keyseed, \text{"AP Peerkey Protocol"}, \text{0x00} \,||\, \text{Max(LOCAL-MAC, PEER-MAC)} \,||\, \text{Min(LOCAL-MAC, PEER-MAC)}) \quad (12\text{-}4)$$

$$\text{PMKID} = \text{Truncate-128}(\text{SHA-256}(Q_1 \,||\, Q_2 \,||\, \text{Max(LOCAL-MAC, PEER-MAC)} \,||\, \text{Min(LOCAL-MAC, PEER-MAC)})) \quad (12\text{-}5)$$

where

KDF-Hash-256	is the key derivation function defined in 12.7.1.6.2 using the hash algorithm identified by the AKM suite selector (see Table 9-151)
0x00	is a single octet with a value of zero
LOCAL-MAC	is the AP's MAC address
PEER-MAC	is the peer AP's MAC address
Q_1	is the public key used by AP1 in the AP PeerKey protocol encoded as an octet stream using the Element to Octet string conversion from 12.4.7.2.3.
Q_2	is the public key used by AP2 in the AP PeerKey protocol encoded as an octet stream using the Element to Octet string conversion from 12.4.7.2.3.
AP1	is the AP whose MAC address equals Max(LOCAL-MAC, PEER-MAC)
AP2	is the AP whose MAC address equals Min(LOCAL-MAC, PEER-MAC)

The Max and Min operations for IEEE 802 addresses are with the address converted to a positive integer treating the first octet as the most significant octet of the integer.

keyseed shall be irretrievably deleted after the PMK is generated.

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The lifetime of the mesh PMKSA shall be set to the value dot11RSNAConfigPMKLifetime.

Upon creation of the PMK, an AEK shall be created per 14.5.7. The mesh PMKSA for this instance of the AP PeerKey protocol shall then be created using the AP's MAC address as the STA's MAC address, the peer AP's MAC address as the peer STA's MAC address, the AEK, the lifetime, and the PMKID. If a mesh PMKSA created by a prior run of the AP PeerKey protocol exists it shall be deleted upon creation of the new PMKSA. All mesh TKSAs created by the old mesh PMKSA shall also be deleted.

Upon creation of the mesh PMKSA, the APME protocol (as defined in 14.5 shall be used to prove possession of the PMK (and implicitly the private key that corresponds to the peer's public key) and generate the mesh TKSA.

Note that it is possible for two APs which simultaneously initiated to each other with different, but acceptable, groups to end up with two mesh PMKSAs. In this unlikely case, the mesh PMKSA from a group with the largest prime in its domain parameter set shall be used with the AMPE protocol. The other mesh PMKSA shall be deleted.

If the AMPE protocol completes successfully, Protected HCCA TXOP Advertisement frames and Protected HCCA TXOP Response frames may be used in the HCCA TXOP negotiation procedures, as defined in 11.26.3 using the MTK from the mesh TKSA. If the AMPE procedure completes successfully, Protected QLoad Request frames and Protected QLoad Report frames may be used in the QLoad report procedures, as defined in 11.26.2 using the MTK from the mesh TKSA. If the AMPE protocol fails, the peer's public key, PMK, and PMKSA shall be deleted.

NOTE 2—The PMK, as well as any key derived from it, is not authenticated in any way nor is it bound to any identity. This protocol protects an AP that cooperates in scheduling its HCCA TXOPs using Protected HCCA TXOP Advertisement frames because no other entity knows its private key and cannot forge Protected HCCA TXOP Advertisement frames. An AP that receives a Protected HCCA TXOP Advertisement frame is assured it was sent by the holder of a particular private key, and no one else, and can, therefore, establish which APs are cooperating in their HCCA TXOP scheduling. An AP that receives a Protected QLoad Report frame is assured it was sent by the holder of a particular private key, and no other STA, and can, therefore, establish which APs are correctly reporting their QoS load.

12.11 Authentication for FILS

12.11.1 General

FILS authentication is an RSNA authentication protocol. The FILS authentication protocol authenticates STAs to each other, using either a shared key or a public key. When FILS Shared Key authentication is used, the authentication exchange can optionally be performed with PFS. When FILS Public Key authentication is used, PFS is always used. When the FILS authentication protocol is performed with PFS, the STA and AP derive ephemeral public and private keys with respect to a particular set of domain parameters that define a finite cyclic group and then exchange public keys. The result of the FILS authentication includes a PTKSA.

The security of FILS authentication depends on the following assumptions:

- When FILS Shared Key authentication is used, each STA shares either a valid rRK as defined in IETF RFC 6696 with a TTP that is capable of being used with EAP-RP, or a PMK cached from a previous authenticated connection.
- When FILS Public Key authentication is used, each STA has a means to trust the public key of the other STA.
- When PFS is used, a finite cyclic group is negotiated where solving the discrete logarithm problem is computationally infeasible.
- When PFS is used, both the STA and AP have in common at least one finite cyclic group from the dot11RSNAConfigDLCGroupTable.

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12.11.2 FILS authentication protocol

12.11.2.1 General

The STA and AP perform key establishment using Authentication frames and perform key confirmation using (Re)Association Request and (Re)Association Response frames.

After exchanging Authentication frames, the STA and AP derive a shared and secret key that will be used to derive a set of secret keys (as defined in 12.11.2.5.2) that are authenticated after exchanging (Re)Association Request and (Re)Association Response frames.

When a shared key is used for FILS authentication, and if the STA shares a valid rRK with the TTP, then EAP-RP as defined in IETF RFC 5295 and IETF RFC 6696 shall be used.

To prevent key reinstallation attacks, the non-AP STA shall maintain a copy of the most recent GTK, most recent IGTK and most recent BIGTK installed as part of the FILS authentication protocol as if they were installed as a result of receipt of EAPOL-Key frames (see 12.7.7.4) and shall refuse to update a GTK, IGTK or BIGTK when the key to be set matches either one of these two keys (see 6.3.19).

12.11.2.2 Discovery of a FILS AP

An AP indicates that it is capable of performing FILS authentication by indicating support for a FILS AKM in an RSN element and including it, and the FILS Indication element, in Beacon and Probe Response frames.

An AP may indicate that it is capable of performing FILS authentication by indicating support for a FILS AKM in the FD RSN Information subfield in a FILS Discovery frame.

An AP indicates support for FILS Shared Key authentication without PFS by setting the FILS Shared Key authentication without PFS supported bit to 1 in the FILS Information field of the FILS Indication element. An AP indicates support for FILS Shared Key authentication with PFS by setting the FILS Shared Key authentication with PFS Supported bit to 1 in the FILS Information field of the FILS Indication element. An AP may advertise between zero and seven realms using the Realm Identifier subfield(s) of the FILS Indication element that is part of Beacon, Probe Response, and FILS Discovery frames. If the STA believes it shares a valid rRK as defined in IETF RFC 6696 with the AP through, e.g., a hashed domain name that matches an AP-advertised realm, a HESSID, or other ANQP information, the STA may begin FILS Shared Key authentication with the AP using EAP-RP. Domain name hashing is specified in 11.45.4. If a STA discovers a FILS AP and the STA believes it shares a PMKSA with the AP, it may begin the FILS authentication protocol with the AP using PMKSA caching.

An AP indicates support for FILS Public Key authentication by setting the FILS Public Key authentication Supported bit to 1 in the FILS Information field of the FILS Indication element. An AP may advertise up to seven public key indicators in the FILS Indication element that is part of Beacon, Probe Response, and FILS Discovery frames. If the STA discovers that it trusts the issuer of an AP's X.509v3 certificate, or that it trusts its uncertified public key identified by matching its hash, the STA may begin the FILS authentication protocol to the AP and perform mutual authentication using trusted public keys.

12.11.2.3 Key establishment with FILS Shared Key authentication

12.11.2.3.1 Overview

This subclause defines the procedure for establishing a shared key between a FILS STA and AP using FILS Shared Key authentication that uses shared symmetric keys between the STA and the TTP.

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A STA may initiate FILS Shared Key authentication either with a FILS AP that is connected to a TTP that shares a valid key, called an rRK, as defined in IETF RFC 6696 with the STA, or with a FILS AP with whom it shares a cached PMKSA. If neither of these cases applies, a full EAP exchange may be performed via IEEE 802.1X authentication to establish rRK as defined in IETF RFC 6696 or another form of FILS authentication may be used to establish a shared PMKSA. When performing a full EAP exchange using RSNA to establish rRK, the Authentication algorithm number 0 (Open System) is used.

EAP-RP signaling as defined in IETF RFC 5295 and IETF RFC 6696 is used to validate the mutual possession of rRK between the STA and the TTP. EAP-RP signaling is encapsulated using a FILS Wrapped Data element in the Authentication frame. The AP unwraps the encapsulated EAP-RP packet received from the STA in the FILS Wrapped Data element and forwards the EAP-RP packet to the TTP using a transport that is out of scope of this standard. When the AP receives an EAP-RP packet from the TTP, the AP forwards the packet to the STA by encapsulating the EAP-RP packet in the FILS Wrapped Data element of the Authentication frame.

The message sequence is depicted in Figure 12-55.

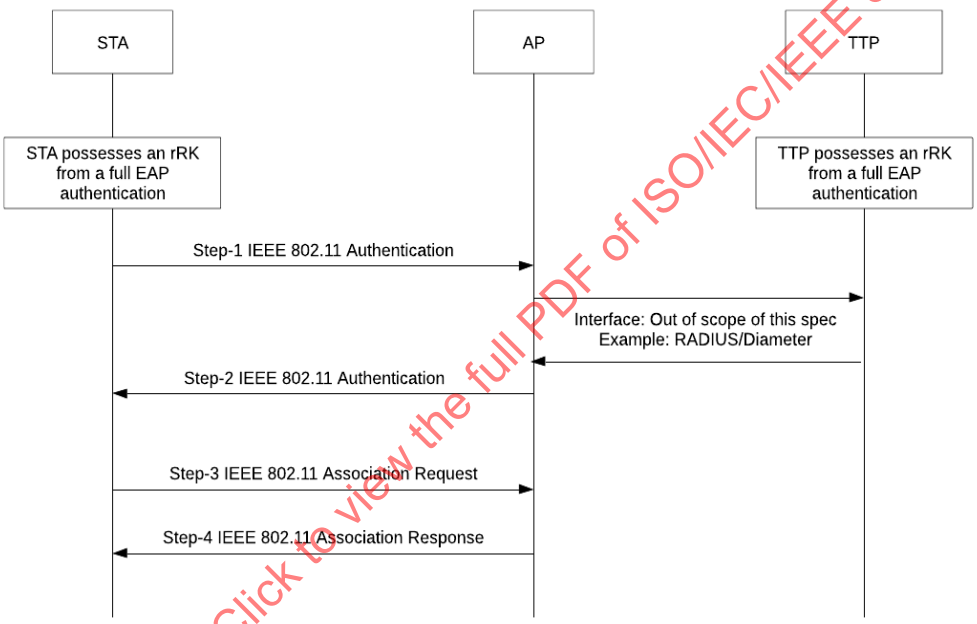

Figure 12-55—FILS Shared Key authentication

The following subclauses are organized per each step as shown in Figure 12-55.

12.11.2.3.2 Non-AP STA construction of Authentication frame

If the STA chooses to initiate FILS Shared Key authentication, it shall first choose a random 16-octet nonce and then determine whether to attempt PMKSA caching. If PMKSA caching is attempted, it shall generate a list of PMKSA identifiers. If the STA attempts to initiate EAP-RP, it shall construct an EAP-Initiate/Reauth packet per IETF RFC 6696, with the following clarifications:

- Regarding EAP-RP Flags:
  - The B flag shall be set to 0, indicating that this is not an EAP-RP bootstrap message.
  - The L flag shall be set to 1, indicating that the TTP with whom the STA shares the rRK is to provide the lifetimes of rRK and rMSK in the EAP-Finish/Reauth Packet.
  - EAP Identifier is set to 0.
- The Cryptosuite field shall not be set to 1.

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If PFS is desired, the STA selects a finite cyclic group from the dot11RSNAConfigDLCGroupTable, which comprises identifying number from a repository maintained by IANA as "Group Description" attributes for IETF RFC 2409 (IKE) [B14][B30]. The STA then generates an ephemeral private key, and performs the group's scalar-op (see 12.4.4.1) with its random ephemeral private key and the generator from the selected finite cyclic group to compute an ephemeral public key.

The STA then constructs an Authentication frame with the Authentication algorithm number set to 4 (FILS Shared Key authentication without PFS) or 5 (FILS Shared Key authentication with PFS) (see 9.4.1.1) depending on whether PFS is used, and the Authentication transaction sequence number set to 1. The random nonce shall be encoded in the FILS Nonce element (see 9.4.2.189). If a list of PMKSA identifiers was generated, it shall be used to construct the PMKID List field in RSNE. The random FILS Session shall be encoded in the FILS Session element (see 9.4.2.179). The EAP-Initiate/Reauth packet, if generated, shall be copied into the FILS Wrapped Data field (see 9.4.2.187). If PFS is desired, the chosen finite cyclic group shall be encoded in the Finite Cyclic Group field (see 9.4.1.42) and the ephemeral public key shall be encoded in the FFE field (see 9.4.1.40) according to the element to octet-string conversion in 12.4.7.2.4.

The STA transmits the Authentication frame to the AP.

12.11.2.3.3 AP processing of Authentication frame

Upon reception of the Authentication frame with the Authentication algorithm number equal to 4 or 5, the AP shall perform the following procedure:

a) If Authentication frame includes a Finite Cyclic Group field, then the AP shall first determine whether the indicated finite cyclic group in the received FILS Authentication frame is supported.

b) If the indicated finite cyclic group in the received FILS Authentication frame is not supported, the AP shall respond with an Authentication frame with the Authentication algorithm number set to 5 (FILS Shared Key authentication with PFS) (see 9.4.1.1) and the Status Code field set to 77 (Authentication is rejected because the offered finite cyclic group is not supported) and shall terminate the exchange.

c) If PFS is being used, the STA's public key shall be converted from an octet string to an element according to the conversion in 12.4.7.2.5. Then the AP shall validate the STA's public key in a group-specific fashion as described in 5.6.2.3 of NIST SP800-56A R2. If validation fails, the AP shall terminate the exchange.

d) The AP shall check whether PMKSA caching is being attempted by the presence of the PMKID List field in RSNE:

   1) If the PMKID List field is present in RSNE, the AP checks whether any PMKSA identifier offered in the PMKID List matches an identifier for a cached PMKSA. If so, the AP selects a PMKID that matches and continues the FILS Shared Key authentication protocol using the PMK from the identified PMKSA.

   2) If a PMKID List field is not present in RSNE or if no PMKSA identifier offered in the PMKID list matches any identifier for a cached PMKSA, the AP checks whether an EAP-Initiate/Reauth packet was included. If not, the AP shall respond with an Authentication frame with the Authentication algorithm number set to 4 or 5 depending on whether PFS is used and the Status Code field set to 53 (invalid PMKID) and shall terminate the exchange.

   3) If an EAP-Initiate/Reauth packet is included and PMKSA caching is not used, the AP shall extract the EAP-Initiate/Reauth data from the FILS Wrapped Data field (see 9.4.2.187) and shall forward it to the Authentication Server. When applicable, the AP communicates with the Authentication Server using the same protocols it uses when authenticating with EAP. Suitable protocols include, but are not limited to, remote authentication dial-in user service RADIUS (as specified in IETF RFC 2865 [B33]) and Diameter (as specified in IETF RFC 6942).

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If PFS is being used, the AP shall also generate an ephemeral private key and perform the group's scalar-op (see 12.4.4.1) to produce its own ephemeral public key. The AP may delay the generation of its ephemeral public/private key pair until after receiving a response from the Authentication Server, if applicable. The Authentication Server processes the EAP-Initiate/Reauth packet as specified in IETF RFC 6696 and returns an EAP-Finish/Reauth packet to the AP. In the case of successful authentication by the Authentication Server, the Authentication Server returns the associated EAP-RP rMSK with the EAP-Finish/Reauth packet. If the Authentication Server responds with a failure indication, then the AP shall produce an Authentication frame with the Authentication Algorithm Number field set to 4 (FILS Shared Key authentication without PFS) or 5 (FILS Shared Key authentication with PFS) (see 9.4.1.1), and the Status Code field set to 15 (Authentication rejected because of challenge failure). In the case of successful authentication by the Authentication Server, the Authentication Server returns the associated EAP-RP rMSK with the EAP-Finish/Reauth packet and processing terminates.

The AP proceeds by constructing an Authentication frame.

12.11.2.3.4 AP construction of Authentication frame

If PMKSA caching is not used and the AP is not connected to, or does not recognize the Authentication Server identified by the STA using the realm in the key Name-NAI field of the EAP-Initiate/Reauth packet, then the AP shall send Authentication frame with Status Code field set to 113, "Authentication rejected due to unknown Authentication Server" to the non-AP STA.

Otherwise, the AP shall generate its own nonce and construct an Authentication frame for the STA. The AP shall copy the FILS Session element from the Authentication frame sent by the non-AP STA to this response Authentication frame. If PMKSA caching is not used, this frame shall contain the FILS wrapped data that encapsulates EAP-Finish/Reauth packet received from the Authentication Server. In addition, if PFS is used, the FFE field of the Authentication frame sent by the AP contains the AP's ephemeral public key. In this frame, the AP shall set the Authentication algorithm number to 4 or 5 depending on whether PFS is used, and the Authentication sequence number to 2. If PMKSA caching is used, the AP indicates the selected PMKID in the PMKID List.

If PFS is being used for the exchange, the AP shall perform the group's scalar-op (see 12.4.4.1) with the STA's ephemeral public key and its own ephemeral private key to produce an ephemeral Diffie-Hellman shared secret, DHss.

The AP transmits the Authentication frame to the STA. Upon transmission of the FILS Authentication frame, the AP proceeds to key establishment per 12.11.2.5.

12.11.2.3.5 Non-AP STA processing of Authentication frame

The STA processes the received Authentication frame as follows:

a) The STA shall abandon FILS authentication if any of the following conditions occur:
   1) The received Authentication frame does not include the Authentication Algorithm Number equal to 4 (FILS Shared Key authentication without PFS) or 5 (FILS Shared Key authentication with PFS) (see 9.4.1.1).
   2) PMKSA caching was attempted and the received Authentication frame includes a PMKID that does not match a PMKID in the Authentication frame sent by the STA.
   3) The received Authentication frame does not include either a PMKID or an EAP-Finish/Reauth packet.
   4) The received Authentication frame does not include the FILS Session element.
   5) The received FILS Session value does not match the one in the Authentication frame sent by the STA.

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b) If the received Authentication frame includes the Status Code field equal to 15 (Authentication rejected because of challenge failure) or 53 (invalid PMKID), then the STA shall abandon the FILS authentication.

c) The STA verifies that the AP transmitted PFS parameters are consistent with the STA's previous transmissions (indicated by whether or not the STA transmitted an ephemeral public key):

   1) If the STA transmitted an ephemeral public key, and the received Authentication frame does not include an ephemeral public key, then the STA shall abandon the FILS authentication.

   2) If the STA did not transmit an ephemeral public key, and the received Authentication frame includes an ephemeral public key, then the STA shall abandon the FILS authentication.

d) If applicable, the STA processes the EAP-Finish/Reauth packet as per IETF RFC 6696:

   1) If the R flag = 0, indicating success, then the STA shall derive rMSK.

   2) If the R flag = 1, indicating failure, then the STA shall abandon the FILS authentication.

e) If PFS is being used for the exchange, the AP's public key shall be converted from an octet string to an element according to the conversion in 12.4.7.2.5. Then the STA shall validate the AP's public key in a group-specific fashion as described in 5.6.2.3 of NIST SP 800-56A R2. If validation fails, the STA shall terminate the FILS authentication protocol. Otherwise, the STA shall perform the group's scalar-op (see 12.4.4.1) with the AP's ephemeral public key and its own ephemeral private key to produce an ephemeral Diffie-Hellman shared secret, DHss.

f) The STA shall perform key derivation per 12.11.2.5 and key confirmation per 12.11.2.6.

If the STA was attempting EAP-RP Authentication and did not receive an Authentication frame, then the STA should perform retransmission procedure as defined in IETF RFC 6696, and with implementation-specific timeouts as guided by the AuthenticateFailureTimeout parameter in the MLME-AUTHENTICATE.request. If the retransmission procedure fails, then the STA shall abandon the FILS authentication and should perform full EAP authentication via IEEE 802.1X authentication.

If the STA was attempting PMKSA caching and did not receive an Authentication frame from the AP, the STA may attempt to use an alternate authentication method.

12.11.2.4 Key establishment with FILS Public Key authentication

12.11.2.4.1 General

This subclause defines the procedure for establishing a shared key between a FILS STA and AP using FILS Public Key authentication.

When using FILS Public Key authentication, a STA shall initiate authentication using either a public key or a cached PMKSA.

12.11.2.4.2 Prior to exchange

FILS Public Key authentication performs key establishment with a Diffie-Hellman exchange. Prior to beginning the exchange, the non-AP STA performs the following:

a) Selects a finite cyclic group from the dot11RSNAConfigDLCGroupTable to perform the Diffie-Hellman exchange.

b) Generates a random 16-octet nonce, generates an ephemeral private key, and uses the selected group's scalar-op (see 12.4.4.1) with its private key to generate its ephemeral public key.

c) Determine whether to attempt PMKSA caching and if so, generates a list of PMKSA identifiers.

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d) Constructs an Authentication frame (see 9.3.3.11) as follows:
   1) The Authentication algorithm number shall be set to 6 (FILS Public Key authentication) (see 9.4.1.1) and the Authentication transaction sequence number shall be set to 1.
   2) The random nonce shall be encoded in the FILS Nonce element (see 9.4.2.189).
   3) The chosen finite cyclic group shall be encoded in the Finite Cyclic Group field (see 9.4.1.42).
   4) The STA's ephemeral public key shall be encoded into the FFE field (see 9.4.1.40) according to the element to octet-string conversion in 12.4.7.2.4.
   5) The random FILS Session shall be encoded in the FILS Session element (see 9.4.2.179).
   6) If a list of PMKSA identifiers was generated, it shall be used to construct the PMKID List field in RSNE.

The STA then transmits the Authentication frame to the AP.

12.11.2.4.3 Processing after receipt

Upon reception of the Authentication frame with the Authentication algorithm number equal to 6, the AP shall perform the following procedure:

a) If the finite cyclic group indicated by the Finite Cyclic Group field is not acceptable, the AP shall respond with an Authentication frame with the status code of 77 ("Authentication is rejected because the offered finite cyclic group is not supported") and terminate the FILS authentication protocol.
b) If the finite cyclic group is acceptable, the AP shall verify the validity of the STA's ephemeral public key:
   1) The public key is converted from an octet string to an element according to the conversion in 12.4.7.2.5.
   2) The public key, as a group element, is verified in a group-specific fashion as described in 5.6.2.3 of NIST SP 800-56A R2. If verification fails, the AP shall terminate the FILS authentication protocol.
c) The STA's nonce and validated ephemeral public key are extracted from the Authentication frame.
d) The AP shall check whether PMKSA caching is being attempted by the presence of the PMKSA List field in RSNE. If the PMKID List field is present in RSNE, the AP checks whether any PMKSA identifier offered in the PMKID List matches an identifier for a cached PMKSA. If so, the AP selects a PMKID that matches and shall continue the FILS Public Key authentication protocol using PMKSA caching, otherwise the AP shall continue the FILS Public Key authentication protocol using digital signatures.

12.11.2.4.4 Post processing

Next, the AP shall

a) Generate a random 16-octet nonce and a random ephemeral private key, and then uses the agreed-upon group's scalar-op (see 12.4.4.1) with its private key to generate its ephemeral public key.
b) Construct an Authentication frame (see 9.3.3.11) as follows:
   1) The Authentication algorithm number is set to 6 (FILS Public Key authentication) (see 9.4.1.1), and the Authentication transaction sequence number is set to 2.
   2) The random nonce is encoded in the FILS Nonce element (see 9.4.2.189).
   3) The finite cyclic group is encoded in the Finite Cyclic Group field (see 9.4.1.42).
   4) The AP's ephemeral public key is encoded in the FFE field (see 9.4.1.40) according to the element to octet-string conversion in 12.4.7.2.4.

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5) The AP copies the FILS Session element from the Authentication frame received from the STA.
6) If the PMKSA caching is used, the AP indicates the selected PMKID in the PMKID List.

c) Transmit the Authentication frame to the STA.
d) Compute the Diffie-Hellman shared secret, DHss, based on the STA's ephemeral public key and its own ephemeral private key with the chosen group's scalar-op.
e) Perform key derivation (see 12.11.2.5).

12.11.2.4.5 Upon receipt

The STA processes the received Authentication frame as follows:

a) The STA shall abandon FILS authentication if any of the following conditions occur:
   1) The received Authentication frame does not include the Authentication Algorithm Number equal to 6 (FILS Public Key authentication) (see 9.4.1.1).
   2) PMKSA caching was attempted and the received Authentication frame includes a PMKID that does not match a PMKID in the Authentication frame sent by the STA.
   3) The received Authentication frame does not include the FILS Session element.
b) Verifies that the finite cyclic group in the AP's response is equal to the group selected by the STA and that the FILS Session element received from the AP is equal to the FILS Session selected by the STA. If these differ, the STA shall terminate the authentication exchange.
c) Verifies the validity of the AP's ephemeral public key:
   1) The public key is converted from an octet string to an element according to the conversion in 12.4.7.2.5.
   2) The public key, as a group element, is verified in a group-specific fashion according to 5.6.2.3 of NIST SP 800-56A R2. If public key validation fails the STA shall terminate the authentication exchange.
d) Extracts the AP's nonce and verified ephemeral public key from the Authentication frame.
e) Compute the Diffie-Hellman shared secret, DHss, based on the AP's ephemeral public key and its own ephemeral private key with the chosen group's scalar-op to derive DHss.
f) Performs key derivation (see 12.11.2.5) and begins key confirmation (see 12.11.2.6).

If the STA was attempting PMKSA caching and did not receive an Authentication frame from the AP, the STA may attempt to use an alternate authentication method.

12.11.2.5 Key establishment with FILS authentication

12.11.2.5.1 General

When not using PMKSA caching, a PMK is created according to 12.11.2.5.2. When using PMKSA caching, a new PMKSA is not created. Instead, the PMKSA used for PMKSA caching remains and continues to be identified by the appropriate PMKID. Regardless of whether PMKSA caching is used or not, a PTKSA shall be generated with each FILS authentication exchange.

PTKSA creation uses the KDF from 12.7.1.6.2 to derive the following keys from the PMK: an integrity check key (ICK), a key encryption key (KEK), and a temporal key (TK).

PTKSA key establishment shall immediately be followed by key confirmation per 12.11.2.6.

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12.11.2.5.2 PMKSA key derivation with FILS authentication

The PMK is derived using the two nonces and the secret(s) from FILS Key establishment. A PMKID used to identify the PMKSA is generated using the hash algorithm from the negotiated AKM on input data specific to the FILS Key Establishment step. The length of the PMK shall be either 256 bits or 384 bits depending on the negotiated AKM, and the length of the PMKID shall be 128 bits. If FILS Shared Key authentication was used to generate input keying material, the PMK and PMKID are derived as follows:

PMK = HMAC-Hash(SNonce || ANonce, rMSK [|| DHss])

PMKID = Truncate-128(Hash(EAP-Initiate/Reauth))

When FILS Public Key authentication is used to generate input keying material, the PMK and PMKID are derived as follows:

PMK = HMAC-Hash(SNonce || ANonce, DHss)

PMKID = Truncate-128(Hash(gSTA || gAP))

where

SNonce	is the STA nonce and ANonce is the AP nonce
rMSK	is the shared secret from the EAP-RP exchange
DHss	is the shared secret derived from the Diffie-Hellman exchange, when performed; when ECC is used, only the x-coordinate from EDCH is included
Brackets	indicate the inclusion of the shared secret when doing a Diffie-Hellman exchange; there is no shared secret to include otherwise
EAP-Initiate/Reauth	is the EAP-RP packet sent by the STA during key establishment with FILS Shared Key authentication
gSTA	is the STA's Diffie-Hellman value
gAP	is the AP's Diffie-Hellman value
Hash	is the hash algorithm specific to the negotiated AKM (see Table 9-151)

Upon completion of PMK and PMKID generation the shared secret, DHss, and rMSK, if applicable, shall be irretrievably deleted.

12.11.2.5.3 PTKSA Key derivation with FILS authentication

For PTKSA key generation, the inputs to the PRF are the PMK of the PMKSA, a constant label, and a concatenation of the STA's MAC address, the AP's BSS's BSSID, the STA's nonce, and the AP's nonce. When the negotiated AKM is 00-0F-AC:14 or 00-0F-AC:16, the length of KEK shall be 256 bits, and the length of the ICK shall be 256 bits. When the negotiated AKM is 00-0F-AC:15 or 00-0F-AC:17, the length of the KEK shall be 512 bits, and the length of ICK shall be 384 bits. When the negotiated AKM is 00-0F-AC:16, FILS-FT is 256 bits; when the negotiated AKM is 00-0F-AC:17, FILS-FT is 384 bits; otherwise, FILS-FT is not derived. The total amount of bits extracted from the KDF shall therefore be 512+TK bits, 896+TK bits, or 1280+TK bits depending on the negotiated AKM, where TK_bits are determined from Table 12-4:

FILS-Key-Data = PRF-X(PMK, "FILS PTK Derivation", SPA || AA || SNonce || ANonce [|| DHss])
ICK = L(FILS-Key-Data, 0, ICK_bits)
KEK = L(FILS-Key-Data, ICK_bits, KEK_bits)
TK = L(FILS-Key-Data, ICK_bits + KEK_bits, TK_bits)

When doing FT initial mobility domain association using FILS authentication,

FILS-FT = L(FILS-Key-Data, ICK_bits + KEK_bits + TK_bits, FILS-FT_bits)

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where

ICK_bits	is the length of ICK in bits
KEK_bits	is the length of KEK in bits
FILS-FT_bits	is the length of FILS-FT in bits when doing FT initial mobility domain association using FILS authentication
X	is 512+TK_bits, 768+TK bits, 896+TK bits, or 1280+TK bits from Table 12-7 depending on the negotiated AKM
PMK	is the PMK from the PMKSA, either created from an initial FILS connection or from a cached PMKSA, when PMKSA caching is used; when doing FT initial mobility domain association using FILS authentication, it is equal to MPMK (see 12.7.1.6.3)
SPA	is the STA's MAC address and the AA is the AP's BSS's BSSID
SNonce	is the STA's nonce
ANonce	is the AP's nonce
DHss	is the shared secret derived from the Diffie-Hellman exchange, when performed, and PMKSA caching is used
Brackets	indicate the inclusion of the shared secret when doing a Diffie-Hellman exchange while using PMKSA caching; there is no shared secret to indicate otherwise

Upon completion of FILS-Key-Data generation the shared secret, DHss, shall be irretrievably deleted if Diffie-Hellman exchange was performed.

12.11.2.6 Key confirmation with FILS authentication

12.11.2.6.1 General

Key confirmation for FILS authentication is a (Re)Association Request frame followed by a (Re)Association Response frame. Components of the (Re)Association Request and (Re)Association Response frames shall be protected using KEK.

12.11.2.6.2 (Re)Association Request for FILS key confirmation

The STA constructs a (Re)Association Request frame for FILS authentication per 9.3.3.5 and 9.3.3.7. Hash algorithms are used to generate the FILS Key Confirmation element and the specific hash algorithm depends on the negotiated AKM (9.4.2.24.3).

If dot11RSNAOperatingChannelValidationActivated is true and AP indicates OCVC capability, the STA shall include OCI element in the request.

For FILS Shared Key authentication and FILS Public Key authentication when using PMKSA caching, the KeyAuth field of the FILS Key Confirmation element is constructed by using the HMAC mode of the negotiated hash algorithm with a key of ICK on a concatenation of the STA's nonce, the AP's nonce, the STA's MAC address, the AP's BSS's BSSID, and conditionally the STA's public Diffie-Hellman value and the AP's public Diffie-Hellman value, in that order:

Key-Auth = HMAC-Hash(ICK, SNonce || ANonce || STA-MAC || AP-BSSID [|| gSTA || gAP])

where

Hash	is the hash algorithm specific to the negotiated AKM (see Table 9-151)
SNonce	is the STA's nonce
ANonce	is the AP's nonce
STA-MAC	is the MAC address of the STA and AP-BSSID is the BSSID of the AP's BSS
gSTA	is the STA's Diffie-Hellman public value
gAP	is the AP's Diffie-Hellman public value

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Brackets indicate the inclusion of the Diffie-Hellman public values when doing PFS with FILS Shared Key authentication or PMKSA caching with FILS Public Key authentication; there are no Diffie-Hellman public values to include otherwise

For FILS Public Key authentication when PMKSA caching is not used, the KeyAuth field of the FILS Key Confirmation element is a digital signature using the STA's private key, of the negotiated hash algorithm on a concatenation of the STA's public Diffie-Hellman value, the AP's public Diffie-Hellman value, the STA's nonce, the AP's nonce, the STA's MAC address, and the AP's BSS's BSSID, in that order:

$$\text{Key-Auth} = \text{Sig-}_{\text{STA}}(\text{gSTA} \parallel \text{gAP} \parallel \text{SNonce} \parallel \text{ANonce} \parallel \text{STA-MAC} \parallel \text{AP-BSSID})$$

where

$\text{Sig-}_{\text{STA}}(\,)$ indicates a digital signature using the STA's private key, analog to the STA's trusted public key

The form of signature depends on the type of public key used by the STA (IETF RFC 3447 for RSA, FIPS 186-4 for DSA, and ISO/IEC 14888-3 for ECDSA). The data to be signed is first hashed and the hash algorithm used with the appropriate digital signature algorithm shall be specific to the negotiated AKM.

The (Re)Association Request frame shall be encrypted using the AEAD algorithm as defined in 12.11.2.7 with the KEK as the key. The AAD used with the AEAD algorithm for the Association Request frame consists of the following data passed as separate components in the following order:

- STA's MAC address
- AP's BSS's BSSID
- STA's nonce
- AP's nonce
- The contents of the (Re)Association Request frame from the Capability Information field (inclusive) to the FILS session element (inclusive)

The plaintext passed to the AEAD algorithm is the data that would follow the FILS Session element in an unencrypted frame body. The output of the AEAD algorithm becomes the data that follows the FILS Session element in the encrypted and authenticated (Re)Association Request frame. The output of the algorithm is as specified in IETF RFC 5116. The resulting (Re)Association Request frame shall be transmitted to the AP.

The AP compares FILS session of the received (Re)Association Request frame with the FILS session that was used to identify the FILS session in the Authentication frames. If they differ, authentication exchange fails.

If dot11RSNAOperatingChannelValidationActivated is true and the STA indicates OCVC capability in the RSNE in the request, AP shall validate the OCI element in the request by ensuring that all of the following are true:

- OCI element is present.
- Channel information in the OCI matches current operating channel parameters (see 12.2.9).

Otherwise, the AP rejects the request by discarding the frame.

The AP decrypts and verifies the received (Re)Association Request frame with the AEAD algorithm as defined in 12.11.2.7 with the KEK as the key. The AAD is reconstructed as defined above and is passed, along with the cipher text of the received frame, to the AEAD decryption operation.

If the output from the AEAD decryption operation returns a failure, the authentication exchange fails. If the output does not return failure, the output plaintext replaces the cipher text as portion of the frame body that

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follows the FILS Session element and processing of the received frame continues by checking the value of the FILS Key Confirmation element.

The AP verifies that the RSNE received in the (Re)Association Request frame has identical AKM suite and cipher suites and RSN capabilities as were included in the RSNE in the Authentication frame from the STA. If these fields differ, the authentication exchange fails.

For FILS Shared Key authentication, the AP constructs a verifier, Key-Auth', in an identical manner as the STA constructed its Key-Auth above.

The AP compares Key-Auth' with the KeyAuth field in the FILS Key Confirmation element of the received frame. If they differ, authentication fails.

For FILS Public Key authentication, the AP uses the STA's (certified) public key from the FILS Public Key element to verify that the signature contained in the KeyAuth field corresponds to the purported signature by the STA over the concatenation of the following:

— STA's public Diffie-Hellman value gSTA
— AP's public Diffie-Hellman value gAP
— STA's nonce SNonce, the AP's nonce ANonce
— STA's MAC address STA-MAC
— AP's BSS's BSSID AP-BSSID

in that order, according to the signature scheme used. Furthermore, the AP checks all certificates in the certificate chain, both cryptographically and from a security policy perspective, according to the procedures for checking certificates and certificate chains in IETF RFC 5280. If any of these verifications fail, authentication fails.

If authentication is deemed a failure, ICK, KEK, TK, and the PTKSA shall be irretrievably deleted and the AP shall return an Authentication frame with a status code set to 112 (Authentication rejected due to FILS authentication failure). If PMKSA caching was not being employed for this failed authentication attempt, the PMKSA shall also be deleted. If PMKSA caching was being employed, the reason for failure might be an impersonation attack. Therefore, when FILS with PMKSA caching fails, the AP may decide to retain the cached PMKSA.

12.11.2.6.3 (Re)Association Response for FILS key confirmation

The AP constructs a (Re)Association Response frame for FILS authentication per 9.3.3.6 and 9.3.3.8. As with the (Re)Association Request frame, hash algorithms are used to generate the FILS Key Confirmation element and the specific hash algorithm depends on the negotiated AKM (see 9.4.2.24.3).

The AP constructs a Key Delivery element indicating the current GTK and Key RSC, the current IGTK and IPN if management frame protection is enabled, and the current BIGTK and BIPN if beacon protection is enabled. The GTK is carried in a GTK KDE with Tx subfield equal to 0. The IGTK and IPN are carried in an IGTK KDE. The BIGTK and BIPN are carried in a BIGTK KDE. The AP puts this element into the (Re)Association Response frame.

If dot11RSNAOperatingChannelValidationActivated is true and STA indicates OCVC capability, the AP shall include OCI element in the response.

For FILS Shared Key authentication and FILS Public Key authentication when using PMKSA caching, the KeyAuth field of the FILS Key Confirmation element is constructed by using the HMAC mode of the negotiated hash algorithm with a key of ICK on a concatenation of the AP's nonce, the STA's nonce, the AP's

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BSS's BSSID, the STA's MAC address, and conditionally the AP's public Diffie-Hellman value and the STA's public Diffie-Hellman value, in that order:

Key-Auth = HMAC-Hash(ICK, ANonce || SNonce || AP-BSSID || STA-MAC [|| gAP || gSTA])

where

Hash	is the hash algorithm specific to the negotiated AKM (see Table 9-151)
ANonce	is the AP's nonce
SNonce	is the STA's nonce
AP-BSSID	is the BSSID of the AP's BSS and STA-MAC is the MAC address of the STA
gAP	is the AP's Diffie-Hellman public value
gSTA	is the STA's Diffie-Hellman public value
Brackets	indicate the inclusion of the Diffie-Hellman public values when doing PFS with FILS Shared Key authentication; there are no Diffie-Hellman public values to include otherwise

For FILS Public Key authentication when PMKSA caching is not used, the KeyAuth field of the FILS Key Confirmation element is a digital signature using the AP's private key of the output from the negotiated hash algorithm on a concatenation of the AP's public Diffie-Hellman value, the STA's public Diffie-Hellman value, the AP's nonce, the STA's nonce, AP's BSS's BSSID, and the STA's MAC address, in that order. The specific construction of the digital signature depends on the crypto-system of the public/private key pair:

Key-Auth = $Sig\text{-}_{AP}$(gAP || gSTA || ANonce || SNonce || AP-BSSID || STA-MAC)

where

$Sig\text{-}_{AP}$() indicates a digital signature using the AP's private key analog to the AP's trusted public key

The form of signature depends on the type of public key used by the AP (IETF RFC 3447 for RSA, FIPS 186-4 for DSA, and ISO/IEC 14888-3 for ECDSA). The data to be signed is first hashed and the hash algorithm used with the appropriate digital signature algorithm shall be specific to the negotiated AKM.

The (Re)Association Response frame shall be encrypted using the AEAD algorithm as defined in 12.11.2.7 with the KEK as the key. The AAD used with the AEAD algorithm for the (Re)Association Response frame consists of the following data passed as separate components in the following order:

— AP's BSS's BSSID
— STA's MAC address
— AP's nonce
— STA's nonce
— The contents of the (Re)Association Response frame from the Capability Information field (inclusive) to the FILS Session element (inclusive)

The plaintext passed to the AEAD algorithm is the data that would follow the FILS Session element in an unencrypted frame body. The output of the AEAD algorithm becomes the data that follows the FILS Session element in the encrypted and authenticated (Re)Association Response frame. The output of the algorithm is as specified in IETF RFC 5116. The resulting (Re)Association Response frame shall be transmitted to the STA.

If dot11RSNAOperatingChannelValidationActivated is true and the AP indicates OCVC capability in its RSNE, the STA shall validate the OCI element in the response by ensuring that all of the following are true:

— OCI element is present
— Channel information in the OCI matches current operating channel parameters (see 12.2.9)

Otherwise, the STA shall discard the frame.

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The STA decrypts and verifies the received (Re)Association Response frame with the AEAD algorithm as defined in 12.11.2.5 with the KEK as the key. The AAD is reconstructed as defined in this subclause above and is passed with the cipher text of the received frame to the AEAD decryption operation.

The STA compares FILS Session of the received frame with the FILS Session it selected to identify the FILS session. If they differ, authentication fails.

If the output from the AEAD decryption operation returns failure, the authentication exchange fails. If the output does not return failure, the output plaintext replaces the cipher text as portion of the frame body that follows the FILS Session element and processing of the received frame continues by checking the value of the FILS Key Confirmation element.

The STA verifies that the RSNE received in the (Re)Association Response frame has identical AKM suites and cipher suites and RSN capabilities as were included in the RSNE in the Beacon, Probe Response, and Authentication frames from the AP. If these fields differ, authentication fails.

For FILS Shared Key authentication, the STA constructs a verifier, Key-Auth', in an identical manner as the AP constructed its Key-Auth above.

The STA compares Key-Auth' with the KeyAuth field in the FILS Key Confirmation element of the received frame. If they differ, authentication fails.

For FILS Public Key authentication, the STA uses the AP's (certified) public key from the FILS Public Key element to verify that the signature contained in the KeyAuth field corresponds to the purported signature by the AP over the concatenation of the following:

- AP's public Diffie-Hellman value gAP
- STA's public Diffie-Hellman value gSTA
- AP's nonce ANonce
- STA's nonce SNonce
- AP's BSS's BSSID AP-BSSID
- STA's MAC address STA-MAC

in that order, according to the signature scheme used. Furthermore, the AP checks all certificates in the certificate chain, both cryptographically and from a security policy perspective, according to the procedures for checking certificates and certificate chains in IETF RFC 5280. If any of these verifications fail, authentication fails.

If authentication is deemed a failure, the ICK, KEK, PMK, and TK shall be irretrievably deleted and the STA shall abandon the exchange. Otherwise authentication succeeds and the STA and AP shall irretrievably delete the nonpersistent secret keying material that is created by executing the key establishment with FILS Shared Key authentication scheme (12.11.2.3) or the key establishment with FILS Public Key authentication scheme (12.11.2.4). The KEK and PMK shall be used for subsequent key management as specified in 12.6. If the lifetime of the rMSK is known, the STA and AP shall set the lifetime of the PMKSA to the lifetime of the rMSK. Otherwise, the STA and AP shall set the lifetime of the PMKSA to the value dot11RSNAConfigPMKLifetime.

Upon successful completion of the FILS authentication procedure, the STA shall process the Key Delivery element in the (Re)Association Response frame. The STA installs the GTK and key RSC, and IGTK and IPN if management frame protection is enabled, and BIGTK and BIPN if present in the key delivery element and dot11BeaconProtectionEnabled is true.

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12.11.2.7 AEAD cipher mode for FILS

FILS authentication uses an AEAD cipher mode to protect (Re)Association Request/Response and EAPOL-Key frames. The AEAD cipher mode is determined by the specific FILS negotiated AKM.

AES-SIV-256 is used when the negotiated AKM is 00-0F-AC:14 or 00-0F-AC:16 and AES-SIV-512 is used when the negotiated AKM is 00-0F-AC:15 or 00-0F-AC:17.

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13. Fast BSS transition

13.1 Overview

Fast BSS transition seeks to reduce the length of time that connectivity is lost between a STA and the DS during a BSS transition. The FT protocols are part of the reassociation service and only apply to STA transitions between APs within the same mobility domain within the same ESS.

The FT protocols require information to be exchanged during the initial association (or a later reassociation) between a STA [known as the *FT Originator* (FTO)] and AP. The initial exchange is referred to as the *FT initial mobility domain association*. Subsequent reassociations to APs within the same mobility domain may make use of the FT protocols.

Two FT protocols are defined:

— *FT protocol.* This protocol is executed when an FTO makes a transition to a target AP and does not require a resource request prior to its transition.

— *FT resource request protocol.* This protocol is executed when an FTO requires a resource request prior to its transition.

For an FTO to move from its current AP to a target AP utilizing the FT protocols, the message exchanges are performed using one of two methods:

— *Over-the-Air.* The FTO communicates directly with the target AP using IEEE 802.11 authentication with the FT authentication algorithm.

— *Over-the-DS.* The FTO communicates with the target AP via the current AP. The communication between the FTO and the target AP is carried in FT Action frames between the FTO and the current AP. Between the current AP and target AP, communication is via an encapsulation method described in 13.10.3. The current AP converts between the two encapsulations.

APs advertise both capabilities and policies for supporting the FT protocols and methods.

Throughout this clause, the notation *Authentication-Request* refers to an Authentication frame with the Authentication Transaction Sequence Number field equal to 1; *Authentication-Response* refers to an Authentication frame with the Authentication Transaction Sequence Number field equal to 2; *Authentication-Confirm* refers to an Authentication frame with the Authentication Transaction Sequence Number field equal to 3; *Authentication-Ack* refers to an Authentication frame with the Authentication Transaction Sequence Number field equal to 4. The first parameter to the above four messages is the authentication algorithm, such as Open System authentication algorithm (i.e., *Open* in figures in this clause) or FT authentication algorithm (i.e., *FTAA* in figures in this clause).

13.2 Key holders

13.2.1 Introduction

The FT key holder architecture, shown in Figure 13-1, describes the FT key management entities and is defined in the context of the IEEE 802.11 basic reference model (see Figure 4-24 in 4.9).

The R0KH and R1KH are part of AP's SME RSNA key management. The computation of PMK-R0 and PMK-R1, and all of the intermediate results in the computations, shall be restricted to the R0KH. The computation of PTK, and all intermediate results in its computation, shall be restricted to the R1KH.

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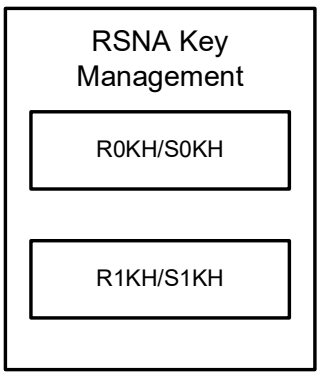

Figure 13-1—FT key holder architecture

The S0KH and S1KH are part of the FTO's SME RSNA key management. The computation of PMK-R0 and PMK-R1, and all of the intermediate results in the computations, shall be restricted to the S0KH. The computation of PTK, and all intermediate results in its computation, shall be restricted to the S1KH.

13.2.2 Authenticator key holders

The R0KH and R1KH are responsible for the derivation of keys in the FT key hierarchy. For fast BSS transition, the functions of the IEEE 802.1X Authenticator are distributed among the R0KH and R1KHs.

The R0KH interacts with the IEEE 802.1X Authenticator to receive the MSK resulting from an EAP authentication. The R1KH interacts with the IEEE 802.1X Authenticator to open the Controlled Port. Both the R0KH and R1KH interactions with the IEEE 802.1X Authenticator occur within the SME.

The R0KH derives the PMK-R0 for use in the mobility domain utilizing the MSK (when the negotiated AKM is 00-0F-AC:3 or 00-0F-AC:13), the PSK (when the negotiated AKM is 00-0F-AC:4) or the PMK (when the negotiated AKM is 00-0F-AC:9), or the FILS-FT (when the negotiated AKM is 00-0F-AC:16 or 00-0F-AC:17). The R0KH shall be responsible for deriving a PMK-R1 for each R1KH within the mobility domain.

The R1KH and S1KH each derive the PTK.

Each R0KH-ID and R1KH-ID is assumed to be expressed as a unique identifier within the mobility domain. This identifier is communicated to the FTO and other key holders. The R0KH-ID is bound into the PMK-R0 derivation and the R1KH-ID is bound into the PMK-R1 derivation.

The R0KH shall meet the following requirements:

— The R0KH shall be collocated with the network access server (NAS) Client functionality of the IEEE 802.1X Authenticator.
— The R0KH-ID shall be set to the identity of the co-resident NAS Client (e.g., NAS-Identifier as defined in IETF RFC 2865 [B33] if RADIUS is used as the backend protocol). R0KH-ID shall not be longer than 48 octets to fit in the length limitation of the FTE.
— When the PMK-R0 lifetime expires, the R0KH shall delete the PMK-R0 security association and shall revoke within the R0KH all PMK-R1s derived from the PMK-R0.
— The R0KH shall not expose the PMK-R0 to other parties.
— The R0KH shall not expose the PMK-R1 to parties other than the authorized R1KH.

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The R1KH shall meet the following requirements:

- The R1KH-ID shall be set to a MAC address of the physical entity that stores the PMK-R1 and uses it to generate the PTK. That same MAC address shall be used to advertise the PMK-R1 identity to the STA and the R0KH.
- The R1KH shall derive and distribute the GTK and IGTK to all connected STAs.
- If beacon protection is enabled, the R1KH shall derive and distribute the BIGTK and BIPN to all connected STAs.
- When the PMK-R1 lifetime expires, the R1KH shall delete the PMK-R1 PMKSA and shall revoke all PTKSAs derived from the PMK-R1 using the MLME-DELETEKEYS primitive.
- The R1KH shall not expose the PMK-R1 to other parties.

dot11FTR0KeyHolderID and dot11FTR1KeyHolderID shall contain the values of R0KH-ID and R1KH-ID as defined in this clause, respectively.

The R0KH and the R1KH are assumed to have a secure channel between them that can be used to exchange cryptographic keys without exposure to any intermediate parties. The cryptographic strength of the secure channel between the R0KH and R1KH is assumed to be greater than or equal to the cryptographic strength of the channels for which the keys are used. This standard assumes that the key transfer includes the PMK-R1, the PMK-R1 PMKSA, the PMK-R1 context, and the associated key authorizations. The protocol for distribution of keying material from the R0KH to the R1KH is outside the scope of this standard.

The PMK-R1 distribution from the R0KH to the R1KHs within the same mobility domain shall satisfy the following assumptions:

- The R0KH authenticates a potential R1KH with the same identity as is included in the PMK-R1 derivation. The cryptographic strength of the authentication is assumed to be greater than or equal to the cryptographic strength of the authentication between the Supplicant and AS.
- The authorization of holding a PMK-R1 is based on the authentication of the R1KH.
- The protected channel provides confidentiality and integrity protection.

13.2.3 Supplicant key holders

The S0KH and S1KH are responsible for the derivation of keys in the FT key hierarchy. The S0KH and S1KH are entities that are assumed to physically reside in the Supplicant.

The S0KH interacts with the IEEE 802.1X functional block (see Figure 4-24 in 4.9) to receive the MSK resulting from an EAP authentication or the FILS-FT resulting from a FILS authentication. The S1KH interacts with the IEEE 802.1X entity to open the Controlled Port. Both the S0KH and S1KH interactions with the IEEE 802.1X entity occur within the SME of a STA.

The S0KH derives the PMK-R0 for use in the mobility domain utilizing the MSK (when the negotiated AKM is 00-0F-AC:3 or 00-0F-AC:13), the PSK (when the negotiated AKM is 00-0F-AC:4) or the PMK (when the negotiated AKM is 00-0F-AC:9), or the FILS-FT (when the negotiated AKM is 00-0F-AC:16 or 00-0F-AC:17).

The S1KH shall derive the PTK mutually with the R1KH.

The S0KH and S1KH shall be identified by the SPA. The S0KH shall not expose the PMK-R0 to other parties and shall not expose the PMK-R1 to parties other than the authorized S1KH. The S1KH shall not expose the PMK-R1 to other parties.

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13.3 Capability and policy advertisement

The FT capability is advertised in the Beacon and Probe Response frames by including the MDE. The MDE is advertised in the Beacon and Probe Response frames to indicate the MDID, FT capability, and the FT policy.

The MDID field shall be dot11FTMobilityDomainID. The Fast BSS Transition Policy bits in the MDE, i.e., Fast BSS Transition over DS subfield and Resource Request Protocol Capability subfield, shall be set by dot11FTOverDSActivated and dot11FTResourceRequestSupported, respectively.

NOTE—It is assumed by this standard that the Fast BSS Transition Policy bits in the MDE are administered consistently across the mobility domain.

The capability is advertised in the Neighbor Report element. See 11.10 and 9.4.2.36.

If an FTE is included in a Request element in a Probe Request frame, the FTE in the Probe Response frame shall contain the R0KH-ID and R1KH-ID (from dot11FTR0KeyHolderID and dot11FTR1KeyHolderID), and all other fields shall be set to 0.

13.4 FT initial mobility domain association

13.4.1 Overview

The FT initial mobility domain association is the first (re)association in the mobility domain, where the SME of the STA enables its future use of the FT procedures.

FT initial mobility domain association is typically the first association within the ESS. In addition to Association Request and Response frames, Reassociation Request and Response frames are supported in the initial mobility domain association to enable both FT and non-FT APs to be present in a single ESS.

13.4.2 FT initial mobility domain association in an RSN

A STA indicates its support for the FT procedures by including the MDE in the (Re)Association Request frame and indicates its support of security by including the RSNE. The AP responds by including the FTE, MDE, and RSNE in the (Re)Association Response frame. After a successful IEEE 802.1X authentication (if needed) or SAE authentication, the STA and AP perform an FT 4-way handshake. At the end of the sequence, the IEEE 802.1X Controlled Port is opened, and the FT key hierarchy has been established. The message flow is shown in Figure 13-2.

A non-DMG STA initiates the FT initial mobility domain association procedures by performing an IEEE 802.11 authentication using the Open System authentication algorithm.

STA→AP: Authentication-Request (Open System authentication algorithm)
AP→STA: Authentication-Response (Open System authentication algorithm, Status)

A DMG STA initiates the FT initial mobility domain association procedures by performing an IEEE 802.11 authentication using the SAE algorithm.

STA→AP: Authentication-Request (SAE algorithm)
AP→STA: Authentication-Response (SAE algorithm, Status)

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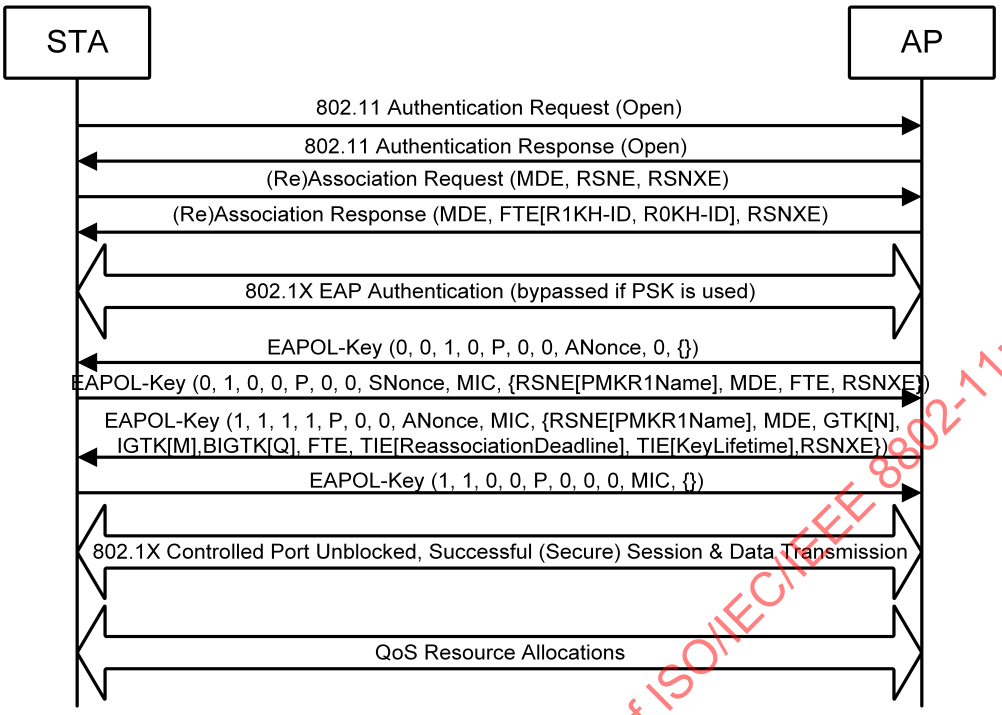

Figure 13-2—FT initial mobility domain association in an RSN

The SME of the STA initiates the authentication exchange, through the use of the MLME-AUTHENTICATE.request primitive, and the SME of the AP responds with MLME-AUTHENTICATE.response primitive. See 11.3.4.

Upon successful IEEE 802.11 Open System or SAE authentication, if using a suite type for which the Authentication type column indicates FT authentication (see Table 9-151), the STA shall send a (Re)Association Request frame to the AP that includes the MDE. The contents of the MDE shall be the values advertised by the AP in its Beacon or Probe Response frames. Additionally, the STA includes its security capabilities in the RSNE.

STA→AP: (Re)Association Request (MDE, RSNE, RSNXE)
AP→STA: (Re)Association Response (MDE, FTE[R1KH-ID, R0KH-ID], RSNXE)

The SME of the STA initiates the (re)association through the use of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive. The SME of the AP responds to the indication with MLME-ASSOCIATE.response or MLME-REASSOCIATE.response primitive. See 11.3.5.

If the contents of the MDE received by the AP do not match the contents advertised in the Beacon and Probe Response frames, the AP shall reject the (Re)Association Request frame with status code STATUS_INVALID_MDE. If an MDE is present in the (Re)Association Request frame and the contents of the RSNE do not indicate a negotiated AKM for which the Authentication type column indicates FT authentication (see Table 9-151), the AP shall reject the (Re)Association Request frame with status code STATUS_INVALID_AKMP.

The (Re)Association Response frame from the AP shall contain an MDE, with contents as presented in Beacon and Probe Response frames. The FTE shall include the key holder identities of the AP, the R0KH-ID and R1KH-ID, set to the values of dot11FTR0KeyHolderID and dot11FTR1KeyHolderID, respectively. The

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FTE shall have a MIC element count of zero (i.e., no MIC present) and have ANonce, SNonce, and MIC fields set to 0. The RSNXE Used subfield of the MIC Control field shall be set to 0.

On successful (re)association, the S0KH on the STA and the R0KH on the AP then proceed with an IEEE 802.1X authentication using EAPOL PDUs carried in IEEE 802.11 Data frames if SAE authentication was not performed (i.e., if the suite type is not 00-0F-AC:9). The S0KH shall use the value of R0KH-ID as the endpoint identifier of the NAS Client (NAS-Identifier if RADIUS is used) in the exchange as defined in IETF RFC 3748.

If IEEE 802.1X authentication was performed, then upon successful completion of authentication, the R0KH receives the MSK and authorization attributes. If SAE authentication was performed, the R0KH receives the PMK, resulting in the successful completion of SAE. If a key hierarchy already exists for this STA belonging to the same mobility domain (i.e., having the same MDID), the R0KH shall delete the existing PMK-R0 security association and PMK-R1 security associations. It then calculates the PMK-R0, PMKR0Name, and PMK-R1 and makes the PMK-R1 available to the R1KH of the AP with which the STA is associated.

If the SME of the STA cannot authenticate the AS, then it shall disassociate with an MLME-DISASSOCIATE.request primitive. If the AS signals the Authenticator that the STA cannot be authenticated, then the SME of the AP shall disassociate with an MLME-DISASSOCIATE.request primitive.

If the MSK lifetime attribute is provided by the AS, the lifetime of the PMK-R0 shall not be more than the lifetime of the MSK. If the MSK lifetime attribute is not provided, the PMK-R0 lifetime shall be dot11FTR0KeyLifetime. For PSK, the PMK-R0 lifetime shall be dot11FTR0KeyLifetime. The lifetime of the PMK-R1s and PTK shall be the same as the lifetime of PMK-R0. When the key lifetime expires, each key holder shall delete its respective PMK-R0, PMK-R1, and PTK SAs.

The R1KH and S1KH then perform an FT 4-way handshake. The EAPOL-Key frame notation is defined in 12.7.4.

R1KH→S1KH: EAPOL-Key(0, 0, 1, 0, P, 0, 0, ANonce, 0, {})
S1KH→R1KH: EAPOL-Key(0, 1, 0, 0, P, 0, 0, SNonce, MIC, {RSNE[PMKR1Name], MDE, FTE, RSNXE})
R1KH→S1KH: EAPOL-Key(1, 1, 1, 1, P, 0, 0, ANonce, MIC, {RSNE[PMKR1Name], MDE, GTK[N], IGTK[M], BIGTK[Q], FTE, TIE[ReassociationDeadline], TIE[KeyLifetime], RSNXE})
S1KH→R1KH: EAPOL-Key(1, 1, 0, 0, P, 0, 0, 0, MIC, {})

The message sequence is described in 12.7.6.

It is assumed by this standard that the reassociation deadline is administered consistently across the mobility domain. The mechanism for such consistent administration is outside the scope of this standard.

The PTK shall be calculated by the R1KH and S1KH according to the procedures given in 12.7.1.6.5.

Upon completion of a successful FT 4-way handshake, the IEEE 802.1X Controlled Port shall be opened on both the non-AP STA and the AP. Subsequent EAPOL-Key frames shall use the key replay counter to detect replayed messages.

Upon completion of a successful FT 4-way handshake, the PTK lifetime timer is initiated. The operation of this timer prevents the PTKSA being used for longer than the value provided in the TIE[KeyLifetime] sent in message 3.

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Once the PTKSA key lifetime expires, as indicated by the TIE[KeyLifetime], to continue its association in the mobility domain the STA shall perform the FT initial mobility domain association procedures. If the AP sends a Deauthentication or Disassociation frame to the STA with reason code INVALID_AUTHENTICATION, then to continue its association in the mobility domain, the STA shall perform the FT initial mobility domain association procedures with any AP in the mobility domain. If the Supplicant EAPOL state machines are triggered to send an EAPOL-Start frame after a successful initial mobility domain association, the STA shall perform the FT initial mobility domain association procedures.

13.4.3 FT initial mobility domain association in a non-RSN

In this sequence, the STA utilizes the FT procedures by including the MDE in the (Re)Association Request frame. The AP responds by including the MDE in the (Re)Association Response frame. The message flow is shown in Figure 13-3.

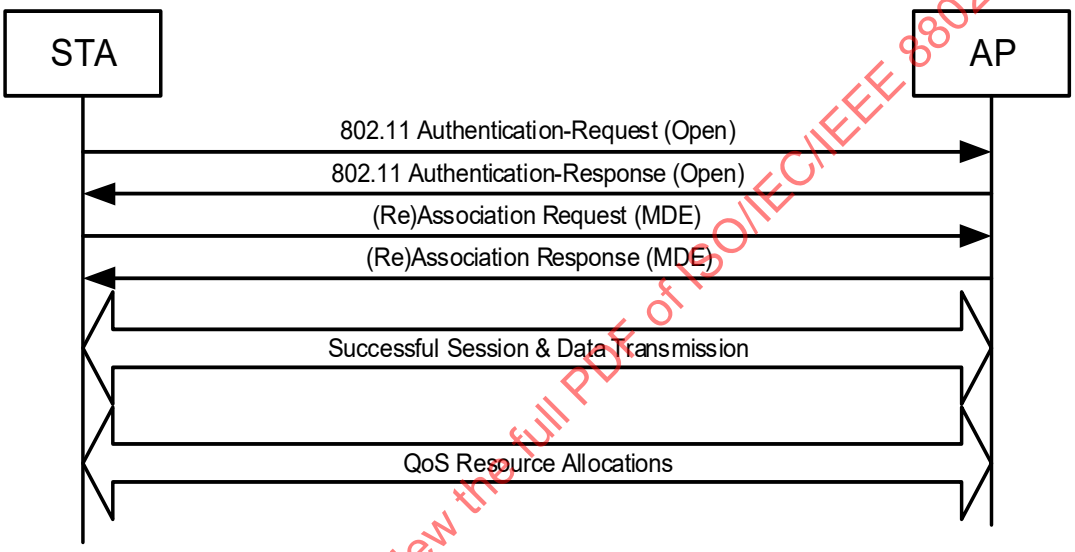

Figure 13-3—FT initial mobility domain association in a non-RSN

The STA initiates the FT initial mobility domain association procedures by performing an IEEE 802.11 authentication using the Open System authentication algorithm.

STA→AP: Authentication-Request (Open System authentication algorithm)
AP→STA: Authentication-Response (Open System authentication algorithm, Status)

The SME of the STA initiates the authentication exchange through the use of the primitive MLME-AUTHENTICATE.request primitive, and the SME of the AP responds with MLME-AUTHENTICATE.response primitive. See 11.3.4.

Upon successful IEEE 802.11 Open System authentication, the STA shall send a (Re)Association Request frame to the AP and shall include the MDE. The contents of the MDE shall be the values advertised by the AP in its Beacon or Probe Response frames.

STA→AP: (Re)Association Request (MDE)
AP→STA: (Re)Association Response (MDE)

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The SME of the STA initiates the (re)association through the use of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive. The SME of the AP responds to the indication with MLME-ASSOCIATE.response or MLME-REASSOCIATE.response primitive. See 11.3.5.

If the contents of the MDE received by the AP do not match the contents advertised in the Beacon and Probe Response frames, the AP shall reject the (Re)Association Request frame with status code STATUS_INVALID_MDE.

The (Re)Association Response frame from the AP shall contain an MDE, with contents as presented in Beacon and Probe Response frames.

On successful (re)association, the AP and the non-AP STA shall transition to State 4 (as defined in 11.3) to enable Data frame transmission.

13.4.4 FT initial mobility domain association over FILS in an RSN

A STA may perform FT initial mobility domain association with an AP using FILS Authentication as specified in this clause if it receives an MDE and FILS Indication element in the Beacon or Probe Response frame from the AP.

A STA indicates its support for the FT procedures by including the MDE in the Authentication frame and indicates its support of security in the RSNE. To establish FT key hierarchy, the AP responds by including the FTE, MDE, and RSNE in the Authentication frame. At the end of the sequence, the FT key hierarchy has been established. The message flow is shown in Figure 13-4.

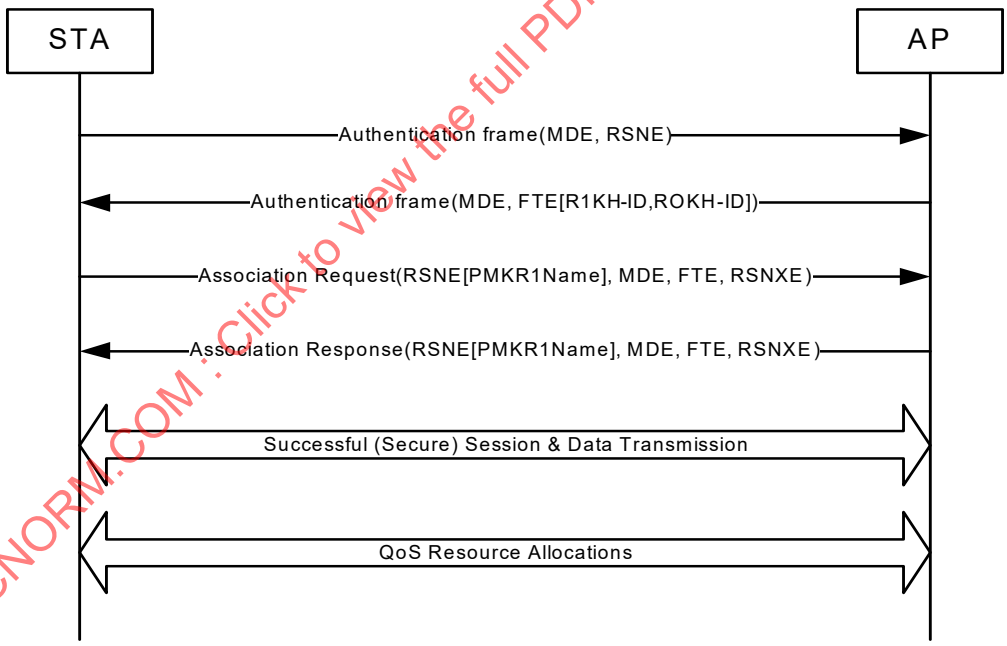

Figure 13-4—FT initial mobility domain association using FILS authentication in an RSN

To establish the FT key hierarchy, the STA shall send an Authentication frame with the MDE and Authentication algorithm number 4, 5, or 6 to the AP. The contents of the MDE shall be the values advertised by the AP in its Beacon or Probe Response frames. Additionally, the STA includes its security capabilities in the RSNE.

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If the contents of the MDE received by the AP do not match the contents advertised in the Beacon and Probe Response frames, the AP shall reject the Authentication frame with status code 54 (“Invalid MDE”). If an MDE is present in the Authentication frame and the contents of the RSNE do not indicate a negotiated AKM of Fast BSS Transition over FILS (suite type 00-0F-AC:16 or 00-0F-AC:17), the AP shall reject the Authentication frame with status code 43 (“Invalid AKMP”).

Upon successful completion of FILS authentication request processing, the R0KH on the AP uses the FILS-FT (see 12.11.2.5.3) to establish key hierarchy. If a key hierarchy already exists for this STA belonging to the same mobility domain (i.e., having the same MDID), the R0KH shall delete the existing PMK-R0 security association and PMK-R1 security associations. It then calculates the PMK-R0, PMKR0Name, and PMK-R1 and makes the PMK-R1 available to the R1KH of the AP to which the STA is associated.

Next, the AP shall construct an Authentication frame. The Authentication frame shall contain an MDE, with contents as presented in Beacon and Probe Response frames. The FTE shall include the key holder identities of the AP, the R0KH-ID and R1KH-ID, set to the values of dot11FTR0KeyHolderID and dot11FTR1KeyHolderID, respectively. The FTE shall have a MIC element count of zero (i.e., no MIC present) and have ANonce, SNonce, and MIC fields set to 0.

The S1KH on STA provides the PMKR1Name in the PMKID List field of the RSNE to be included in the (Re)Association Request frame. The PMKR1Name shall be as calculated by the S1KH according to the procedures of 12.7.1.6.4; all other fields of the RSNE shall be identical to the RSNE present in the Authentication frame. The S1KH shall provide the FTE and MDE; the FTE and MDE shall be the same as those provided in the AP’s Authentication frame. If the S1KH set to any subfield, except the Field Length subfield, of the Extended RSN Capabilities field in the RSNXE, the S1KH shall provide the RSNXE.

Finally, the R1KH provides the PMKR1Name in the PMKID List field of the RSNE to be included in (Re)Association Response frame. The PMKR1Name shall be as calculated by the R1KH according to the procedures of 12.7.1.6.4 and shall be the same as the PMKR1Name in the Association Request frame; all other fields of the RSNE shall be identical to the RSNE present in the Beacon or Probe Response frames. The R1KH shall also provide the FTE and the MDE. The FTE and MDE shall be the same as in the Authentication frame. If the RSNXE is present in the Beacon or Probe Response frames that the AP transmits, the AP shall also provide the RSNXE.

When FILS authentication is used to establish the FT key hierarchy, TK and KEK for the initial mobility domain association are derived as part of the FILS authentication as defined in 12.11.2.5.3.

NOTE—This means that the PTK derivation as described in 12.7.1.6.5 is not used in the case of FT initial mobility domain association over FILS.

13.5 FT protocol

13.5.1 Overview

STAs with dot11FastBSSTransitionActivated equal to true shall support the FT protocol.

The FT protocol supports resource requests as part of the reassociation. The optional FT resource request protocol (see 13.6) supports resource requests prior to reassociation.

A STA shall not use any authentication algorithm except the FT authentication algorithm when using the FT protocol.

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To prevent key reinstallation attacks, the non-AP STA shall maintain a copy of the most recent GTK, IGTK, and BIGTK when present installed as part of the FT protocol as if they were installed as a result of receipt of EAPOL-Key frames (see 12.7.7.4) and shall refuse to update a GTK, IGTK, or a BIGTK when the key to be set matches either one of these two keys (see 6.3.19).

13.5.2 Over-the-air FT protocol authentication in an RSN

The over-the-air FT protocol in an RSN is shown in Figure 13-5.

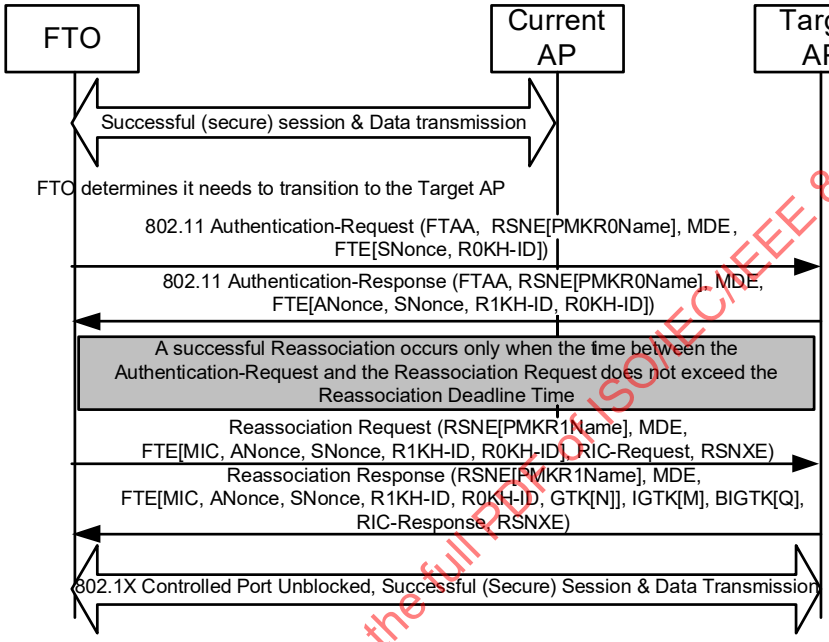

Figure 13-5—Over-the-air FT protocol in an RSN

The FTO and AP use the FT authentication sequence to specify the PMK-R1 security association and to provide values of SNonce and ANonce that enable a liveness proof, replay protection, and PTK separation. This exchange enables a fresh PTK to be computed in advance of reassociation. The PTKSA is used to protect the subsequent reassociation transaction, including the optional RIC-Request.

To perform an over-the-air fast BSS transition to a target AP, the FTO and target AP shall perform the following exchange:

FTO→Target AP: Authentication-Request (FTAA, 0, RSNE[PMKR0Name], MDE, FTE[SNonce, R0KH-ID])

Target AP→FTO: Authentication-Response (FTAA, Status, RSNE[PMKR0Name], MDE, FTE[ANonce, SNonce, R1KH-ID, R0KH-ID])

The SME of the FTO initiates the authentication exchange, through the use of the MLME-AUTHENTICATE.request primitive, and the SME of the AP responds with an MLME-AUTHENTICATE.response primitive. See 11.3.4. The MLME primitives for Authentication when the FT authentication algorithm is selected use only authentication transaction sequence number values 1 and 2.

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In the Authentication-Request frame, the SA field of the message header shall be set to the MAC address of the FTO, and the DA field of the message header shall be set to the BSSID of the target AP's BSS. The elements in the frame, and their required contents, shall be as given in 13.8.2.

If the contents of the MDE received by the AP do not match the contents advertised in the Beacon and Probe Response frames, the AP shall reject the authentication request with status code STATUS_INVALID_MDE. If the Authentication-Request frame contains an authentication algorithm equal to FT authentication and the contents of the RSNE do not indicate a negotiated AKM for which the Authentication type column indicates FT authentication (see Table 9-151), the AP shall reject the authentication request with status code STATUS_INVALID_AKMP. If the FTE in the FT Request frame contains an invalid R0KH-ID, the AP shall reject the FT Request frame with status code STATUS_INVALID_FTE. If the RSNE in the Authentication-Request frame contains an invalid PMKR0Name and the AP has determined that it is an invalid PMKR0Name, the AP shall reject the authentication request with status code STATUS_INVALID_PMKID. If the requested R0KH is not reachable, the AP shall respond to the authentication request with status code R0KH_UNREACHABLE. If the FTO selects a pairwise cipher suite in the RSNE that is different from the ones used in the Initial mobility domain association, then the AP shall reject the authentication request with status code STATUS_INVALID_PAIRWISE_CIPHER. Subsequent to a rejection of an authentication request, the FTO may retry the authentication request.

In the Authentication-Response frame, the SA field of the message header shall be set to the BSSID of the target AP's BSS, and the DA field of the message header shall be set to the MAC address of the FTO. The Status Code field shall be a value from the options listed in 9.4.1.9. The elements in the frame, and their required contents, shall be as given in 13.8.3.

The R1KH of the target AP uses the value of PMKR0Name and other information in the frame to calculate PMKR1Name. If the target AP does not have the key identified by PMKR1Name, it may retrieve that key from the R0KH identified by the FTO. See 13.2. Upon receiving a new PMK-R1 for a STA, the target AP shall delete the prior PMK-R1 security association and PTKSAs derived from the prior PMK-R1.

The FTO and the target AP compute the PTK and PTKName using the PMK-R1, PMKR1Name, ANonce, and SNonce, as specified in 12.7.1.6.5. The PTKSA shall be deleted by the target AP if it does not receive a Reassociation Request frame from the FTO within the reassociation deadline timeout value.

If the FTO does not receive a response to the Authentication-Request frame, it may reissue the request following the restrictions given for Authentication frames in 11.3. If the Status Code field value returned by the target AP is SUCCESS, the FTO and target AP transition to State 2 (as defined in 11.3); the FTO may continue with reassociation (13.7.1). Handling of errors returned in the Status Code field shall be as specified in 11.3.

13.5.3 Over-the-DS FT protocol in an RSN

A STA shall not initiate an over-the-DS FT authentication to a target AP whose MDE contains the Fast BSS Transition over DS bit equal to 0.

The over-the-DS FT protocol in an RSN is shown in Figure 13-6.

To perform an over-the-DS fast BSS transition to a target AP, the FTO and the target AP (through the current AP) shall perform the following exchange:

FTO→Target AP:	FT Request (FTO address, TargetAP address, RSNE[PMKR0Name], MDE, FTE[SNonce, R0KH-ID])
Target AP→FTO:	FT Response (FTO address, TargetAP address, Status, RSNE[PMKR0Name], MDE, FTE[ANonce, SNonce, R1KH-ID, R0KH-ID])

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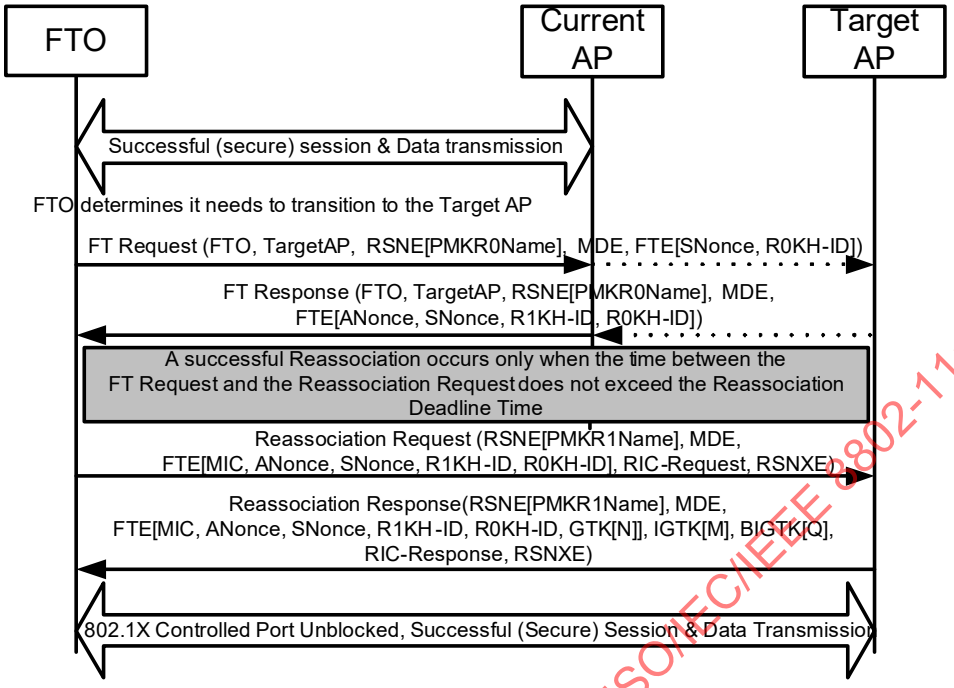

Figure 13-6—Over-the-DS FT protocol in an RSN

The SME of the FTO initiates the FT Request frame to the target AP by issuing an MLME-REMOTE-REQUEST.request primitive with parameters including the contents of the FT Request frame (FT Action frame with an FT Action field value indicating FT Request) to be sent. The MAC of the FTO transmits this Action frame. For processing at the current AP and target AP, see 13.10. When the MAC of the FTO receives the FT Response frame (FT Action frame with an FT Action field value indicating FT Response), it passes it to the SME by use of MLME-REMOTE-REQUEST.indication primitive, with parameters including the contents of the received Action frame. The MLME interfaces on the FTO, current AP, and the target AP for executing the over-the-DS fast BSS transition are shown in Figure 13-7.

The STA Address field of the FT Request frame shall be set to the MAC address of the FTO, and the Target AP Address field of the FT Request frame shall be set to the BSSID of the target AP's BSS. The elements in the FT Request frame, and their required contents, shall be as given in 13.8.2.

If the contents of the MDE received by the target AP do not match the contents advertised in the Beacon and Probe Response frames, the target AP shall reject the FT Request frame with status code STATUS_INVALID_MDE. If the contents of the RSNE do not indicate a negotiated AKM for which the Authentication type column indicates FT authentication (see Table 9-151), the AP shall reject the FT Request frame with status code STATUS_INVALID_AKMP. If the FTE in the FT Request frame contains an invalid R0KH-ID, the AP shall reject the FT Request frame with status code STATUS_INVALID_FTE. If the RSNE in the FT Request frame contains an invalid PMKR0Name, and the AP has determined that it is an invalid PMKR0Name, the AP shall reject the authentication request with status code STATUS_INVALID_PMKID. If the requested R0KH is not reachable, the AP shall respond to the FT Request frame with status code R0KH_UNREACHABLE. The AP may reject the FT Request frame for limiting the FTO's reassociation to this AP by using the status code REQUEST_DECLINED. If the FTO selects a pairwise cipher suite in the RSNE that is different from the ones used in the initial mobility domain association, then the AP shall reject the FT Request frame with status code STATUS_INVALID_PAIRWISE_CIPHER.

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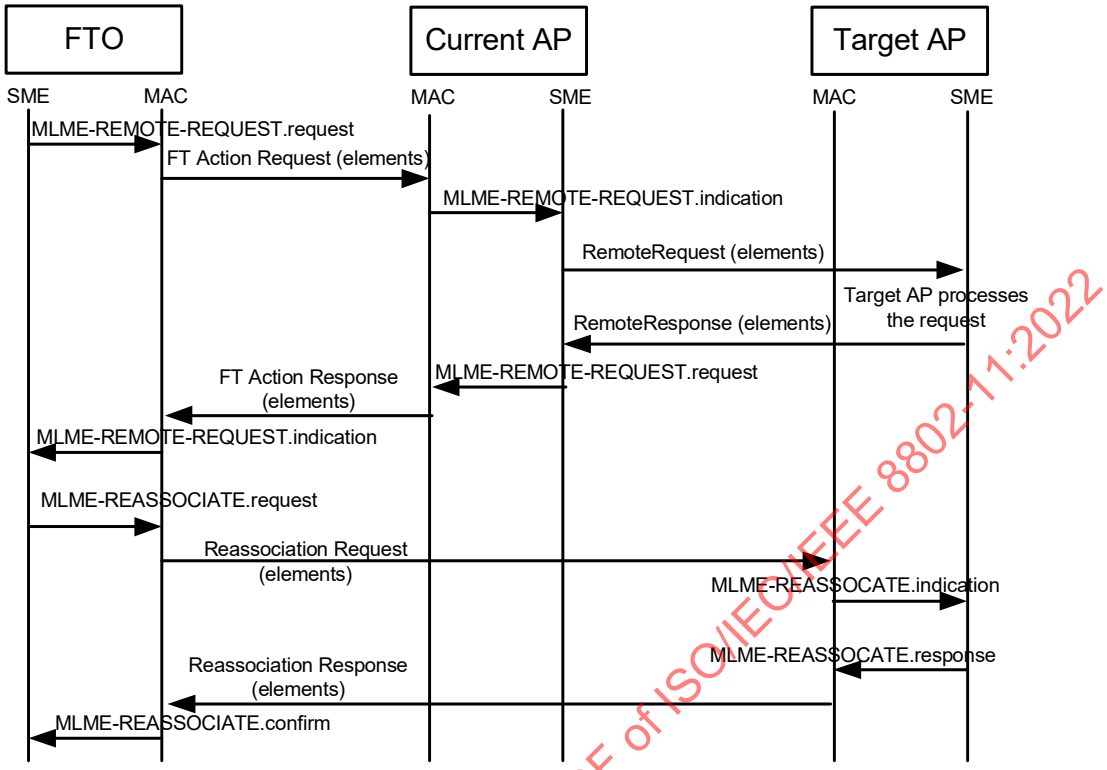

Figure 13-7—MLME interfaces for over-the-DS FT protocol messages

The STA Address field of the FT Response frame shall be set to the MAC address of the FTO, and the Target AP Address field of the FT Response frame shall be set to the BSSID of the target AP's BSS. The elements in the FT Response frame, and their required contents, shall be as given in 13.8.3. The Status Code field shall be a value from the options listed in 9.4.1.9.

The R1KH of the target AP uses the value of PMKR0Name and other information from the frame to calculate PMKR1Name. If the target AP does not have the key identified by PMKR1Name, it may retrieve that key from the R0KH identified by the STA. See 13.2. Upon receiving a new PMK-R1 for a STA, the target AP shall delete the prior PMK-R1 security association and PTKSAs derived from the prior PMK-R1.

The FTO and the target AP compute the PTK and PTKName using the PMK-R1, PMKR1Name, ANonce, and SNonce, as specified in 12.7.1.6.5. The PTKSA shall be deleted by the target AP if it does not receive a Reassociation Request frame from the FTO within the reassociation deadline timeout value.

If the FTO does not receive a response to the FT Request frame, it may reissue the request following the restrictions given for Authentication frames in 11.3. If the Status Code field value returned by the target AP is SUCCESS, the FTO and target AP transition to State 2 (as defined in 11.3); the FTO may continue with reassociation (13.7.1). Handling of errors returned in the Status Code field shall be as specified for Authentication frames in 11.3.

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13.5.4 Over-the-air FT protocol in a non-RSN

The over-the-air FT protocol in a non-RSN is shown in Figure 13-8.

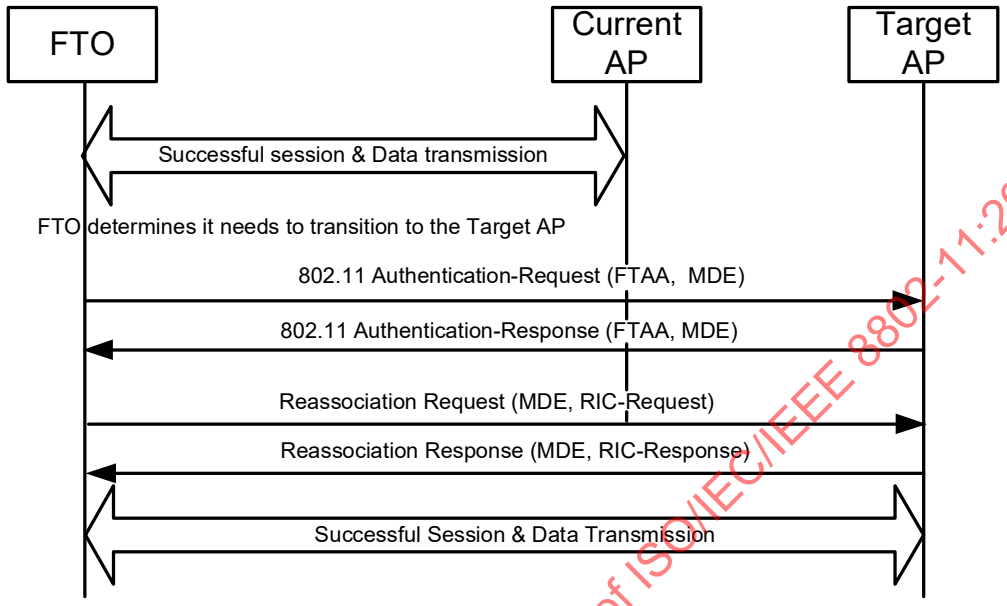

Figure 13-8—Over-the-air FT protocol in a non-RSN

To perform an over-the-air fast BSS transition to a target AP in a non-RSN, the FTO and target AP shall perform the following exchange:

FTO→Target AP: Authentication-Request (FTAA, 0, MDE)
Target AP→FTO: Authentication-Response (FTAA, Status, MDE)

In the Authentication-Request frame, the SA field of the message header shall be set to the MAC address of the FTO, and the DA field of the message header shall be set to the BSSID of the target AP's BSS. The elements in the frame, and their required contents, shall be as given in 13.8.2.

If the contents of the MDE received by the target AP do not match the contents advertised in the Beacon and Probe Response frames, the target AP shall reject the authentication request with status code STATUS_INVALID_MDE.

In the Authentication-Response frame, the SA field of the message header shall be set to the BSSID of the target AP's BSS, and the DA field of the message header shall be set to the MAC address of the FTO. The Status Code field shall be a value from the options listed in 9.4.1.9. The elements in the frame, and their required contents, shall be as given in 13.8.3.

If the FTO does not receive a response to the Authentication-Request frame, it may reissue the request following the restrictions given for Authentication frames in 11.3. If the Status Code field value returned by the target AP is SUCCESS, the FTO and target AP transition to State 2 (as defined in 11.3); the FTO may continue with reassociation (13.7.2). Handling of errors returned in the Status Code field shall be as specified in 11.3.

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13.5.5 Over-the-DS FT protocol in a non-RSN

The over-the-DS FT protocol in a non-RSN is shown in Figure 13-9.

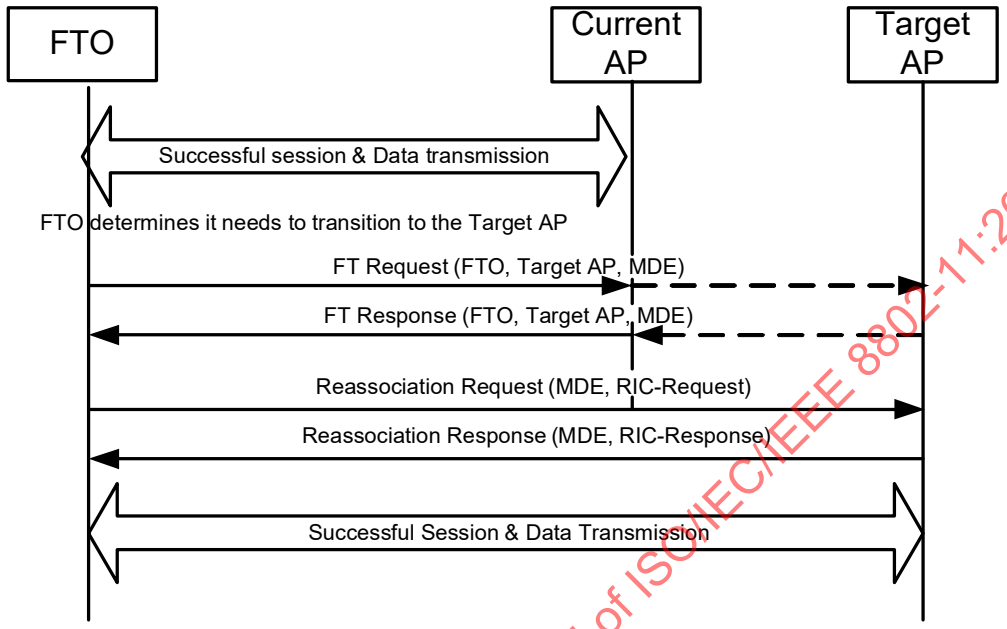

Figure 13-9—Over-the-DS FT protocol in a non-RSN

To perform an over-the-DS fast BSS transition to a target AP in a non-RSN, the FTO and the target AP (through the current AP) shall perform the following exchange:

FTO→Target AP: FT Request(FTO, TargetAP, MDE)
Target AP→FTO: FT Response(FTO, TargetAP, Status, MDE)

The STA Address field of the FT Request frame shall be set to the MAC address of the FTO, and the Target AP Address field of the FT Request frame shall be set to the BSSID of the target AP's BSS. The elements in the FT Request frame, and their required contents, shall be as given in 13.8.2.

If the contents of the MDE received by the target AP do not match the contents advertised in the Beacon and Probe Response frames, the target AP shall reject the FT Request frame with status code STATUS_INVALID_MDE.

The STA Address field of the FT Response frame shall be set to the MAC address of the FTO, and the Target AP Address field of the FT Response frame shall be set to the BSSID of the target AP's BSS. The elements in the FT Response frame, and their required contents, shall be as given in 13.8.3. The Status Code field shall be a value from the options listed in 9.4.1.9.

If the FTO does not receive a response to the FT Request frame, it may reissue the request following the restrictions given for Authentication frames in 11.3. If the Status Code field value returned by the target AP is SUCCESS, the FTO and target AP transition to State 2 (as defined in 11.3); the FTO may continue with reassociation (13.7.2). Handling of errors returned in the Status Code field shall be as specified for Authentication frames in 11.3.

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13.6 FT resource request protocol

13.6.1 Overview

The FT resource request protocol involves an additional message exchange after the Authentication-Request/Response frame, or FT Request/Response frame, and prior to reassociation.

APs capable of fast BSS transition may allow FTOs to request resources prior to reassociation. Availability of the FT resource request protocol is advertised by the target AP in the MDE. If the Resource Request Protocol Capability subfield is 0, then the FTO shall not send an Authentication-Confirm nor FT Confirm frame to the AP. An AP that receives an Authentication-Confirm or FT Confirm frame from a STA and does not support the FT resource request protocol shall respond with status code INVALID_PARAMETERS.

The additional message exchange for the FT resource request protocol shall be performed using the same method (over-the-air or over-the-DS) as was used for the Authentication-Request/Response frame or FT Request/Response frame. An AP that receives an FT Confirm frame that did not previously receive an FT Request frame from the same STA shall reject the request with status code STATUS_INVALID_FT_ACTION_FRAME_COUNT. An AP that receives an Authentication-Confirm frame that did not previously receive an Authentication-Request frame from the same STA shall reject the request with status code TRANSACTION_SEQUENCE_ERROR.

13.6.2 Over-the-air fast BSS transition with resource request

The over-the-air FT resource request protocol in an RSN is shown in Figure 13-10.

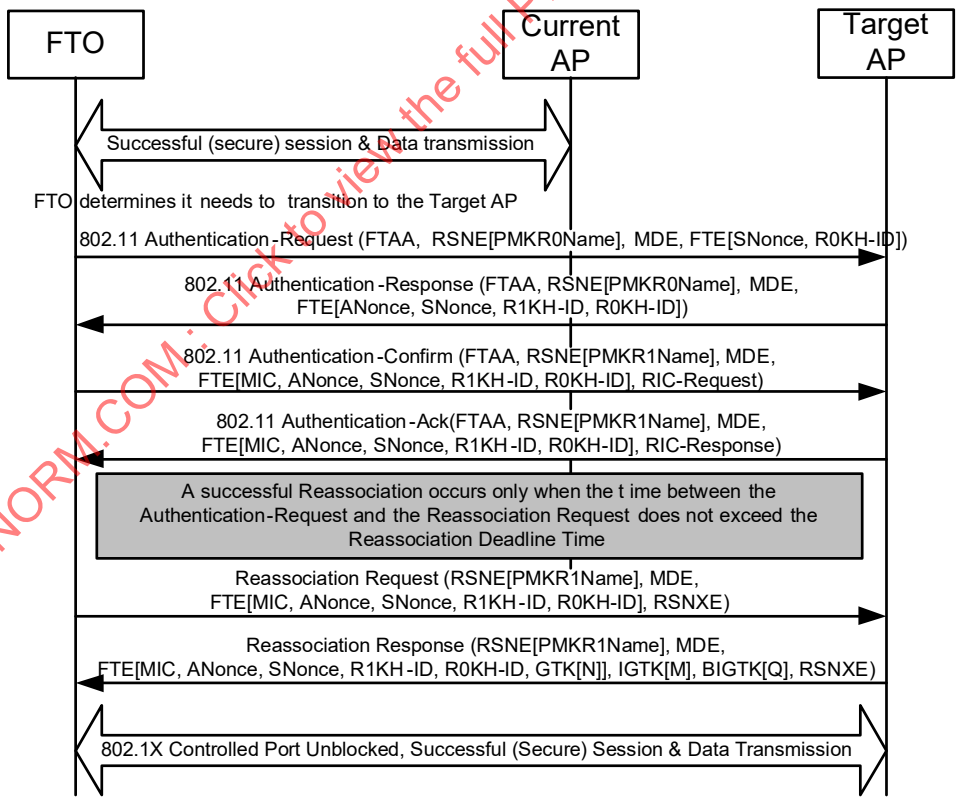

Figure 13-10—Over-the-air FT resource request protocol in an RSN

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The over-the-air FT resource request protocol in a non-RSN is shown in Figure 13-11.

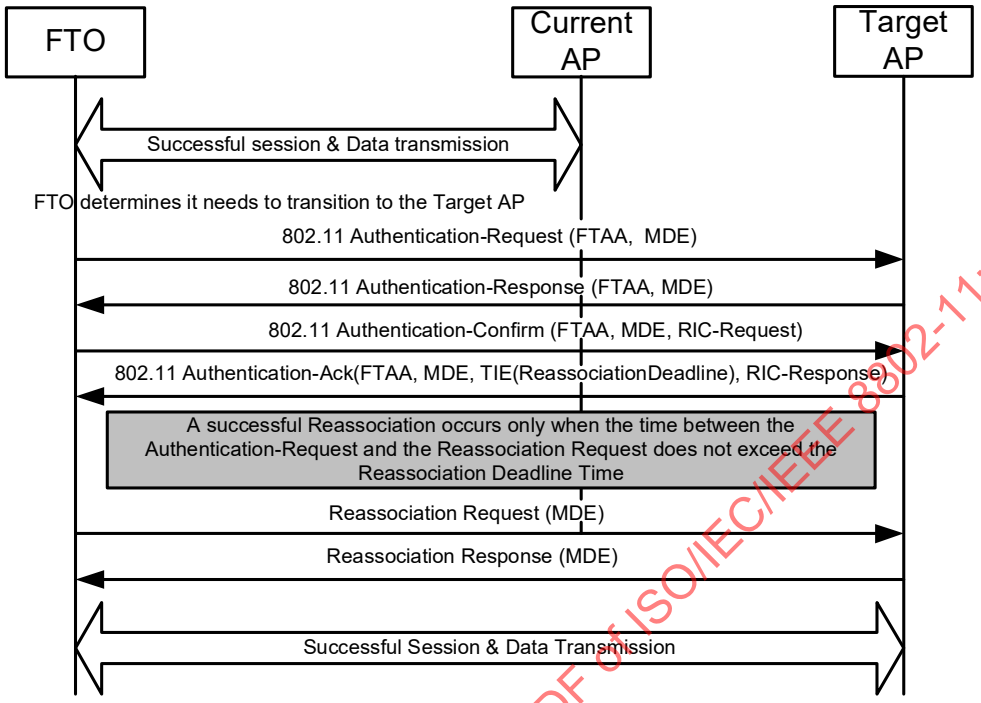

Figure 13-11—Over-the-air FT resource request protocol in a non-RSN

To perform an over-the-air FT resource request protocol to a target AP, after completing the Authentication-Request/Response frame exchange given in 13.5.2 or 13.5.4, the FTO and target AP shall perform the following exchange:

FTO→Target AP: Authentication-Confirm (FTAA, 0, RSNE[PMKR1Name], MDE, FTE[MIC, ANonce, SNonce, R1KH-ID, R0KH-ID], RIC-Request)

Target AP→FTO: Authentication-Ack (FTAA, Status, RSNE[PMKR1Name], MDE, FTE[MIC, ANonce, SNonce, R1KH-ID, R0KH-ID], RIC-Response)

The SME of the FTO initiates the resource request exchange through the use of the primitive MLME-RESOURCE-REQUEST.request primitive, and the SME of the AP responds with MLME-RESOURCE-REQUEST.response primitive.

In the Authentication-Confirm frame, the SA field of the message header shall be set to the MAC address of the FTO, and the DA field of the message header shall be set to the BSSID of the target AP's BSS. In a non-RSN, the FTE and RSNE shall not be present. The elements in the frame, the element contents, and MIC calculation shall be as given in 13.8.4.

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If the contents of the MDE received by the target AP do not match the contents advertised in the Beacon and Probe Response frames, the target AP shall reject the Authentication-Confirm frame with status code STATUS_INVALID_MDE.

In an RSN, the R1KH of the target AP verifies the MIC in the FTE in the Authentication-Confirm frame and shall discard the request if it is incorrect. If the FTE in the Authentication-Confirm frame contains a different R0KH-ID, R1KH-ID, ANonce, or SNonce, the AP shall reject the Authentication-Confirm frame with status code STATUS_INVALID_FTE. If the RSNE in the Authentication-Confirm frame contains an invalid PMKR1Name, the AP shall reject the Authentication-Confirm frame with status code STATUS_INVALID_PMKID.

In the Authentication-Ack frame, the SA field of the message header shall be set to the BSSID of the target AP's BSS, and the DA field of the message header shall be set to the MAC address of the FTO. In a non-RSN, the FTE and RSNE shall not be present. The Status Code field shall be a value from the options listed in 9.4.1.9. The elements in the frame, the element contents, and MIC calculation shall be as given in 13.8.5.

In an RSN, the S1KH of the FTO verifies the MIC in the FTE in the Authentication-Ack frame and shall discard the response if the MIC is incorrect.

The FTO may make a request for resources by including a RIC-Request (see 13.11) in the Authentication-Confirm frame. The RIC-Request is generated by the procedures of 13.11.3.1, and the RIC-Response is generated by the procedures of 13.11.3.2.

If the value of the Status Code field returned by the target AP in the Authentication-Ack frame is not SUCCESS, then the FTO shall abandon this transition attempt.

In an RSN, on successful completion of the FT authentication exchange of the FT resource request protocol, the PTKSA has been established and proven live. The key replay counter shall be initialized to 0, and the subsequent EAPOL-Key frames (e.g., GTK, IGTK, and BIGTK updates) shall use the key replay counter to detect and discard replays. The PTKSA shall be deleted by the target AP if it does not receive a Reassociation Request frame from the FTO within the reassociation deadline timeout value.

In a non-RSN, the Authentication-Ack frame contains a TIE with a reassociation deadline. If the FTO does not send a Reassociation Request frame to the target AP within that interval, the FTO shall abandon this transition attempt.

The exchange between the FTO and the target AP may continue with reassociation (13.7.1 or 13.7.2).

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13.6.3 Over-the-DS fast BSS transition with resource request

The over-the-DS FT resource request protocol in an RSN is shown in Figure 13-12.

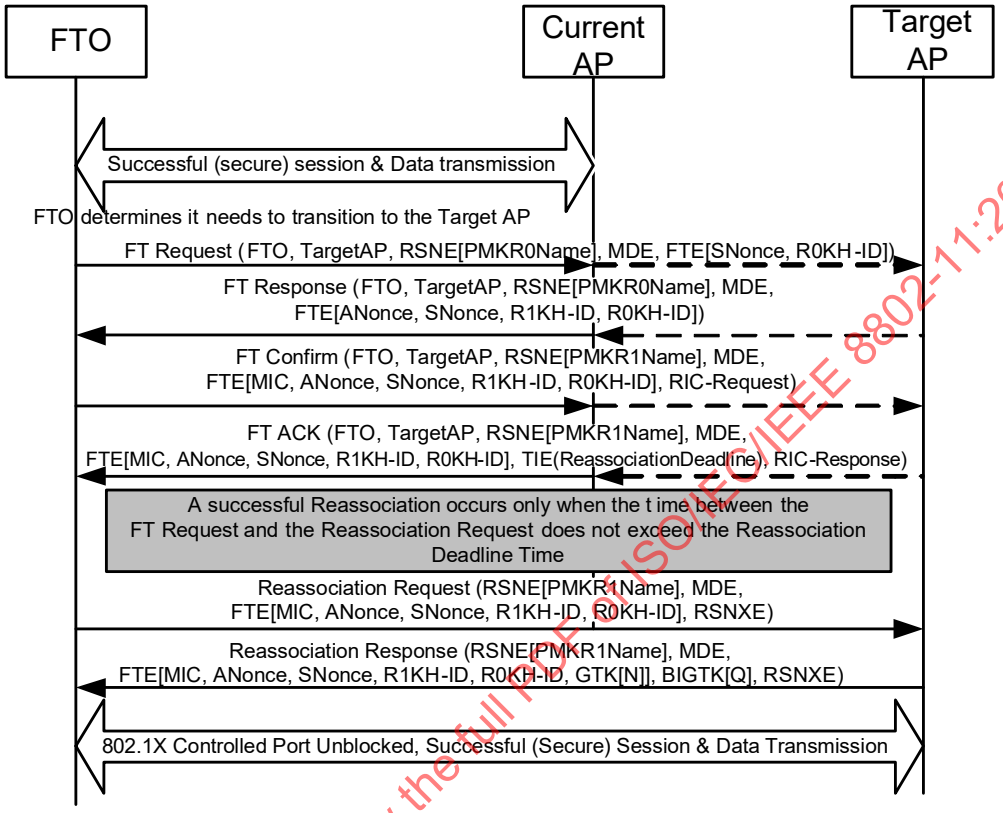

Figure 13-12—Over-the-DS FT resource request protocol in an RSN

The over-the-DS FT resource request protocol in a non-RSN is shown in Figure 13-13.

To perform an Over-the-DS FT resource request protocol to a target AP, after completing the FT Request/Response frame exchange given in 13.5.3 or 13.5.5, the FTO and target AP (through the current AP) shall perform the following exchange, using the mechanism described in 13.10:

FTO→Target AP: FT Confirm (FTO, TargetAP, RSNE[PMKR1Name], MDE, FTE[MIC, ANonce, SNonce, R1KH-ID, R0KH-ID], RIC-Request)

Target AP→FTO: FT Ack (FTO, TargetAP, Status, RSNE[PMKR1Name], MDE, FTE[MIC, ANonce, SNonce, R1KH-ID, R0KH-ID], TIE[ReassociationDeadline], RIC-Response)

The SME of the FTO initiates the FT Confirm frame to the target AP by issuing an MLME-REMOTE-REQUEST.request primitive with parameters including the contents of the FT Confirm frame (FT Action frame with an FT Action field value indicating FT Confirm) to be sent. The MAC of the FTO transmits this Action frame. For processing at the current AP and target AP, see 13.10. When the MAC of the FTO receives the FT Ack frame (FT Action frame with an FT Action field value indicating FT Ack), it passes it to the SME by use of an MLME-REMOTE-REQUEST.indication primitive, with parameters including the contents of the received Action frame.

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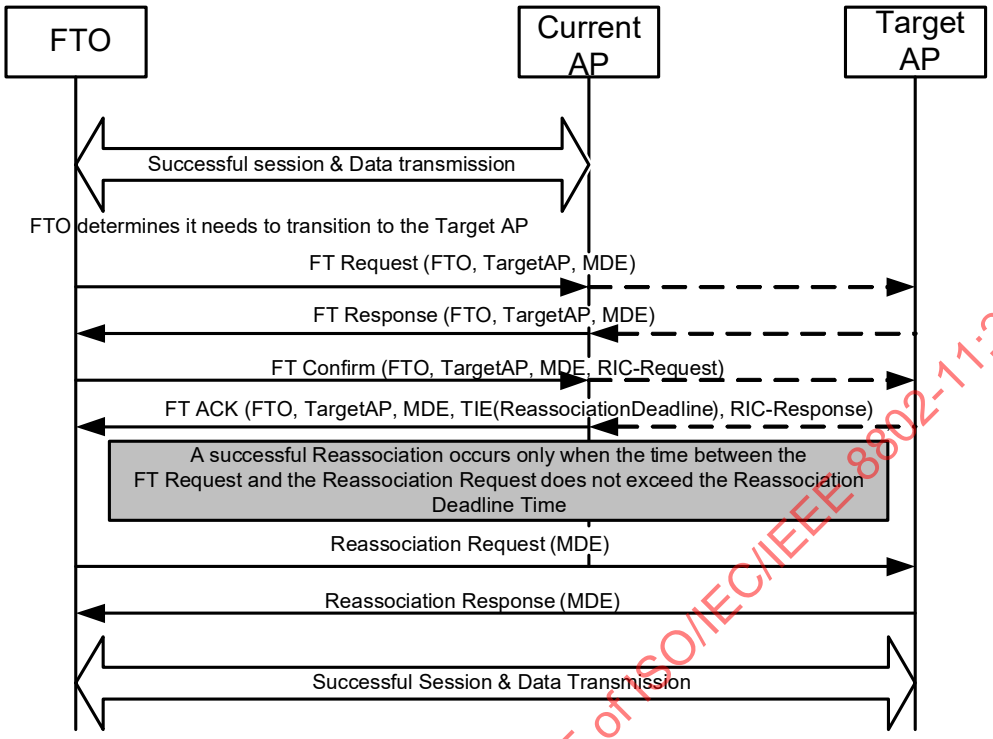

Figure 13-13—Over-the-DS FT resource request protocol in a non-RSN

The STA Address field of the FT Confirm frame shall be set to the MAC address of the FTO, and the Target AP Address field of the FT Confirm frame shall be set to the BSSID of the target AP's BSS. The elements in the FT Confirm frame, the element contents, and the MIC calculation shall be as given in 13.8.4. In a non-RSN, the FTE and RSNE shall not be present.

If the contents of the MDE received by the target AP do not match the contents advertised in the Beacon and Probe Response frames, the target AP shall reject the FT Confirm frame with status code STATUS_INVALID_MDE.

In an RSN, the R1KH of the target AP verifies the MIC in the FTE and shall discard the request if it is incorrect. If the FTE in the FT Confirm frame contains a different R0KH-ID, R1KH-ID, ANonce, or SNonce from the values sent in the FT Response frame, the AP shall reject the FT Confirm frame with status code STATUS_INVALID_FTE. If the RSNE in the FT Confirm frame contains an invalid PMKR1Name, the AP shall reject the FT Confirm frame with status code STATUS_INVALID_PMKID.

The STA Address field of the FT Ack frame shall be set to the MAC address of the FTO, and the Target AP Address field of the FT Ack frame shall be set to the BSSID of the target AP's BSS. The elements in the FT Ack frame, the element contents, and the MIC calculation shall be as given in 13.8.5. In a non-RSN, the FTE and RSNE shall not be present. The Status Code field value shall be a value from the options listed in 9.4.1.9, and a TIE may appear.

In an RSN, the S1KH of the FTO verifies the MIC in the FTE in the FT Ack frame and shall discard the response if the MIC is incorrect.

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The FTO may make a request for resources by including a RIC-Request (see 13.11) in the FT Confirm frame. The RIC-Request is generated by the procedures of 13.11.3.1, and the RIC-Response is generated by the procedures of 13.11.3.2.

In order to recover from over-the-DS frame losses, the FTO may retransmit the FT Confirm frame until the reassociation deadline time is reached. If the FTO does not receive a response to the FT Confirm frame or if the value of the Status Code field returned by the target AP in the FT Ack frame is not SUCCESS, then the FTO shall abandon this transition attempt.

In an RSN, on successful completion of the FT Confirm/Acknowledgment frame exchange, the PTKSA has been established and proven live. The key replay counter shall be initialized to 0, and the subsequent EAPOL-Key frames (e.g., GTK, IGTK, and BIGTK updates) shall use the key replay counter to detect and discard replays. The PTKSA shall be deleted by the target AP if it does not receive a Reassociation Request frame from the FTO within the reassociation deadline timeout value. Resource request procedures are specified in 13.11.

In a non-RSN, the FT Ack frame contains a TIE with a reassociation deadline. If the FTO does not send a Reassociation Request frame to the target AP within that interval, the FTO shall abandon this transition attempt.

The exchange between the FTO and the target AP may continue with reassociation (13.7.1 or 13.7.2).

13.7 FT reassociation

13.7.1 FT reassociation in an RSN

If the FTO does not send a Reassociation Request frame to the target AP within the reassociation deadline interval received during the FT initial mobility domain association, the target AP may delete the PTKSA, and the FTO shall abandon this transition attempt.

The FTO shall perform a reassociation directly with the target AP via the following exchange:

FTO→Target AP: Reassociation Request(RSNE[PMKR1Name], MDE, FTE[MIC, ANonce, SNonce, R1KH-ID, R0KH-ID], RIC-Request, RSNXE)

Target AP→FTO: Reassociation Response(RSNE[PMKR1Name], MDE, FTE[MIC, ANonce, SNonce, R1KH-ID, R0KH-ID, GTK[N], IGTK[M], BIGTK[Q]], RIC-Response, RSNXE)

The SME of the FTO initiates the reassociation through the use of the MLME-REASSOCIATE.request primitive. The SME of the AP responds to the indication with MLME-REASSOCIATE.response primitive. See 11.3.5.

In the Reassociation Request frame, the SA field of the message header shall be set to the MAC address of the FTO, and the DA field of the message header shall be set to the BSSID of the target AP's BSS. The elements in the frame, the element contents, and the MIC calculation shall be as given in 13.8.4.

The R1KH of the target AP verifies the MIC in the FTE in the Reassociation Request frame and shall discard the request if the MIC is incorrect.

If the target AP includes an RSNXE in its Beacon and Probe Response frames and the RSNXE Used subfield of the MIC Control field of the FTE is set to 1, but the Reassociation Request frame does not include an RSNXE, the R1KH of the target AP shall discard the request.

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If dot11RSNAOperatingChannelValidationActivated is true and the FTO indicates OCVC capability, the target AP shall ensure that OCI subelement of the FTE matches by ensuring that all of the following are true:

— OCI subelement is present
— Channel information in the OCI matches current operating channel parameters (see 12.2.9)

Otherwise, the AP shall reject the Reassociation Request frame with status code STATUS_INVALID_FTE.

If the contents of the MDE received by the target AP do not match the contents advertised in the Beacon and Probe Response frames, the target AP shall reject the Reassociation Request frame with status code STATUS_INVALID_MDE. If the FTE in the Reassociation Request frame contains a different R0KH-ID, R1KH-ID, ANonce, or SNonce, the AP shall reject the Reassociation Request frame with status code STATUS_INVALID_FTE. If the RSNE in the Reassociation Request frame contains an invalid PMKR1Name, the AP shall reject the Reassociation Request frame with status code STATUS_INVALID_PMKID.

In the Reassociation Response frame, the SA field of the message header shall be set to the BSSID of the target AP's BSS, and the DA field of the message header shall be set to the MAC address of the FTO. The Status Code field shall be a value from the options listed in 9.4.1.9. The elements in the frame, the element contents, and the MIC calculation shall be as given in 13.8.5.

The S1KH of the FTO verifies the MIC in the FTE in the Reassociation Response frame and shall discard the response if the MIC is incorrect.

If in the Reassociation Response frame the RSNE fields other than the PMKID Count field and the PMKID List field are not identical to the corresponding RSNE fields in the Beacon and Probe Response frames received from the target AP, the S1KH of the FTO shall discard the response. If the PMKID List field does not include the correct PMKR1Name value, the S1KH of the FTO shall discard the response.

If the Beacon and Probe Response frames received from the target AP did not include an RSNXE, but the RSNXE Used subfield of the MIC Control field of the FTE is set to 1, the S1KH of the FTO shall discard the response.

If the Reassociation Response frame includes the RSNXE, the S1KH of the FTO shall verify that this element matches information included in the Beacon and Probe Response frames received from the target AP. If those frames did not include the RSNXE or if the contents of the RSNXE are not identical, the S1KH of the FTO shall discard the response.

If dot11RSNAOperatingChannelValidationActivated is true and the target AP indicates OCVC capability, FTO shall ensure that OCI subelement of the FTE matches by ensuring that all of the following are true

— OCI subelement is present
— Channel information in the OCI matches current operating channel parameters (see 12.2.9)

Otherwise, the FTO reject the Reassociation Response frame by discarding the frame.

If an FTO is performing a reassociation exchange as part of the FT resource request protocol, then the FTO shall not include the RIC-Request in the Reassociation Request frame, and the AP shall not include the RIC-Response in the Reassociation Response frame. If the reassociation exchange is part of the FT resource request protocol and the AP is unable to honor the resources that have been placed in the accepted state for that FTO, then the AP shall reject the Reassociation Request frame and may use status code DENIED_INSUFFICIENT_BANDWIDTH.

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If the FTO did not utilize the FT resource request protocol, the FTO may make a request for resources by including a RIC-Request (see 13.11) in the Reassociation Request frame. The RIC-Request is generated by the procedures of 13.11.3.1, and the RIC-Response is generated by the procedures of 13.11.3.2.

If the Status Code field value returned by the target AP in the response is REFUSED_REASON_UNSPECIFIED, TRANSACTION_SEQUENCE_ERROR, or REJECTED_SEQUENCE_TIMEOUT, then the FTO shall abandon this transition attempt. Handling of other errors returned in the Status Code field shall be as specified in 11.3.

Upon a successful reassociation, the PTKSA has been established and proven live. The SME of the AP shall open the IEEE 802.1X Controlled Port. The FTO shall transition to State 4 (as defined in 11.3). If the target AP is distinct from the previous AP, the FTO shall enter State 1 with respect to the previous AP.

Upon a successful reassociation, the FTO shall delete any corresponding PTKSA with its previous AP. The SME of the FTO shall issue an MLME-DELETEKEYS.request primitive to delete the pairwise keys with the previous AP, and the FTO and the AP shall issue an MLME-SETKEYS.request primitive and MLME-SETPROTECTION.request primitive to install the pairwise keys. The PTK lifetime timer shall be initialized with the value calculated as the difference between the TIE[KeyLifetime] sent in message 3 of the FT initial mobility domain association and the time since the completion of the FT 4-way handshake during the FT initial mobility domain association.

When the IEEE 802.1X Controlled Port is opened, the EAPOL-Key frame replay counter shall be initialized to 0. The R1KH shall increment the key replay counter on each successive EAPOL-Key frame that it transmits.

13.7.2 FT reassociation in a non-RSN

The FTO shall perform a reassociation with the target AP via the following exchange:

FTO→Target AP:	Reassociation Request(MDE, RIC-Request)
Target AP→FTO:	Reassociation Response(MDE, RIC-Response)

The SME of the FTO initiates the reassociation through the use of the MLME-REASSOCIATE.request primitive. The SME of the AP responds to the indication with MLME-REASSOCIATE.response primitive. See 11.3.5.

In the Reassociation Request frame, the SA field of the message header shall be set to the MAC address of the FTO, and the DA field of the message header shall be set to the BSSID of the target AP's BSS. The elements in Reassociation Request frame, and their required contents, shall be as given in 13.8.4.

If the contents of the MDE received by the target AP do not match the contents advertised in the Beacon and Probe Response frames, the target AP shall reject the Reassociation Request frame with status code STATUS_INVALID_MDE.

In the Reassociation Response frame, the SA field of the message header shall be set to the BSSID of the target AP's BSS, and the DA field of the message header shall be set to the MAC address of the FTO. The elements in Reassociation Response frame, and their required contents, shall be as given in 13.8.5. The Status Code field shall be a value from the options listed in 9.4.1.9.

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If the FTO is performing a reassociation exchange as part of the FT resource request protocol, then the FTO shall not include the RIC-Request in the Reassociation Request frame, and the AP shall not include the RIC-Response in the Reassociation Response frame.

If the FTO did not utilize the FT resource request protocol, the FTO may make a request for resources by including a RIC-Request (see 13.11) in the Reassociation Request frame. The RIC-Request is generated by the procedures of 13.11.3.1, and the RIC-Response is generated by the procedures of 13.11.3.2.

If the Status Code field value returned by the target AP in the response is REFUSED_REASON_UNSPECIFIED, TRANSACTION_SEQUENCE_ERROR, or REJECTED_SEQUENCE_TIMEOUT, then the FTO shall abandon this transition attempt. Handling of other errors returned in the Status Code field shall be as specified in 11.3.

If the AP has dot11RSNAActivated equal to true, upon a successful reassociation, the SME shall open the IEEE 802.1X Controlled Port.

Upon a successful reassociation, the target AP and the FTO shall transition to State 4 (as defined in 11.3). If the target AP is distinct from the previous AP, then the FTO shall enter State 1 with respect to the previous AP.

13.8 FT authentication sequence

13.8.1 Overview

The FT authentication sequence comprises four sets of FT elements. Each set of FT elements is referred to in 13.8 as a *message*. These messages are included in the FT Protocol frames or FT Resource Request Protocol frames to initiate a fast BSS transition. The FT authentication sequence is always initiated by the FTO and responded to by the target AP.

In an RSN, the first two messages in the sequence allow the FTO and target AP to provide association instance identifiers, SNonce and ANonce, respectively. SNonce and ANonce are chosen randomly or pseudorandomly and are used to generate a fresh PTK. The first two messages also enable the target AP to provision the PMK-R1 and the FTO and target AP to compute the PTK. The third and fourth messages demonstrate liveness of the peer, authenticate the elements, and enable an authenticated resource request.

When an FTO invokes the FT protocol, then the first two messages of the sequence are both carried in Authentication frames or both carried in Action frames, and these messages are described in 13.8.2 and 13.8.3. The third and fourth messages in the sequence are carried in the Reassociation Request and Reassociation Response frames and are described in 13.8.4 and 13.8.5.

When the FTO invokes the FT resource request protocol, then the first four messages of the sequence are all carried in Authentication frames or all carried in Action frames, and these messages are described in 13.8.2 to 13.8.5. The fifth and sixth frames of the FT resource request protocol are carried in the Reassociation Request frame and Reassociation Response frame and are described in 13.8.4 and 13.8.5.

Regardless of the transport mechanism, the information contained in the FT authentication sequence consists of the set of elements shown in Table 13-1.

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Table 13-1—FT authentication elements

Information	Presence in Authentication Sequence messages	Description
RSN	The RSNE is present if dot11RSNAActivated is true.	9.4.2.24
Mobility Domain	The Mobility Domain element is present.	9.4.2.46
Fast BSS Transition	The Fast BSS Transition element is present if dot11RSNAActivated is true.	9.4.2.47
Timeout Interval (reassociation deadline)	The Timeout Interval element is optionally present in the fourth message of the sequence if dot11RSNAActivated is not true.	9.4.2.48
RIC	The RIC Data element is optionally present in the third and fourth messages.	9.4.2.49
RSNXE	The RSNXE is present in the third message if an RSNXE is present in a Beacon or Probe Response frame that the FTO has received from the target AP and the FTO set to 1 any subfield, except the Field Length subfield, of the Extended RSN Capabilities field in this element, and is present in the fourth message if an RSNXE was present in the third message and the target AP set to 1 any subfield, except the Field Length subfield, of the Extended RSN Capabilities field in this element.	9.4.2.241

The first message is used by the FTO to initiate a fast BSS transition. When RSNA is enabled, the FTO shall include the R0KH-ID and the SNonce in the FTE and the PMKR0Name in the RSNE. The target AP can use the PMKR0Name to derive the PMKR1Name, and if the target AP does not have the PMK-R1 identified by PMKR1Name, it may attempt to retrieve that key from the R0KH identified by R0KH-ID. See 13.2. The FTO includes a fresh SNonce as its contribution to the association instance identifier and to provide key separation of the derived PTK; it is selected randomly to serve as a challenge that demonstrates the liveness of the peer in the fourth message.

The second message is used by the target AP to respond to the requesting FTO. The target AP provides the key holder identifiers and key names used to generate the PTK. The target AP also includes a fresh ANonce as its contribution to the association instance identifier and to provide key separation of the derived PTK. The response includes a status code.

In an RSN, the third message is used by the FTO to assert to the target AP that it has a valid PTK. If no resources are required, then the FTO omits inclusion of the RIC.

The fourth message is used by the target AP to respond to the requesting FTO. This message serves as final confirmation of the transition, establishes that the AP possesses the PMK-R1 and is participating in this association instance, and protects against downgrade attacks. Note, however, that the RIC is absent if no resources were requested in the third message. This also includes a status code and may include a reassociation deadline.

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13.8.2 FT authentication sequence: contents of first message

If present, the RSNE shall be set as follows:

— Version field shall be set to 1.
— PMKID Count field shall be set to 1.
— PMKID List field shall contain the PMKR0Name.
— All other fields shall be as specified in 9.4.2.24 and 12.6.3.

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The MDE shall contain the MDID field and the FT Capability and Policy field settings obtained from the target AP, as advertised by the target AP in Beacon and Probe Response frames. The MDID shall be identical to that obtained during the FT initial mobility domain association exchange.

If present, the FTE shall be set as follows:

— R0KH-ID shall be the value of R0KH-ID obtained by the FTO during its FT initial mobility domain association exchange.
— SNonce shall be set to a value chosen randomly by the FTO, see 12.7.5 for a recommended procedure.
— All other fields shall be set to 0.

13.8.3 FT authentication sequence: contents of second message

If the status code is SUCCESS, then the following rules apply.

If present, the RSNE shall be set as follows:

— Version field shall be set to 1.
— PMKID Count field shall be set to 1.
— PMKID List field shall be set to the value contained in the first message of this sequence.
— All other fields shall be identical to the contents of the RSNE advertised by the AP in Beacon and Probe Response frames.

The MDE shall contain the MDID and FT Capability and Policy fields. This element shall be the same as the MDE advertised by the target AP in Beacon and Probe Response frames.

If present, the FTE shall be set as follows:

— R0KH-ID shall be identical to the R0KH-ID provided by the FTO in the first message.
— R1KH-ID shall be set to the R1KH-ID of the target AP, from dot11FTR1KeyHolderID.
— ANonce shall be set to a value chosen randomly by the target AP, see 12.7.5 for a recommended procedure.
— SNonce shall be set to the value contained in the first message of this sequence.
— All other fields shall be set to 0.

13.8.4 FT authentication sequence: contents of third message

If present, the RSNE shall be set as follows:

— Version field shall be set to 1.
— PMKID Count field shall be set to 1.
— PMKID List field shall contain the PMKR1Name.
— All other fields shall be as specified in 9.4.2.24 and 12.6.3.

The MDE shall contain the MDID and FT Capability and Policy fields. This element shall be identical to the MDE contained in the first message of this sequence.

If present, the FTE shall be set as follows:

— ANonce, SNonce, R0KH-ID, and R1KH-ID shall be set to the values contained in the second message of this sequence.
— The Element Count subfield of the MIC Control field shall be set to the number of elements protected in this frame (variable).

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- The RSNXE Used subfield of the MIC Control field shall be set to 1 if the FTO set to 1 any subfield, except the Field Length subfield, of the Extended RSN Capabilities field in the RSNXE; otherwise this subfield shall be set to 0.
- When the negotiated AKM is 00-0F-AC:3, 00-0F-AC:4, or 00-0F-AC:9, the MIC shall be calculated using the KCK and the AES-128-CMAC algorithm. The output of the AES-128-CMAC shall be 128 bits.
- When the negotiated AKM is 00-0F-AC:13, the MIC shall be calculated using the KCK and the HMAC-SHA-384 algorithm. The output of the HMAC-SHA-384 shall be truncated to 192 bits.
- When the negotiated AKM is 00-0F-AC:16, the MIC shall be calculated using the KCK2 and the AES-128-CMAC algorithm. The output of the AES-128-CMAC shall be 128 bits.
- When the negotiated AKM is 00-0F-AC:17, the MIC shall be calculated using the KCK2 and the HMAC-SHA-384 algorithm. The output of the HMAC-SHA-384 shall be truncated to 192 bits.
- If dot11RSNAOperatingChannelValidationActivated is true and Authenticator indicates OCVC capability, the supplicant shall include FT OCI subelement in FTE.
- The MIC shall be calculated on the concatenation of the following data, in the order given here:
  - FTO's MAC address (6 octets)
  - Target AP's MAC address (6 octets)
  - Transaction sequence number (1 octet), which shall be set to the value 5 if this is a Reassociation Request frame and, otherwise, set to the value 3
  - RSNE
  - MDE
  - FTE, with the MIC field of the FTE set to 0
  - Contents of the RIC-Request (if present)
  - RSNXE (if present)
- All other fields shall be set to 0.

If resources are being requested by the FTO, then a sequence of elements forming the RIC-Request shall be included.

The RSNXE shall be present if an RSNXE was present in a Beacon or Probe Response frame that the FTO has received from the target AP and the FTO set to 1 any subfield, except the Field Length subfield, of the Extended RSN Capabilities field in this element.

13.8.5 FT authentication sequence: contents of fourth message

If the status code is SUCCESS, then the following rules apply.

If present, the RSNE shall be set as follows:

- Version field shall be set to 1.
- PMKID Count field shall be set to 1.
- PMKID List field shall contain the PMKR1Name
- All other fields shall be identical to the contents of the RSNE advertised by the target AP in Beacon and Probe Response frames.

The MDE shall contain the MDID and FT Capability and Policy fields. This element shall be identical to the MDE contained in the second message of this sequence.

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If present, the FTE shall be set as follows:

- ANonce, SNonce, R0KH-ID, and R1KH-ID shall be set to the values contained in the second message of this sequence.
- The Element Count subfield of the MIC Control field shall be set to the number of elements protected in this frame (variable).
- The RSNXE Used subfield of the MIC Control field shall be set to 1 if the target AP includes an RSNXE in its Beacon and Probe Response frames; otherwise this subfield shall be set to 0.
- If dot11RSNAOperatingChannelValidationActivated is true and Supplicant indicates OCVC capability, the Authenticator shall include FT OCI subelement in FTE.
- When this message of the authentication sequence appears in a Reassociation Response frame, the Optional Parameter(s) field in the FTE may include the GTK, IGTK and BIGTK subelements. If a GTK, an IGTK or a BIGTK are included, the Key field of the subelement shall be wrapped using KEK or KEK2 and the appropriate key wrap algorithm, as specified in Table 12-10 and 12.7.2. The padding consists of appending a single octet 0xdd followed by zero or more 0x00 octets. When processing a received message, the receiver shall ignore this trailing padding. Addition of padding does not change the value of the Key Length field. Note that the length of the encrypted Key field can be determined from the length of the GTK, IGTK or BIGTK subelement.
- When the negotiated AKM is 00-0F-AC:3, 00-0F-AC:4, or 00-0F-AC:9, the MIC shall be calculated using the KCK and the AES-128-CMAC algorithm. The output of the AES-128-CMAC algorithm shall be 128 bits.
- When the negotiated AKM is 00-0F-AC:13, the MIC shall be calculated using the KCK and the HMAC-SHA-384 algorithm. The output of the HMAC-SHA-384 shall be truncated to 192 bits.
- When the negotiated AKM is 00-0F-AC:16, the MIC shall be calculated using the KCK2 and the AES-128-CMAC algorithm. The output of the AES-128-CMAC shall be 128 bits.
- When the negotiated AKM is 00-0F-AC:17, the MIC shall be calculated using the KCK2 and the HMAC-SHA-384 algorithm. The output of the HMAC-SHA-384 shall be truncated to 192 bits.
- The MIC shall be calculated on the concatenation of the following data, in the order given here:
  - FTO's MAC address (6 octets)
  - Target AP's MAC address (6 octets)
  - Transaction sequence number (1 octet), which shall be set to the value 6 if this is a Reassociation Response frame or, otherwise, set to the value 4
  - RSNE
  - MDE
  - FTE, with the MIC field of the FTE set to 0
  - Contents of the RIC-Response (if present)
  - RSNXE (if present)
- All other fields shall be set to 0.

If this message is other than a Reassociation Response frame and dot11RSNAActivated is false, a TIE may appear. If this message is other than a Reassociation Response frame, includes a RIC-Response, and dot11RSNAActivated is false, then a timeout interval shall appear. If it appears, it shall be set as follows:

- Timeout Interval Type field shall be set to 1 (reassociation deadline).
- Timeout Interval Value field shall be set to the reassociation deadline time.

If resources were requested by the FTO, then a RIC-Response shall be included.

The RSNXE shall be present if an RSNXE was present in the third message and the target AP set to 1 any subfield, except the Field Length subfield, of the Extended RSN Capabilities field in this element.

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13.9 FT security architecture state machines

13.9.1 Introduction

The FT state machines describe the interaction between the RSNA key management and IEEE 802.11 architectural components.

RSNA key management uses the MA-UNITDATA service primitives to send/receive EAPOL-Key frames for FT initial association; MLME interfaces described below for FT methods; and MLME-SETKEYS, MLME-DELETEKEYS, and MLME-SETPROTECTION primitives. FT key management uses the following primitives for key management delivery and reception:

— The MLME-REMOTE-REQUEST primitives for FT key management over the DS
— The MLME-AUTHENTICATE primitives for FT key management over the air
— The MLME-RESOURCE-REQUEST primitives for FT resource request over the air
— The MLME-REASSOCIATE primitives for FT key management over the air and over the DS

Some of the state machine design considerations are as follows:

— Details of error handling are not included in the state machines. See 13.4, 13.5, and 13.6.
— Retransmission of FT Authentication and (Re)Association Request and Response frames are not included in the state machines; see 13.5 and 13.6.

Various signals are used to communicate between the R0KH and the R1KH state machines. Note that these interactions may be between separate entities, rather than within a single SME. These interactions are as follows:

— In the R0KH state machine, FT-PMKR1-SA (PMKR1-SA) sends a PMK-R1 PMKSA to the R1KH.
— In the R1KH state machine, FT-FULL-AUTH (R1KH-ID) requests a key from the R0KH.
— In the R1KH state machine, FT-Transition-Auth (R1KH-ID) requests a key from the R0KH that was used for the initial mobility domain association.

The interactions between the R0KH and IEEE Std 802.1X, between the R1KH and IEEE Std 802.1X, and between the S1KH and IEEE Std 802.1X occur within the SME. At both the target AP and at the FTO, the R1KH and S1KH initialize the IEEE 802.1X EAPOL state machines in the respective SMEs. The Controlled Port is opened without an EAP exchange when the reassociation completes.

13.9.2 R0KH state machine

13.9.2.1 General

There is one R0KH state machine, which includes FT key management.

The state diagram in Figure 13-14 consists of a set of states that handle R0KH functions including key hierarchy instantiation, key generation, and cleanup. This state machine interacts with the R1KH state machine.

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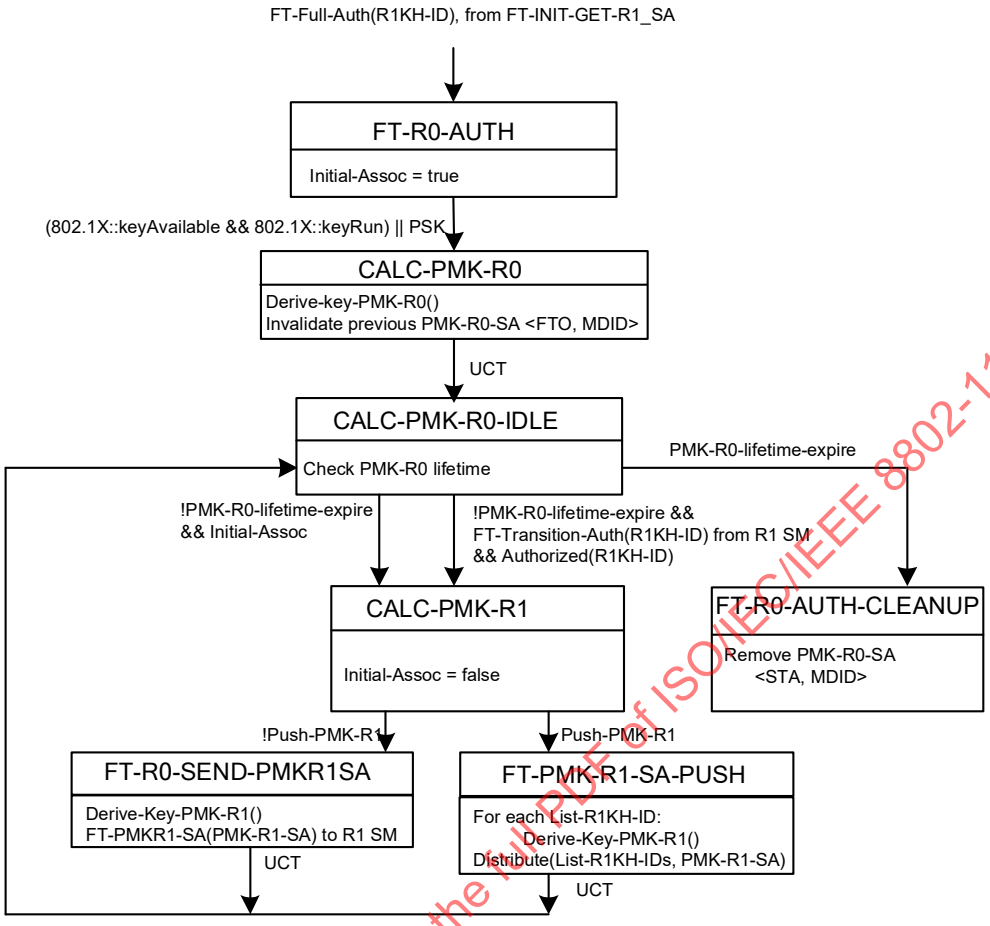

Figure 13-14—R0KH state machine

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13.9.2.2 R0KH state machine states

The following list summarizes the states of the R0KH state machine:

- **CALC-PMK-R0**: This state is entered after the MSK from EAP authentication or PSK is available.
- **CALC-PMK-R0-IDLE**: This state is an intermediate state for the R0KH to wait for new requests from R1KHs.
- **CALC-PMK-R1**: For FT initial association, this state is entered as an unconditional transfer. For FT methods, this state is entered through the event from an R1KH state machine.
- **FT-PMK-R1-SA-PUSH**: This state is entered if Push-PMK-R1 is true. PMK-R1s are derived and distributed to all of the configured R1KHs.
- **FT-R0-AUTH-CLEANUP**: This state is entered when the PMK-R0 lifetime expires.
- **FT-R0-AUTH**: This state is entered through the event from the R1KH state machine. The R1KH state machine sends this event when it determines that a new PMK-R0 is needed.
- **FT-R0-SEND-PMKR1SA**: This state is entered from CALC-PMK-R1 when a request for the PMK-R1 security association is received from an R1KH. PMK-R1 security association is derived and distributed to the requesting R1KH.

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13.9.2.3 R0KH state machine variables

The following list summarizes the variables used by the R0KH state machine:

— *Initial-Assoc.* This variable is used to indicate whether the current authentication is the initial association, in order to trigger the initial derivation of PMK-R1.

— *List-R1KH-IDs.* This variable contains a list of all of the R1KH-IDs in the mobility domain. This list is populated by the key distribution protocol as required in 13.2.

— *PMK-R0-lifetime-expire.* This variable is set to true when PMK-R0 lifetime is deemed expired.

— *PSK.* This variable is set to true when authentication is performed by use of a preshared key.

— *Push-PMK-R1.* This variable is set to true when R0KH can push the PMK-R1 security associations to R1KHs.

13.9.2.4 R0KH state machine procedures

The following list summarizes the procedures used by the R0KH state machine:

— **Authorized(R1KH-ID).** This procedure returns a value of true if the R1KH is a known key holder in the mobility domain.

— **Distribute (List-R1KH-IDs, PMK-R1 PMKSA).** Distributes the PMK-R1-SAs for the current instance of the key hierarchy to the list of R1KH-IDs.

— **Derive-Key-PMK-R0().** This procedure derives the PMK-R0 from the MSK or PSK, derives the PMKR0Name (as described in 12.7.1.6.3), and creates PMK-R0 security association.

— **Derive-Key-PMK-R1 (R1KH-ID).** From the PMK-R0, and the R1KH-ID (as described in 12.7.1.6.4) for the R1KH identified by R1KH-ID, this procedure derives the PMK-R1 and creates a PMK-R1 security association.

13.9.3 R1KH state machine

13.9.3.1 General

The R1KH state machine includes functions for FT initial association and FT protocols. The R1KH states performing FT initial association and the R1KH states performing FT protocol exchanges interact differently with the R0KH state machine.

The R1KH state machine and other portions of the SME are defined in Figure 13-15 and Figure 13-16 and consist of a set of states that handle FT initial mobility domain association, PMK-R1 reception, PTK handshake and session establishment, FT protocols (including resource requests), and cleanup. This state machine interacts with the R0KH state machine to generate a fresh FT key hierarchy for the initial mobility domain association and to get the PMK-R1 security association (PMK-R1 PMKSA) for the FT protocols. While the figures show the over-the-air message exchanges, the over-the-DS exchanges are handled similarly.

A new instance of the R1KH state machine is created each time initial mobility domain association or fast BSS transition is initiated.

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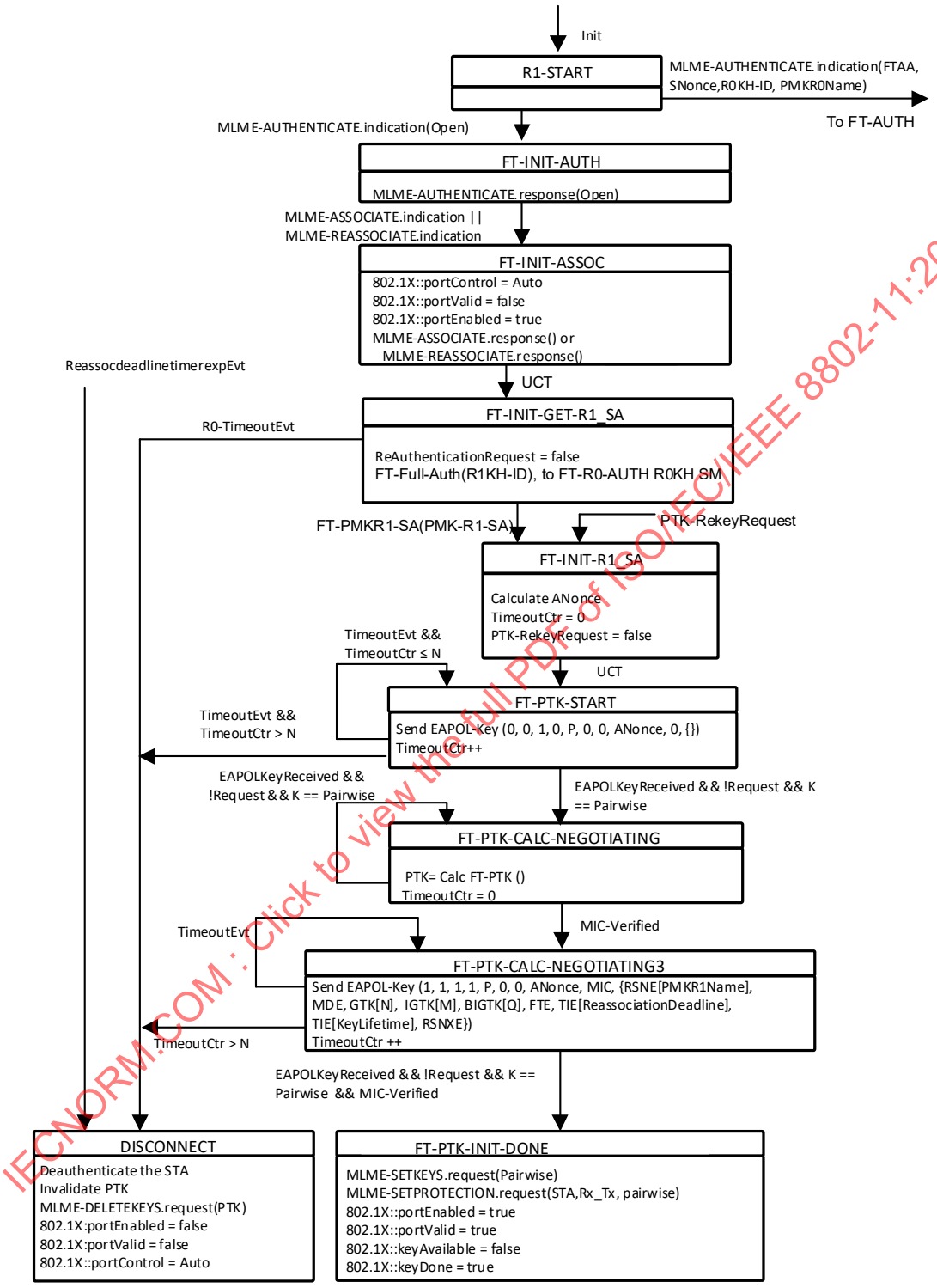

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Figure 13-15—R1KH state machine, including portions of the SME (part 1)

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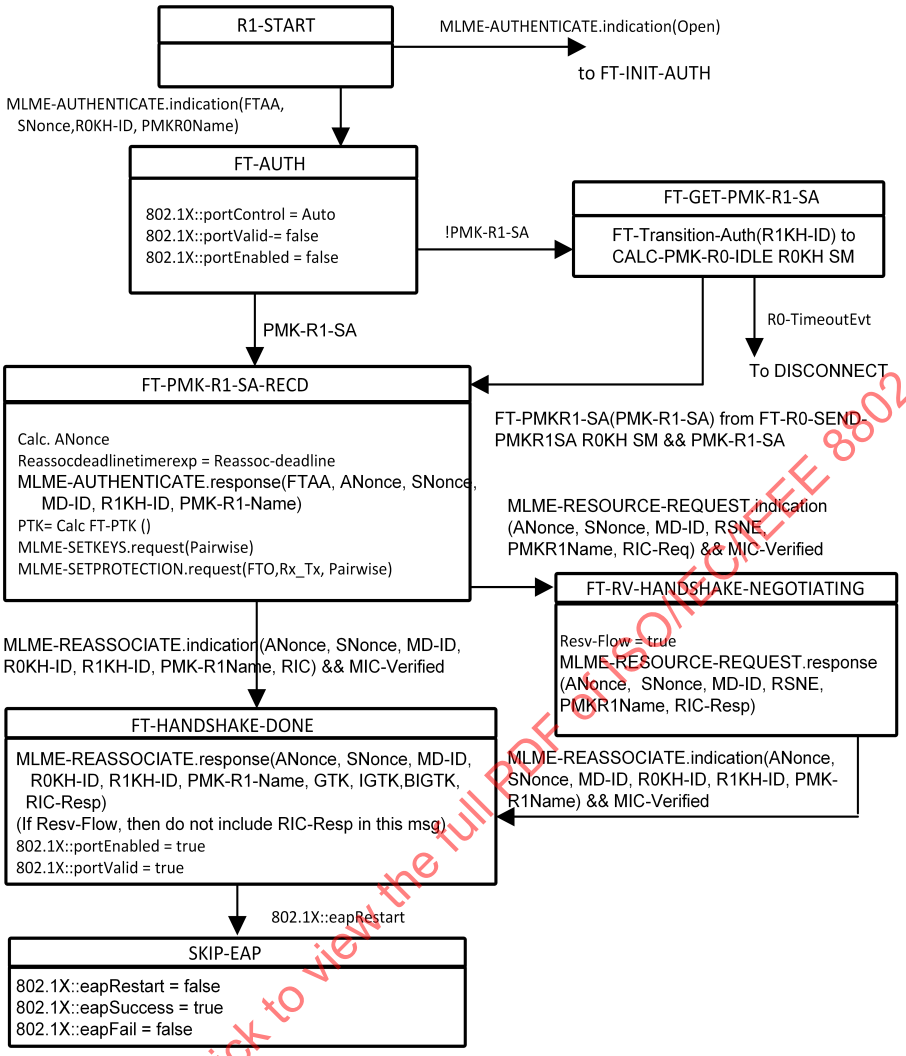

Figure 13-16—R1KH state machine, including portions of the SME (part 2)

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13.9.3.2 R1KH state machine states

The following list summarizes the states of the R1KH state machine:

— **DISCONNECT**: This state is entered when the current session ends or when errors occur.

— **FT-AUTH**: This state is entered upon receipt of an indication that an FT protocol or FT resource request protocol is invoked.

— **FT-GET-PMK-R1-SA**: This state is entered when R1KH sends a message to the R0KH to get the PMK-R1-SA.

— **FT-HANDSHAKE-DONE**: This state is entered when reassociation indication parameters are validated. The Reassociation Response frame is then sent.

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— **FT-INIT-ASSOC**: This state is entered upon receipt of a (Re)Association Request frame during initial mobility domain association.
— **FT-INIT-AUTH**: This state is entered upon receipt of an indication that initial association is invoked.
— **FT-INIT-GET-R1_SA**: This state is entered when the R1KH determines that a new key hierarchy is required.
— **FT-INIT-R1_SA**: This state is entered on receiving the PMK-R1-SA from the R0KH and when rekeying the PTK.
— **FT-PMK-R1-SA-RECD**: This state is entered on receiving the PMK-R1-SA from the R0KH. An FT Authenticate response is sent in this state. This state then calculates the PTK and delivers the key to the MAC.
— **FT-PTK-INIT-DONE**: This state is entered on successful validation of the fourth EAPOL-Key frame. In this state, keys are provided to the MAC.
— **FT-PTK-CALC-NEGOTIATING**: This state is entered when a second EAPOL-Key frame is received.
— **FT-PTK-CALC-NEGOTIATING3**: This state is entered on successful validation of the second EAPOL-Key frame. In this state, the third EAPOL-Key frame is sent.
— **FT-PTK-START**: This state is entered when the PMK-R1-SA is present. This state is the beginning of the 4-way handshake to derive a fresh PTK.
— **FT-RV-HANDSHAKE-NEGOTIATING**: This state is entered when an FT resource request is received. The FT resource response is sent.
— **R1-START**: This is the start of the R1KH state machine.
— **SKIP-EAP**: This state is entered after successful completion of the FT protocol. In this state, the EAPOL state machine is triggered to open the IEEE 802.1X port.

13.9.3.3 R1KH state machine variables

The following list summarizes the variables used by the R1KH state machine:

— *Init.* This variable is set to true to initialize the R1KH the state machine.
— *EAPOLKeyReceived.* This variable is set to true when an EAPOL-Key frame is received.
— *K.* This variable is one of the values of the Key Type bit in the EAPOL-Key frame received and is either Pairwise or Group.
— *MIC-Verified.* This variable is set to true when the message authentication code integrity check passes.
— *Pairwise.* This variable is one of the values of the Key Type bit in the EAPOL-Key frame.
— *PMK-R1-SA.* This variable is set to true when a PMK-R1-SA is present at the R1KH.
— *PTK-RekeyRequest.* This variable is set to true when a PTK rekey request is received.
— *Reassocdeadlinetimerexp.* This variable contains the reassociation deadline timer value.
— *ReassocdeadlinetimerexpEvt.* This variable is set to true when the reassociation deadline timer expires.
— *Request.* This variable is the value of the Request bit in the Key Information field in the EAPOL-Key frame.
— *Resv-flow.* This variable is set to true when an indication of an FT resource request protocol is received.
— *R0-TimeoutEvt.* This variable is set to true when the timeout for R0KH authentication expires (e.g., when the EAP authentication session timeout expires).

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— *TimeoutCtr.* This variable contains the number of successive timeouts waiting for protocol responses.
— *TimeoutEvt.* This variable is set to true when a timeout for receiving EAPOL-Key response expires.

13.9.3.4 R1KH state machine procedures

The following list summarizes the procedure used by the R1KH state machine:

— **Calc-FT-PTK().** This procedure calculates the PTK.

13.9.4 S0KH state machine

13.9.4.1 General

There is one S0KH state machine within the Supplicant, defined in Figure 13-17, which incorporates the FT initial association and key management.

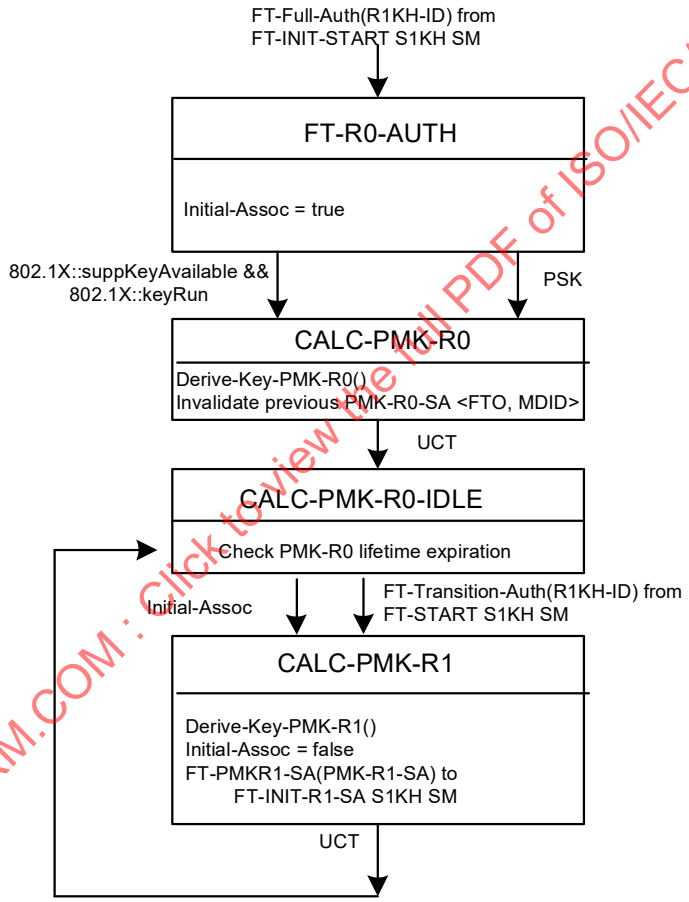

Figure 13-17—S0KH state machine

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13.9.4.2 S0KH state machine states

The following list summarizes the states of the S0KH state machine:

— **CALC-PMK-R0**: This state is entered after the key is received, either from the EAP authentication or from the PSK.

— **CALC-PMK-R0-IDLE**: This state is entered after the PMK-R0 has been calculated and either continues with initial association or waits for requests from an S1KH for a PMK-R1.

— **CALC-PMK-R1**: For FT initial association, this state is entered as an unconditional transfer. For FT protocols, this state is entered through the event from the S1KH state machine. In this state, the PMK-R1 is sent to the S1KH.

— **FT-R0-AUTH**: This state is entered when the FT-Full-Auth event occurs during initial association in the S1KH state machine. The S1KH state machine sends this event when it determines that a new PMK-R0 is needed.

13.9.4.3 S0KH state machine variables

The following list summarizes the variables used by the S0KH state machine:

— *Initial-Assoc.* This variable is used to indicate whether the current authentication is the initial association, in order to trigger the initial derivation of PMK-R1.

— *PSK.* This variable is set to true when authentication is performed by use of a preshared key.

13.9.4.4 S0KH state machine procedures

The following list summarizes the procedures used by the S0KH state machine:

— **Derive-Key-PMK-R0().** This procedure derives the PMK-R0 and PMKR0Name and creates PMK-R0 security association.

— **Derive-Key-PMK-R1 (R1KH-ID).** This procedure derives the PMK-R1 and PMKR1Name from PMK-R0 for the indicated R1KH and creates PMK-R1 security association.

13.9.5 S1KH state machine

13.9.5.1 General

The S1KH state machine includes functions for fast BSS transitions, including initial association. The S1KH state machine and other portions of the SME are defined in Figure 13-18 and Figure 13-19 and consist of a set of states that handle FT initial association, PTK handshake and session establishment, resource requests, cleanup, and teardown. This state machine interacts with the S0KH state machine to generate a fresh key hierarchy.

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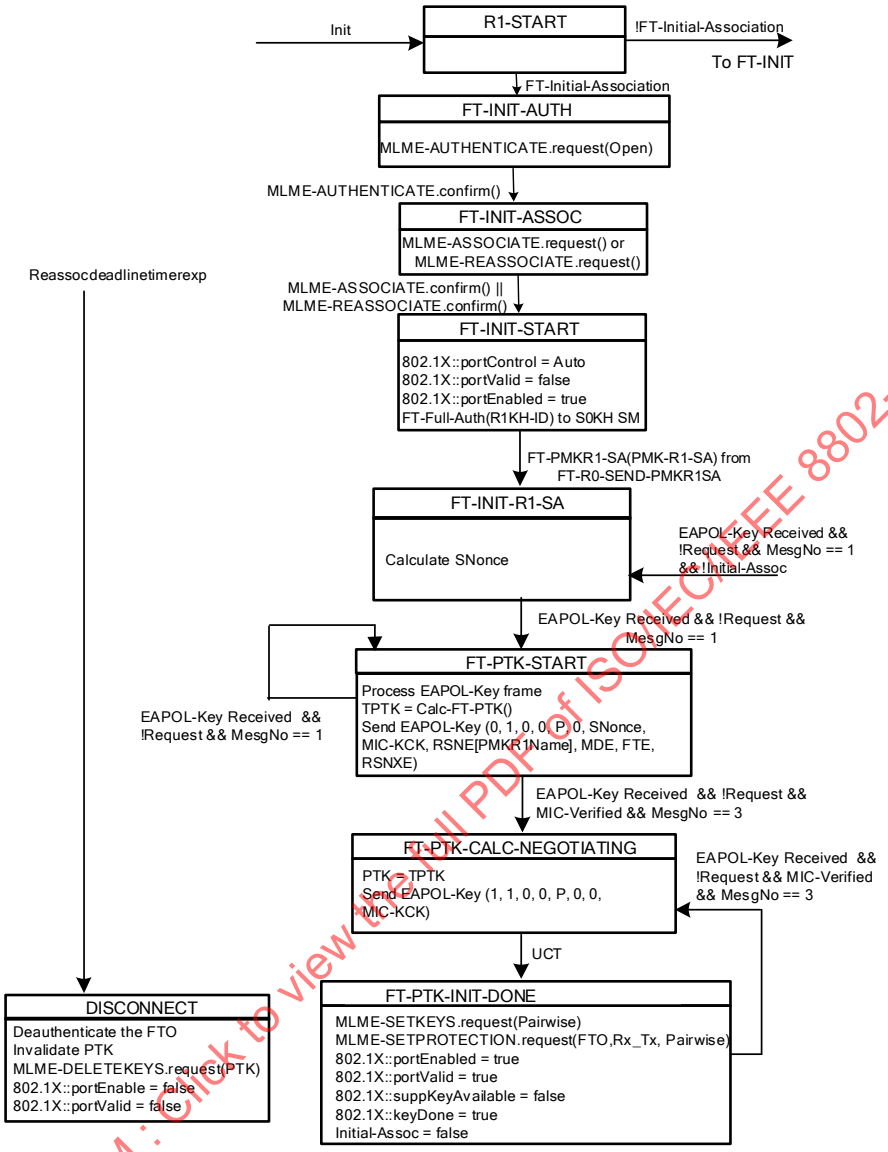

Figure 13-18—S1KH state machine, including portions of the SME (part 1)

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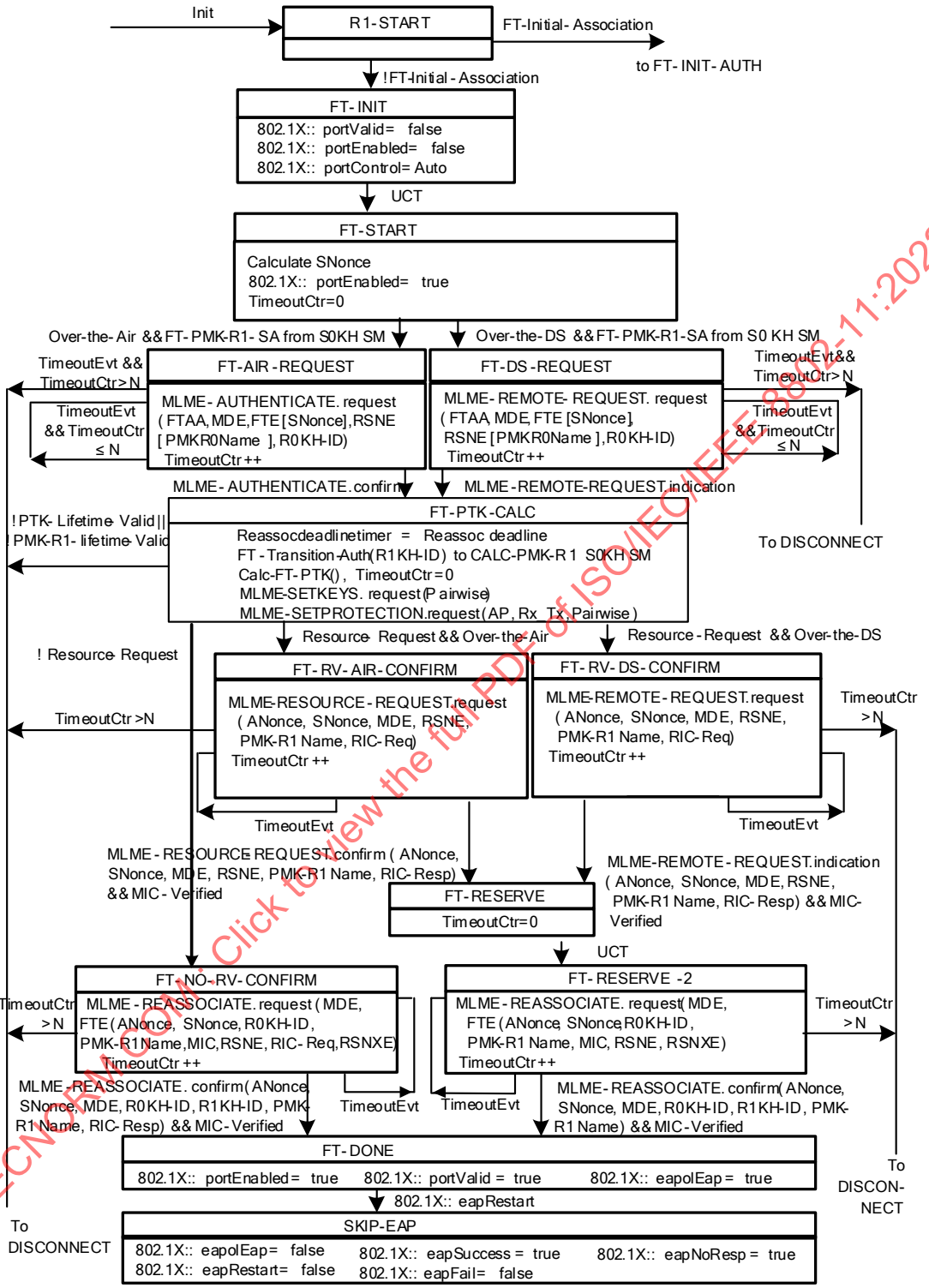

Figure 13-19—S1KH state machine, including portions of the SME (part 2)

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13.9.5.2 S1KH state machine states

The following list summarizes the states of the S1KH state machine:

- **DISCONNECT**: This state is entered when the current session expires.
- **FT-AIR-REQUEST**: This state is entered when it is determined that an over-the-air FT method is to be executed. This state sends the Authentication-Request frame over the air.
- **FT-DONE**: This state is entered when a Reassociation Response frame is received.
- **FT-DS-REQUEST**: This state is entered when it is determined that an over-the-DS FT method is to be executed. This state sends the Authentication-Request frame over the DS.
- **FT-INIT**: This state is entered when an FT method is initiated.
- **FT-INIT-ASSOC:** This state is entered when authentication for initial mobility domain association has been completed.
- **FT-INIT-AUTH**: This state is entered when an FT initial association event is initiated.
- **FT-INIT-START:** This state is entered when association for initial mobility domain association has been completed.
- **FT-INIT-R1-SA**: This state is entered on receiving the PMK-R1-SA from the S0KH and when the Authenticator is starting PTK rekeying by sending out EAPOL-Key frame 1.
- **FT-NO-RV-CONFIRM**: This state is entered when performing FT protocol (i.e., not the FT resource request protocol). This state is entered for both over-the-air and over-the-DS processing. This state sends the Reassociation Request frame.
- **FT-PTK-CALC**: This state is entered when the over-the-air Authentication-Response frame is received if an over-the-air Authentication-Request frame was sent or when over-the-DS FT Response frame is received if an over-the-DS FT Request frame was sent. The PTK is calculated and installed in the MAC.
- **FT-PTK-INIT-DONE**: This state is entered after sending the fourth EAPOL-Key frame. This state establishes the PTK into the MAC.
- **FT-PTK-CALC-NEGOTIATING**: This state is entered when a third EAPOL-Key frame is received. This state sends the fourth EAPOL-Key frame.
- **FT-PTK-START**: This state is entered to derive a new PTK when the PMK-R1-SA is present and when the EAPOL-Key 4-way handshake message 1 is received. This state sends the EAPOL-Key 4-way handshake message 2.
- **FT-RESERVE**: This state is entered when the over-the-air Authentication-Ack frame is received if an over-the-air Authentication-Confirm frame was sent or when over-the-DS FT Ack frame is received if an over-the-DS FT Confirm frame was sent.
- **FT-RESERVE-2**: The Reassociation Request frame is sent in this state after completion of FT resource request.
- **FT-RV-AIR-CONFIRM**: This state is entered for over-the-air FT resource request protocol processing. The Authentication-Confirm frame containing the FT resource request is sent.
- **FT-RV-DS-CONFIRM**: This state is entered for over-the-DS FT resource request protocol processing. The Authentication-Confirm frame containing the FT resource request is sent.
- **FT-START**: This state is entered when all FT parameters are validated and FT needs to be initiated.
- **R1-START**: This is the start of the S1KH state machine.
- **SKIP-EAP**: This state is entered after successful completion of the FT protocol. In this state, the EAPOL state machine is triggered to open the IEEE 802.1X port.

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13.9.5.3 S1KH state machine variables

The following list summarizes the variables used by the S1KH state machine:

- *EAPOLKeyReceived.* This variable is set to true when an EAPOL-Key frame is received.
- *FT-Initial-Association.* This variable is set to true when the S1KH is performing an initial association.
- *Init.* This variable is set to true to initialize the S1KH state machine. In addition, this variable is used to restart the state machine when transitioning to a new AP.
- *MesgNo.* In conjunction with *EAPOLKeyReceived*, this variable indicates which message in the 4-way handshake has been received.
- *MIC-Verified.* This variable is set to true when the message authentication integrity check is valid.
- *N.* This variable contains the limit of timeout events before considering the transition a failure.
- *Over-the-Air.* This variable is set to true when the FT protocol is to be exchanged over the air. Note that both *Over-the-Air* and *Over-the-DS* cannot be equal to true at the same time.
- *Over-the-DS.* This variable is set to true when the FT protocol is to be exchanged over the DS. Note that both *Over-the-Air* or *Over-the-DS* cannot be equal to true at the same time.
- *PMK-R1-Lifetime-Valid.* This variable is set to true when the PMK-R1 lifetime is valid.
- *PTK-Lifetime-Valid.* This variable is set to true when the PTK lifetime is valid.
- *Reassocdeadlinetimer.* This variable contains the reassociation deadline timer value.
- *ReassocdeadlinetimerExp.* This variable is set to true when the reassociation deadline timer expires.
- *Resource-request.* This variable is set to true when the FT resource request protocol is to be executed.
- *TimeoutCtr.* This variable contains the number of successive timeouts waiting for protocol responses.
- *TimeoutEvt.* This variable is set to true when a timeout event occurs.
- *TPTK.* This variable contains the newly calculated PTK, which is installed after receipt of message 3 of the 4-way handshake.

13.9.5.4 S1KH state machine procedures

The following list summarizes the procedure used by the S1KH state machine:

- **Calc-FT-PTK().** This procedure calculates the PTK.

13.10 Remote request broker (RRB) communication

13.10.1 Overview

The RRB mechanism allows the FTO to communicate with a target AP through the FTO's existing association (with the current AP). The FTO transmits an FT Action frame (including the address of the FTO and the BSSID of the target AP's BSS) to the current AP. The current AP includes the contents of the FT Action frame (Request or Confirm) inside a Remote Request frame and transmits it to the target AP over the DS. The target AP processes the remote request and responds to the FTO by sending an FT Action frame (Response or Acknowledgment) through the current AP.

The SME of the FTO initiates an exchange with a target AP by issuing an MLME-REMOTE-REQUEST.request primitive with parameters including the contents of the FT Action frame to be sent. The MAC of the FTO transmits this Action frame. When the MAC of the current AP receives an FT Action frame, it passes it to the RRB by use of an MLME-REMOTE-REQUEST.indication primitive, with parameters including the contents of the received Action frame.

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When the RRB of the current AP has received a response from the target AP, it uses the MLME-REMOTE-REQUEST.request primitive to send the response, as an FT Action frame, to the requesting FTO. The MAC of the current AP transmits this Action frame. When the MAC of the FTO receives an FT Action frame, the MAC passes the Action frame to the SME by use of an MLME-REMOTE-REQUEST.indication primitive, with parameters including the contents of the received Action frame.

13.10.2 Remote request broker (RRB)

The RRB resides in the SME on the APs and acts as a forwarding agent (at the current AP) and termination point (at the target AP) for protocol messages over the DS.

The RRB allows APs that are part of the same mobility domain to exchange information over the DS. APs that advertise the same MDID shall be reachable over the DS and support the over-the-DS communication.

As a termination point, when the RRB at the target AP receives a request frame from the current AP, it interacts with the MAC and other parts of the SME to process the request and respond with a Remote Response frame, through the RRB on the current AP, back to the requesting FTO.

As a forwarding agent, when the RRB at the current AP receives a request from an FTO directed to another AP in the same mobility domain, the current AP forwards the request to that target AP. The RRB on the current AP converts Action frames into Remote Request frames and converts Remote Response frames into Action frames.

The target AP and the current AP shall reside in the same mobility domain. The RRB on the current AP shall transmit Remote Request frames to the target AP based on the BSSID of the target AP's BSS (supplied in the FT Action frames) using the same procedures as preauthentication, as described in 12.6.10.2.

The message flow for a resource request over the DS is given in Figure 13-20. The FTO indicates the destination target AP BSSID as part of the FT Action frame. The RRB on the current AP encapsulates the FT Action frame and supplies the current AP BSSID in the Remote Request frame.

13.10.3 Remote Request/Response frame definition

This subclause defines a mechanism to transport the remote request and remote response between the current AP and the target AP. Any other mechanism may be used.

The Remote Request frame is transmitted over the DS from the current AP to the target AP. The Payload for the Remote Request/Response frame is given in Table 13-2. Remote Request/Response frames shall use an Ethertype of 89-0d, as specified in Annex H. The Remote Request/Response frame contains Version, Type, and Length fields, along with the AP Address.

Table 13-2—Remote Request/Response Payload format

Size	Information
1	FT Packet Type
2	FT Action Length
6	AP Address
Variable	FT Action Frame

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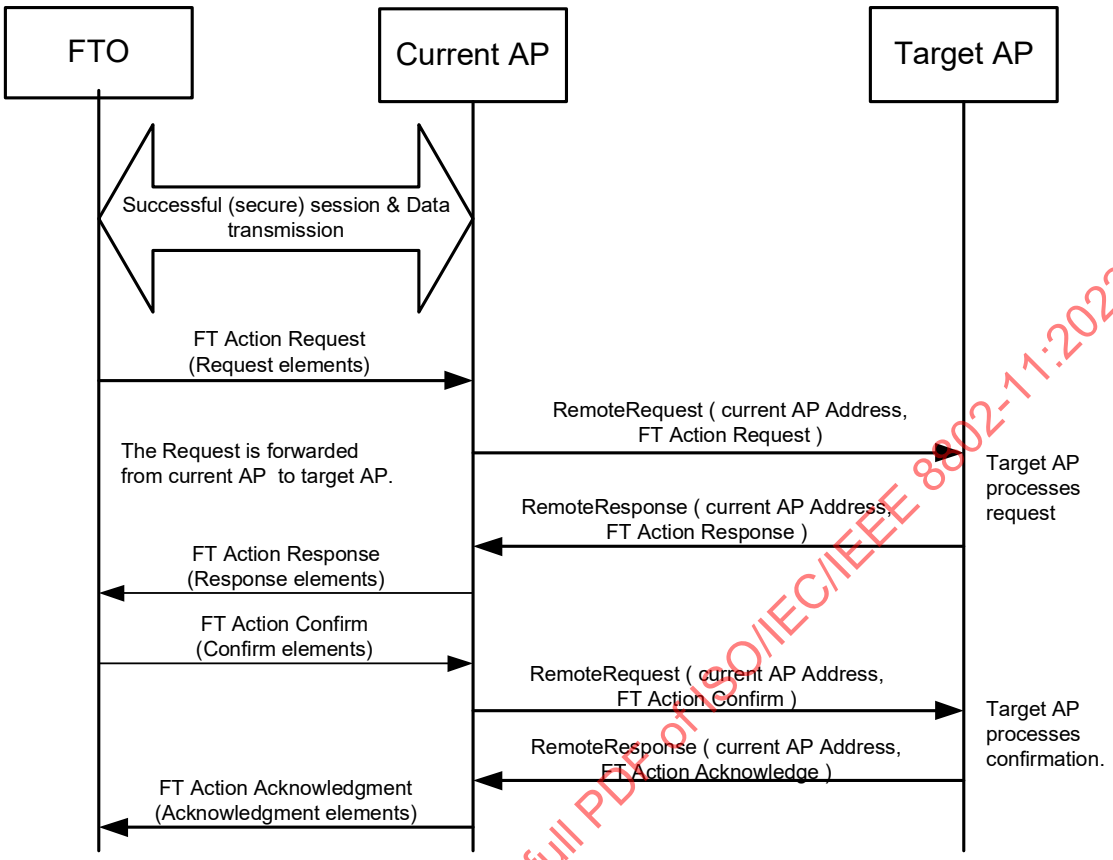

Figure 13-20—Sample message flow for over-the-DS resource request

The FT Packet Type field shall be set to 0 for remote request and to 1 for remote response.

The FT Action Length field shall be set to an unsigned number representing the length in octets of the FT Action Frame field, following the bit ordering conventions of 9.2.2.

The AP Address field shall be set to the BSSID of the current AP's BSS. The target AP shall use this address as the destination address when sending the Remote Response frame as a response to the Remote Request.

The FT Action Frame field shall be set to the contents of the FT Action frame, from the Category field to the end of the Action frame body.

13.11 Resource request procedures

13.11.1 General

When using the resource request procedure, the FTO has the option to request a resource allocation at the target AP. To request resources, the FTO creates a resource information container (RIC) and inserts it in an appropriate request message to the target AP. The request message is sent to the target AP either directly (over the air), or via the current AP (over the DS), according to the FT procedures described in 13.5 and 13.6. In an RSNA, resource requests and responses are exchanged only after the establishment of the PTK and are protected by MICs.

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The RIC contains a complete list of resources requested by the FTO. An AP that receives a resource request from an FTO shall discard any previous resource request from that FTO. In an RSN, this resource request shall first be authenticated by the AP through checking of the MIC before the AP discards any previous resource request.

If an FTO is performing a fast BSS transition according to the FT protocol, described in 13.5, it shall generate a RIC and process the RIC-Response according to the procedures of 13.11.3.1, performing the exchange in the Reassociation Request/Response frames.

If an FTO is performing a fast BSS transition according to the FT resource request protocol, described in 13.6, it shall generate a RIC and process the RIC-Response according to the procedures of 13.11.3.1, performing the exchange in the Authentication-Confirm and Authentication-Ack frames (over the air) or FT Confirm and FT Ack frames (over the DS).

13.11.2 Resource information container (RIC)

The RIC refers to a collection of elements that are used to express a resource request or response.

When used in making a request, a RIC has one or more Resource Requests, as shown in Figure 13-21.

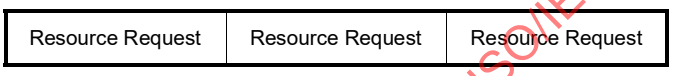

Figure 13-21—RIC-Request format

Each Resource Request consists of an RDE followed by one or more alternative Resource Descriptors. An example of a Resource Request is shown in Figure 13-22.

Figure 13-22—Resource Request format

Each Resource Descriptor consists of one or more elements. The possible Resource Descriptors that may appear in a RIC, and the elements that they contain, are given in Table 13-3.

Table 13-3—Resource types and resource descriptor definitions

Resource type	Resource Descriptor definition	Notes
802.11 QoS	In a request: TSPEC (see 9.4.2.29), followed by zero or more TCLAS (see 9.4.2.30), followed by zero or one TCLAS Processing elements (see 9.4.2.32), followed by zero or one Expedited Bandwidth Request elements (see 9.4.2.93). In a response: a TSPEC element (see 9.4.2.29), followed by zero or one Schedule elements (see 9.4.2.33), followed by zero or more Delay elements (see 9.4.2.31), followed by other optional elements as specified in 11.4.	May be sent by a QoS STA that is an FTO to a QoS AP. Definition of TSPEC elements shall be as given in 11.4. Definition of TCLAS, TCLAS Processing, Expedited Bandwidth Request, and Schedule elements, and the rules for including them in requests and responses, shall be as given in 11.4. Resource request procedures shall be as given in 11.4.

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Table 13-3—Resource types and resource descriptor definitions *(continued)*

Resource type	Resource Descriptor definition	Notes
Block Ack Parameters	In a request: RIC Descriptor (see 9.4.2.50), containing a Resource Type field identifying Block Ack. In a response: RIC Descriptor (see 9.4.2.50), containing a Resource Type field identifying Block Ack.	Resource request procedures shall be as given in 11.5.
Vendor Specific	RDE is followed by any Vendor Specific elements required to specify this resource.	

If there are multiple Resource Descriptors, then they are treated as choices by the target AP. The AP attempts to allocate whatever is specified in the first Resource Descriptor; if this fails, the AP attempts to allocate whatever is specified in the next Resource Descriptor instead, and so on until a successful allocation or the AP reaches the end of the Resource Descriptor list. Thus, an OR relationship exists between Resource Descriptors that follow an RDE, with the Resource Descriptors appearing in order of preference.

An example of a Resource Request consisting of two alternative Resource Descriptors is shown in Figure 13-23.

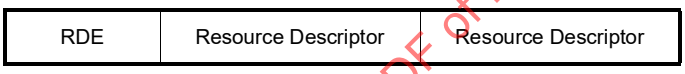

Figure 13-23—Resource Request example #1

For example, when the resource being requested is QoS for downstream traffic, a TSPEC element may be followed by one or more TCLAS elements and, when multiple TCLAS elements are present, a TCLAS Processing element and an Expedited Bandwidth Request (EBR) element. Such an example Resource Request with two alternative TSPECs, the second of which has an EBR, is shown in Figure 13-24.

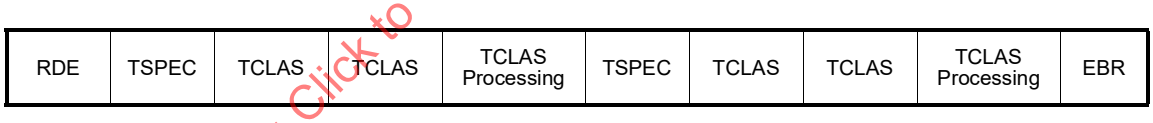

Figure 13-24—Resource Request example #2

An example of a RIC with two resource requests, each with a single TSPEC, is given in Figure 13-25.

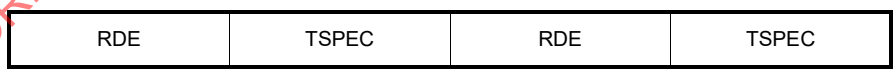

Figure 13-25—RIC-Request example #1

An example of a RIC with one resource request, with a choice of two TSPECs, is given in Figure 13-26. This indicates that the target AP can select one of the two TSPECs.

Figure 13-26—RIC-Request example #2

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An example of a RIC with a RIC Descriptor is given in Figure 13-27. The target AP can acknowledge if the resource specified in the RIC Descriptor is available.

Figure 13-27—RIC-Request example #3

When sent by an AP in response to a RIC-Request, the RIC-Response consists of a list of one or more Resource Responses including one response for each of the Resource Requests that was contained in the RIC-Request. The basic format of a RIC-Response is shown in Figure 13-28.

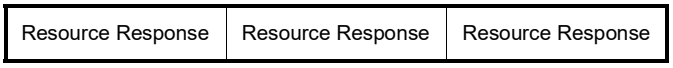

Figure 13-28—RIC-Response format

Each Resource Response consists of an RDE with the RDE identifier matching the RDE identifier in the request, in the same order as the RDEs appeared in the request. The RDE is followed by zero or one Resource Descriptors. If the request was not successful (as indicated in the RDE status), then the AP may include a suggestion that could have been successful. If the resource request was successful, then the particular Resource Descriptor (of the alternatives given by the FTO) is included in the response, as modified by the AP during the processing of the resource request. For example, when the resource being requested is QoS for upstream traffic, the TSPEC element may be followed by a Schedule element.

An example of a RIC-Response with two QoS resource responses, each with a single TSPEC and Schedule element, is given in Figure 13-29.

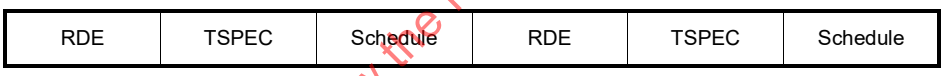

Figure 13-29—Example QoS RIC-Response

13.11.3 Creation and handling of a resource request

13.11.3.1 FTO procedures

The resource request enables an FTO to request resources based on specified Resource Descriptors (e.g., TSPECs) before or at the time the FTO associates with the target AP. In using TSPECs for requesting QoS resources, the TSPECs in the request need not belong to only active TSs; the FTO can send TSPECs for any TS that it intends to use after the transition and request the same resources that would be requested by a later ADDTS exchange. For each resource, the FTO may provide the AP with a choice of Resource Descriptors in order of preference, any one of which meets the needs of the application.

The FTO shall construct the RIC with a number of Resource Requests, each delineated by an RDE.

The FTO shall indicate the resources required at the target AP. For QoS resources, each TS shall be requested by a separate RDE and associated TSPEC(s). The RDE Identifier field in the RDE shall be an arbitrary value chosen by the FTO that uniquely identifies the RDE within the RIC. The Status Code field shall be set to SUCCESS, and the Resource Count field shall be set to the number of alternative Resource Descriptors that follow.

Following each RDE, the FTO shall include one or more Resource Descriptors that define the resources required for this TS. When multiple TSPECs follow an RDE as part of a single QoS resource request, a

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logical “OR” relationship exists between them, and at most one of these TSPECs shall be accepted by the AP. The FTO shall order the Resource Descriptors in decreasing order of preference.

In generating the RDE for QoS resources for a TS, the procedures of 11.4 shall be followed for the generation of TSPECs and inclusion of TCLAS, TCLAS Processing, and Expedited Bandwidth Request elements. If the TS is a downstream flow, then the RDE may also include one or more TCLAS element(s) (defined in 9.4.2.30) and a TCLAS Processing element (defined in 9.4.2.32) if multiple TCLAS elements are included, and an optional Expedited Bandwidth Request (EBR) element, defined in 9.4.2.93. If present, the TCLAS shall appear after the corresponding TSPEC. If present, an EBR element shall appear after the corresponding TSPEC, TCLAS, and TCLAS Processing elements of the TSPEC.

A resource request is considered successful if the status code SUCCESS is returned in each RDE.

If the frame containing the response to the resource request contains a status code other than SUCCESS, the FTO considers that the request has failed and that no resources are being held at the target AP.

The response from the target AP contains a RIC-Response, with the RDEs in the response indicating which resources were considered by the target AP and the setting of the status code indicating which Resource Descriptors were accepted by the AP.

The RDE Identifier field in the RDE enables the FTO to match the response with the RDE in the request. The value of the Status Code field is interpreted as follows:

— Status code = SUCCESS indicates that the request has been accepted. The RDE may be followed by the Resource Descriptor that was accepted.

— Status code = not SUCCESS (one of the values from 9.4.1.9) indicates that the resources could not be accepted. The RDE may be followed by a suggested Resource Descriptor that could have been accepted.

A response to a successful resource request (other than in a Reassociation Request frame) may contain a reassociation deadline. If the FTO does not initiate a Reassociation Request frame with the target AP within the reassociation deadline (if appropriate), then the AP releases resources held for that FTO.

13.11.3.2 AP procedures

When a RIC appears in a request message, the AP shall check its ability to allocate one resource for each RDE in the RIC in the order appearing in the RIC. In a Reassociation Request frame, the QoS Capability element shall be processed prior to the QoS resource requests in the RIC.

The behavior of the AP shall be identical to that described in the flowchart in Figure 13-30.

As shown in Figure 13-30, the Resource Descriptors are examined by the AP in the order presented, and the first that could have been allocated is accepted. Thus the preference ordering by the FTO is honored.

The target AP’s SME examines the resource requests in the RIC. For requests that require processing by the MAC sublayer, the SME generates an MLME-RESOURCE-REQUEST-LOCAL.request primitive. The MAC shall respond with MLME-RESOURCE-REQUEST-LOCAL.confirm primitive that indicates whether the MAC has accepted the resource request. The SME may also send these resource requests to an external entity such as a backend QoS module for its consideration; these procedures are beyond the scope of this standard. The acceptance of a TSPEC by the target AP results in the resource allocation for a TS at the target AP.

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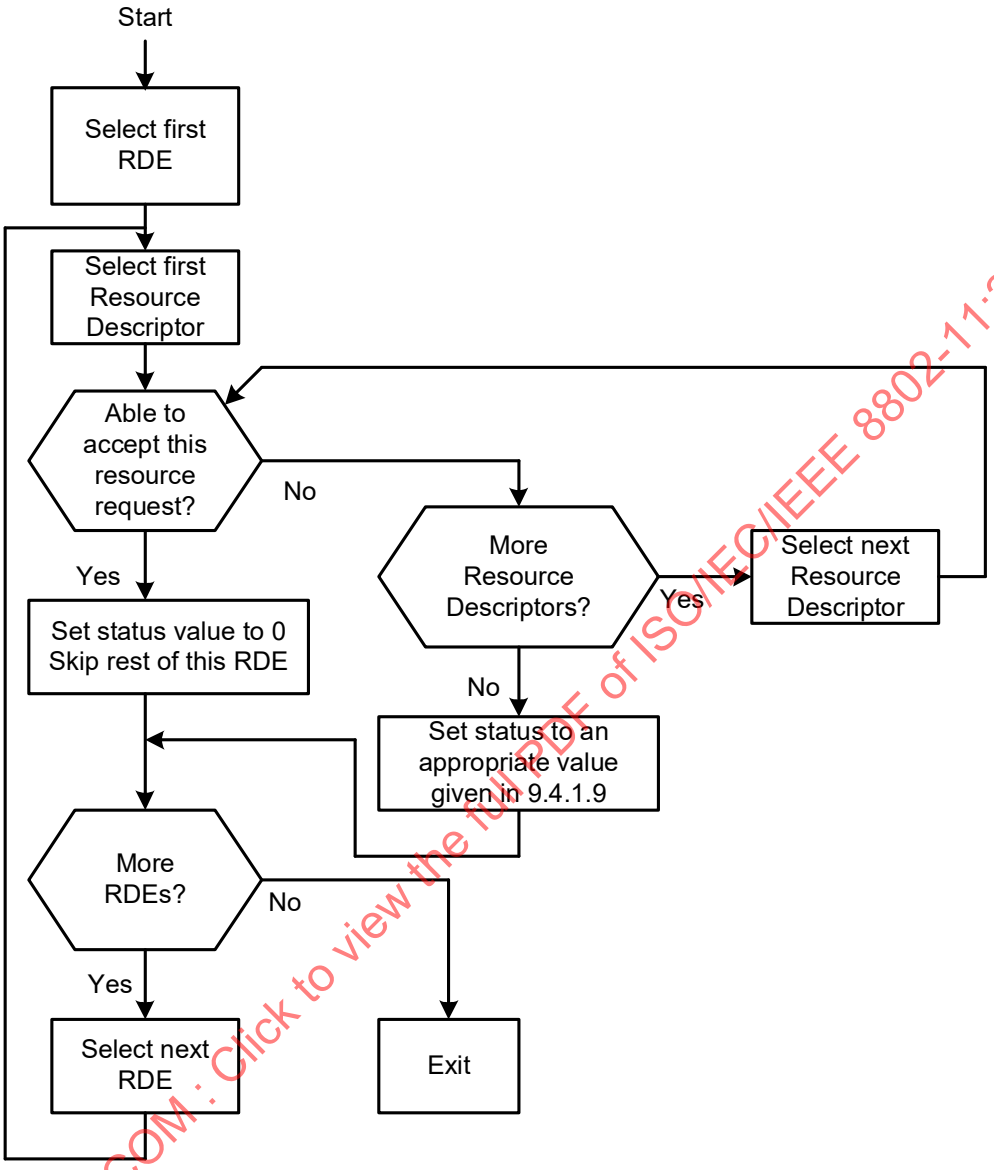

Figure 13-30—Overview of RIC processing at an AP

In response to a RIC-Request, the AP shall construct a RIC-Response. The RIC-Response shall contain one RDE for each RDE in the RIC-Request. The RDEs shall be in the same order as in the request, and the RDE Identifier field in each RDE shall be the value of the RDE Identifier field in the corresponding RDE in the request. The Status Code field in the RDE shall be set according to the result of the allocation request as follows:

— Status code = SUCCESS indicates that the resource request has been accepted. The RDE shall also be followed by the Resource Descriptor that was accepted.

— Status code = not SUCCESS indicates that the resources could not be accepted. The Status Code field contains a value from 9.4.1.9 indicating the reason for the failure. In this case, the AP may include a single Resource Descriptor following the RDE indicating a suggested resource that could have been accepted. The Resource Count field shall be set to 0 or 1 depending whether the suggested

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Resource Descriptor is attached. A not SUCCESS status code in an RDE shall not cause a not SUCCESS status code in the frame containing the RIC.

If the resource request included QoS resources and is successful, then the procedures for handling of TSPEC, TCLAS, TCLAS Processing and Expedited Bandwidth Request elements shall be as specified in 11.4, and the AP shall place the TSs into the accepted state. The RIC-Response shall contain the updated accepted TSPEC. Each RDE may also include a Schedule element (as defined in 9.4.2.33) after the accepted TSPEC. Upon reassociation, AP shall move all of the TSs from the accepted state into the active state.

If the FTO does not invoke a reassociation within the reassociation deadline, then the TSs that had been accepted shall become inactive, and the resources shall be released. At the point that the FTO reassociates with the target AP (within the reassociation deadline, if appropriate), the TSs are put into the active state. This may be immediate if the RIC-Request was part of a Reassociation Request frame.

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14. MLME mesh procedures

14.1 Mesh STA dependencies

When dot11MeshActivated is true, the STA is a mesh STA.

When dot11MeshActivated is true, following shall be true.

— dot11QosOptionImplemented
— dot11ExtendedChannelSwitchActivated (only when dot11SpectrumManagementRequired is true)

When dot11MeshActivated is true, following shall be false.

— dot11OCBActivated
— dot11FastBSSTransitionActivated

A mesh STA does not support functionalities that depend on AP or are only available in an infrastructure BSS, such as HCCA, traffic specifications (TSPECs), traffic stream (TS) management, admission control, automatic power save delivery (APSD), or tunneled direct-link setup (TDLS).

An HT mesh STA does not support PSMP or STBC.

When dot11DMGOptionImplemented or dot11S1GOptionImplemented is true, dot11MeshActivated shall be false.

A mesh STA with dot11EPDImplemented true shall set dot11EPDRequired to true.

14.2 Mesh discovery

14.2.1 General

A mesh STA shall perform either active scanning or passive scanning to discover an operating mesh BSS using the MLME-SCAN.request primitive (see 6.3.3). A mesh profile, a set of parameters identifying the mesh BSS configuration, is also obtained through the scanning process, and it is used to determine the scanning mesh STA's active mesh profile. Based on the result of the scan, the mesh STA may establish a new mesh BSS or become a member of the existing mesh BSS, using the START primitive (see 6.3.11). The MLME-START.request primitive triggers beaconing that facilitates the discovery of the mesh STA by the neighbor mesh STAs. A mesh STA that becomes a member of a mesh BSS should establish a mesh peering with one or more neighbor mesh STAs that are in the same mesh BSS.

14.2.2 Mesh identifier

The Mesh ID is an identifier of an MBSS. The Mesh ID may be installed in mesh capable devices by a variety of means that are beyond the scope of this standard. For example, the Mesh ID might be set by the user, e.g., "Mike's Mesh." A mesh STA shall include the Mesh ID element (see 9.4.2.98) in its Beacon and Probe Response frames, in order to advertise its identity. The mesh STA shall also include the Mesh ID element in its Mesh Peering Open frames, Mesh Peering Confirm frames, and Mesh Peering Close frames.

The mesh STA shall set the SSID element (see 9.4.2.2) in Beacon, Probe Request, and Probe Response frames to the wildcard SSID.

NOTE—The wildcard SSID is used to notify nonmesh STAs that the mesh STA is neither a part of an infrastructure BSS nor an IBSS, so that the nonmesh STAs do not try to join the mesh BSS.

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14.2.3 Mesh profile

A mesh profile is a set of parameters that specifies the attributes of a mesh BSS. A mesh profile consists of the following:

a) A Mesh ID—specified by dot11MeshID
b) A path selection protocol identifier—specified by dot11MeshActivePathSelectionProtocol
c) A path selection metric identifier—specified by dot11MeshActivePathSelectionMetric
d) A congestion control mode identifier—specified by dot11MeshActiveCongestionControlMode
e) A synchronization method identifier—specified by dot11MeshActiveSynchronizationMethod
f) An authentication protocol identifier—specified by dot11MeshActiveAuthenticationProtocol
g) EPD support—specified by dot11EPDImplemented

In a mesh BSS all mesh STAs use the same mesh profile. Two mesh profiles are considered to be the same if all of their parameters match.

Before establishing a mesh BSS or becoming a member of a mesh BSS, a mesh STA shall configure one mesh profile. The mesh STA shall not change its mesh profile unless it leaves the mesh BSS of which it is a member. When the mesh STA leaves the mesh BSS of which it is a member, it should explicitly close all of its active mesh peerings using Mesh Peering Close frames (see 14.3.8) and shall discard all session information obtained while the mesh profile was active, such as local forwarding information, security associations (and related keys), etc. The MLME receives the mesh STA's mesh profile from the SME upon receipt of the MLME-START.request primitive.

The mesh profile is signaled by means of the Mesh ID element and the Mesh Configuration element. The mesh profile is included in the Beacon and Probe Response frames, so that the mesh profile can be obtained by its neighbor mesh STAs through scanning. Mesh Peering Open and Mesh Peering Confirm frames also contain a mesh profile.

14.2.4 Mesh STA configuration

The mesh STA configuration consists of the mesh profile (see 14.2.3), the Supported Rates and BSS Membership Selectors element, the Extended Supported Rates and BSS Membership Selectors element, the HT Operations element (if present), and the VHT Operations element (if present).

Mesh STA configurations are identical if the following conditions hold:

— The mesh profiles are identical.
— The BSSBasicRateSet parameter of the MLME-START.request primitive is identical to the basic rate set indicated by the Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element, if present, received in the MLME-MESHPEERINGMANAGEMENT.indication primitive.
— For HT mesh STAs, the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive is identical to the HT Operation element received in the MLME-MESHPEERINGMANAGEMENT.indication primitive.
— For VHT mesh STAs, the Basic VHT-MCS and NSS Set field in the VHT Operation element of the MLME-START.request primitive is identical to the Basic VHT-MCS and NSS Set field in the VHT Operation element received in the MLME-MESHPEERINGMANAGEMENT.indication primitive.

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14.2.5 Supplemental information for the mesh discovery

A mesh STA shall signal whether it is able to establish additional mesh peerings. A mesh STA signals its ability to establish additional mesh peerings by setting the Accepting Additional Mesh Peerings subfield in the Mesh Capability field in the Mesh Configuration element to 1 (see 9.4.2.97.8).

The mesh STA sets the Accepting Additional Mesh Peerings subfield in the Mesh Capability field in the Mesh Configuration element to 0 when it is not able to accept new mesh peerings. This parameter is dynamically controlled by the SME and given to the MLME by dot11MeshAcceptingAdditionalPeerings.

NOTE—This control is driven by internal policies. When the Accepting Additional Mesh Peering subfield is 1, the mesh STA is assumed to have sufficient internal resources to accommodate more mesh peerings. The internal policy is outside the scope of this standard. For instance, a mesh STA might be configured to be able to maintain only two mesh peerings.

A mesh STA shall announce its topological information through the Mesh Formation Info field in the Mesh Configuration element. The contents of the Mesh Formation Info field shall be coded to reflect the current configuration.

14.2.6 Scanning mesh BSSs

A mesh STA shall perform active scanning or passive scanning, depending on the value of the ScanMode parameter of the MLME-SCAN.request primitive (see 11.1.4), to discover neighbor mesh STAs. Upon receipt of an MLME-SCAN.request primitive with the Mesh ID parameter set to the wildcard Mesh ID, the STA shall passively scan for any Beacon frames, or actively transmit Probe Request frames containing the wildcard Mesh ID, as appropriate, depending on the value of ScanMode. Upon completion of scanning, an MLME-SCAN.confirm primitive is issued by the MLME indicating all of the discovery information received. Further, a mesh STA shall comply with the passive scan procedure as described in 11.1.4.2 and the active scan procedure as described in 11.1.4.3.

14.2.7 Candidate peer mesh STA

When a mesh STA discovers a neighbor mesh STA through the scanning process and the discovered mesh STA is considered a candidate peer mesh STA, it may become a member of the mesh BSS of which the discovered mesh STA is a member and establish a mesh peering with the neighbor mesh STA.

The discovered neighbor mesh STA shall be considered a candidate peer mesh STA if and only if all of the following conditions are met:

a) The mesh STA uses the same mesh profile as the received Beacon or Probe Response frame indicates for the neighbor mesh STA.

   NOTE—If the scanning mesh STA has not become a member of any MBSS yet, it might simply activate the same mesh profile as the discovered neighbor mesh STA's profile to fulfill this condition.

b) The Accepting Additional Mesh Peerings subfield in the Mesh Capability field in the received Beacon or Probe Response frame equals 1.

c) The mesh STA supports the data rates indicated by the BSSBasicRateSet of the received Beacon or Probe Response frame.

d) If both the scanning mesh STA and the discovered neighbor STA are HT STAs, the STA has the same value in the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive as the received Beacon or Probe Response frame indicates for the neighbor mesh STA.

e) If both the scanning mesh STA and the discovered neighbor STA are VHT STAs, the mesh STA uses the same value for the Basic VHT-MCS And NSS Set field in its VHT Operation element as received in the Beacon or Probe Response frame from the neighbor mesh STA.

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f) If the scanning mesh STA has dot11MeshSecurityActivated equal to true and the dot11MeshActiveAuthenticationProtocol is ieee8021x (2), either the scanning mesh STA has an active connection to an AS or the discovered mesh STA has the Connected to AS subfield in the Mesh Formation field in the Mesh Configuration element equal to 1 in the received Beacon or Probe Response frame.

14.2.8 Establishing or becoming a member of a mesh BSS

The Mesh Formation Info field in the Mesh Configuration element is available to assist scanning mesh STAs in choosing the mesh BSS of which to become a member. The details of the usage of this information are beyond the scope of this standard.

NOTE 1—Selection of the mesh BSS of which the scanning mesh STA becomes a new member is outside the scope of this standard. That is, the mesh STA might freely select the mesh BSS of a candidate peer mesh STA of which it becomes a new member.

After the determination of the active mesh profile, the mesh STA may establish a new mesh BSS or become a new member to an existing mesh BSS.

When dot11MBCAActivated is true, the mesh STA shall perform the TBTT selection procedure described in 14.13.4.3 using TimeStamp, Local Time, Beacon Period, and Beacon Timing in the BSSDescriptionSet parameter given by the MLME-SCAN.confirm primitive, before starting its beaconing.

When dot11MCCAActivated is true, the mesh STA shall choose a DTIM interval with a duration of $2^n \times 100$ TU with n a non-negative integer less than or equal to 17.

NOTE 2—It is allowed that a different value for the DTIM interval is used for mesh STAs that use MCCA in an MBSS that is centrally controlled and the central authority provides a coordination of the DTIM interval of mesh STAs that use MCCA in the MBSS.

The mesh STA establishes a new mesh BSS by activating a mesh profile that is different from any mesh profile discovered during the scanning of mesh BSSs (see 14.2.6).

The mesh STA becomes a new member of an existing mesh BSS by activating the same mesh profile as received from a candidate peer mesh STA of this mesh BSS (see 14.2.6 and 14.2.7).

In either case, the mesh STA shall start beaconing using the START primitive. Upon receipt of the MLME-START.request primitive, the mesh STA shall initialize and start its TSF timer as specified by its active synchronization method as described in 14.13.2, and begin transmitting Beacon frames as described in 14.13.3.

If the mesh STA has become a new member of an existing mesh BSS, it should establish a mesh peering with one or more candidate peer mesh STAs of this mesh BSS (see 14.2.9) in order to form the MBSS.

If the mesh STA has become a new member of an existing mesh BSS, it shall adopt the BSSBasicRateSet parameter from a candidate peer mesh STA of this mesh BSS.

After establishing or becoming a member of an MBSS, the mesh STA may continue the discovery procedure described in 14.2.6 to discover other candidate peer mesh STAs.

14.2.9 Establishing mesh peerings

Mesh peerings shall be established only with candidate mesh STAs that are members of the same MBSS.

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A mesh peering is established between the mesh STA and the candidate peer mesh STA after the successful completion of the mesh peering management (MPM) protocol (see 14.3) or of the authenticated mesh peering exchange (AMPE) (see 14.5). When establishing a secure mesh peering, mesh STAs authenticate each other and create a mesh PMKSA before processing the AMPE (see 14.3.3).

A candidate peer mesh STA becomes a peer mesh STA when a mesh peering is established between the two mesh STAs.

When dot11MeshActiveSynchronizationMethod is neighborOffsetSynchronization (1), a mesh STA may establish mesh peerings with up to dot11MeshNbrOffsetMaxNeighbor mesh STAs (see 14.13.2.2.1).

14.3 Mesh peering management (MPM)

14.3.1 General

The mesh peering management (MPM) protocol is used to establish, maintain, and close mesh peerings between mesh STAs when dot11MeshSecurityActivated is false. When dot11MeshSecurityActivated is true, the peers establish an authenticated mesh peering using the authenticated mesh peering exchange (AMPE) protocol. The AMPE protocol requires an existing mesh PMKSA. If a mesh PMKSA with the candidate peer mesh STA exists, the AMPE shall use that mesh PMKSA. If no mesh PMKSA exists, the peers shall first authenticate to establish a mesh PMKSA; see 14.5.

Figure 14-1 shows the logical flow of protocol interactions in the peering management framework.

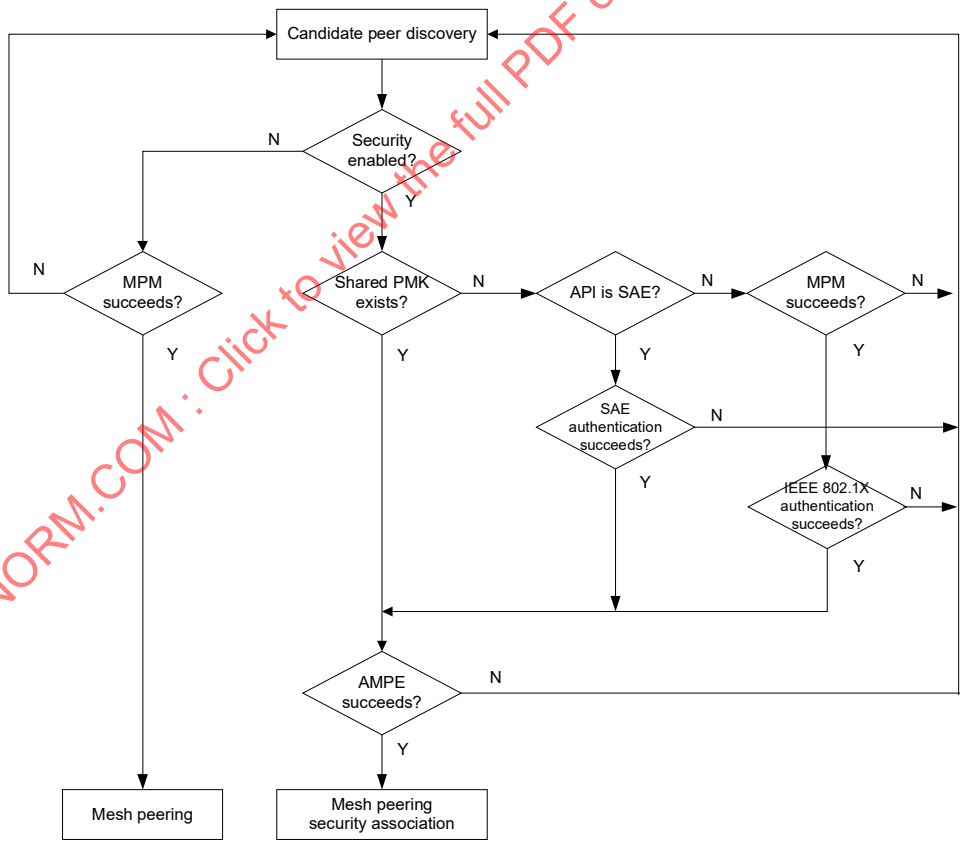

Figure 14-1—Logical flowchart of protocol interaction in the mesh peering management framework

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The MPM protocol uses Mesh Peering Open frames, Mesh Peering Confirm frames, and Mesh Peering Close frames to establish, manage, and tear down a mesh peering.

The protocol succeeds in establishing a mesh peering when the following requirements are satisfied: 1) both mesh STAs have sent and received (and correctly processed) a Mesh Peering Open frame for this mesh peering; 2) both mesh STAs have sent and received (and correctly processed) a corresponding Mesh Peering Confirm frame for this mesh peering.

A mesh STA that receives and accepts a Mesh Peering Open frame (see 14.3.6.2) shall assign a unique AID among its neighbor peer mesh STAs to the transmitter of the frame. Since the AID is used in the encoding of the TIM element in the Beacon frame (see 9.4.2.5), the setting of the AID value is constrained as described in 9.4.1.8. AID 0 (zero) is reserved to indicate the presence of buffered group addressed MSDUs and MMPDUs (see 14.14.4).

14.3.2 State variable management

A mesh STA keeps an enumerated state variable (see 11.3.1) for each neighbor STA with which direct communication via the WM is needed. This state variable expresses the relationship between the local STA and a neighbor STA that varies depending on the active authentication protocol. It takes on the values shown in Table 14-1.

Table 14-1—State variables for mesh STAs

State	Active authentication		
	None	SAE	IEEE Std 802.1X
State 1	Initial start state, mesh peering not established	Initial start state, unauthenticated, mesh peering not established	Initial start state, unauthenticated, mesh peering not established
State 2	N/A	Authenticated, mesh peering not established	N/A
State 3	Mesh peering established	Authenticated, mesh peering established	Unauthenticated, mesh peering established (Pending IEEE 802.1X authentication)
State 4	N/A	N/A	Authenticated, mesh peering established

The state transitions in accordance with the protocol interaction shown in Figure 14-1.

The current state existing between the neighbor STAs determines the IEEE 802.11 frame types that may be exchanged between that pair of STAs (see Clause 9). The allowed frame types are grouped into classes and the classes correspond to the STA state. The allowed frame types and the frame classes in each state are defined in 11.3.3.

A mesh STA shall not transmit frames other than the ones used for candidate peer mesh STA discovery, MPM, and SAE to a neighboring mesh STA until a mesh peering has been established with the mesh STA.

14.3.3 Mesh authentication

See 12.6.1.3.4.

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14.3.4 Mesh peering instance controller

14.3.4.1 Overview

A mesh STA uses a mesh peering instance controller to manage all mesh peering instances.

The mesh peering instance controller performs the following functions:

— Create and delete MPM finite state machines and AMPE finite state machines
— Manage instance identifiers for each mesh peering instance
— Manage mesh TKSAs for each mesh peering instance when dot11MeshSecurityActivated is true
— Preprocess the incoming mesh peering Management frames and pass the frames to the finite state machine with matching instance identifier
— Pass internal commands to the finite state machine with matching instance identifier

A mesh peering instance is identified by a mesh peering instance identifier. The mesh peering instance identifier is the set of localLinkID, localMAC, and peerMAC.

A mesh peering instance consists of its identifier (the localLinkID, localMAC, peerMAC), a peerLinkID (an integer generated by the peer mesh STA or candidate peer mesh STA), and the configuration and capability negotiated and agreed upon by exchanging Mesh Peering Open frames (see 9.6.15.2) and Mesh Peering Confirm frames (see 9.6.15.3). If dot11MeshSecurityActivated is true, the mesh peering instance also contains a PMKID identifying the shared PMKSA, a localNonce chosen by the mesh STA and a peerNonce chosen by the peer mesh STA or candidate peer mesh STA.

The localMAC is the MAC address of the mesh STA that is managing this mesh peering instance. The peerMAC is the MAC address of the peer mesh STA or the candidate peer mesh STA. The localLinkID is an integer generated by the mesh STA. The localLinkID shall be unique among all existing link identifiers used by the mesh STA for its MPM finite state machines. The mesh STA selects the localLinkID to provide high assurance that the same number has not been used to identify a recent MPM finite state machine. The peerLinkID is the localLinkID of the peer mesh STA or candidate peer mesh STA and is supplied in the Mesh Peering Management element (see 9.4.2.101) of the Mesh Peering Open and Mesh Peering Confirm frames.

A mesh peering instance is controlled by an MPM finite state machine (see Table 14-2 in 14.4.5) or an AMPE finite state machine (see Table 14-3 in 14.5.6.3).

14.3.4.2 Creating a new mesh peering instance

The mesh peering instance controller creates a new mesh peering instance after either of the following two events:

— The receipt of a Mesh Peering Open frame from a candidate peer mesh STA according to the rules of 14.3.5
— The receipt of an MLME-MESHPEERINGMANAGEMENT.request primitive with a Mesh Peering Open frame

A unique localLinkID shall be generated for the mesh peering instance. If the mesh peering instance is established by AMPE, a random local nonce shall also be generated.

A mesh STA may create multiple mesh peering instances to establish a peering with the same candidate peer mesh STA.

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14.3.4.3 Deleting mesh peering instances

The mesh peering instance controller deletes a mesh peering instance after any of the following events:

- Expiration of a holding timer (see 14.4.4)
- Acceptance of a peer's response to an existing request to close the peering (see 14.4.3)
- Indication from the SME that the peer mesh STA, or candidate peer mesh STA, has deauthenticated

When the deletion occurs, the mesh TKSA that is bound to the mesh peering shall be deleted.

14.3.5 Mesh peering instance selection

The content of a mesh peering Management frame received from a candidate peer mesh STA, and the set of mesh peering instances in the mesh peering instance controller determine whether

- A new mesh peering instance is created (see 14.3.4.2), or
- An existing mesh peering instance is updated.

If dot11MeshSecurityActivated is true and the mesh STA shares a PMK with the candidate peer mesh STA but the Mesh Peering Protocol Identifier field in the Mesh Peering Management element of the frame indicates "mesh peering management protocol," the frame shall be silently discarded.

If dot11MeshSecurityActivated is true and the mesh STA shares a PMK with the candidate peer mesh STA but either the Mesh Peering element or the MIC element are not present in the frame, the frame shall be silently discarded.

If dot11MeshSecurityActivated is false but the Mesh Peering Protocol Identifier field in the Mesh Peering Management element of the received frame indicates "authenticated mesh peering exchange," the frame shall be silently discarded.

If dot11MeshSecurityActivated is false but either the Mesh Peering element or the MIC element is present in the frame, the frame shall be silently discarded.

If the frame contains a group address in TA or RA, it shall be silently discarded.

If the incoming mesh peering Management frame is for AMPE and the Chosen PMK from the received frame contains a PMKID that does not identify a valid mesh PMKSA, the frame shall be silently discarded.

If the mesh peering Management frame has not been silently discarded, the mesh peering instance controller attempts to locate a matching mesh peering instance identifier. A match is determined by comparing the contents of the mesh peering Management frame with each peering instance. A match is found if all of the following conditions are true:

- The transmitter's MAC address (Address 2) is the same as the peerMAC of the mesh peering instance
- The receiver's MAC address (Address 1) is the same as the localMAC of the mesh peering instance
- The value of the Peer Link ID field is the same as the localLinkID of the mesh peering instance

If the incoming frame is a Mesh Peering Open frame and no matching peering instance was found, a new mesh peering instance is created (and a new Mesh TSKA if dot11MeshSecurityActivated is true). See 14.3.4.2.

If the incoming frame is a Mesh Peering Confirm or Mesh Peering Close frame and no matching mesh peering instance is found, it shall be silently discarded.

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If the incoming mesh peering Management frame is for AMPE and has not been discarded it shall be further processed as follows:

— If the Peer Nonce field is present in the received frame, and the localNonce in the mesh peering instance is different from the Peer Nonce field of the received frame, the frame shall be dropped.

— If the peerNonce in the mesh peering instance exists and is different from the Local Nonce field of the received frame, the frame shall be dropped.

14.3.6 Mesh peering open

14.3.6.1 Generating Mesh Peering Open frames

A Mesh Peering Open frame is generated as a result of a sendOpen() action (see 14.4.3).

The contents of the frame are described in 9.6.15.2.2.

14.3.6.2 Mesh Peering Open frame processing

The mesh STA checks that the Mesh ID element and Mesh Configuration element of the Mesh Peering Open frame is identical to its own mesh STA configuration as specified in 14.2.3 and 14.2.4. If a mismatch is found the frame shall be rejected with a reason code of MESH-CONFIGURATION-POLICY-VIOLATION and the mesh peering establishment attempt shall be terminated.

When the mesh STA has established a mesh PMKSA with the candidate peer mesh STA, the mesh peering instance controller shall silently discard the Mesh Peering Open frame in the following two conditions:

— The Mesh Peering Open frame supports MPM protocol and the negotiated active authentication is SAE, or

— The Mesh Peering Open frame supports AMPE but the PMKID in the Chosen PMK field in the Authenticated Mesh Peering Exchange element does not identify a mesh PMKSA.

If the Mesh Peering Open frame is not discarded, the mesh peering instance controller actively rejects or accepts the mesh peering open request (see 14.4). If dot11MeshAcceptingAdditionalPeerings is set to 0 the Mesh Peering Open request shall be rejected with reason code MESH-MAX-PEERS.

If the peerLinkID in the mesh peering instance has not been set, the Local Link ID field of the Mesh Peering Open request shall be copied into the peerLinkID in the mesh peering instance. If the incoming Mesh Peering Open frame is for AMPE and the peerNonce in the mesh peering instance has not been set, the Local Nonce field in the incoming Mesh Peering Open frame shall be copied into the peerNonce in the mesh peering instance.

The mesh peering open request may be rejected due to an internal reason with a reason code of MESH-PEERING-CANCELED.

NOTE—Example internal reasons to reject new mesh peering request could be the mesh STA is configured to reject mesh peering request from another specific peer mesh STA.

If the Mesh Peering Open request is rejected, the REQ_RJCT event shall be passed with the specified reason code to the protocol finite state machine to actively reject the mesh peering open request.

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14.3.7 Mesh peering confirm

14.3.7.1 Generating Mesh Peering Confirm frames

A Mesh Peering Confirm frame is generated as a result of a sendConfirm() action (see 14.4.3).

The contents of the frame are described in 9.6.15.3.2.

14.3.7.2 Mesh Peering Confirm frame processing

The mesh STA shall check that the Mesh ID element and Mesh Configuration element of the Mesh Peering Confirm frame match its own mesh STA configuration as specified in 14.2.3 and 14.2.4. If a mismatch is found, the frame shall be rejected with the reason code of MESH-INCONSISTENT-PARAMETERS.

If the Mesh Peering Confirm frame is rejected, the REQ_RJCT event shall be passed with the specified reason code to the protocol finite state machine to actively reject the mesh peering confirm.

Otherwise, the mesh STA accepts the Mesh Peering Confirm frame and performs the actions described in 14.4.

If the peerLinkID in the mesh peering instance has not been set, the Local Link ID field of the Mesh Peering Confirm request shall be copied into the peerLinkID in the mesh peering instance. If the incoming Mesh Peering Confirm frame is for AMPE and the peerNonce in the mesh peering instance has not been set, the Local Nonce field in the incoming Mesh Peering Confirm frame shall be copied into the peerNonce in the mesh peering instance.

14.3.8 Mesh peering close

14.3.8.1 Generating Mesh Peering Close frames

A Mesh Peering Close frame is generated as a result of a sendClose() action (see 14.4.3).

The contents of the frame are described in 9.6.15.4.2.

When the Mesh Peering Close is generated as a result of a CNCL event, the reason code is MESH-PEERING-CANCELED. When the Mesh Peering Close is generated as a result of a CLS_ACPT event, the reason code is MESH-CLOSE-RCVD.

14.3.8.2 Mesh Peering Close frame processing

The mesh STA shall reject the Mesh Peering Close frame if the value in the Mesh ID element is not the same as the mesh STA's mesh profile. Otherwise, the mesh STA accepts the Mesh Peering Close frame and performs the actions described in 14.4.

14.4 Mesh peering management finite state machine (MPM FSM)

14.4.1 General

Each mesh peering instance, including its states and resource, are managed by a mesh peering management finite state machine (MPM FSM). The MPM FSM uses MLME primitives to control the mesh STA to send and receive mesh peering Management frames.

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14.4.2 States

The MPM FSM uses the following six states:

— IDLE. IDLE state is a terminal state. In the IDLE state, the MPM FSM is ready to start a new mesh peering instance by either passively listening for an incoming Mesh Peering Open frame or actively initiating a mesh peering instance.

— OPN_SNT. In the OPN_SNT state, the finite state machine has sent a Mesh Peering Open frame and is waiting for a Mesh Peering Open frame and Mesh Peering Confirm frame from the candidate peer mesh STA.

— CNF_RCVD. In the CNF_RCVD state, the finite state machine has received a Mesh Peering Confirm frame, but has not received a Mesh Peering Open frame. The mesh STA has not sent the corresponding Mesh Peering Confirm frame yet.

— OPN_RCVD. In the OPN_RCVD state, the finite state machine has received only the Mesh Peering Open frame but not the Mesh Peering Confirm. The mesh STA has also sent a Mesh Peering Confirm frame upon receiving a Mesh Peering Open frame.

— ESTAB. In the ESTAB state, the finite state machine has received both the Mesh Peering Open and Mesh Peering Confirm frames. The mesh STA has also sent both the Mesh Peering Open frame and Mesh Peering Confirm frame. The mesh peering is established and configured for exchanging frames with the peer mesh STA in the ESTAB state.

— HOLDING. In the HOLDING state, the finite state machine is closing the mesh peering instance with the peer mesh STA or the candidate peer mesh STA.

14.4.3 Events and actions

The finite state machine uses three types of events: 1) events for state machine transitions; 2) external events generated by frame processing; and 3) events associated with internal timers.

The events for state machine transitions are as follows:

— CNCL(localLinkID, peerMAC, ReasonCode). Used to instruct the mesh peering instance to cancel the mesh peering with the peer mesh STA. localLinkID identifies the MPM FSM for the corresponding mesh peering instance. peerMAC is the MAC address of the peer mesh entity. ReasonCode is used to inform the reason to cancel the mesh peering instance. See 14.3.8.2.

— ACTOPN(peerMAC, localLinkID). The SME uses this event to create a new mesh peering instance to actively initiate the mesh peering establishment with the candidate peer mesh STA whose MAC address is peerMAC. localLinkID identifies the MPM FSM.

The events generated by frame processing are as follows:

— OPN_ACPT. PeeringOpen_Accept(peerMAC, peerLinkID) event indicates that a Mesh Peering Open frame meeting the correctness criteria of 14.3.6 has been received from peerMAC for the mesh peering instance identified by peerLinkID.

— OPN_RJCT. PeeringOpen_Reject(peerMAC, peerLinkID, meshConfiguration, reasonCode) event indicates that a Mesh Peering Open frame from peerMAC for the mesh peering instance identified by peerLinkID is rejected due to incomplete or erroneous mesh STA configuration (see 14.2.4), as indicated by meshConfiguration, with reasonCode being the specific reason for rejection of the Mesh Peering Open frame. See 14.3.6.2.

— CNF_ACPT. PeeringConfirm_Accept(peerMAC, localLinkID, peerLinkID) event indicates that a Mesh Peering Confirm frame meeting the correctness criteria of 14.3.7 has been received from peerMAC for the mesh peering instance identified by localLinkID and peerLinkID.

— CNF_RJCT. PeeringConfirm_Reject(peerMAC, localLinkID, peerLinkID, reasonCode) event indicates that a Mesh Peering Confirm frame from peerMAC for the mesh peering instance

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identified by localLinkID and peerLinkID is rejected due to incomplete or erroneous configuration, and reasonCode is the specific reason for rejection of the Confirm frame. See 14.3.7.2.

— CLS_ACPT. PeeringClose_Accept(peerMAC, localLinkID, peerLinkID, reasonCode) event indicates that a Mesh Peering Close frame meeting the correctness criteria of 14.3.8 has been received from peerMAC for the mesh peering instance identified by localLinkID and peerLinkID. The reasonCode specifies the reason that caused the generation of the Mesh Peering Close frame. See 14.3.8.2.

— REQ_RJCT. PeeringRequest_Reject(peerMAC, peerLinkID, reasonCode) event indicates a special incidence that the mesh STA rejects the incoming Mesh Peering Open frame requesting to set up a new mesh peering for some specified reason. The incoming request is identified by the peerMAC, peerLinkID is the peerLinkID received from the Mesh Peering Open frame, and reasonCode is the specific reason for rejection of the Mesh Peering Open frame. See 14.3.6.2.

The finite state machine may take an action triggered by an event. It uses two types of actions: sending a mesh peering Management frame and handling a timer.

Actions related to sending a mesh peering Management frame are as follows:

— sndOPN. sendOpen(peerMAC, localLinkID, meshConfiguration) is the action that the mesh STA takes to send its localLinkID and mesh STA Configuration in a Mesh Peering Open frame to the candidate peer mesh STA, whose MAC address is peerMAC. The MLME-MESHPEERINGMANAGEMENT.request primitive shall be invoked to send the frame to the peer mesh entity.

— sndCNF. sendConfirm(peerMAC, localLinkID, peerLinkID, meshConfiguration) is the action that the mesh STA takes to send its localLinkID and meshConfiguration in a Mesh Peering Confirm frame to the candidate peer mesh STA, whose MAC address is peerMAC. peerLinkID is the peerLinkID received from the Mesh Peering Open frame. The MLME-MESHPEERINGMANAGEMENT.request primitive shall be invoked to send the frame to the peer mesh entity.

— sndCLS. sendClose(peerMAC, localLinkID, peerLinkID, reasonCode) is the action that the mesh STA takes to send its localLinkID in a Mesh Peering Close frame to the peer mesh STA or candidate peer mesh STA, whose MAC address is peerMAC. peerLinkID is the peerLinkID received from the Mesh Peering Open frame, and reasonCode is the specific reason for closing the mesh peering. The MLME-MESHPEERINGMANAGEMENT.request primitive shall be invoked to send the frame to the peer mesh entity.

14.4.4 Timers

The following three timers are used by the finite state machine:

a) The retryTimer triggers a resend of the Mesh Peering Open frame when a Mesh Peering Confirm frame was not received as a response. The retryTimer is set to the dot11MeshRetryTimeout.

b) The confirmTimer signals that a link establishment attempt should be aborted because a Mesh Peering Confirm frame responding to a Mesh Peering Open frame was never received. The confirmTimer is set to dot11MeshConfirmTimeout.

c) The holdingTimer signals that its mesh peering instance may be completely closed and facilitates graceful shutdown. The holdingTimer is set to dot11MeshHoldingTimeout.

The events associated with internal timers are represented in the state machine table as acronyms that indicate timer expiration. With each timer event there is an associated action.

— TOR1. This event indicates that the retryTimer has expired and the retry counter is less than dot11MeshMaxRetries. The Mesh Peering Open frame shall be resent, an action represented in the state machine table by setR.

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— TOR2. This event indicates that the retryTimer has expired and the retryCounter is equal to dot11MeshMaxRetries. The mesh peering instance shall be closed when TOR2 occurs.
— TOC. This event indicates that the confirmTimer has expired. When TOC event occurs, the mesh peering instance shall be closed, an action represented in the state machine table as setC.
— TOH. This event indicates that the holdingTimer has expired. When TOH occurs, the mesh peering instance shall be closed and the finite state machine shall transition to IDLE state, an action represented in the state machine table as setH.

14.4.5 State transitions

Table 14-2 and Figure 14-2 summarize the state transitions for the MPM protocol.

In Table 14-2, each row represents state transitions from the state to all other states. A blank entry indicates an impossible transition.

Table 14-2—MPM finite state machine

From State	To State					
	IDLE	OPN_SNT	CNF_RCVD	OPN_RCVD	ESTAB	HOLDING
IDLE	REQ_RJCT / sndCLS	ACTOPN / (sndOPN, setR)		OPN_ACPT/ (sndOPN, sndCNF, setR)		
OPN_SNT		TOR1 / (sndOPN, setR)	CNF_ACPT / (clR, setC)	OPN_ACPT/ (sndCNF)		CLS_ACPT, OPN_RJCT, CNF_RJCT, TOR2, CNCL / (sndCLS, clR, setH)
CNF_RCVD					OPN_ACPT / (clC, sndCNF)	CLS_ACPT, OPN_RJCT, CNF_RJCT, CNCL / (sndCLS, clC, setH) TOC / (sndCLS, setH)
OPN_RCVD				OPN_ACPT/ sndCNF TOR1 / (sndOPN, setR)	CNF_ACPT / clR	CLS_ACPT, OPN_RJCT, CNF_RJCT,TOR2, CNCL / (sndCLS, clR, setH)
ESTAB					OPN_ACPT / sndCNF	CLS_ACPT, OPN_RJCT, CNF_RJCT, CNCL / (sndCLS, setH)
HOLDING	TOH / —, CLS_ACPT / clH					OPN_ACPT, CNF_ACPT, OPN_RJCT, CNF_RJCT / sndCLS

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In Figure 14-2, each arrow represents a state transition.

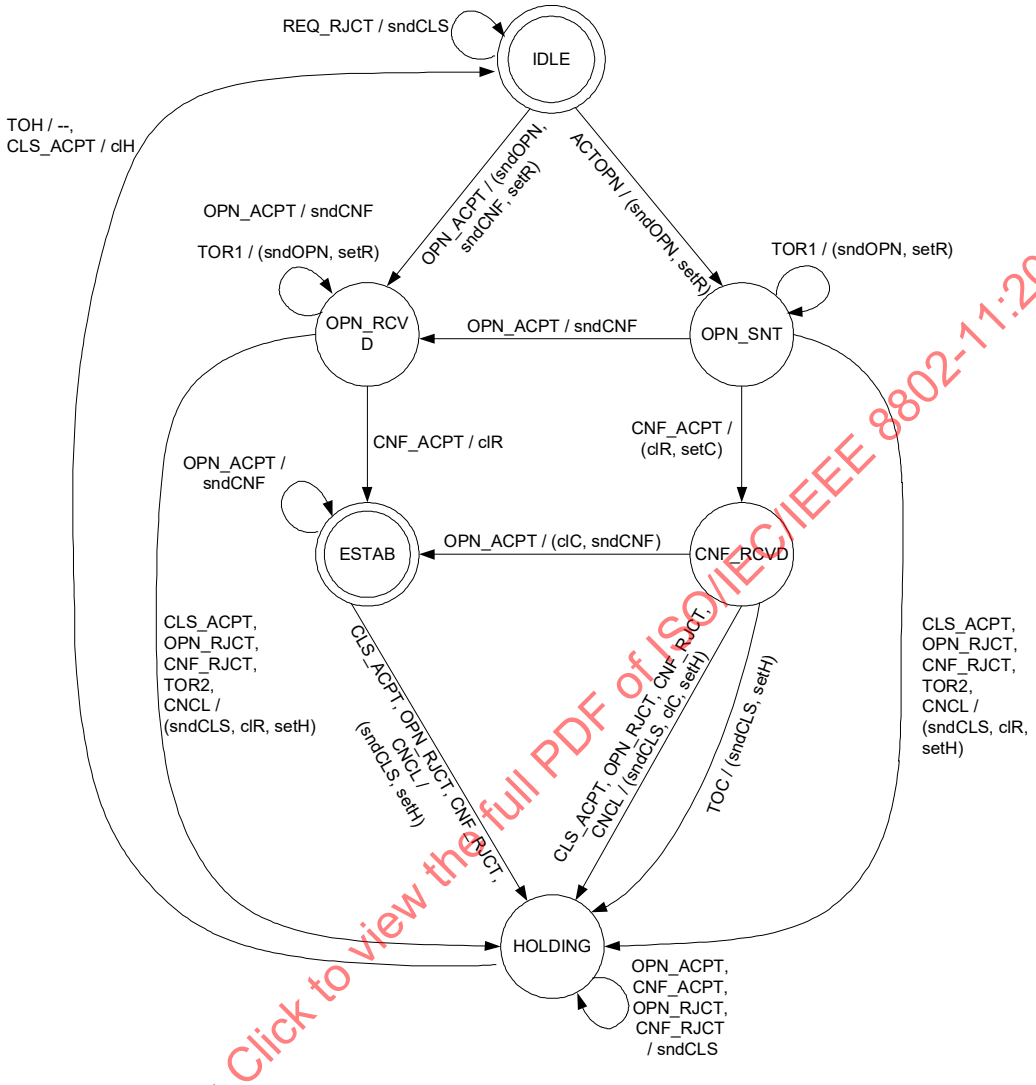

Figure 14-2—Finite state machine of the MPM protocol

The event/action representation is defined as the following. “E/A” string represents that the action A is taken given that the event E occurs. “E1, E2/A” string represents that the action A is taken given that the event E1 or event E2 occurs. “E/(A1, A2)” string represents that the action A1 and A2 are taken at a time when event E occurs.

Note that Table 14-2 and Figure 14-2 are used for illustration purposes. The protocol behavior is in the following subclauses.

14.4.6 IDLE state

IDLE is a quiescent state the finite state machine enters prior to establishing a new mesh peering.

When ACTOPN event occurs, the mesh STA shall set a retryCounter to 0, and perform a sndOPN action. The retryTimer shall be set and the finite state machine shall transition to OPN_SNT state.

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When an OPN_ACPT event occurs, the mesh STA shall perform a sndOPN action and sndCNF action, and set the retryTimer. The finite state machine shall transition to OPN_RCVD state.

When an REQ_RJCT event occurs, a Mesh Peering Close frame shall be sent to reject the mesh peering open request. The reason code in the Mesh Peering Close frame shall be set to the reason code in REQ_RJCT event. The finite state machine shall stay in the IDLE state.

All other events are ignored in this state.

14.4.7 OPN_SNT state

In the OPN_SNT state, the mesh STA waits for a Mesh Peering Confirm frame. In this state, the retryTimer is set.

When a CNCL event occurs, the mesh STA shall clear the retryTimer, perform a sndCLS using the reason code specified by the CNCL event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a CLS_ACPT event occurs, the mesh STA shall clear the retryTimer, perform a sndCLS using the reason code specified by the CLS_ACPT event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When an OPN_ACPT event occurs, the mesh STA shall send perform a sndCNF action. The finite state machine shall transition to OPN_RCVD state.

NOTE—The retryTimer is still in effect after the state transition.

When an OPN_RJCT event occurs, the mesh STA shall clear the retryTimer, perform a sndCLS using the reason code specified by the OPN_RJCT event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a CNF_ACPT event occurs, the mesh STA shall clear the retryTimer and shall set the confirmTimer and the finite state machine shall transition to CNF_RCVD state.

When a CNF_RJCT event occurs, the mesh STA shall clear the retryTimer, perform a sndCLS action using the reason code specified by the CNF_RJCT event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a TOR1 event occurs, the Mesh STA shall perform a sndOPN action and the retryCounter shall be incremented. The retryTimer shall be and the finite state machine shall stay in the OPN_SNT state.

When a TOR2 event occurs, the mesh STA shall perform a sndCLS action using the reason code MESH-MAX-RETRIES. The holdingTimer shall be set, and the finite state machine shall transition to HOLDING state.

All other events shall be ignored in this state.

14.4.8 CNF_RCVD state

In the CNF_RCVD state, the mesh STA has received a Mesh Peering Confirm frame and is waiting for a Mesh Peering Open frame.

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When a CNCL event occurs, the mesh STA shall clear the confirmTimer, perform a sndCLS action using the reason code MESH-PEERING-CANCELED, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a CLS_ACPT event occurs, the mesh STA shall clear the confirmTimer, perform a sndCLS using the reason code MESH-CLOSE-RCVD, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When an OPN_ACPT event occurs, the mesh STA shall clear the confirmTimer and shall perform a sndCNF action. The finite state machine shall transition to ESTAB state.

When an OPN_RJCT event occurs, the mesh STA shall clear the confirmTimer, perform a sndCLS action using the reason code as specified by the OPN_RJCT event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a CNF_RJCT event occurs, the mesh STA shall clear the confirmTimer, perform a sndCLS action using the reason code as specified by the CNF_RJCT event, and set the holdingTimer The finite state machine shall transition to HOLDING state.

When TOC event occurs, the mesh STA shall perform a sndCLS action using the reason code MESH-CONFIRM-TIMEOUT and set the holdingTimer. The finite state machine shall transition to HOLDING state.

All other events shall be ignored in this state.

14.4.9 OPN_RCVD state

In the OPN_RCVD state, the mesh STA has received a Mesh Peering Open frame and sent a Mesh Peering Open frame and the corresponding Mesh Peering Confirm frame. An incoming Mesh Peering Confirm is expected.

When a CNCL event occurs, the mesh STA shall clear the retryTimer, perform a sndCLS action using the reason code MESH-PEERING-CANCELED, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a CLS_ACPT event occurs, the mesh STA shall clear the retryTimer, perform a sndCLS action, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When an OPN_ACPT event occurs, the mesh STA shall perform a sndCNF action. The finite state machine shall stay in the OPN_RCVD state.

When an OPN_RJCT event occurs, the mesh STA shall clear the retryTimer, perform a sndCLS action using the reason code as specified by the OPN_RJCT event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a CNF_ACPT event occurs, the retryTimer shall be cleared. The finite state machine shall transition to ESTAB state.

When a CNF_RJCT event occurs, the mesh STA shall clear the retryTimer, perform a sndCLS action using the reason code as specified by the CNF_RJCT event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a TOR1 event occurs, the Mesh STA shall perform a sndOPN action, increment the retryCounter, and set the retryTimer. The finite state machine shall stay in the OPN_RCVD state.

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When a TOR2 event occurs, the mesh STA shall perform a sndCLS action using the reason code MESH-MAX-RETRIES. The holdingTimer shall be set, and the finite state machine shall transition to HOLDING state.

All other events shall be ignored in this state.

14.4.10 ESTAB state

In the ESTAB state, mesh peering has been successfully established with the peer mesh STA.

When a CNCL event occurs, the mesh STA shall perform a sndCLS action using the reason code MESH-PEERING-CANCELED, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a CLS_ACPT event occurs, the mesh STA shall perform a sndCLS action using the reason code MESH-CLOSE-RCVD, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When an OPN_RJCT event occurs, the mesh STA shall perform a sndCLS action using the reason code as specified by the OPN_RJCT event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a CNF_RJCT event occurs, the mesh STA shall perform a sndCLS action using the reason code as specified by the CNF_RJCT event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When an OPN_ACPT event occurs, the mesh STA shall respond by performing a sndCNF action. The finite state machine shall stay in the ESTAB state.

All other events shall be ignored in this state.

14.4.11 HOLDING state

In HOLDING state, the mesh STA is closing the mesh peering. The holdingTimer has been set according to the value of dot11MeshHoldingTimeout.

When a CLS_ACPT event occurs, the holdingTimer shall be cleared. The finite state machine shall transition to IDLE state.

When any of the following four events occurs—OPN ACPT, CNF_ACPT, OPN_RJCT, CNF_RJCT—the mesh STA shall send a Mesh Peering Close frame. The finite state machine shall stay in the HOLDING state.

When a TOH event occurs, the finite state machine shall transition to IDLE state.

All other events are ignored in this state.

14.5 Authenticated mesh peering exchange (AMPE)

14.5.1 Overview

The authenticated mesh peering exchange (AMPE) establishes an authenticated mesh peering between the mesh STAs, under the assumption that mesh PMKSA has already been established before the initiation of

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the protocol. An authenticated mesh peering includes a mesh peering, corresponding mesh TKSA, and the two mesh STAs mesh GTKSAs.

The AMPE is also used to establish an authenticated peering between two APs that support the AP PeerKey protocol (as defined in 12.10) under the assumption that a PMK and PMKID have already been established before the initiation of the AMPE exchange.

The AMPE uses mesh peering Management frames. Parameters are exchanged via the RSNE, the Authenticated Mesh Peering Exchange element, and the MIC element.

The major functions provided by AMPE are security capabilities selection, key confirmation, and key management.

— The security capabilities selection function (specified in 14.5.2) is performed by agreeing on the security parameters used for the protocol instance.
— Key confirmation using the shared PMK is performed by verifying that the protection on the mesh peering Management frame is correct.
— Key management (specified in 14.5.7) is performed by the derivation of the temporal key in the mesh TKSA and the exchange of each mesh STA's MGTK.

During the AMPE handshake, the mesh STAs generate nonces and transmit them via mesh peering Management frames. The mesh STA shall generate a random value for its localNonce, as specified in 12.7.5. The candidate peer mesh STA is expected to generate a random value for the peerNonce, which the mesh STA receives from the candidate peer mesh STA in Confirm and Close Action frames.

Mesh peering Management frames used in the AMPE are protected using the deterministic authenticated encryption mode of AES-SIV (IETF RFC 5297).

14.5.2 Security capabilities selection

14.5.2.1 Instance Pairwise Cipher Suite selection

Pairwise cipher suite selectors WEP-40, WEP-104, and TKIP shall not be used as the pairwise cipher suite when dot11MeshSecurityActivated, dot11ProtectedTXOPNegotiationActivated, or dot11ProtectedQLoadReportActivated is true.

If the pairwise cipher suite has not been selected, a STA shall attempt to reach the agreement on the pairwise cipher suite using the following procedure in four steps:

a) The STA shall announce the list of pairwise cipher suites it supports using an ordered list in the RSNE in the Mesh Peering Open frame. The first value in the list is the STA's most preferred cipher suite, and the last value the least preferred.
b) If the STA receives a Mesh Peering Open frame from the candidate peer STA, the STA shall make its decision on the selected pairwise cipher suite based on the intersection of its own ordered list and the received ordered list.
    1) If the intersection is empty, the pairwise cipher suite selection fails and the STA generates the failure reason code MESH-INVALID-SECURITY-CAPABILITY and then takes the corresponding actions specified in 14.5.6.
    2) If the intersection contains more than one value, the selected cipher suite shall be the entry in the intersection list most preferred by the STA that has the largest MAC address in the lexicographic ordering.

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c) If the STA receives a Mesh Peering Confirm frame from the candidate peer STA before receiving a Mesh Peering Open frame, the STA shall verify that it supports the pairwise cipher suite chosen by the candidate peer STA. Otherwise, the selection fails and the STA shall generate the failure reason code MESH-INVALID-SECURITY-CAPABILITY.
Furthermore, upon receiving a Mesh Peering Open frame, the STA shall verify that the accepted selected pairwise cipher suite matches the pairwise cipher suite chosen in step b). If they do not match, the selection fails and the STA shall generate the failure reason code MESH-INVALID-SECURITY-CAPABILITY. Otherwise, the pairwise cipher suite selection succeeds, and the STA shall proceed to step d).

d) If the STA is generating a Mesh Peering Confirm frame, it shall set the Selected Pairwise Cipher Suite to the selected pairwise cipher suite upon successful pairwise cipher suite selection.

14.5.2.2 Group cipher suite selection

Group cipher suite selectors WEP-40, WEP-104, and TKIP shall not be used as the group cipher suite when dot11MeshSecurityActivated is true.

The mesh STA shall not use a different group cipher suite than the one used by the peer mesh STA or candidate peer mesh STA in the same MBSS.

A mesh STA shall announce in a Mesh Peering Open frame the group cipher suite it uses for broadcast protection. When it receives a Mesh Peering Open frame from a candidate peer, it shall verify that it supports the candidate's announced group cipher suite. In addition, if the mesh STA receives a Mesh Peering Confirm frame, it shall verify that it supports the group cipher suite listed in that frame. If either selection fails, the mesh STA shall issue the appropriate reply frame with the MESH-INVALID-SECURITY-CAPABILITY reason code.

14.5.3 Construction and processing AES-SIV-protected mesh peering Management frames

AES-SIV performs deterministic authenticated encryption and takes additional data that is authenticated but not encrypted (AAD). When encrypting and authenticating, AES-SIV takes a key, plaintext data to protect, and multiple distinct components of AAD, to produce a synthetic initialization vector and a cipher text. When verifying encrypted and authenticated data AES-SIV takes a key, a synthetic initialization vector, cipher text data to decrypt and verify, and AAD, to produce either plaintext or the symbol "FAIL," indicating failure to decrypt and verify. Note that the AAD used in the encryption process shall be identical to the AAD used in the decryption process and the synthetic initialization vector produced by the encryption process shall be used in the decryption process.

When the mesh STA constructs a mesh peering Management frame, it shall follow the following procedure:

- The input key shall be the AEK
- The input plaintext shall be the Authenticated Mesh Peering element (see 9.6.15.2, 9.6.15.3, and 9.6.15.4)
- The input AAD shall be three distinct components consisting of
  - The localMAC
  - The peerMAC
  - The contents of the mesh peering Management frame from the category (inclusive) to the MIC element (exclusive)
- The output synthetic initialization vector shall be copied into the MIC field of the MIC element in the mesh peering Management frame
- The output cipher text shall become the remainder of the mesh peering Management frame after the MIC element

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When the mesh STA verifies a mesh peering Management frame, it shall follow the following procedure:

- The input key shall be the AEK
- The input synthetic initialization vector shall be the MIC field of the MIC element in the mesh peering Management frame
- The input cipher text shall be the part of the mesh peering Management frame following the MIC element
- The input AAD shall be three distinct components consisting of
  - The peerMAC
  - The localMAC
  - The contents of the mesh peering Management frame from the category (inclusive) to the MIC element (exclusive)
- If AES-SIV returns the symbol "FAIL" processing of the frame shall be deemed a failure with a behavior dependent on the type of mesh peering Management frame
- If AES-SIV returns plaintext it shall be treated as the components of the mesh peering Management frame and processed accordingly

14.5.4 Distribution of group transient keys in an MBSS

The MGTK shall be a random or pseudorandom number. The mesh STA shall distribute the MGTK to the peer mesh STA using the Mesh Peering Open frame during the AMPE. Upon successful completion of AMPE, each mesh STA shall establish states for the peer mesh STA's mesh GTKSA. The GTKdata subfield in the Authenticated Mesh Peering Exchange element shall contain the MGTK concatenated with the Key RSC and the GTKExpirationTime (as specified in 9.4.2.117).

When dot11RSNAProtectedManagementFramesActivated is true, a mesh STA shall distribute the IGTK to the peer mesh STA using the Mesh Peering Open frame during the AMPE. Upon successful completion of AMPE, each mesh STA shall establish an IGTKSA (see 12.6.1.1.9) with the mesh peer. The IGTKdata subfield in the Authentication Mesh Peering Exchange element shall contain the Key ID concatenated with the IPN and the IGTK (as specified in 9.4.2.117).

14.5.5 Mesh peering Management frames for AMPE

14.5.5.1 General

The AMPE is inclusive of the mesh peering management (MPM) protocol. mesh peering Management frames for AMPE have additional processing and construction requirements on top of those for mesh peering Management frames.

The mesh peering Management frames shall be generated with additional information using the RSNE and the Authenticated Mesh Peering Exchange element to support AMPE.

14.5.5.2 Mesh peering open for AMPE

14.5.5.2.1 Generating Mesh Peering Open frames for AMPE

In addition to contents for establishing a mesh peering as specified in 14.3.6.1, the Mesh Peering Open frame, if used for the AMPE, shall contain the following:

- In the Mesh Peering Management element, the Mesh Peering Protocol Identifier shall be set to 1 "authenticated mesh peering exchange protocol."
- In the Mesh Peering Management element, the Chosen PMK field shall be set to PMKID that identifies the mesh PMKSA the mesh STA established with the candidate peer mesh STA.

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— The RSNE shall be identical to the RSNE in the STA's Beacon and Probe Response frames.
— In the Authenticated Mesh Peering Exchange element:
  — The Selected Pairwise Cipher Suite field shall be set to the first cipher suite selector in the Pairwise Cipher Suite List field in RSNE.
  — The Local Nonce field shall be set to the localNonce value generated by the mesh STA for identifying the current mesh peering instance.
  — The Peer Nonce field shall be set to 0.
  — If dot11MeshSecurityActivated is true, the GTKdata field shall be present and shall contain the data for the mesh STA's MGTK. The GTKdata field shall not be present when AMPE is being used as part of the AP PeerKey protocol (12.10.2). The components of the GTKdata field are specified in 14.5.4.

The Mesh Peering Open frame shall be protected using AES-SIV as specified in 14.5.3.

14.5.5.2.2 Processing Mesh Peering Open frames for AMPE

On receiving a Mesh Peering Open frame, the mesh STA shall verify the received frame. If AES-SIV returns the symbol "FAIL" the OPN_RJCT event shall be invoked to the corresponding AMPE finite state machine and the reason code "MESH-INVALID-GTK" is generated. Otherwise, processing continues.

The received frame shall be rejected if the security capability selection fails (see 14.5.2). The OPN_RJCT event shall be invoked to the corresponding AMPE finite state machine.

If dot11RSNAOperatingChannelValidationActivated is true and the received RSNE indicates OCVC capability, the mesh STA shall validate the OCI element in the Mesh Peering Open frame by ensuring that all of the following are true:

— OCI element is present
— Channel information in the OCI matches current operating channel parameters (see 12.2.9)

Otherwise, the mesh STA shall discard the frame.

The peer mesh STA's MGTK extracted from the Mesh Peering Open frame shall be added to the Receive MGTK SA in which the peer's MAC address equals the MGTK Source mesh STA MAC address.

If all operations succeed, the mesh STA shall proceed to process the Mesh Peering Open frame on basic parameters as specified in 14.3.6.2.

14.5.5.3 Mesh peering confirm for AMPE

14.5.5.3.1 Generating Mesh Peering Confirm frames for AMPE

In addition to contents for establishing a mesh peering as specified in 14.3.7.1, the Mesh Peering Confirm frame, when used with the AMPE, shall contain the following:

— In the Mesh Peering Management element, the Mesh Peering Protocol Identifier shall be set to 1 "authenticated mesh peering exchange protocol."
— The RSNE shall be the same as sent in the Mesh Peering Open frame.
— In the Authenticated Mesh Peering Exchange element:
  — The Selected Pairwise Cipher Suite field shall be set to the cipher suite selector that indicates the successfully selected pairwise cipher suite (specified in 14.5.2.1).
  — The Peer Nonce field shall be set to the nonce value chosen by the peer mesh STA as received in the Local Nonce field in the Mesh Peering Open frame from the candidate peer mesh STA.

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— The GTKdata field shall not be present.
— The IGTKdata field shall not be present.
— The rest of fields are set to the same values sent in the Mesh Peering Open frame.

The Mesh Peering Confirm frame shall be protected using AES-SIV as specified in 14.5.3.

14.5.5.3.2 Processing Mesh Peering Confirm frames for AMPE

On receiving a Mesh Peering Confirm frame, the mesh STA shall verify the received frame. The received frame shall be discarded if AES-SIV returns the symbol "FAIL."

If AES-SIV returns plaintext, the following operations shall be performed in order:

a) The Selected Pairwise Cipher Suite is checked. If the security capability selection has been done and the received value from Chosen Pairwise Cipher Suite field is not the same as the agreed pairwise cipher suite, the STA shall reject the received frame and the CNF_RJCT event is invoked to the corresponding AMPE finite state machine with the failure reason code MESH-INVALID-SECURITY-CAPABILITY.
b) If dot11MeshSecurityActivated is true the group cipher suite is checked. If the received group cipher suite is not supported by the mesh STA, the mesh STA shall reject the received Mesh Peering Confirm frame and the CNF_RJCT event is invoked to the corresponding AMPE finite state machine with the failure reason code MESH-INVALID-SECURITY-CAPABILITY.
c) If dot11RSNAOperatingChannelValidationActivated is true and the received RSNE indicates OCVC capability, the mesh STA shall validate the OCI element in the Mesh Peering Confirm frame by ensuring that all of the following are true:
   — OCI element is present
   — Channel information in the OCI matches current operating channel parameters (see 12.2.9)

   Otherwise, the mesh STA shall discard the frame.

If none of the cases is true, the mesh STA shall proceed to process the Mesh Peering Confirm Action frame on basic parameters as specified in 14.3.7.2.

14.5.5.4 Mesh peering close for AMPE

14.5.5.4.1 Generating Mesh Peering Close frames for AMPE

In addition to contents for closing a mesh peering as specified in 14.3.8.1, the Mesh Peering Close frame, when used for the AMPE, shall contain the following:

— In the Mesh Peering Management element, the Mesh Peering Protocol Identifier shall be set to 1 "authenticated mesh peering exchange protocol."
— In the Mesh Peering Management element, the Chosen PMK field shall be set to the same value as sent in the Mesh Peering Open frame.
— In the Authenticated Mesh Peering Exchange element:
   — The Selected Pairwise Cipher Suite field shall be set to the same value as sent in the Mesh Peering Open frame.

     NOTE—If the reason for sending the Mesh Peering Close is the pairwise cipher suite selection failure, the information in this field is used to inform the candidate peer mesh STA what was announced by the mesh STA for the mesh peering instance.

   — The Local Nonce field shall be set to the same value as sent in the Mesh Peering Open frame.

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— The Peer Nonce field shall be set to the same value as received in the Local Nonce field of the Authenticated Mesh Peering Exchange element of the incoming mesh peering Management frame from the candidate peer mesh STA.

The Mesh Peering Close frame shall be protected using AES-SIV as specified in 14.5.3.

14.5.5.4.2 Processing Mesh Peering Close frames for AMPE

On receiving a Mesh Peering Close frame, the mesh STA shall verify the received frame. The received frame shall be discarded if AES-SIV returns the symbol "FAIL."

If AES-SIV returns plaintext, the mesh STA shall proceed to process the Mesh Peering Close frame on basic parameters as specified in 14.3.8.2.

14.5.6 AMPE finite state machine

14.5.6.1 Overview

The finite state machine for AMPE supports all of the states, events, and actions defined for the finite state machine for the MPM protocol. In addition, new events, actions, and state transitions are added to specify the security functions for AMPE.

When a finite state machine is generated and activated for an AMPE instance, the localNonce shall be generated and used together with a new localLinkID to identify the instance.

14.5.6.2 Additional events and actions to MPM FSM

All events for rejecting or ignoring received Action frames shall report the corresponding reason code related to AMPE functions as described in 14.5.5.

In addition, there is one new event as follows:

— TOR3—This event indicates that the retryTimer has expired, the dot11MeshMaxRetries has been reached, the AMPE is enabled, but the mesh STA failed to confirm the selection of the shared mesh PMKSA. When this event triggers, the protocol instance shall be closed, but no Mesh Peering Close frame shall be sent.

The actions of sending mesh peering Management frames are updated as the following:

— sndOPN—Generate a Mesh Peering Open frame for the current AMPE protocol instance (as specified in 14.5.5.2.1) and send it to the candidate peer mesh STA.

— sndCNF—Generate a Mesh Peering Confirm frame for the current AMPE protocol instance (as specified in 14.5.5.3.1) and send it to the candidate peer mesh STA.

— sndClose—Generate a Mesh Peering Close frame for the current AMPE protocol instance (as specified in 14.5.5.4.1) and send it to the candidate peer mesh STA.

14.5.6.3 State transitions

All state transitions specified in MPM FSM shall be used for AMPE finite state machine.

In OPN_SNT state, the following are additional state transitions and actions:

When TOR3 event occurs, the retryTimer shall be cleared and the holdingTimer shall be set. The finite state machine shall transition to HOLDING state.

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In OPN_RCVD state, the following are the additional actions:

When CNF_ACPT event occurs, in addition to the actions for MPM protocol, the mesh STA shall signal the completion of key management by utilizing the MLME-SETKEYS.request primitive to configure the agreed-upon mesh temporal pairwise key into the IEEE 802.11 MAC and by calling the MLME-SETPROTECTION.request primitive to enable its use.

In CNF_RCVD state, the following are the additional actions:

When OPN_ACPT event occurs, in addition to the actions for MPM protocol, the mesh STA shall signal the completion of key management by utilizing the MLME-SETKEYS.request primitive to configure the agreed-upon mesh temporal pairwise key into the IEEE 802.11 MAC and received MGTK and by calling the MLME-SETPROTECTION.request primitive to enable the usage.

Table 14-3 and Figure 14-3 specify the state transitions of the finite state machine for AMPE.

Table 14-3—AMPE finite state machine

From State	To State					
	IDLE	**OPN_SNT**	**CNF_RCVD**	**OPN_RCVD**	**ESTAB**	**HOLDING**
IDLE	REQ_RJCT / sndCLS	ACTOPN / (sndOPN, setR)		OPN_ACPT / (sndOPN, sndCNF, setR)		
OPN_SNT		TOR1 / (sndOPN, setR)	CNF_ACPT / (clR, setC)	OPN_ACPT / (sndCNF)		CLS_ACPT, OPN_RJCT, CNF_RJCT, TOR2, CNCL / (sndCLS, clR, setH) TOR3 / (clR, setH)
CNF_RCVD					OPN_ACPT / (clC, sndCNF)	CLS_ACPT, OPN_RJCT, CNF_RJCT, CNCL / (sndCLS, clC, setH) TOC / (sndCLS, setH)
OPN_RCVD				TOR1 / (sndOPN, setR) OPN_ACPT / sndCNF	CNF_ACPT / clR	CLS_ACPT, OPN_RJCT, CNF_RJCT,TOR2, CNCL / (sndCLS, clR, setH)
ESTAB					OPN_ACPT / sndCNF	CLS_ACPT, OPN_RJCT, CNF_RJCT, CNCL / (sndCLS, setH)
HOLDING	TOH / —, CLS_ACPT / clH					OPN_ACPT, CNF_ACPT, OPN_RJCT, CNF_RJCT / sndCLS

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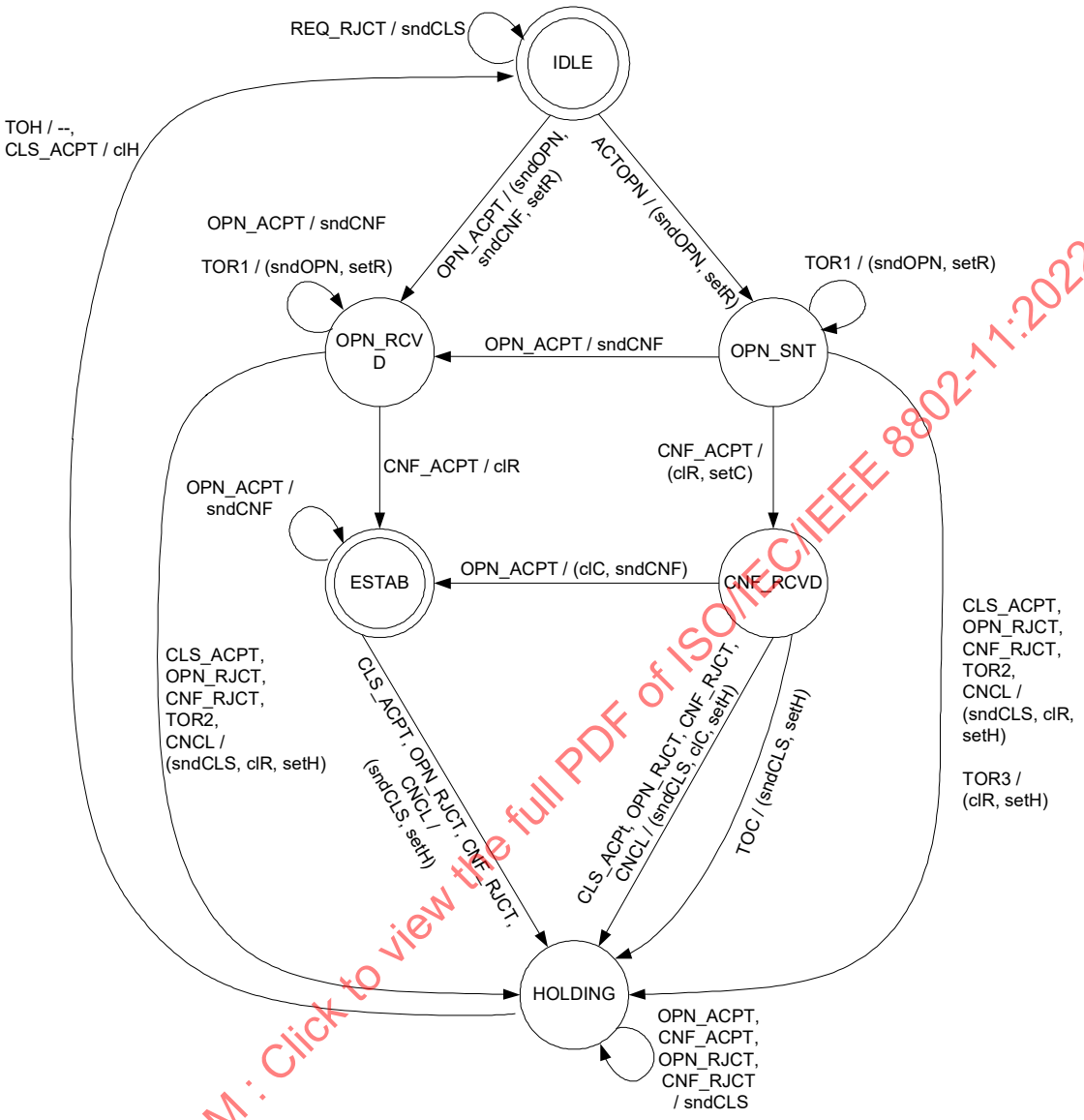

Figure 14-3—Finite state machine of the AMPE protocol

14.5.7 Keys and key derivation algorithm for the authenticated mesh peering exchange (AMPE)

To execute the AMPE and mesh group key handshake with a candidate peer STA, the local STA shall derive an authenticated encryption key (AEK) and a mesh temporal key (MTK) using the PMK it shares with the candidate peer STA.

The AEK is derived statically from the shared PMK. The MTK is derived from the shared PMK and dynamic information provided by the STA and candidate peer STA.

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The AEK is mutually derived by the local STA and the peer STA once a new PMK has been selected. The AEK shall be derived from the PMK by

AEK ← KDF-Hash-256(PMK, "AEK Derivation", Selected AKM Suite ||
min(localMAC, peerMAC) || max(localMAC, peerMAC))

where

KDF-Hash-256	is the key derivation function defined in 12.7.1.6.2 using the hash algorithm identified by the AKM suite selector (see Table 9-151)
Selected AKM Suite	is a 4-octet string formed by concatenating the OUI or CID and suite type

The temporal key (MTK) shall be derived from the PMK by

MTK ← KDF-Hash-Length(PMK, "Temporal Key Derivation", min(localNonce, peerNonce) ||
max(localNonce, peerNonce) || min(localLinkID, peerLinkID) || max(localLinkID, peerLinkID)
|| Selected AKM Suite || min(localMAC, peerMAC) || max(localMAC, peerMAC))

where

KDF-Hash-Length	is the key derivation function defined in 12.7.1.6.2 using the hash algorithm identified by the AKM suite selector (see Table 9-151)
Length	is cipher-suite dependent and defined by the TK bits value in Table 12-7
Selected AKM Suite	is a 4-octet string formed by concatenating the OUI or CID and suite type
"min" and "max" operations for IEEE 802 addresses	are with the address converted to a positive integer, treating the first transmitted octet as the most significant octet of the integer as specified in 12.7.1.3
"min" and "max" operations for nonces	are encoded as specified in 9.2.2
"min" and "max" operations for LinkIDs	select the minimum and maximum, respectively, of the two unsigned integers (In the KDF context, LinkIDs are encoded as 16-bit unsigned integers, represented using the bit ordering conventions of 9.2.2.)

The MTK is used to protect communications between two peer STAs. The local STA and peer STA derive an MTK per peering instance and may rekey the MTK using AMPE.

14.6 Mesh group key handshake

14.6.1 General

The mesh group key handshake may be used by either mesh STA, after a secure mesh peering has been established, to update the MGTK that it uses to protect group addressed MPDUs that it transmits to its peer mesh STAs.

The mesh STA may update its MGTK when a mesh peering is terminated.

To update the MGTK, the mesh STA shall execute the mesh group key handshake with each of its current peer mesh STAs. The "MGTK source" is the mesh STA that is sending the MGTK to a peer mesh STA using this protocol. A "MGTK recipient" is a mesh STA receiving the MGTK being sent by the MGTK Source.

The mesh group key handshake shall include the following two messages:

— Message 1: Mesh Group Key Inform frame
— Message 2: Mesh Group Key Acknowledge frame

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Mesh Group Key Inform frame and Mesh Group Key Acknowledge frame are conventionally referred to as *mesh group key handshake frames*.

The mesh STA shall do an AMPE handshake before a mesh group key handshake if both are required to be done.

NOTE—It is impossible that the MGTK source initiates the mesh group key handshake before the AMPE completes successfully.

14.6.2 Protection on mesh group key handshake frames

Mesh group key handshake frames used in mesh group key handshake are protected using the deterministic authenticated encryption mode of AES-SIV (IETF-RFC 5297) when dot11MeshSecurityActivated is true.

When constructing protection on mesh group handshake frames, the following procedure shall be used:

- The key shall be the AEK from the current active security association with the peer mesh STA that receives the mesh group key handshake frame.
- The input plaintext shall be the AMPE Authenticated Mesh Peering element (see 9.6.15.5 and 9.6.15.6).
- The plaintext shall be the Authenticated Mesh Peering Exchange element.
- AAD shall be three distinct components as follows:
  - The localMAC
  - The peerMAC
  - The contents of the mesh group key handshake frame from the category (inclusive) to the MIC element (exclusive)
- The synthetic initialization vector produced by AES-SIV shall be copied into the MIC field of the MIC element in the frame.
- The produced cipher text shall become the remainder of the mesh group key handshake frame after the MIC element.

When verifying the protection on the mesh group handshake frames, the following procedure shall be used:

- The key shall be the AEK from the current active security association with the peer mesh STA that receives the mesh group key handshake frame.
- AAD shall be three distinct components as follows:
  - The peerMAC
  - The localMAC
  - The contents of the mesh group key handshake frame from the category (inclusive) to the MIC element (exclusive)
- The synthetic initialization vector shall be the MIC field of the MIC element in the frame.
- The cipher text shall be the content after the MIC element in the frame.
- If AES-SIV validation function takes above input.
  - If the function returns the special symbol “FAIL,” the frame shall be discarded.
  - If the plaintext is returned successfully, the produced plaintext shall be treated as the contents after the MIC element in the frame.

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14.6.3 Mesh Group Key Inform frame construction and processing

Mesh Group Key Inform frame shall be constructed as follows:

- The Authenticated Mesh Peering Exchange element shall be set as the following:
  - The Selected Pairwise Cipher Suite field shall be set to 4 octets of zero.
  - The Local Nonce field shall be set to the same value as sent in the Mesh Peering Open frame that established the mesh peering instance.
  - The Peer Nonce field shall be set to the same value as received in the Local Nonce field of the Authenticated Mesh Peering Exchange element of the incoming Mesh Peering Open frame that established the peering instance.
  - The Key Replay Counter field shall be set to the mesh STA's local replay counter value, incremented by 1, for the mesh peering. After setting this field, the local replay counter shall also be incremented by 1.
  - The GTKdata field shall be present and shall contain the data for the MGTK from MGTK source. The components of the GTKdata are specified in 14.5.4.
  - If management frame protection is used, the IGTKdata field shall be present and shall contain the data for the IGTK from IGTK source. The components of the IGTKdata are specified in 14.5.4.
- The MIC element shall be set according to the protection mechanism in 14.6.2.

The construction of AES-SIV protection on Mesh Group Key Inform frame shall use the construction procedure as in 14.6.2.

The MGTK source sends the Mesh Group Key Inform frame to the MGTK recipient.

On reception of Mesh Group Key Inform frame, the MGTK recipient shall use the verification procedure in 14.6.2 to validate the AES-SIV construction.

- If the validation recovers the plaintext successfully, the MGTK recipient shall proceed with the following procedure:
  - Verify that values in the Local Nonce field and the Peer Nonce field in the Authenticated Mesh Peering Exchange element are the same as in the current valid mesh TKSA that the MGTK recipient established with the sender of the Mesh Group Key Inform frame. If there is any mismatch, the received Mesh Group Key Inform frame shall be discarded and no further action shall be taken.
  - Verify that the Key Replay Counter has not yet been seen before, i.e., its value is strictly larger than that in any other mesh Group Key Inform frame received thus far during this security association. If this verification fails, the received Mesh Group Key Inform frame shall be discarded and no further action shall be taken.
  - Use the MLME-SETKEYS.request primitive to configure the temporal MGTK into the MAC.
  - Respond by constructing and sending mesh group key handshake acknowledge to the MGTK source and incrementing the replay counter.

  NOTE—The MGTK source increments and uses a new Key Replay Counter field value on every Mesh Group Key Inform frame, even retries, because the Mesh Group Key Acknowledge frame responding to an earlier Mesh Group Key Inform frame might have been lost. If the MGTK source did not increment the replay counter, the MGTK receiver discards the retry, and no responding Mesh Group Key Acknowledge frame will ever arrive.
- If the AES-SIV validation returns a special symbol "FAIL," the Mesh Group Key Inform frame shall be discarded. No further action shall be taken.

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14.6.4 Mesh Group Key Acknowledge frame construction and processing

Mesh Group Key Acknowledge frame shall be constructed as follows:

- The Authenticated Mesh Peering Exchange element shall be set as follows:
  - The Selected Pairwise Cipher Suite field shall be set to 4 octets of zero.
  - The Local Nonce field shall be set to the same value as sent in the Mesh Peering Open frame that established the mesh peering instance.
  - The Peer Nonce field shall be set to the same value as received in the Local Nonce field of the Authenticated Mesh Peering Exchange element of the incoming Mesh Peering Open frame that established the peering instance.
  - The Key Replay Counter shall be set to the same value as received in the Mesh Group Key Inform frame.
  - The GTKdata field shall not be present.
  - The IGTKdata field shall not be present.
- The MIC element shall be set according to the protection mechanism in 14.6.2.

The construction of AES-SIV protection on Mesh Group Key Acknowledge frame shall use the construction procedure as in 14.6.2.

The MGTK recipient sends the Mesh Group Key Acknowledge frame to the MGTK source.

On reception of Mesh Group Key Acknowledge frame, the MGTK source shall use the verification procedure in 14.6.2 to validate the AES-SIV construction.

- If the validation recovers the plaintext successfully, the MGTK source shall set the content of the Authenticated Mesh Peering Exchange element using the recovered plaintext and proceed with the following procedure:
  - Verify that values in the Local Nonce field and the Peer Nonce field in the Authenticated Mesh Peering Exchange element are the same as in the current valid mesh TKSA that the MGTK source established with the sender of the Mesh Group Key Acknowledge frame. If there is any mismatch, the received Mesh Group Key Acknowledge frame shall be discarded and no further action shall be taken.
  - Verify that the Key Replay Counter value matches the one that it has used for the mesh group key handshake. If this verification fails, the received Mesh Group Key Acknowledge frame shall be discarded and the MGTK source may invoke a retry to send a new Mesh Group Key Inform frame with a new Key Replay Counter value.
- If the validation returns a special symbol “FAIL,” the Mesh Group Key Acknowledge frame shall be discarded and the MGTK source may invoke a retry to send a new Mesh Group Key Inform frame with a new Key Replay Counter value.

14.6.5 Mesh group key implementation considerations

If the MGTK source does not receive a Mesh Group Key Acknowledge frame to its Mesh Group Key Inform frames, it shall attempt dot11MeshConfigGroupUpdateCount additional transmissions of the Mesh Group Key Inform frame. The retransmit timeout value shall be 100 ms for the first timeout, half the listen interval for the second timeout, and the listen interval for subsequent timeouts. If there is no listen interval or the listen interval is zero, then 100 ms shall be used for all timeout values. If it still has not received a response after this, then the MGTK source shall tear down the mesh peering and mesh TKSA with this MGTK recipient, by generating a CNCL event for the peering instance, and pass the event to the mesh peering instance controller.

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14.7 Mesh security

During the AMPE, the peers negotiate, and agree upon, a pairwise ciphersuite and a group cipher suite. They also establish a mesh TKSA and mesh GTKSA to be used with the pairwise cipher suite and group cipher suite, respectively.

When dot11MeshSecurityActivated is true, all individually addressed mesh Data frames and individually addressed robust Management frames (see 12.2.7) shall be protected by the mesh TKSA, and all group addressed Data frames and group addressed Action frames that are indicated as "Group Addressed Privacy" in Table 9-51 shall be protected by the mesh GTKSA.

When dot11RSNAProtectedManagementFramesActivated is true, group addressed robust Management frames that are not protected by the mesh GTKSA shall be protected using BIP (see 11.12).

14.8 Mesh path selection and metric framework

14.8.1 General

The term *mesh path selection* is used to describe selection of multi-hop paths between mesh STAs at the link layer. Mesh path selection creates forwarding information that is utilized for MSDU/MMPDU forwarding as described in 10.38.

14.8.2 Extensible path selection framework

This standard allows for alternative and flexible implementations of path selection protocols and metrics.

A mesh STA may include multiple protocol implementations (that is, the default protocol, vendor-specific protocols, etc.) as well as multiple metric implementations, but only one path selection protocol and only one path selection metric shall be used by a mesh STA at a time.

As described in 14.2.3 and 14.2.7, mesh STAs use the Mesh Configuration element (9.4.2.97) to announce the active path selection protocol and active path selection metric of the MBSS. This allows a neighbor mesh STA to identify if it should become a member of the MBSS and how it should establish mesh peerings with its members. This standard does not force an existing MBSS that is using a protocol other than the default protocol to switch to the default protocol when a new mesh STA requests mesh peering establishment. While it is possible, in principle, to implement such behavior, an algorithm to coordinate such reconfiguration is beyond the scope of this standard.

Path selection protocol and path selection metric are identified by a unique identifier as defined in 9.4.2.97.2 and 9.4.2.97.3, respectively. Also, each path selection protocol and each path selection metric specifies the following:

— Data type of metric values
— Length of the metric field
— Operator for aggregation of link metrics to a path metric; the symbol ⊕ is used to identify an arbitrary operator for aggregation
— Comparison operator for determining a better or worse path; how this is performed depends on the actual comparison operator
— Initial value of the path metric (path selection metric only)

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The standard defines HWMP as a default path selection protocol (see 14.10). The standard defines the airtime link metric as a default path selection metric and the high PHY rate airtime link metric as a path selection metric for mesh STAs capable of transmitting frames with a PHY rate higher than 54 Mb/s (see 14.9.2). The default path selection protocol and default path selection metric shall be implemented on all mesh STAs.

14.8.3 Link metric reporting

A mesh STA may submit a link metric report to or request a link metric report from its neighbor peer mesh STA by transmitting a Mesh Link Metric Report frame. A mesh STA receiving a Mesh Link Metric Report element with the Request subfield of the Flags field equal to 1 shall reply with a Mesh Link Metric Report frame containing the link metric value for the corresponding link.

Upon reception of a Mesh Link Metric Report frame, the mesh STA may update its local link metric information using the link metric information received. The procedure to update the local link metric information with the link metric information received from a neighbor peer mesh STA is outside the scope of the standard.

14.9 Path selection link metric

14.9.1 General

A path selection link metric is used by the path selection protocol in the assessment of the link quality to identify an efficient radio-aware path. Subclause 14.9.2 defines two link metrics: a) a default link metric, the airtime link metric; and b) the high PHY rate airtime link metric. A STA should use the high PHY rate airtime link metric when its PHY entity is capable of transmitting frames with PHY rate higher than 54 Mb/s.

The extensibility framework allows the default link metric to be overridden by another path selection metric as specified in the mesh profile.

14.9.2 Airtime link metric and high PHY rate airtime link metric

The airtime link metric is used when dot11MeshActivePathSelectionMetric is airtimeLinkMetric (1); the high PHY rate airtime link metric is used when dot11MeshActivePathSelectionMetric is highPHYRateAirtimeLinkMetric (2) (see 14.2.3).

Airtime reflects the amount of channel resources consumed by transmitting the frame over a particular link. This measure is approximate and designed for ease of implementation and interoperability.

The airtime for each link is calculated as follows:

$$c_a = \left[\frac{O}{n} + \frac{B_t}{r}\right]\frac{1}{1 - e_f}$$

where

O, n, and B_t	are constants listed in Table 14-4
input parameter r	is the estimated PHY data rate (in Mb/s) at which the mesh STA would transmit a nominal frame containing a frame body of size B_t based on current link conditions; its estimation is dependent on local implementation of rate adaptation

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input parameter e_f is the estimated frame error rate. It is the probability that when a nominal frame containing a frame body of size B_t is transmitted at the PHY data rate r, the frame is corrupted; its estimation is a local implementation choice. Failures due to exceeding Mesh TTL should not be included in this estimate as they are not correlated with link performance

Table 14-4—Airtime cost constants for airtime link metric and high PHY rate airtime link metric

Parameter	Recommended value	Description
O	Varies depending on PHY	Channel access overhead (in μs), which includes frame headers, training sequences, access protocol frames, etc.
n	Varies depending on implementation	1 for the airtime link metric, i.e., when dot11MeshActivePathSelectionMetric is airtimeLinkMetric (1). Otherwise, number of MSDUs aggregated in a single Data frame. It represents the number of MSDUs that the mesh STA would transmit in a typical Data frame; its estimation is dependent on local implementation of the A-MSDU and A-MPDU construction.
B_t	8192	Number of bits in the frame body of a nominal frame

The airtime link metric shall be encoded as an unsigned integer in units of 0.01 TU. An example of the airtime link metric is shown in S.5.

The high PHY rate airtime link metric shall be encoded as an unsigned integer in units of 0.01 μs.

Table 14-5 gives the parameters of the airtime link metric for the extensible path selection framework.

Table 14-5—Parameters of the airtime link metric and high PHY rate airtime link metric for extensible path selection framework

Parameter	Notes
Path Selection Metric ID	See Table 9-240 in 9.4.2.97.3
Data type	Unsigned integer, 0 ≤ metric value < 4 294 967 296
Length of metric field	4 octets
Operator for metric aggregation	addition (+)
Comparison operator	*less than, equal to, greater than* as used with integers — metric *a* is *better than* metric *b* if $a < b$ — metric *a* is *equal to* metric *b* if $a = b$ — metric *a* is *worse than* metric *b* if $a > b$
Initial value of path metric	0

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14.10 Hybrid wireless mesh protocol (HWMP)

14.10.1 General

The hybrid wireless mesh protocol (HWMP) is a mesh path selection protocol that combines the flexibility of on-demand path selection with proactive topology tree extensions. The combination of reactive and proactive elements of HWMP enables efficient path selection in a wide variety of mesh networks (with or without access to the infrastructure).

HWMP uses a common set of protocol elements, generation and processing rules inspired by Ad Hoc On-Demand Distance Vector (AODV) protocol (IETF RFC 3561 [B38]) adapted for MAC address-based path selection and link metric awareness. HWMP is completely specified herein and does not require reference to AODV specifications or descriptions.

HWMP supports two modes of operation depending on the configuration. These modes provide different levels of functionality as follows:

— On-demand mode: The functionality of this mode is always available, independent of whether a root mesh STA is configured in the MBSS or not. It allows mesh STAs to communicate using peer-to-peer paths.
— Proactive tree building mode: In this mode, additional proactive tree building functionality is added to the on-demand mode. This can be performed by configuring a mesh STA as root mesh STA using either the proactive PREQ mechanism or proactive RANN mechanism. The proactive PREQ mechanism creates paths from the mesh STAs to the root, using only group addressed communication. The RANN mechanism creates paths between the root and each mesh STA using acknowledged communication.

These modes are not exclusive. On-demand and proactive modes are used concurrently, because the proactive modes are extensions of the on-demand mode.

NOTE—One example of concurrent usage of on-demand and proactive mode is for two mesh STAs that are part of the same mesh BSS (or STAs that are proxied by mesh STAs in the same MBSS) to begin communicating using the proactively built tree but subsequently to perform an on-demand discovery for a direct path. This type of concurrent usage of the proactive and on-demand modes allows communication to begin immediately (by forwarding all traffic to the root, which knows all mesh STAs and addresses proxied by mesh STAs in the MBSS) while an on-demand discovery finds a shorter path between two mesh STAs (or STAs that are proxied by mesh STAs in the same MBSS).

All HWMP modes of operation utilize common processing rules and primitives. HWMP elements are the PREQ (path request) element, PREP (path reply) element, PERR (path error) element, and RANN (root announcement) element. The metric cost of the links determines which paths HWMP builds. In order to propagate the metric information between mesh STAs, a Metric field is used in the PREQ, PREP, and RANN elements.

Path selection in HWMP uses a sequence number mechanism to enable mesh STAs to distinguish current path information from stale path information at all times in order to maintain loop-free connectivity. Each mesh STA maintains its own HWMP SN, which is propagated to other mesh STAs in the HWMP elements. Rules for maintaining HWMP SNs are given in 14.10.8.3.

14.10.2 Terminology

This subclause describes terminology for HWMP, especially for the process of path discovery. Terms such as path originator or path target designate very specific entities within the path discovery process. They stay with the same assigned entity for the whole path discovery process and other procedures related to this path discovery. Figure 14-4 illustrates an example utilizing this terminology.

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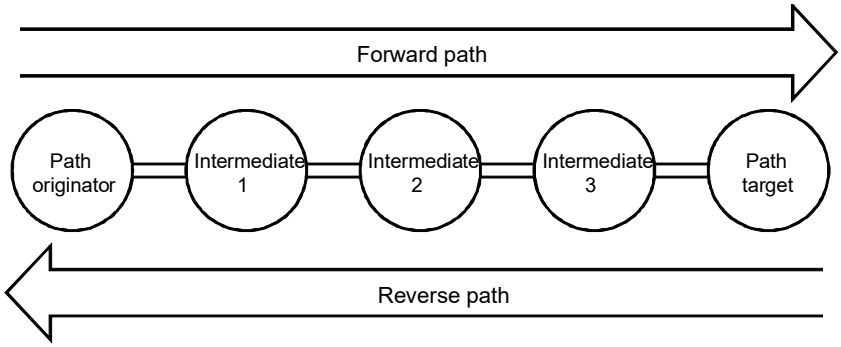

Figure 14-4—Illustration of definitions

NOTE 1—Both the path target and path originator are a path destination for the forward path and the reverse path respectively.

The following terms are used within the context of a single PREQ element / PREP element pair, a so-called HWMP path discovery:

- **path originator:** The path originator is the mesh STA that triggers the path discovery.
- **path originator address:** The MAC address of the path originator.
- **path target:** The path target is the entity to which the path originator attempts to establish a path.

  NOTE 2—When an originator mesh STA initially attempts to establish a path to a target, it does not know whether the target is a mesh STA in the mesh BSS or not. Only when the originator receives a PREP element does it learn if the target is a mesh STA in the mesh BSS or not. If the target is in the mesh BSS, it is referred to as a *target mesh STA*. If the target is outside the mesh BSS, the term target proxy mesh gate refers to the mesh gate proxying for the target.
- **path target address:** The MAC address of the path target.
- **intermediate mesh STA:** The intermediate mesh STA is the mesh STA that participates in path selection and is neither path originator nor path target.
- **intermediate mesh STA address:** The MAC address of the intermediate mesh STA.
- **forward path:** The forward path is the mesh path to the path target, set up at the path originator and intermediate mesh STAs.
- **reverse path:** The reverse path is the mesh path to the path originator, set up at the path target and intermediate mesh STAs.
- **HWMP sequence number (HWMP SN):** Each mesh HWMP path selection element contains an HWMP SN that allows recipients to distinguish newer from stale information. An HWMP SN is specific to a mesh STA. See also 14.10.8.3.
- **forwarding information:** The forwarding information maintained by an originator mesh STA, an intermediate mesh STA, or a target mesh STA that allows the mesh STA to perform its path selection and forwarding functions.

  The terminology used when discussing forwarding information is relative to the mesh STA (reference mesh STA, given mesh STA or local mesh STA) and a particular mesh destination of the path. The following terms are specific to a given instance of the forwarding information:

  - **destination mesh STA:** The end station (mesh STA) of a (forward or reverse) path.
  - **destination mesh STA address:** The MAC address of the destination mesh STA.
  - **destination HWMP SN:** The HWMP SN of the destination mesh STA.
  - **next-hop mesh STA:** The next-hop mesh STA is the next peer mesh STA on the mesh path to the destination mesh STA.
  - **next-hop mesh STA address:** The MAC address of the next-hop mesh STA.

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  - **precursor mesh STA:** A precursor mesh STA is a neighbor peer mesh STA on the mesh path that identifies a given mesh STA as the next-hop mesh STA to the destination mesh STA.
  - **precursor mesh STA address:** The MAC address of the precursor mesh STA.
  - **lifetime:** The time during which forwarding information remains active (see 14.10.8.4)
- **unreachable destination:** A destination mesh STA is considered unreachable by a source mesh STA or an intermediate mesh STA if the link to the next hop of the mesh path to this destination mesh STA, as derived from its forwarding information, is no longer usable.
- **element time to live (Element TTL)**: An integer number that is used to limit the number of hops an HWMP element may be processed and propagated. Note that this Element TTL is different from the Mesh TTL in the Mesh Control field (see 9.2.4.7.3).
- **root mesh STA:** A root mesh STA is configured to originate proactive PREQ elements or RANN elements. It is the root of a path selection tree.

Table 14-6 and Table 14-7 show the roles of the various mesh STAs in the forward path and reverse path generated as a result of the full PREQ element and PREP element processing as shown in Figure 14-4. Each row in the table contains the roles of a forward/reverse path from the reference mesh STA's perspective.

Table 14-6—Precursor and next hop examples (forward path)

Forward path (to Path Target)			
Reference mesh STA	**Precursor mesh STA**	**Next-hop mesh STA**	**Destination mesh STA**
Path originator	N/A	Intermediate 1	Path target
Intermediate 2	Intermediate 1	Intermediate 3	Path target
Path Target	Intermediate 3	N/A	Path Target

Table 14-7—Precursor and next hop examples (reverse path)

Reverse path (to path originator)			
Reference mesh STA	**Precursor mesh STA**	**Next-hop mesh STA**	**Destination mesh STA**
Path originator	Intermediate 1	N/A	Path originator
Intermediate 2	Intermediate 3	Intermediate 1	Path originator
Path target	N/A	Intermediate 3	Path originator

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14.10.3 On-demand path selection mode

If a source mesh STA needs to find a path to a destination mesh STA using the on-demand path selection mode, it broadcasts a PREQ element with the path target specified in the list of targets and the metric field initialized to the initial value of the active path selection metric.

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When a mesh STA receives a new PREQ element, it creates or updates its path information to the originator mesh STA and propagates the PREQ element to its neighbor peer mesh STAs if the PREQ element contains a greater HWMP SN, or the HWMP SN is the same as the current path and the PREQ element offers a better metric than the current path. Each mesh STA may receive multiple copies of the same PREQ element that originated at the originator mesh STA, each PREQ element traversing a unique path.

Whenever a mesh STA propagates a PREQ element, the metric field in the PREQ element is updated to reflect the cumulative metric of the path to the originator mesh STA.

If the mesh STA that received a PREQ element is the target mesh STA, it sends a PREP element back to the originator mesh STA after creating or updating a path to the originator mesh STA.

The PREQ element provides the TO (Target Only) subfield that allows path selection to take advantage of existing paths to the target mesh STA by allowing an intermediate mesh STA to return a PREP element to the originator mesh STA. If the TO (Target Only) subfield is 1, only the target mesh STA responds with a PREP element. The effect of setting the TO (Target Only) subfield to 0 is the quick establishment of a path using the PREP element generated by an intermediate mesh STA, allowing the forwarding of MSDUs with a low path selection delay. In order to select (or validate) the best path during the path selection procedure, the intermediate mesh STA that responded with a PREP element propagates the PREQ element with the TO (Target Only) subfield set to 1. This prevents all other intermediate mesh STAs on the way to the target from sending a PREP element.

Intermediate mesh STAs create a path to the target mesh STA on receiving the PREP element, and also forward the PREP element toward the originator. When the originator receives the PREP element, it creates a path to the target mesh STA. If the target mesh STA receives further PREQ elements with a better metric, then the target updates its path to the originator with the new path and also sends a new PREP element to the originator along the updated path. A bidirectional, best metric end-to-end path is established between the originator and target mesh STA.

14.10.4 Proactive tree building mode

14.10.4.1 General

There are two mechanisms for proactively disseminating path selection information for reaching the root mesh STA. The first method uses a *proactive* PREQ element and is intended to create paths between all mesh STAs and the root mesh STA in the network proactively. The second method uses a RANN element and is intended to distribute path information for reaching the root mesh STA but there is no forwarding information created.

A mesh STA configured as root mesh STA sends either proactive PREQ elements or proactive RANN elements periodically.

14.10.4.2 Proactive PREQ mechanism

The PREQ tree building process begins with a proactive PREQ element sent by the root mesh STA, with the Target Address set to all 1s and the TO subfield set to 1. The PREQ element contains the path metric (set to the initial value of the active path selection metric by the root mesh STA) and an HWMP SN. The proactive PREQ element is sent periodically by the root mesh STA, with increasing HWMP SNs.

A mesh STA receiving a proactive PREQ element creates or updates its forwarding information to the root mesh STA, updates the metric and hop count of the PREQ element, records the metric and hop count to the root mesh STA, and then transmits the updated PREQ element. Information about the presence of and distance to available root mesh STA(s) is disseminated to all mesh STAs in the network.

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Each mesh STA may receive multiple copies of a proactive PREQ element, each traversing a unique path from the root mesh STA to the mesh STA. A mesh STA updates its current path to the root mesh STA if and only if the PREQ element contains a greater HWMP SN, or the HWMP SN is the same as the current path and the PREQ element offers a better metric than the current path to the root mesh STA. The processing of the proactive PREQ element is the same as the processing of the PREQ element in the on-demand mode described in 14.10.3.

If the proactive PREQ element is sent with the Proactive PREP subfield set to 0, the recipient mesh STA may send a proactive PREP element. A proactive PREP element is necessary, for example, if the mesh STA has data to send to the root mesh STA, thus requiring the establishment of a forward path from the root mesh STA. During the time the forward path is required, the recipient mesh STA shall send a proactive PREP element even if the Proactive PREP subfield is set to 0. Guidance on controlling the generation of proactive PREQ elements in such a case is given in S.7.

If the PREQ element is sent with a Proactive PREP subfield set to 1, the recipient mesh STA shall send a proactive PREP element. The proactive PREP element establishes the path from the root mesh STA to the mesh STA.

14.10.4.3 Proactive RANN mechanism

The root mesh STA periodically propagates a RANN element into the network. The information contained in the RANN element is used to disseminate path metrics to the root mesh STA, but reception of a RANN element does not establish a path.

Upon reception of a RANN element, each mesh STA that has to create or refresh a path to the root mesh STA sends an individually addressed frame containing a PREQ element to the root mesh STA via the mesh STA from which it received the RANN element.

The root mesh STA sends a PREP element in response to each PREQ element. The individually addressed frame containing a PREQ element creates the reverse path from the root mesh STA to the originator mesh STA, while the PREP element creates the forward path from the mesh STA to the root mesh STA.

14.10.5 Collocated STAs

HWMP terminology strictly refers to a STA whose address is used for destination mapping (i.e., the originator address, the intermediate mesh STA address, or the target address). HWMP terminology does not make any assumption about the address used for communication over the WM (i.e., the Transmitter Address and the Receiver Address). For example, there is no requirement that the path originator or the path target of an HWMP path are the same as the address used for transmitting the first and receiving the last (respectively) HWMP Mesh Path Selection frame containing a PREQ element.

The corollary to this is that the first hop of a PREQ element may have a transmitter address that is not the same as the originator address in the PREQ element and that the first hop may have a transmitter address that is not the same as the source address. In order to determine whether a transmission is a first hop or not, mesh STAs should not compare the source and transmitter addresses. Instead, this determination can be made by looking at the hop count field of the PREQ element (which is not used as an acceptance criterion).

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14.10.6 Parameters for extensible path selection framework

Table 14-8 gives the parameters of HWMP for the extensible path selection framework (see 14.8.2).

Table 14-8—Parameters of HWMP for extensible path selection framework

Parameter	Notes
Path Selection Protocol ID	See Table 9-239 in 9.4.2.97.2
Data type of metric field	As defined by active path selection metric
Length of metric field	4 octets
Operator for metric aggregation	As defined by active path selection metric
Comparison operator	As defined by active path selection metric
Initial value of path metric	As defined by active path selection metric

14.10.7 Addressing of HWMP Mesh Path Selection frame

All HWMP elements are sent in an HWMP Mesh Path Selection frame (see 9.6.16.3). The RANN element may also be sent in a Beacon frame. "Cases" refer to the different conditions that trigger the transmission of an HWMP Mesh Path Selection frame. PREQ element cases are specified in 14.10.9.3. PREP element cases are specified in 14.10.10.3. PERR element cases are specified in 14.10.11.3. RANN element cases are specified in 14.10.12.3.

Note that the PREQ Addressing Mode subfield in the Flags field identifies the propagation mode of the PREQ element; an Addressing Mode subfield equal to 0 indicates that the PREQ element is group addressed, an Addressing Mode subfield equal to 1 indicates that the PREQ element is individually addressed.

The addresses of the HWMP Mesh Path Selection frame shall be as follows:

- PREQ element group addressed—Addressing Mode subfield = 0 [Case A: Path Discovery (Original transmission), Case B: Path Maintenance (Original transmission), Case C: Proactive PREQ element (Original transmission), and Case E: PREQ element Propagation; see 14.10.9.3]:
  - Address 1: Group address
  - Address 2: Address of the mesh STA sending the PREQ element
  - Address 3: Same as Address 2
- PREQ element individually addressed—Addressing Mode subfield = 1 [Case D: Root Path Confirmation (Original transmission); see 14.10.9.3]:
  - Address 1: Address 2 of the frame containing the RANN element that triggered the PREQ element
  - Address 2: Address of the mesh STA sending the PREQ element
  - Address 3: Same as Address 2
- PREQ element individually addressed—Addressing Mode subfield = 1 [Case E: PREQ element Propagation; see 14.10.9.3]:
  - Address 1: Next-hop MAC address to the mesh STA identified in the Target MAC Address field in the PREQ element
  - Address 2: Address of the mesh STA sending the PREQ element
  - Address 3: Same as Address 2

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- PREP element [Case A: Original transmission, Case C: Intermediate reply, Case D: Proactive PREP element in Proactive PREQ element mode; see 14.10.10.3]:
  - Address 1: Address of the next hop to the originator mesh STA address in the PREQ element that triggered the PREP element
  - Address 2: Address of the mesh STA sending the PREP element
  - Address 3: Same as Address 2
- PREP element [Case B: PREP element Propagation; see 14.10.10.3]:
  - Address 1: Address of the next hop to the originator mesh STA address in the PREP element that triggered the PREP element
  - Address 2: Address of the mesh STA sending the PREP element
  - Address 3: Same as Address 2
- PERR element individually addressed [Case A: Original transmission—next hop is unusable; see 14.10.11.3]:
  - Address 1: Address of each one of the precursors for which the active forwarding information has been invalidated
  - Address 2: Address of the mesh STA sending the PERR element
  - Address 3: Same as Address 2
- PERR element individually addressed [Case B: Original transmission—missing forwarding information; see 14.10.11.3]:
  - Address 1: Address of the transmitter of the frame that triggered the PERR element
  - Address 2: Address of the mesh STA sending the PERR element
  - Address 3: Same as Address 2
- PERR element individually addressed [Case C: Original transmission (proxy information is unusable); see 14.10.11.3]:
  - Address 1: Address of each one of the neighbor peer mesh STAs
  - Address 2: Address of the mesh STA sending the PERR element
  - Address 3: Same as Address 2
- PERR element individually addressed [Case D: PERR element propagation; see 14.10.11.3]:
  - Address 1: Address of each one of the precursors for which the active forwarding information has been invalidated
  - Address 2: Address of the mesh STA sending the PERR element
  - Address 3: Same as Address 2
- PERR element group addressed [all cases; see 14.10.11.3]:
  - Address 1: Group address
  - Address 2: Address of the mesh STA sending the PERR element
  - Address 3: Same as Address 2
- RANN element [all cases; see 14.10.12.3]:
  - Address 1: Group address
  - Address 2: Address of the mesh STA sending the RANN element
  - Address 3: Same as Address 2

Multiple HWMP elements may be sent in the same HWMP Mesh Path Selection frame if they share the same intended Address 1.

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14.10.8 General rules for processing HWMP elements

14.10.8.1 General

This subclause describes the rules for the processing of the following components of the HWMP elements:

— HWMP SN
— Element TTL
— Metric

14.10.8.2 HWMP propagation

The term *propagate* is used to describe the means by which elements are not transmitted "as is" across the network but are processed and modified along the way. Many HWMP elements are intended to be processed and propagated across an MBSS by mesh STAs. Each propagation is subject to certain rules or limitations as explained in the following subclauses. Certain parameters in the HWMP elements are updated during the propagation. See 14.10.9, 14.10.10, 14.10.11, and 14.10.12.

The originator of an HWMP element sets the initial value of the Element TTL. The mesh STA that receives the HWMP element shall propagate it if the received value of Element TTL is greater than 1. Before propagating the HWMP element, the mesh STA decrements the Element TTL value.

In general, the propagation of an HWMP element is not subject to a delay. Exception exists for the RANN element as described in 14.10.12.

14.10.8.3 HWMP sequence numbering

HWMP uses sequence numbers to prevent the creation of path loops and to distinguish stale and fresh path information. Each mesh STA keeps its own HWMP SN that it increments, uses in HWMP elements, and processes according to the HWMP rules. HWMP SNs for other mesh STAs are maintained in the forwarding information (see 14.10.8.4).

An HWMP SN is included in the PREQ, PREP, PERR, and RANN elements. The HWMP SN in the forwarding information is updated whenever a mesh STA receives new (i.e., not stale) information about the HWMP SN from a PREQ, PREP, or PERR element that may be received relative to that originator mesh STA, target mesh STA, or destination mesh STA.

HWMP depends on each mesh STA in the network to own and maintain its HWMP SN to guarantee the loop-freedom of all paths toward that mesh STA. A mesh STA increments its own HWMP SN in the following two circumstances:

— If it is an originator mesh STA, it shall increment its own HWMP SN immediately before it starts a path discovery. This prevents conflicts with previously established reverse paths toward the originator mesh STA. However, it might be advantageous not to increment the HWMP SN too frequently. An optional mechanism for achieving this is described in 14.10.8.6.
— If it is a target mesh STA, it shall update its own HWMP SN to maximum (current HWMP SN, target HWMP SN in the PREQ element) + 1 immediately before it generates a PREP element in response to a PREQ element. The target HWMP SN of the PREQ element is relevant when a link was broken along the path and the stored sequence number was increased at an intermediate mesh STA.

Comparing HWMP SNs is done using a circular modulo 2^{32} comparison.

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In general, when a mesh STA receives an element with an HWMP SN that is less than the HWMP SN in the corresponding forwarding information, it discards the received element. If they are the same, the outcome (element processed or not) depends on the type of the element and some additional conditions. These cases are noted in the applicable element descriptions.

The only circumstance in which a mesh STA may change the HWMP SN of another mesh STA in the forwarding information independently of the reception of an HWMP element originated by this mesh STA is in response to a broken or no longer usable link to the next hop toward that destination mesh STA. The mesh STA determines which destinations use a particular next hop by consulting its forwarding information. In this case, for each destination that uses the next hop, the mesh STA increments the HWMP SN in the forwarding information and marks the path as invalid (see also 14.10.11). Whenever any forwarding information containing an HWMP SN greater than the recorded HWMP SN for an affected destination is received by a mesh STA that has marked that recorded forwarding information as invalid, the mesh STA shall update its forwarding information according to the information contained in the update.

14.10.8.4 Forwarding information

In addition to the parameters contained in the basic forwarding information as described in 10.38.2, the forwarding information to a destination defined by HWMP also contains at least the destination HWMP SN, the path metric, and the number of hops.

Upon PREQ element and PREP element processing, a mesh STA shall create or update the forwarding information as follows:

- The mesh STA may create or update its forwarding information to the transmitter of the element if the path metric improves.
- The mesh STA shall create or update its forwarding information to the originator mesh STA, if it received a PREQ element, and one of the following conditions is met:
  - The originator HWMP SN > HWMP SN in the forwarding information for this originator mesh STA, or
  - The originator HWMP SN = HWMP SN in the forwarding information for this originator mesh STA AND the updated path metric is better than the path metric in the forwarding information.
- The mesh STA shall create or update its forwarding information to the target mesh STA, if it received a PREP element, and one of the following conditions is met:
  - The Target HWMP SN > HWMP SN in the forwarding information for this target mesh STA, or
  - The Target HWMP SN = HWMP SN in the forwarding information for this target mesh STA AND the updated path metric is better than the path metric in the forwarding information.

Table 14-9 defines the values to be stored in the different fields of the forwarding information after a PREQ element or PREP element has been received. Details of PREQ element processing and PREP element processing are described in 14.10.9 and 14.10.10, respectively.

Upon PREP element processing, a mesh STA shall validate the forwarding information as follows:

- When the mesh STA transmits a PREP element, it shall validate its forwarding information to the originator mesh STA of the PREP element.
- When the mesh STA receives a PREP element, it shall validate its forwarding information to the target mesh STA of the PREP element.

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Table 14-9—Data for creation and update of forwarding information due to PREQ element and PREP element

Field of forwarding information	Received PREQ element		Received PREP element	
	Forwarding information for transmitter of PREQ element	Forwarding information for originator mesh STA	Forwarding information for transmitter of PREP element	Forwarding information for target mesh STA
HWMP SN	Invalid if created, no change if updated	PREQ element field Originator HWMP Sequence Number	Invalid if created, no change if updated	PREP element field Target HWMP Sequence Number
Next hop	Transmitter address of the Management frame containing the PREQ element	Transmitter address of the Management frame containing the PREQ element	Transmitter address of the Management frame containing the PREP element	Transmitter address of the Management frame containing the PREP element
Path metric	Accumulation of the initial value of the path metric with the metric of the link to the transmitter of the PREQ element	Accumulation of the value of PREQ element field Metric with the metric of the link to the transmitter of the PREQ element	Accumulation of the initial value of the path metric with the metric of the link to the transmitter of the PREP element	Accumulation of the value of PREP element field Metric with the metric of the link to the transmitter of the PREP element
Number of hops	1	Value of PREQ element field Hop Count + 1	1	Value of PREP element field Hop Count + 1
Precursor list	No change	No change except in case of an intermediate reply [see 14.10.9.4.3 step f)]	No change	See 14.10.10.4.3 step d)
Lifetime	The longer one of the lifetime of the stored forwarding information and the value of PREQ element field Lifetime	The longer one of the lifetime of the stored forwarding information and the value of PREQ element field Lifetime	The longer one of the lifetime of the stored forwarding information and the value of PREP element field Lifetime	The longer one of the lifetime of the stored forwarding information and the value of PREP element field Lifetime

If the mesh STA is unable to forward an MSDU/MMPDU to a next-hop STA as indicated in the forwarding information, it shall invalidate the corresponding forward information (See 14.10.11.3). When a mesh STA receives PERR element, it shall invalidate the forwarding information to the unreachable destination mesh STA indicated in the PERR element. The forwarding information shall be invalidated if its lifetime has expired.

Table 14-10 summarizes the timing to validate or invalidate the forwarding information.

Details of PREP element processing and PERR element processing are described in 14.10.10 and 14.10.11, respectively.

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Table 14-10—Validation and invalidation of the forwarding information

Event	Action
Transmitted PREP element	Validate forwarding information to the originator mesh STA of the PREP element
Received PREP element	Validate forwarding information to the target mesh STA of the PREP element
Unable to forward MSDU/ MMPDU to a next-hop STA	Invalidate forwarding information that uses the next-hop STA
Received PERR element	Invalidate forwarding information to the unreachable destination STA indicated in the Destination Address field in the PERR element
Forwarding information lifetime expiration	Invalidate forwarding information that the lifetime is expired

14.10.8.5 Repeated attempts at path discovery

Repeated attempts by a mesh STA at path discovery toward a single target shall be limited to dot11MeshHWMPmaxPREQretries. The minimum waiting time for the repeated attempt at path discovery to a single target is 2 × dot11MeshHWMPnetDiameterTraversalTime. For each attempt, the HWMP SN is incremented and a new Path Discovery ID is chosen.

14.10.8.6 Limiting the rate of HWMP SN increments

In order to improve path stability (and further reduce overhead), a mesh STA may use the same originator HWMP SN for a certain time interval. In this case, the originator HWMP SN shall not be incremented until at least dot11MeshHWMPnetDiameterTraversalTime has elapsed since the previous increment. This mechanism prevents mesh STAs from changing the path frequently to the originator mesh STA every time the originator mesh STA sends a burst of PREQ elements within a very short time. This element of the protocol allows an originator mesh STA to immediately initiate on-demand path discovery to a new target without affecting recently refreshed paths to the originator in other mesh STAs.

14.10.9 Path request (PREQ) mechanism

14.10.9.1 General

This subclause describes the function, generation, and processing of the PREQ element.

14.10.9.2 Function

The PREQ element, described in 9.4.2.112, is used for the following purposes:

— Discovering a path to one or more target mesh STAs
— Maintaining a path (optional)
— Building a proactive (reverse) path selection tree to the root mesh STA
— Confirming a path to a target mesh STA (optional)

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14.10.9.3 Conditions for generating and sending a PREQ element

A mesh STA shall send a PREQ element in an HWMP Mesh Path Selection frame, as defined in 9.6.16.3, in the following cases:

Case A: Path Discovery (Original Transmission)

All of the following conditions apply:

— The mesh STA needs to establish an on-demand path to one or more targets for which there is no ongoing path discovery initiated by this mesh STA.

— The mesh STA has not sent a PREQ element for the target mesh STAs less than dot11MeshHWMPpreqMinInterval TUs ago. If this is the case, the transmission of the PREQ element has to be postponed until this condition becomes true.

— The mesh STA has not made more than (dot11MeshHWMPmaxPREQretries – 1) repeated attempts at path discovery toward the target of the PREQ element.

The content of a PREQ element in Case A shall be as shown in Table 14-11.

Table 14-11—Contents of a PREQ element in Case A

Field	Value
Element ID	Value given in Table 9-92 for the PREQ element
Length	26 + N × 11 (if Bit 6 (AE subfield) in the Flags field = 0) 32 + N × 11 (if Bit 6 (AE subfield) in the Flags field = 1)
Flags	Bit 0: 0 (gate announcement not applicable) Bit 1: 0 (group addressed) Bit 2: 0 (no proactive PREP element applicable) Bit 3–5: Reserved Bit 6: (1 – if external address present, 0 – otherwise) Bit 7: Reserved
Hop Count	0
Element TTL	Maximum number of hops allowed for this element, e.g., dot11MeshHWMPnetDiameter
Path Discovery ID	New unique Path Discovery ID, for instance, previous Path Discovery ID + 1
Originator Mesh STA Address	MAC address of the path originator
Originator HWMP Sequence Number	Previous originator HWMP SN + 1; see 14.10.8.6
Originator External Address	Present only if Bit 6 in Flags field = 1; this value is set to the external address, which is the source address of the MSDU (from outside the mesh BSS) that triggered the path discovery at the originator
Lifetime	The time for which mesh STAs receiving the PREQ element consider the forwarding information to be valid, e.g., dot11MeshHWMPactivePathTimeout
Metric	Initial value of active path selection metric
Target Count	N (N ≥ 1)

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Table 14-11—Contents of a PREQ element in Case A *(continued)*

Field		Value
Per Target	Per Target Flags	Bit 0 (TO): dot11MeshHWMPtargetOnly Bit 1: Reserved Bit 2 (USN): 0 if forwarding information for Target Address with valid HWMP SN exists, 1 otherwise Bit 3–7: Reserved
	Target Address	MAC address of requested target
	Target HWMP Sequence Number	If Per Target Flags Bit 2 (USN) is 0, the latest HWMP SN stored by the originator mesh STA for the target mesh STA from the forwarding information (see 14.10.8.4); otherwise, reserved

Case B: Path Maintenance (Original Transmission) (optional)

All of the following conditions apply:

— The mesh STA has a path to a given target mesh STA that is not a root mesh STA.

— The last PREQ element to this target was sent dot11MeshHWMPmaintenanceInterval TUs (or more) ago.

The content of a PREQ element in Case B shall be as shown in Table 14-12.

Table 14-12—Contents of a PREQ element in Case B

Field	Value
Element ID	Value given in Table 9-92 for the PREQ element
Length	26 + N × 11
Flags	Bit 0: 0 (gate announcement not applicable) Bit 1: 0 (group addressed) Bit 2: 0 (no proactive PREP element applicable) Bit 3–5: Reserved Bit 6: 0 (no address extension) Bit 7: Reserved
Hop Count	0
Element TTL	Maximum number of hops allowed for this element, e.g., dot11MeshHWMPnetDiameter
Path Discovery ID	New unique Path Discovery ID, for instance, previous Path Discovery ID + 1
Originator Mesh STA Address	MAC address of the originator of the PREQ element
Originator HWMP Sequence Number	Originator HWMP SN + 1; see 14.10.8.6
Originator External Address	Field not present
Lifetime	The time for which mesh STAs receiving the PREQ element consider the forwarding information to be valid, e.g., dot11MeshHWMPactivePathTimeout
Metric	Initial value of active path selection metric

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Table 14-12—Contents of a PREQ element in Case B *(continued)*

Field		Value
Target Count		N (N ≥ 1)
Per Target	Per Target Flags	Bit 0 (TO): 1 (target only) Bit 1: Reserved Bit 2 (USN): 0 Bit 3–7: Reserved
	Target Address	MAC Address of target mesh STA
	Target HWMP Sequence Number	The latest HWMP SN for this target known to the originator mesh STA

Case C: Proactive PREQ element (Original Transmission)

All of the following conditions apply:

— The root mesh STA is configured as root mesh STA using proactive PREQ elements ([dot11MeshHWMProotMode = proactivePREQnoPREP (2)] OR [dot11MeshHWMProotMode = proactivePREQwithPREP (3)]).

— The root mesh STA sent its previous proactive PREQ element dot11MeshHWMProotInterval TUs ago.

The contents of a PREQ element in Case C shall be as shown in Table 14-13.

Table 14-13—Contents of a PREQ element in Case C

Field	Value
Element ID	Value given in Table 9-92 for the PREQ element
Length	37
Flags	Bit 0: 1 if dot11MeshGateAnnouncements is true (gate announcement), 0 otherwise Bit 1: 0 (group addressed) Bit 2: 0 if dot11MeshHWMProotMode = proactivePREQnoPREP(2), 1 if dot11MeshHWMProotMode = proactivePREQwithPREP(3) (proactive PREP) Bit 3–5: Reserved Bit 6: 0 (no address extension) Bit 7: Reserved
Hop Count	0
Element TTL	Maximum number of hops allowed for this element, e.g., dot11MeshHWMPnetDiameter
Path Discovery ID	New unique Path Discovery ID, for instance, previous Path Discovery ID + 1
Originator Mesh STA Address	MAC address of the root mesh STA
Originator HWMP Sequence Number	Originator HWMP SN + 1; see 14.10.8.6
Originator External Address	Field not present

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Table 14-13—Contents of a PREQ element in Case C *(continued)*

Field		Value
Lifetime		dot11MeshHWMPactivePathToRootTimeout
Metric		Initial value of active path selection metric
Target Count		1
Per Target	Per Target Flags	Bit 0 (TO): 1 Bit 1: Reserved Bit 2 (USN): 1 Bit 3–7: Reserved
	Target Address	Broadcast address
	Target HWMP Sequence Number	0

Case D: Root Path Confirmation (Original Transmission)

One of the following conditions applies:

— The mesh STA has received a RANN element and the metric (RANN metric ⊕ metric to the transmitter of the RANN element) is better than the metric to the root in the current forwarding information.

— The mesh STA has a path to a root mesh STA and the last PREQ element to the root mesh STA was sent dot11MeshHWMPconfirmationInterval TUs (or more) ago.

The content of a PREQ element in Case D shall be as shown in Table 14-14.

Table 14-14—Contents of a PREQ element in Case D

Field	Value
Element ID	Value given in Table 9-92 for the PREQ element
Length	As required
Flags	Bit 0: 0 (gate announcement not applicable) Bit 1: 1 (individually addressed) Bit 2: 0 (no proactive PREP element applicable) Bit 3–5: Reserved Bit 6: 0 (no address extension) Bit 7: Reserved
Hop Count	0
Element TTL	Maximum number of hops allowed for this element, e.g., dot11MeshHWMPnetDiameter
Path Discovery ID	Not used
Originator Mesh STA Address	MAC address of the originator mesh STA
Originator HWMP Sequence Number	Originator HWMP SN + 1; see 14.10.8.6

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Table 14-14—Contents of a PREQ element in Case D *(continued)*

Field		Value
Originator External Address		Field not present
Lifetime		The time for which mesh STAs receiving the PREQ element consider the forwarding information to be valid, e.g., dot11MeshHWMPactivePathToRootTimeout
Metric		Initial value of active path selection metric
Target Count		1
Per Target	Per Target Flags	Bit 0 (TO): 1 Bit 1: Reserved Bit 2 (USN): 0 Bit 3–7: Reserved
	Target Address	Root mesh STA MAC Address
	Target HWMP Sequence Number	The latest HWMP SN for this target known to the originator mesh STA

Case E: PREQ element Propagation

Case E1 (target count = 1, no PREP element generation as intermediate mesh STA):

All of the following conditions apply:

- The mesh STA has received and accepted a PREQ element; see 14.10.9.4.2.
- dot11MeshForwarding is true.
- [The active forwarding information for the originator mesh STA was created or updated according to the rules defined in 14.10.8.4] OR [{the originator HWMP SN of the accepted PREQ element = HWMP SN in the forwarding information for this originator mesh STA} AND {the mesh STA has not previously received a PREQ element with the same originator mesh STA address and the same Path Discovery ID}].
- The Element TTL field is greater than 1; see 14.10.8.2.
- Target Count = 1.
- [The mesh STA is not the target of the PREQ element)]
  OR
  [the target of the PREQ element is the MAC broadcast address (all 1s)].
- The mesh STA is not the proxy of the target address.
- [The TO (Target Only) subfield of the target in the PREQ element is set (TO = 1)]
  OR
  [{the TO (Target Only) subfield of the target in the PREQ element is not set (TO = 0)} AND {mesh STA has no active forwarding information for the requested target}].

The content of a PREQ element in Case E1 shall be as shown in Table 14-15.

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Table 14-15—Contents of a PREQ element in Case E1

Field		Value
Element ID		Value given in Table 9-92 for the PREQ element
Length		As received
Flags		As received
Hop Count		As received + 1
Element TTL		As received – 1
Path Discovery ID		As received
Originator Mesh STA Address		As received
Originator HWMP Sequence Number		As received
Originator External Address		As received; this field is present if Bit 6 of the Flags field (AE subfield) is 1; it is not present otherwise
Lifetime		As received
Metric		As received ⊕ own metric toward transmitter of received PREQ element
Target Count		1
Per Target	Per Target Flags	As received
	Target MAC Address	As received
	Target HWMP Sequence Number	As received

Case E2 (target count = 1, PREP element generation as intermediate mesh STA):

All of the following conditions apply:

- The mesh STA has received and accepted a PREQ element; see 14.10.9.4.2.
- dot11MeshForwarding is true.
- [The active forwarding information for the originator mesh STA was created or updated according to the rules defined in 14.10.8.4]
  OR
  [{the originator HWMP SN of the accepted PREQ element = HWMP SN in the forwarding information for this originator mesh STA} AND {the mesh STA has not previously received a PREQ element with the same originator mesh STA address and the same Path Discovery ID}].
- The Element TTL field is greater than 1; see 14.10.8.2.
- Target Count = 1.
- The mesh STA is not the target of the PREQ element.
- The mesh STA is not the proxy of the target address.
- The mesh STA has active forwarding information for the requested target.

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— [The TO (Target Only) subfield of the target in the PREQ element is not set (TO = 0)]
AND
[the mesh STA has active forwarding information for the requested target].

The contents of a PREQ element in Case E2 shall be as shown in Table 14-16.

Table 14-16—Contents of a PREQ element in Case E2

Field		Value
Element ID		Value given in Table 9-92 for the PREQ element
Length		As received
Flags		As received
Hop Count		As received + 1
Element TTL		As received – 1
Path Discovery ID		As received
Originator Mesh STA Address		As received
Originator HWMP Sequence Number		As received
Originator External Address		As received; this field is present if Bit 6 of the Flags field (AE subfield) is 1; it is not present otherwise
Lifetime		As received
Metric		As received ⊕ own metric toward transmitter of received PREQ element
Target Count		1
Per Target	Per Target Flags	Bit 0 (TO): 1 (target only because mesh STA sent a PREP element) Bit 1: Reserved Bit 2 (USN): As received Bit 3–7: Reserved
	Target MAC Address	As received
	Target HWMP Sequence Number	As received

Case E3 (target count > 1):

All of the following conditions apply:

— The mesh STA has received and accepted a PREQ element; see 14.10.9.4.2.
— dot11MeshForwarding is true.
— [The active forwarding information for the originator mesh STA was created or updated according to the rules defined in 14.10.8.4
OR

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[{the originator HWMP SN of the accepted PREQ element = HWMP SN in the forwarding information for this originator mesh STA} AND {the mesh STA has not previously received a PREQ element with the same originator mesh STA address and the same Path Discovery ID}].

— The Element TTL field is greater than 1; see 14.10.8.2.

— Target Count > 1.

— There is at least one requested target that is neither the recipient MAC address nor an external MAC address proxied by the recipient.

The contents of a PREQ element in Case E3 shall be as shown in Table 14-17.

Table 14-17—Contents of a PREQ element in Case E3

Field		Value
Element ID		Value given in Table 9-92 for the PREQ element
Length		26 + N × 11
Flags		As received
Hop Count		As received + 1
Element TTL		As received – 1
Path Discovery ID		As received
Originator Mesh STA Address		As received
Originator HWMP Sequence Number		As received
Originator External Address		As received; this field is present if Bit 6 of the Flags field (AE subfield) is set to 1; it is not present otherwise
Lifetime		As received
Metric		As received ⊕ own metric toward the transmitter of the received PREQ element
Target Count		1 ≤ target count ≤ received target count received target count less the number of requested destinations, for which the processing mesh STA — Is the target mesh STA or — Is the target proxy mesh gate
Per Target #A	Per Target Flags #A	As received
	Target MAC Address #A	As received
	Target HWMP Sequence Number #A	As received

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Table 14-17—Contents of a PREQ element in Case E3 *(continued)*

Field		Value
Per Target #B	Per Target Flags #B	Bit 0 (TO): 1 (target only because mesh STA sent PREP element) Bit 1: As received Bit 2 (USN): As received Bit 3–7: As received
	Target MAC Address #B	As received
	Target HWMP Sequence Number #B	As received

For the per target fields (Per Target Flags, Target Address, Target HWMP Sequence Number) assume the following:

— Target #A: If target A would have been the only requested target, it would generate a PREQ element for propagation according to case E1.

— Target #B: If target B would have been the only requested target, it would generate a PREQ element for propagation according to case E2.

14.10.9.4 PREQ element processing

14.10.9.4.1 General

Received PREQ elements are subject to certain acceptance criteria. Processing and actions taken depend on the contents of the PREQ element and the information available to the receiving mesh STA. See also 14.10.8.

14.10.9.4.2 Acceptance criteria

The PREQ element shall not be accepted (and shall not be processed as described in 14.10.9.4.3) if any of the following is true:

— (The target address of the PREQ element is neither the recipient MAC address, broadcast address, nor an external MAC address proxied by the recipient) AND (dot11MeshForwarding is false)

— (Bit 1 (Addressing Mode subfield) of the Flags field in the PREQ element is equal to 1) AND (there is no valid forwarding information with the destination mesh STA address equal to the Target Address of the PREQ element)

Otherwise, the PREQ element is accepted. See also 14.10.8.

14.10.9.4.3 Effect of receipt

A mesh STA receiving a PREQ element according to the acceptance criteria in 14.10.9.4.2 shall record the Path Discovery ID and the originator mesh STA address. The receiving mesh STA shall create or update the active forwarding information it maintains for the originator mesh STA of the PREQ element according to the rules defined in 14.10.8.4.

If the active forwarding information for the originator mesh STA was created or updated according to the rules defined in 14.10.8.4 or if the Target HWMP SN of the PREQ element is the same as the HWMP SN in the forwarding information for the Target Mesh STA and there has been no record of the originator mesh STA and Path Discovery ID, the following applies:

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a) If the mesh STA is the target of the PREQ element or is the proxy of the target MAC address it shall initiate the transmission of a PREP element to the originator mesh STA (14.10.10.3 Case A). If the PREQ element carries an external address (indicated by the AE subfield in the Flags field), the mesh STA shall update its proxy information with the originator external address as external address, the PREQ element Originator Mesh STA Address as the corresponding proxy, the HWMP Sequence Number as proxy information sequence number, and for the proxy lifetime the longer one of the value of the PREQ element Lifetime field and the proxy lifetime if the proxy information already exists (see also 14.11.4.3).

b) If step a) was not applicable for the mesh STA and the AE subfield in the Flags field in the PREQ element is 1, the mesh STA may update its proxy information with the originator external address as external address, the PREQ element Originator Mesh STA Address as the corresponding proxy, the HWMP Sequence Number as proxy information sequence number, and for the proxy lifetime the longer one of the value of the PREQ element Lifetime field and the proxy lifetime if the proxy information already exists (see also 14.11.4.3).

c) If the mesh STA has valid forwarding information to any of the requested targets and the TO (Target Only) subfield for such a target is not set (TO = 0), it initiates the transmission of a PREP element for each of these targets (see 14.10.10.3 Case C).

d) If the mesh STA is initiating a PREP element transmission on behalf of another target according to step c) (intermediate reply), it shall process all of the following:
   - Update the precursor list in its forwarding information for the target mesh STA with the next hop from the forwarding information of the originator mesh STA.
   - Update the lifetime for this precursor that is the longer one of the lifetime of the forwarding information of the target mesh STA.
   - Update the lifetime of the precursor list entry in case it already exists.
   - Update the precursor list in its forwarding information for the originator mesh STA with the next hop toward the target mesh STA.
   - Update the lifetime for this precursor that is the longer one of the lifetime of the forwarding information of the originator mesh STA.
   - Update the lifetime of the precursor list entry in case it already exists.

e) If the received PREQ element is a proactive PREQ element [target address is set to all 1s, TO subfield is set (TO = 1)], the mesh STA generates a proactive PREP element to the root mesh STA (see 14.10.10.3 Case D) depending on the setting of the Proactive PREP subfield. If the Proactive PREP subfield is 1, a proactive PREP element is generated, if it is 0, a proactive PREP element is generated only if a bidirectional path to the root mesh STA is required (see S.7).

f) If there are individually addressed targets in the PREQ element that have not been processed in step a) or that have been processed in step c) or in step e), the receiving mesh STA shall propagate the PREQ element as defined in 14.10.9.3 Case E.

14.10.10 Path reply (PREP) mechanism

14.10.10.1 General

Subclause 14.10.10 describes the function, generation, and processing of the PREP element.

14.10.10.2 Function

The PREP element is transmitted in individually addressed frames and is described in 9.4.2.113. The purpose of the PREP element is as follows:

- To establish the forward path to a target mesh STA or target proxy mesh gate.
- To confirm the reverse path to the originator.

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14.10.10.3 Conditions for generating and sending a PREP element

A mesh STA sends out a PREP element in an HWMP Mesh Path Selection frame, as defined in 9.6.16.3, in the following cases:

Case A: Path Discovery (Original Transmission)

A PREP element is transmitted if the mesh STA has received and accepted a PREQ element (see 14.10.9.4.2) fulfilling any one of the following conditions:

— The Target Address of the PREQ element is the same as MAC address of the receiving mesh STA.
— The Target Address of the PREQ element is an external address currently proxied by the mesh STA.

The content of the generated PREP element in Case A shall be as shown in Table 14-18.

Table 14-18—Contents of a PREP element in Case A

Field	Value
Element ID	Value given in Table 9-92 for the PREP element
Length	As required
Flags	Bit 0–5: Reserved Bit 6 (AE): (1 = external address present, 0 = otherwise) Bit 7: Reserved
Hop Count	0
Element TTL	Maximum number of hops allowed for this element
Target Mesh STA Address	MAC address of the target mesh STA or target proxy mesh gate
Target HWMP Sequence Number	HWMP SN of the target mesh STA or target proxy mesh gate after it has been updated according to 14.10.8.3
Target External Address	External target address on behalf of which the PREP element is sent. Present only if Bit 6 (AE subfield) in the Flags field is 1
Lifetime	As per the PREQ element that triggered the transmission of this PREP element
Metric	Initial value of active path selection metric
Originator Mesh STA Address	MAC address of the originator mesh STA
Originator HWMP Sequence Number	HWMP SN of the originator mesh STA

Case B: PREP element propagation

A PREP element is propagated if all of the following conditions apply:

— The mesh STA has received and accepted the PREP element; see 14.10.10.4.2.
— The mesh STA is not the path originator.

The contents of a PREP element in Case B shall be as shown in Table 14-19.

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Table 14-19—Contents of a PREP element in Case B

Field	Value
Element ID	Value given in Table 9-92 for the PREP element
Length	As received
Flags	As received
Hop Count	As received + 1
Element TTL	As received – 1
Target Mesh STA Address	As received
Target HWMP Sequence Number	As received
Target External Address	As received
Lifetime	As received
Metric	As received ⊕ own metric toward the transmitting mesh STA
Originator Mesh STA Address	As received
Originator HWMP Sequence Number	As received

Case C: Intermediate reply (Original Transmission)

A PREP element is transmitted if the mesh STA has received a PREQ element fulfilling all of the following conditions:

- The TO (Target Only) subfield in the corresponding Per Target Flags field in the PREQ element is not set (TO = 0)
- The receiving mesh STA has active forwarding information with
  - A destination that is the same as the Target Address of the PREQ element
  - An HWMP SN that is greater than or equal to the Target HWMP SN of the PREQ element
  - A nonzero lifetime

The content of the generated PREP element in Case C shall be as shown in Table 14-20.

Table 14-20—Contents of a PREP element in Case C

Field	Value
Element ID	Value given in Table 9-92 for the PREP element
Length	31
Flags	Bit 0–5: Reserved Bit 6 (AE): 0 Bit 7: Reserved
Hop Count	0
Element TTL	Maximum number of hops allowed for this element
Target Mesh STA Address	Target MAC address from the PREQ element

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Table 14-20—Contents of a PREP element in Case C *(continued)*

Field	Value
Target HWMP Sequence Number	HWMP SN of the stored forwarding information of the Target of the PREQ element
Target External Address	Not present
Lifetime	As per the PREQ element that triggered the transmission of this PREP element
Metric	Value of path metric taken from the active forwarding information for the target address of the PREQ element
Originator Mesh STA Address	MAC address of the originator mesh STA
Originator HWMP Sequence Number	HWMP SN of the originator mesh STA

Case D: Proactive PREP element in Proactive PREQ element mode (Original Transmission)

One of the following conditions applies:

— The mesh STA has received a proactive PREQ element with the Proactive PREP subfield set to 0 AND the mesh STA needs to establish or update a bidirectional path to the root mesh STA.

— The mesh STA has received a proactive PREQ element with the Proactive PREP subfield set to 1.

Note that a proactive PREQ element is a PREQ element with a Target Address set to all 1s and its TO subfield set (TO=1).

The content of the generated PREP element in Case D shall be as shown in Table 14-21.

Table 14-21—Contents of a PREP element in Case D

Field	Value
Element ID	Value given in Table 9-92 for the PREP element
Length	31
Flags	Bit 0–5: Reserved Bit 6 (AE): 0 Bit 7: Reserved
Hop Count	0
Element TTL	Maximum number of hops allowed for this element
Target Mesh STA Address	MAC address of the mesh STA
Target HWMP Sequence Number	HWMP SN of the mesh STA
Target External Address	Not present
Lifetime	Lifetime of the PREQ element that triggered the transmission of this PREP element
Metric	Initial value of active path selection metric

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Table 14-21—Contents of a PREP element in Case D *(continued)*

Field	Value
Originator Mesh STA Address	MAC address of the root mesh STA (originator mesh STA of the PREQ element)
Originator HWMP Sequence Number	HWMP SN of the root mesh STA (originator HWMP SN of the PREQ element)

When a mesh STA sends out a PREP element in an HWMP Mesh Path Selection frame, it shall validate the forwarding information to the originator mesh STA indicated in the PREP element.

14.10.10.4 PREP element processing

14.10.10.4.1 General

Received PREP elements are subject to certain acceptance criteria. Processing and actions taken depend on the contents of the PREP element and the information available to the receiving mesh STA.

14.10.10.4.2 Acceptance criteria

The PREP element shall not be accepted (and shall not be processed as described in 14.10.10.4.3) if any of the following is true:

— (The originator mesh STA address of the PREP element is neither the recipient MAC address nor an external MAC address proxied by the recipient) AND (dot11MeshForwarding is false).

Otherwise, the PREP element shall be accepted.

14.10.10.4.3 Effect of receipt

A mesh STA receiving a PREP element according to the acceptance criteria in 14.10.10.4.2 shall create or update the forwarding information it maintains for the target mesh STA of the PREP element (according to the rules defined in 14.10.8.4). Further, the mesh STA shall validate the forwarding information to the target mesh STA indicated in the PREP element. If the conditions for creating or updating the forwarding information have not been met in those rules, no further steps are applied to the PREP element.

If the active forwarding information was created or updated according to the rules defined in 14.10.8.4, the following apply:

a) If the receiving mesh STA is not the final destination of the PREP element (originator mesh STA) and the Element TTL field > 1, the PREP element is propagated as defined in 14.10.10.3 Case B.

b) If the receiving mesh STA is the final destination of the PREP element (originator mesh STA) and its AE subfield in the Flags field is 1, the mesh STA shall store the Target External Address, the Target Mesh STA Address, and the HWMP Sequence Number as proxy information sequence number in its proxy information. The proxy lifetime is the longer one of the value of the PREP element Lifetime field and the proxy lifetime if the proxy information already exists (see also 14.11.4.3).

c) If the receiving mesh STA is not the final destination of the PREP element (originator mesh STA) and its AE subfield in the Flags field is 1, the mesh STA may store the Target External Address, the Target Mesh STA Address, and the HWMP Sequence Number as proxy information sequence number in its proxy information. The proxy lifetime is the longer one of the value of the PREP element Lifetime field and the proxy lifetime if the proxy information already exists (see also 14.11.4.3).

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d) If the mesh STA propagates the PREP element, the precursor list for the Target Mesh STA Address is updated by adding the next-hop mesh STA to which the PREP element is propagated. In addition, at the mesh STA the precursor list for the originator mesh STA address is updated by adding the next-hop mesh STA toward the Target Address. The lifetimes of these entries in the precursor lists are the values of the lifetimes of the corresponding forwarding information.

14.10.11 Path error (PERR) mechanism

14.10.11.1 General

Subclause 14.10.11 describes the function, generation, and processing of the PERR element.

14.10.11.2 Function

The PERR element is used for announcing one or more unreachable destination(s). The announcement is sent to all traffic sources that have a known active path to the destination(s). The active forwarding information associated with the unreachable destination(s) should no longer be used for forwarding.

A PERR element may be either group addressed (if there are many precursors), individually addressed (if there is only one precursor), or individually addressed iteratively to all precursors (see 14.10.7, item “PERR element individually addressed”). The PERR element is processed as a single element when iteratively individually addressed to several precursors. The PERR element contains the destinations that are unreachable.

A PERR element is propagated by mesh STAs receiving a PERR element if certain conditions are met.

A mesh STA generating or receiving a PERR element may attempt to establish paths to unreachable destinations using any of the available HWMP mechanisms.

14.10.11.3 Conditions for generating and sending a PERR element

A mesh STA shall send out a PERR element in an HWMP Mesh Path Selection frame, as defined in 9.6.16.3, in the following cases:

Case A: Original transmission (next hop is unusable)

The mesh STA has not sent a PERR element less than dot11MeshHWMPperrMinInterval TUs ago, and the following condition applies:

— The mesh STA determines that the link to the next hop of an active path in its forwarding information is no longer usable.

NOTE—The detection might be triggered by the fact that a mesh STA is unable to forward an MSDU/MMPDU to a next-hop mesh STA.

The HWMP SN in the forwarding information of all unreachable destinations announced in this PERR element is incremented by 1. The forwarding information for each unreachable destination announced in this PERR element is invalidated.

The contents of a PERR element in Case A shall be as shown in Table 14-22.

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Table 14-22—Contents of a PERR element in Case A

Field	Value
Element ID	Value given in Table 9-92 for the PERR element
Length	2 + N × 13
Element TTL	The maximum number of hops the element is propagated before being discarded
Number of Destinations	Number of announced unreachable destinations in the PERR element
Flags #1	Bit 0–5: Reserved Bit 6 (AE): 0 Bit 7: Reserved
Destination Address #1	MAC address of unreachable destination #1
HWMP Sequence Number #1	HWMP SN for Destination Address #1 from the forwarding information after above increment
Reason Code #1	"MESH-PATH-ERROR-DESTINATION-UNREACHABLE" (see 9.4.1.7)
...	...

Case B: Original transmission (missing forwarding information)

The mesh STA has not sent a PERR element less than dot11MeshHWMPperrMinInterval TUs ago, and one of the following conditions applies:

— The mesh STA receives an individually addressed frame with a destination address not matching its own MAC address for which it has no forwarding information.

— The mesh STA receives an individually addressed frame with a destination address not matching its own MAC address and dot11MeshForwarding is false.

The contents of a PERR element in Case B shall be as shown in Table 14-23.

Table 14-23—Contents of a PERR element in Case B

Field	Value
Element ID	Value given in Table 9-92 for the PERR element
Length	2 + N × 13
Element TTL	The maximum number of hops the element is propagated before being discarded
Number of Destinations	Number of announced destinations with missing forwarding information in the PERR element
Flags #1	Bit 0–5: Reserved Bit 6 (AE): 0 Bit 7: Reserved
Destination Address #1	MAC address of destination with missing forwarding information #1; this is Address 3 of the received individually addressed frame

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Table 14-23—Contents of a PERR element in Case B *(continued)*

Field	Value
HWMP Sequence Number #1	Reserved
Reason Code #1	"MESH-PATH-ERROR-NO-FORWARDING-INFORMATION" (see 9.4.1.7)
...	...

Case C: Original transmission (proxy information is unusable)

The mesh STA has not sent a PERR element less than dot11MeshHWMPperrMinInterval TUs ago, and the following condition applies:

— The mesh STA is a proxy mesh gate and determines that an active proxy information where the mesh STA is the proxy mesh gate is no longer usable.

The contents of a PERR element in Case C shall be as shown in Table 14-24.

Table 14-24—Contents of a PERR element in Case C

Field	Value
Element ID	Value given in Table 9-92 for the PERR element
Length	2 + N × 19
Element TTL	The maximum number of hops the element is propagated before being discarded
Number of Destinations	Number of announced unreachable external destinations in the PERR element
Flags #1	Bit 0–5: Reserved Bit 6 (AE): 1 Bit 7: Reserved
Destination Address #1	MAC address of proxy mesh gate #1 with unusable active proxy information
HWMP Sequence Number #1	Last used HWMP SN for Destination Address #1
Destination External Address #1	External MAC address of the active proxy information that is not longer usable and for which the mesh STA is the proxy mesh gate
Reason Code #1	"MESH-PATH-ERROR-NO-PROXY-INFORMATION" (see 9.4.1.7
...	...

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Case D: PERR element propagation

The mesh STA has not sent a PERR element less than dot11MeshHWMPperrMinInterval TUs ago, and all of the following conditions apply:

— The mesh STA received a PERR element from a neighbor peer mesh STA.
— A destination in the PERR element is the same as one of the destinations in the active forwarding information of the mesh STA where the next hop is the transmitter of the received PERR element, and the forwarding information or the proxy information has been invalidated according to conditions in 14.10.11.4.3 case b), case c), or case d).
— dot11MeshForwarding is true.
— The Element TTL field in the received PERR element is greater than 1.

The contents of a PERR element in Case D shall be as shown in Table 14-25.

Table 14-25—Contents of a PERR element in Case D

Field	Value
Element ID	Value given in Table 9-92 for the PERR element
Length	if AE subfield = 0: 2 + N × 13 if AE subfield = 1: 2 + N × 19
Element TTL	Element TTL in received PERR element – 1
Number of Destinations	1 ≤ number of destinations in the PERR element ≤ received value Received number of destinations less the number of received destinations for which the transmitter of the PERR element is not the next hop
Flags #1	As received
Destination Address #1	MAC address of unreachable destination #1, as received
HWMP Sequence Number #1	If Reason Code #1 = "MESH-PATH-ERROR-NO-FORWARDING-INFORMATION" and received value = 0, then HWMP SN for Destination Address #1 from the forwarding information after the increment of 14.10.10.4.3 step b) Otherwise, as received
Destination External Address #1	As received; this field is present if Bit 6 (AE subfield) of the Flags field #1 is 1; it is not present otherwise
Reason Code #1	As received
...	...

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14.10.11.4 PERR element processing

14.10.11.4.1 General

Received PERR elements are subject to certain acceptance criteria. Processing and actions taken depend on the contents of the PERR element and the information available to the receiving mesh STA. See also 14.10.8.

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14.10.11.4.2 Acceptance criteria

The PERR element shall be accepted (and shall be processed as described in 14.10.11.4.3) if the following applies:

- The mesh STA that receives the PERR element has forwarding information stored where
  - The destination is contained in the list of unreachable destinations of the PERR element, and
  - The next hop is the transmitter of the received PERR element.

Otherwise, the PERR element shall be discarded.

14.10.11.4.3 Effect of receipt

The following applies only to a PERR element that was accepted according to the acceptance criteria in 14.10.11.4.2:

a) The mesh STA creates a list of unreachable destinations consisting of those destinations from the received PERR element for which the next hop in the local active forwarding information is the transmitter of the PERR element. Step b) to step e) are applied to the destinations in this list.

b) If the Reason Code is "MESH-PATH-ERROR-NO-FORWARDING-INFORMATION" and the HWMP Sequence Number is 0, the receiving mesh STA increments the HWMP SN in the forwarding information of the listed unreachable destination by 1 and invalidates the forwarding information.

c) If the Reason Code is "MESH-PATH-ERROR-NO-FORWARDING-INFORMATION" and the HWMP Sequence Number is not 0 or the Reason Code is "MESH-PATH-ERROR-DESTINATION-UNREACHABLE" and the received HWMP SN for a listed unreachable destination is higher than the current HWMP SN in the forwarding information for that destination, the receiving mesh STA shall consider that destination unreachable and shall set the HWMP SN in the forwarding information to the HWMP SN received in the PERR element and shall invalidate the forwarding information associated with this unreachable destination.

d) If the Reason Code is "MESH-PATH-ERROR-NO-PROXY-INFORMATION," the receiving mesh STA shall consider the corresponding Destination External Address unreachable and shall invalidate the proxy information associated with this unreachable external destination (proxy mesh gate is the Destination Address of the PERR element, external MAC address is the Destination External Address of the PERR element, proxy information sequence number is the HWMP Sequence Number).

e) A PERR element is propagated according to the conditions defined in 14.10.11.3 Case D.

14.10.12 Root announcement (RANN) mechanism

14.10.12.1 General

Subclause 14.10.12 describes the function, generation, and processing of the RANN element.

14.10.12.2 Function

The RANN element, described in 9.4.2.111, is used for announcing the presence of a mesh STA configured as root mesh STA using the proactive RANN mechanism. RANN elements are sent out periodically by the root mesh STA.

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The RANN element propagates path metric information across the network so that each mesh STA can select a best metric path to the announced root mesh STA. This mechanism allows bidirectional trees to be built, using a robust procedure based on individually addressed frames initiated by the mesh STAs. This procedure makes the root mesh STA aware of all mesh STAs.

A receiving mesh STA shall propagate the RANN element as described in 14.10.12.3 Case B.

14.10.12.3 Conditions for generating and sending a RANN element

A mesh STA sends out a RANN element in an HWMP Mesh Path Selection frame, as defined in 9.6.16.3, in the following cases:

Case A: Original transmission

All of the following conditions apply:

— The mesh STA is configured as a root mesh STA using the proactive RANN mechanism [dot11MeshHWMProotMode = rann (4)].
— The root mesh STA sent its previous RANN element dot11MeshHWMPrannInterval TUs ago.

The contents of a RANN element in Case A shall be as shown in Table 14-26.

Table 14-26—Contents of a RANN element in Case A

Field	Value
Element ID	Value given in Table 9-92 for the RANN element
Length	21
Flags	Bit 0: set to 1 if dot11MeshGateAnnouncements is true; set to 0 otherwise Bit 1–7: Reserved
Hop Count	0
Element TTL	Maximum number of hops allowed for this element
Root Mesh STA Address	MAC address of the root mesh STA
HWMP Sequence Number	Last used HWMP SN of the root mesh STA + 1
Interval	dot11MeshHWMPrannInterval
Metric	Initial value of active path selection metric

Case B: Propagation

All of the following conditions apply:

— The mesh STA has valid forwarding information to a root mesh STA using the proactive RANN mechanism [dot11MeshHWMProotMode = rann (4)].
— The mesh STA sent its previous RANN element dot11MeshHWMPrannInterval TUs ago.
— dot11MeshForwarding is true.
— The Element TTL field is greater than 1; see 14.10.8.2.

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The contents of a RANN element in Case B shall be as shown in Table 14-27.

Table 14-27—Contents of a RANN element in Case B

Field	Value
Element ID	Value given in Table 9-92 for the RANN element
Length	As received
Flags	As received
Hop Count	As received + 1
Element TTL	As received – 1
Root Mesh STA Address	As received
HWMP Sequence Number	As received
Interval	As received
Metric	As received ⊕ own link metric toward the transmitting mesh STA

14.10.12.4 RANN element reception

14.10.12.4.1 General

Received RANN elements are subject to certain acceptance criteria. Processing and actions taken depend on the content of the RANN element and the forwarding information maintained by the receiving mesh STA. See also 14.10.8.

14.10.12.4.2 Acceptance criteria

The RANN element shall not be accepted (and shall not be processed as described in 14.10.12.4.3) if any of the following is true:

— The HWMP Sequence Number < previous HWMP SN from this originating root mesh STA
— (The HWMP Sequence Number = previous HWMP SN) AND (updated path metric is *worse than* previous path metric)

Otherwise, the RANN element shall be accepted.

14.10.12.4.3 Effect of receipt

The following applies only to a RANN element that was accepted according to the acceptance criteria in 14.10.12.4.2:

a) The receiving mesh STA shall set dot11MeshHWMPrannInterval to the value of the Interval field of the received RANN element.
b) The receiving mesh STA may initiate a PREQ element / PREP element exchange with the root mesh STA to set up or update a path to the root mesh STA. See 14.10.9.3 Case D.
c) The receiving mesh STA may record the Root Mesh STA Address, together with the HWMP Sequence Number, Hop Count, and Metric in order to assist in executing 14.10.9.3 Case D.

The receiving mesh STA shall transmit a RANN element if the conditions defined in 14.10.12.3 Case B are true.

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14.10.13 Considerations for support of STAs without mesh functionality

The verification, by the mesh STA collocated with the AP, of disjunct MAC addresses between a non-AP STA without mesh functionality and mesh STAs during authentication and association of the non-AP STA without mesh functionality (see 11.3.6) may be done by issuing a PREQ element for the MAC address of the non-AP STA without mesh functionality by the mesh STA collocated with the AP. The TO (Target Only) subfield of the Per Target Flags field of the PREQ element shall be set to 1.

The MAC address of the non-AP STA already exists in the MBSS if the AP with mesh functionality receives a PREP element for the MAC address of the non-AP STA and it can be derived from the PREP element that the requested MAC address is originated from a mesh STA. (The AE subfield of the Flags field of the PREP element is set to 0; see 9.4.2.113.)

14.11 Interworking with the DS or an attached bridge

14.11.1 Overview of interworking between a mesh BSS and a DS or an attached bridge

A mesh STA that has direct access to a DS is called a *mesh gate*. Other mesh STAs in an MBSS access the DS via the mesh gate. A GLK mesh STA accesses external networks through its attached bridge. An MBSS functions like an IEEE 802 LAN segment that is compatible with IEEE Std 802.1D. The MBSS appears as a single access domain.

An MBSS may contain two or more mesh gates and/or GLK mesh STAs. When multiple mesh gates and/or GLK mesh STAs in an MBSS have access to the same bridged network or DS, the MBSS has more than one "port" (in the sense of IEEE Std 802.1D-2004, for example) through which it accesses the DS or bridged network. This situation may lead to broadcast loops. Therefore, mesh gates should cooperate with the DS if present to implement a loop preventing protocol in the DS.

NOTE 1—Bridged networks already have a loop preventing protocol, such as Rapid Spanning Tree Protocol (RSTP) as specified in IEEE Std 802.1D-2004. With RSTP the resulting active DS or bridged network topology forms a tree. With such cooperation, even if multiple mesh gates and/or GLK mesh STAs connect with the same bridged network or DS, there will not be a loop.

A GLK mesh STA creates a virtual point-to-point LAN to each other GLK mesh STA in the MBSS. Each of these point-to-point LANs is presented by the GLK convergence function as a unique Internal Sublayer Service SAP that is mapped to an IEEE 802.1Q bridge port. Each such SAP is identified by a locally unique service_access_point_identifier, generated by the STA and the GLK convergence function (see 5.2.2).

When dot11MeshGateAnnouncements is true, the mesh gate announces its presence to other mesh STAs in the MBSS. The mesh gate uses the gate announcement protocol (see 14.11.2) or alternatively one of the HWMP proactive path selection methods with the Gate Announcement field equal to 1:

— The proactive PREQ mechanism (see 14.10.4.2), with the Gate Announcement field equal to 1 (see 14.10.9.3)
— The proactive RANN mechanism (see 14.10.4.3), with the Gate Announcement field equal to 1 (see 14.10.12.3)

When the mesh gate uses one of the HWMP proactive path selection methods, the gate announcement protocol is not used.

A mesh STA discovers the presence of a mesh gate with access to the external network by receiving GANN elements (or PREQ element and RANN element with the Gate Announcement field equal to 1 if using such mechanisms). Mesh STAs propagate these elements to neighbor mesh STAs in order to propagate the information throughout the MBSS.

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NOTE 2—The decision to set dot11MeshGateAnnouncements to true is beyond the scope of the standard. In general, the mesh gate announces that it has access to a broader network beyond the MBSS, using gate announcement protocol or HWMP proactive path selection methods with the Gate Announcement field equal to 1. One example of this configuration is that the mesh gate has access to a portal through the DS.

When a mesh gate has access to IEEE 802 STAs outside the mesh BSS (a mesh STA collocated with an AP, another mesh STA that belongs to another MBSS, etc.), the mesh gate acts as an intermediary for the IEEE 802 STAs outside the MBSS so that the forwarding information inside the MBSS only contains addresses that belong to the MBSS. The mesh gate acting as an intermediary for external STAs is termed proxy mesh gate. When the end station of an IEEE 802 communication is an external STA, mesh STAs handle addresses of the end-to-end IEEE 802 communication as depicted in Figure 9-81. Proxy mesh gate operation is described in 14.11.4.

14.11.2 Gate announcement (GANN)

14.11.2.1 General

Subclause 14.11.2 describes the function, generation, and processing of the GANN element.

14.11.2.2 Function

The GANN element, described in 9.4.2.110, is used to announce the presence of a mesh gate with dot11MeshGateAnnouncements equal to true in the mesh BSS. Gate announcements allow mesh STAs to discover such a mesh gate and, if necessary, to build a path toward it.

14.11.2.3 Conditions for generating and sending a GANN element

A mesh STA shall send a GANN element in a Gate Announcement frame, as defined in 9.6.16.4, in the following cases:

Case A: Original transmission

The mesh STA is a mesh gate not sending PREQ element or RANN element with the Gate Announcement field equal to 1 and dot11MeshGateAnnouncements is true. The mesh STA shall transmit the Gate Announcement frame at every dot11MeshGateAnnouncementInterval.

The content of a GANN element in Case A shall be as shown in Table 14-28.

Table 14-28—Contents of a GANN element in Case A

Field	Value
Element ID	Value given in Table 9-92 for the GANN element
Length	15
Flags	Reserved
Hop Count	0
Element TTL	Maximum number of hops allowed for the gate announcement
Mesh Gate Address	Mesh STA MAC address
GANN Sequence Number	Previous GANN sequence number + 1
Interval	dot11MeshGateAnnouncementInterval

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The mesh gate shall assign the GANN Sequence Number from a single modulo 2^{32} counter, starting at 0 and incrementing by 1 for each GANN element transmission.

Case B: Propagation

All of the following conditions are met:

— The mesh STA has received and accepted a gate announcement.
— The decremented Element TTL of the gate announcement is greater than or equal to 1.
— dot11MeshForwarding is true.

The content of a GANN element in Case B shall be as shown in Table 14-29.

Table 14-29—Contents of a GANN element in Case B

Field	Value
Element ID	Value given in Table 9-92 for the GANN element
Length	15
Flags	As received
Hop Count	As received + 1
Element TTL	As received – 1
Mesh Gate Address	As received
GANN Sequence Number	As received
Interval	As received

14.11.2.4 GANN element processing

14.11.2.4.1 General

A received gate announcement is subject to certain acceptance criteria. Processing depends on the contents of the gate announcement and the information available at the receiving mesh STA.

14.11.2.4.2 Acceptance criteria

The GANN element shall not be accepted (and shall not be processed as described in 14.11.2.4.3) if the GANN Sequence Number of the gate announcement is equal or lower than the GANN Sequence Number of the most recently accepted gate announcement with the same Mesh Gate Address.

14.11.2.4.3 Effect of receipt

The following applies only to a GANN element that was accepted according to the acceptance criteria in 14.11.2.4.2. The receiving mesh STA shall transmit a gate announcement as described in 14.11.2.3 Case B.

The Mesh Gate Address field of the GANN contains the address of the mesh gate, and may be stored for the purpose of determining paths to the mesh gates. Paths to mesh gates allow mesh STAs to forward MSDUs to addresses for which no path could be determined (see 10.38.8).

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14.11.3 Data forwarding at proxy mesh gates

14.11.3.1 General

Forwarding of MSDUs from the DS into the MBSS by a proxy mesh gate follows the procedures given in 10.38.2.

Forwarding of MSDUs from the MBSS into the DS by a proxy mesh gate follows the procedures that apply for the specific collocated network.

A proxy mesh gate learns the addresses of the other proxy mesh gates in the MBSS and of external addresses proxied by them through the receipt of path selection messages and messages carrying proxy information (for example, see 9.4.2.115).

14.11.3.2 Forwarding of MSDUs from the MBSS to the DS

On receipt of an individually addressed mesh Data frame from the MBSS with Address Extension Mode equal to "Address5&6" (see Table 9-26), a proxy mesh gate shall perform the following:

- If Address 5 is a known destination MAC address in the proxy information (external address) and proxied by the proxy mesh gate, the proxy mesh gate forwards the MSDU to the external address through the DS.
- If Address 5 is a known destination MAC address in the proxy information (external address) and proxied by a different proxy mesh gate, the MSDU is forwarded through the MBSS to the proxy mesh gate that proxies the external address. The MSDU is sent into the MBSS according to the procedures in 10.38.3.1 as an individually addressed mesh Data frame with Address 3 set to the MAC address of the proxy mesh gate of the proxy information proxying Address 5, Address 4 set to the MAC address of this proxy mesh gate, and Address 5 and Address 6 kept unchanged.
- If Address 5 is unknown to the proxy mesh gate, the mesh gate forwards the MSDU to the DS. The mesh gate may send an error notification to the mesh source of the MSDU. In HWMP, this is done by sending a PERR element as described in 14.10.11.3 Case C.

On receipt of group addressed mesh Data frame from the MBSS with Address Extension Mode equal to "Address4" (see Table 9-26), a proxy mesh gate shall forward the MSDU to the DS using a group addressed frame.

14.11.3.3 Forwarding of MSDUs from the DS to the MBSS

On receipt of an individually addressed MSDU from the DS, a proxy mesh gate shall perform the following depending on the possible destination:

a) If the destination of the MSDU is a mesh STA address that the mesh gate knows to be inside the MBSS, the mesh gate forwards the MSDU according to the procedures for frame addressing and data forwarding at source mesh STAs in an MBSS (10.38.3.1). The MSDU shall be transmitted using a frame with the four-address MAC header format [with the Address Extension Mode subfield in the Mesh Control field set to "Address5&6" (see Table 9-26)], where the Mesh Address Extension subfield in the Mesh Control field carries the addresses of the end stations, as specified in row "Mesh Data (proxied, individually addressed)" of Table 9-47. The address fields are set as follows:
   - Address 1: The address of the next-hop mesh STA (toward the destination mesh STA according to the forwarding information; see 10.38.2).
   - Address 2: The address of the proxy mesh gate.
   - Address 3: The address of the destination mesh STA.
   - Address 4: The address of the proxy mesh gate.

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— Address 5: The address of the destination end mesh STA that is the same as Address 3.
— Address 6: The address of the source end mesh STA that is the source address of the MSDU received from the DS.

b) If the destination of the MSDU is an external address that is proxied by another proxy mesh gate in the MBSS, the mesh gate forwards the MSDU according to the procedures for frame addressing and data forwarding at source mesh STAs in an MBSS (10.38.3.1). The MSDU shall be transmitted using a frame with the four-address MAC header format [with the Address Extension Mode subfield in the Mesh Control field set to "Address5&6" (see Table 9-26)], where the Mesh Address Extension subfield in the Mesh Control field carries the addresses of the end stations, as specified in row "Mesh Data (proxied, individually addressed)" of Table 9-47. The address fields are set as follows:
   — Address 1: The address of the next-hop mesh STA [toward the proxy mesh gate of the destination of the MSDU as derived from the proxy information (see 14.11.4.2) and according to the forwarding information; see 10.38.2].
   — Address 2: The address of this proxy mesh gate.
   — Address 3: The address of the proxy mesh gate of the destination of the MSDU as derived from the proxy information (see 14.11.4.2).
   — Address 4: The address of this proxy mesh gate.
   — Address 5: The address of the destination end mesh STA that is the destination address of the MSDU received from the DS.
   — Address 6: The address of the source end mesh STA that is the source address of the MSDU received from the DS.

c) If the MSDU has a destination address that is unknown to the mesh gate, the mesh gate forwards the MSDU to other known mesh gates in the MBSS as an individually addressed frame according to the procedures for frame addressing and data forwarding of individually addressed frames at source mesh STAs in an MBSS (10.38.3.1). The MSDU shall be transmitted using a frame with the four-address MAC header format [with the Address Extension Mode subfield in the Mesh Control field set to "Address5&6" (see Table 9-26)], where the Mesh Address Extension subfield in the Mesh Control field carries the addresses of the end stations, as specified in row "Mesh Data (proxied, individually addressed)" of Table 9-47. The address fields are set as follows:
   — Address 1: The address of the next-hop mesh STA (toward the other known mesh gate in the MBSS according to the forwarding information; see 10.38.2).
   — Address 2: The address of this proxy mesh gate.
   — Address 3: The address of the other known mesh gate in the MBSS.
   — Address 4: The address of this proxy mesh gate.
   — Address 5: The address of the destination end mesh STA that is the unknown destination address of the MSDU received from the DS.
   — Address 6: The address of the source end mesh STA that is the source address of the MSDU received from the DS.

Note that the procedure to determine that an address is unknown depends on the active path selection protocol. It might require an attempt to establish a path to the destination (see 14.8).

On receipt of a group addressed MSDU from the DS, the mesh gate forwards the MSDU according to the procedures for frame addressing and data forwarding of group addressed frames at source mesh STAs in an MBSS (10.38.4.1). The MSDU shall be transmitted using a frame with the three-address MAC header format [with the Address Extension Mode subfield in the Mesh Control field set to "Address4" (see Table 9-26)], where the Mesh Address Extension subfield in the Mesh Control field carries the address of

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the source end stations, as specified in row "Mesh Data (proxied, group addressed)" of Table 9-47. The address fields are set as follows:

— Address 1: The group address.
— Address 2: The address of the proxy mesh gate.
— Address 3: The address of the proxy mesh gate.
— Address 4: The address of the source external STA.

14.11.4 Proxy information and proxy update

14.11.4.1 General

Forwarding information of mesh STAs only contains addresses of mesh STAs that belong to the MBSS. However, the end station of the IEEE 802 communication may be an IEEE 802 station outside the MBSS, and such station is called *external STA*. Examples of external STAs are as follows:

— STAs that are associated with an AP that is collocated with a mesh STA
— STAs that are behind a mesh gate

Mesh STAs forward MSDUs to external STAs by treating MAC addresses of the external STAs as external addresses. The mesh STAs that are the destination mesh STAs of the messages destined to external STAs are called *proxy mesh gates*, and their MAC addresses are called *proxy addresses*.

NOTE—External STAs are reached using mesh services solely, i.e., they are not part of an MBSS. The mechanism by which the proxy mesh gate bridges the MBSS and the external STAs is beyond the scope of the standard. However, the standard describes the method by which mesh STAs use the external addresses that are discovered and bridged by the proxy mesh gate.

14.11.4.2 Proxy information

Proxy mesh gates and source mesh STAs of MSDUs destined to external STAs maintain proxy information. Proxy information contains the external address, the corresponding proxy address, the sequence number of the proxy information, and the corresponding proxy information lifetime.

Mesh STAs can learn the addresses of proxy mesh gates and of the external stations proxied by these proxy mesh gates through the receipt of proxy update messages or path selection messages carrying proxy information. Particularly, proxy information is updated in the following circumstances:

— A mesh STA receives and processes a proxy update (see 14.11.4.3).
— A mesh STA receives and processes an element of the active path selection protocol containing proxy information. In HWMP, these are PREQ elements (see 14.10.9.4.3), PREP elements (see 14.10.10.4.3), and PERR elements (see 14.10.11.4.3).

Additionally, proxy mesh gates may also proactively maintain proxy information on external STAs.

When the proxy information lifetime is specified, a mesh STA shall maintain the proxy information as valid information until the lifetime expires. Details of the lifetime are described in 14.11.4.3.4.

The sequence number of the proxy information and the proxy mesh gate address define a chronological order of the proxy information of an external STA at a specific proxy mesh gate.

When the proxy information is created at the proxy mesh gate, the proxy sequence number is initialized to an arbitrary value. The proxy information sequence number in the proxy information at the proxy mesh gate is incremented by 1 before the transmission of the proxy information to another mesh station. The proxy information sequence number shall be incremented if the proxy information is invalidated.

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If proxy information is transmitted in HWMP elements (PREQ, PREP, and PERR), the proxy information sequence number is set to the HWMP SN of the HWMP element containing this proxy information.

Comparison of the proxy information sequence numbers is performed using a circular modulo 2^{32} comparison.

Valid proxy information is used to determine and set Address 5 and Address 6 in individually addressed mesh Data frames, or Address 4 in group addressed mesh Data frames.

14.11.4.3 Proxy update (PXU)

14.11.4.3.1 General

Subclause 14.11.4.3 describes the function, generation, and processing of the PXU element.

14.11.4.3.2 Function

A mesh STA generates a PXU element to inform a destination mesh STA about proxy information of external addresses that are reachable through the proxy mesh gate specified in the PXU element.

NOTE—Typically, a proxy mesh gate generates and sends a PXU element to another proxy mesh gate in the MBSS or a mesh STA that originates traffic to the external stations proxied by the proxy mesh gate. However, the standard also allows other usage of the PXU element.

The PXU element is transmitted in a Proxy Update frame (an individually addressed frame). The Proxy Update frame may contain multiple PXU elements when needed (for instance, the proxy mesh gate has a large number of proxy information).

14.11.4.3.3 Conditions for generating and sending a PXU element

A proxy mesh gate may transmit a PXU when it adds, updates, or deletes an external address to (or from) its proxy information. A proxy mesh gate may also transmit a PXU at periodic intervals.

A mesh STA that holds proxy information of a proxy mesh gate in the MBSS may also transmit a PXU.

A mesh STA may retransmit the same PXU element repeatedly until the mesh STA receives a PXUC element from the destination mesh STA. See 14.11.4.4.

The content of a PXU element shall be as shown in Table 14-30.

The proxy mesh gate shall assign the PXU ID from a single modulo 256 counter, starting at 0 and incrementing by 1 for each PXU element.

Table 14-30—Contents of a PXU element

Field	Value/description
Element ID	Value given in Table 9-92 for the PXU element
Length	8 + length of N Proxy Information fields
PXU ID	Previous PXU ID + 1
PXU Originator MAC Address	MAC address of the originator of the PXU

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Table 14-30—Contents of a PXU element *(continued)*

Field		Value/description
Number of Proxy Information (N)		Number of proxy information reported to the destination mesh STA (N ≥ 1)
Per Proxy Information	Flags	Bit 0: 0: add proxy information; 1: delete proxy information Bit 1: 0: Proxy MAC Address field present; 1: Proxy MAC Address = PXU originator MAC address, Proxy MAC Address field not present Bit 2: 0: Proxy Information Lifetime field not present; 1: Proxy Information Lifetime field present; if Bit 0 is 1, Bit 1 shall be set to 0 Bit 3–7: Reserved
	External MAC Address	MAC address of the STA proxied by the proxy mesh gate
	Proxy Information Sequence Number	Proxy information sequence number of the proxy information after being incremented; see 14.11.4.2
	Proxy MAC Address	MAC address of the proxy mesh gate; this field is present if Bit 1 of the Flags field is 0; it is not present otherwise
	Proxy Information Lifetime	The proxy information lifetime of the proxy information as taken from the proxy information of the originator of the PXU

14.11.4.3.4 Effect of receipt of a PXU element

A mesh STA that receives the PXU element shall update its proxy information with the list of proxy information reported in the PXU under the following conditions:

— Proxy information for the external MAC address and the proxy mesh gate reported in the Proxy Information field of the PXU does not exist at the mesh STA.

— Proxy information for the external MAC address and the proxy mesh gate reported in the Proxy Information field of the PXU does exist at the mesh STA and the value of the Proxy Information Sequence Number subfield in the received PXU is larger than the value of the proxy information sequence number in the proxy information at the mesh STA.

When multiple PXU elements are contained in the received Proxy Update frame, the recipient mesh STA shall process all of the PXU elements in the frame.

The MAC address of the proxy mesh gate is taken from the Proxy MAC Address subfield in the Proxy Information field when bit 1 in the Flags subfield is equal to 0, and from the PXU Originator MAC Address field in the PXU element when bit 1 in the Flags subfield is equal to 1.

The MAC address of the external STA is taken from the External MAC Address subfield of the corresponding Proxy Information field in the received PXU element.

The sequence number of the proxy information is taken from the Proxy Information Sequence Number subfield of the corresponding Proxy Information field in the received PXU element.

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If the Proxy Information Lifetime subfield is present (the Lifetime subfield in the Flags subfield is 1) and there is already proxy information stored for the proxy mesh gate and external address reported in the proxy information of the PXU element, the mesh STA shall set the proxy lifetime to the larger one of the proxy lifetime reported by the PXU and the stored proxy information.

If the Proxy Information Lifetime subfield is present (bit 2 of the Flags subfield is 1) and there is proxy information stored for the proxy mesh gate and external address reported in the proxy information of the PXU element, the mesh STA shall set the proxy information lifetime to the value in the Proxy Information Lifetime subfield.

If the Proxy Information Lifetime subfield is not present, the lifetime of the proxy information is the same as the lifetime of the path to the proxy address. Alternatively, the lifetime of the proxy information may be set to a value representing infinity.

The destination mesh STA that received the PXU shall send a PXUC element to the originator mesh STA of the PXU as described in 14.11.4.4.3.

14.11.4.4 Proxy update confirmation (PXUC)

14.11.4.4.1 General

Subclause 14.11.4.4 describes the function, generation, and processing of the PXUC element.

14.11.4.4.2 Function

A PXUC element is generated by the destination mesh STA of a PXU to inform the sender of the PXU that the PXU has been properly received.

The PXUC element is transmitted in a Proxy Update Confirmation frame (an individually addressed frame). The Proxy Update Confirmation frame may contain multiple PXUC elements in order to confirm the reception of multiple PXU elements to the destination of the Proxy Update Confirmation frame.

14.11.4.4.3 Conditions for generating and sending a PXUC element

The destination mesh STA of a Proxy Update frame containing a PXU element shall send a PXUC element to the originator mesh STA of the PXU element.

The content of a PXUC element shall be as shown in Table 14-31.

Table 14-31—Contents of a PXUC element

Field	Value/description
Element ID	Value given in Table 9-92 for the PXUC element
Length	7
PXU ID	PXU ID of the PXU that is being confirmed
Destination mesh STA Address	MAC address of the originator of the PXUC

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14.11.4.4.4 Effect of receipt of PXUC element

If a mesh STA receives a PXUC element in a PXUC frame in response to a PXU element it originated, the mesh STA shall no longer send any PXUs with the same PXU ID as given in the received PXUC element.

14.11.5 Mesh STA collocation

A mesh STA collocated with another STA shall use a MAC address that is different from the one used by the collocated STA. This precludes ambiguities relating to the presence of the Mesh Control field in the Frame Body (see 9.2.4.7), GTK use (see 12.6.1.1.10), and proxy information (see 14.11.4.2).

Path selection with collocated mesh STAs using HWMP is described in 14.10.5.

14.12 Intra-mesh congestion control

14.12.1 General

Intra-mesh congestion control is based on the following three main mechanisms:

a) Local congestion monitoring and congestion detection
b) Congestion control signaling
c) Local rate control

A mesh STA shall activate a congestion control protocol specified by dot11MeshActiveCongestionControlMode. At any given time, there is only one congestion control protocol active in a particular MBSS, signaled in the Congestion Control Mode Identifier field of the Mesh Configuration element. This standard specifies the congestion control signaling protocol that shall be available in any MBSS with an activated congestion control.

NOTE—This standard allows for inclusion of more advanced or alternative congestion control schemes through the Congestion Control Mode Identifier in the Mesh Configuration element.

14.12.2 Congestion control signaling protocol

When dot11MeshActiveCongestionControlMode is congestionControlSignaling (1), the mesh STA activates the congestion control signaling protocol. The congestion control signaling protocol specifies the signaling messages used with intra-mesh congestion control. Specific algorithms for local congestion monitoring and congestion detection are beyond the scope of the congestion control signaling protocol.

The congestion control signaling protocol is triggered after congestion is detected at a mesh STA. A mesh STA that detects congestion, and the traffic destination causing this congestion, may transmit a Congestion Control Notification frame to the mesh STAs of the traffic source and other neighboring mesh STAs. The frame contains one or more Congestion Notification elements, each of which specifies the traffic destination causing the congestion and the expected duration of the congestion per AC per mesh destination as estimated by the congested mesh STA.

Upon receipt of a Congestion Notification frame a mesh STA may stop forwarding, or reduce the rate of forwarding, traffic to the destinations listed in the Congestion Notification elements via the mesh STA reporting congestion for the duration specified in the Congestion Notification element. It may also send its own Congestion Control Notification frame to mesh STAs that are the source of the reported congestion, and other neighboring mesh STAs. Any time difference between receipt of the original Congestion Control

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Notification frame and the transmission of this new Congestion Control Notification frame should be reflected in the duration indicated in the new congestion control notification in such a way that any timers set by mesh STAs in response to the first report of congestion for a given destination all expire at the same time.

If the Destination MAC Address field in a received Congestion Notification element is the group address, it should be interpreted to mean that communication with the transmitter of this frame should be stopped, or reduced, for the duration specified in the Congestion Notification element. This event should not result in the transmission of a Congestion Notification element with a Destination MAC Address field set to the group address to any neighbor mesh STAs.

When the duration of a traffic congestion report has expired, a mesh STA should resume forwarding traffic to the destinations that were listed in the traffic congestion report via the mesh STA that reported congestion.

NOTE 1—Local policies/mechanisms implemented in a mesh STA might be required to achieve timely transmission of the congestion control signaling messages and to avoid transmission of stale messages that might reduce network efficiency.

NOTE 2—A mesh STA that receives a Congestion Control Notification frame might choose to adjust its frame rate, defined by the number of transmitted frames per a unit of time, to the sender of the Congestion Control Notification frame in the identified congested AC(s) for the duration specified in the Congestion Notification element. The reduction of the frame rate to a congested mesh STA avoids waste of the mesh resources for transmission of frames that with high probability will not be handled/forwarded by the congested mesh STA.

14.13 Synchronization and beaconing in MBSSs

14.13.1 TSF for MBSSs

A mesh STA shall initialize and update its TSF timer according to the MBSS's active synchronization method. Each mesh STA shall maintain a TSF timer as described in 11.1.3.1, and comply with the TSF timer accuracy as described in 11.1.3.9.

14.13.2 Extensible synchronization framework

14.13.2.1 General

This standard introduces an extensible framework to enable the implementation of multiple synchronization methods for mesh STAs. Within the extensible synchronization framework, the neighbor offset synchronization method is defined as the default mandatory synchronization method in order to enable minimal synchronization capabilities and interoperability between mesh STAs that use MCCA, MBCA, or operate in light or deep sleep mode. The framework allows the integration of other synchronization methods into MBSSs. A vendor may implement any synchronization method using this framework to meet special application needs. Although a mesh STA may include multiple implementations of synchronization methods, only one synchronization method at a time shall be used by a mesh STA. All mesh STAs in an MBSS use the same synchronization method; see 14.2.7 item a). The MBSS's active synchronization method is controlled by the SME and given to the MLME by dot11MeshActiveSynchronizationMethod.

A mesh STA shall announce the MBSS's active synchronization method using the Synchronization Method Identifier field in the Mesh Configuration element in their Beacon and Probe Response frames.

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14.13.2.2 Neighbor offset synchronization method

14.13.2.2.1 General

When dot11MeshActiveSynchronizationMethod is neighborOffsetSynchronization (1), the mesh STA shall use the neighbor offset synchronization method as its active synchronization method, and maintain the timing offset value between its own TSF timer and the TSF timer of each neighbor STA with which it synchronizes. The mesh STA shall set the Synchronization Method Identifier field in the Mesh Configuration element to 1.

The mesh STA shall maintain synchronization with all of its neighbor peer mesh STAs up to dot11MeshNbrOffsetMaxNeighbor mesh STAs. The mesh STA should maintain synchronization with additional neighbor mesh STAs that are in the same MBSS up to a total of dot11MeshNbrOffsetMaxNeighbor mesh STAs and also, additional neighbor mesh STAs that are outside of the MBSS up to a total of dot11MeshNbrOffsetMaxNeighbor mesh STAs.

Upon receipt of an MLME-MESHNEIGHBOROFFSETSYNCSTART.request primitive, the MLME shall start synchronization using the neighbor offset synchronization method with the specified peer STA. Upon receipt of an MLME-MESHNEIGHBOROFFSETSYNCSTOP.request primitive, the MLME shall stop synchronization using the neighbor offset synchronization method with the specified peer STA.

A mesh STA that utilizes the neighbor offset synchronization method may start its TSF timer independently of other mesh STAs. The mesh STA shall calculate the timing offset value with respect to the neighbor STA with which it maintains synchronization, as described in 14.13.2.2.2. The mesh STA shall adjust its TSF timer based on time stamps received in Beacon or Probe Response frames from neighbor STAs with which it maintains synchronization, as described in 14.13.2.2.3.

When the mesh STA alternates awake state and doze state, it might not always listen to the Beacon frames of a neighbor mesh STA with which it maintains synchronization. However, it shall comply with the clock drift compensation procedures and TSF jitter allowance as described in 14.13.2.2.3. See S.3.6 for more guidelines.

14.13.2.2.2 Timing offset calculation

When dot11MeshActiveSynchronizationMethod is neighborOffsetSynchronization (1), the mesh STA shall calculate the timing offset value with respect to the neighbor STA with which it maintains synchronization. The calculation of the timing offset value is based on time stamps from the received Beacon and Probe Response frames as follows:

$$T_{offset} = T_t - T_r$$

where

T_{offset} is the timing offset value
T_t is the value in the Timestamp field in the received frame
T_r is the frame reception time measured in the TSF timer of the mesh STA

The offset value is represented as a signed integer. The unit of the offset value is μs. The mesh STA shall keep the T_{offset} value calculated from the latest Beacon or Probe Response frame received from each neighbor STA with which it maintains synchronization.

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A mesh STA may translate the time measured in the TSF of the neighbor STA into the time base of its own TSF as follows:

$$T_{self} = T_{neighbor} - T_{offset}$$

where

T_{self} is the translated time in its own TSF

$T_{neighbor}$ is the time measured in the TSF timer of the neighbor STA

Upon receipt of an MLME-MESHNEIGHBOROFFSETCALCULATE.request primitive, the MLME shall receive a Beacon or Probe Response frame from the specified neighbor STA, calculate the T_{offset} from the received frame, and report the calculated T_{offset} to the SME by responding with an MLME-MESHNEIGHBOROFFSETCALCULATE.confirm primitive. T_{offset} is used to provide the timing reference of neighbor STAs.

14.13.2.2.3 Clock drift adjustment

When dot11MeshActiveSynchronizationMethod is neighborOffsetSynchronization (1), the mesh STA shall examine the reception time of the Beacon frames from neighbor STAs with which it maintains synchronization and adjust its TSF timer to compensate the relative timing error among neighbor mesh STAs caused by the clock drift. The mesh STA adjusts its TSF so that its TSF counting is aligned to the most delayed neighbor STA.

When the mesh STA receives a Beacon frame or a Probe Response frame from one of the neighbor STAs with which it maintains synchronization, the mesh STA shall perform the following measurement procedure:

a) The mesh STA checks if the transmitter of the Beacon frame or Probe Response frame is in the process of the TBTT adjustment (see 14.13.4.4.3). If the received frame contains the Mesh Configuration element and the TBTT Adjusting subfield in the Mesh Configuration field is 1, the mesh STA shall invalidate the T_{offset} value for this neighbor STA and shall not perform the following steps.

b) The mesh STA checks if it has a valid T_{offset} value obtained from the previous Beacon or Probe Response frame reception from the transmitter of the received frame. If it does not have the valid T_{offset} value, it shall not perform the following steps.

c) The mesh STA calculates the clock drift amount $T_{ClockDrift}$ by comparing the $T_{offset,p}$,the offset value obtained previously for this neighbor STA, and the $T_{offset,c}$, the offset value obtained from the current frame reception.

$$T_{ClockDrift} = T_{offset,\,p} - T_{offset,\,c}$$

where

$T_{ClockDrift}$ is the clock drift amount in µs represented as a signed integer.

d) The mesh STA shall compare the $T_{ClockDrift}$ value with the $T_{MaxClockDrift}$, the largest $T_{ClockDrift}$ value obtained from other neighbor STA within this beacon period. If the $T_{ClockDrift}$ value for this neighbor STA is greater than the $T_{MaxClockDrift}$ value, the mesh STA replaces the $T_{MaxClockDrift}$ value with the $T_{ClockDrift}$ value, in order to determine the largest $T_{ClockDrift}$ value among neighbor STAs.

When the previous $T_{ClockDrift}$ values have been stable for a neighbor mesh STA, the mesh STA may substitute the previous $T_{ClockDrift}$ value for the $T_{ClockDrift}$ value in the measurement procedure and process the step d), at the time of a TBTT of the neighbor STA, without receiving a Beacon frame.

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Before the mesh STA transmits a Beacon frame, it shall perform the following adjustment procedure:

— The mesh STA checks if the current $T_{MaxClockDrift}$ value is greater than zero. If the $T_{MaxClockDrift}$ value is greater than zero, it shall continue the following steps. Otherwise, it shall initialize the $T_{MaxClockDrift}$ with zero and shall not perform the following step.

— If the $T_{MaxClockDrift}$ value is smaller than 0.04% of its beacon interval, the mesh STA shall adjust its TSF timer so that the next TBTT will be delayed for the duration of the $T_{MaxClockDrift}$ and initialize the $T_{MaxClockDrift}$ value with zero. Otherwise, it shall adjust its TSF timer so that the next TBTT will be delayed for the duration of 0.04% of its beacon interval and subtract the value of 0.04% of its beacon interval from the $T_{MaxClockDrift}$.

The mesh STA may adjust its TSF timer only to slow the counting. The mesh STA may adjust its TSF timer within the range of 0.04% in a beacon period.

When the delay amount at each beacon period is not stable, the mesh STA should frequently listen to neighbor STAs' Beacon frames. An implementation might reduce TSF timer jitter caused by the adjustment procedure by making additional adjustments to the $T_{MaxClockDrift}$, as long as the mesh STA's TSF count is aligned to the most delayed neighbor mesh STA. The means of making these additional adjustments is beyond the scope of this standard.

NOTE—This clock drift compensation procedure does not intend to maintain a strict synchronization. It aims to stop TBTT drifting away among neighbor mesh STAs, allowing some jitter of TSF timer.

14.13.3 Beaconing

14.13.3.1 Beacon generation in MBSSs

A mesh STA transmits Beacon frames that are specific to an MBSS. Beacon frames for MBSS, infrastructure BSS, or IBSS are differentiated by the Capability Information field in the Beacon frame as specified in 9.4.1.4. A mesh STA that collocates with an AP generates Beacon frames for the MBSS independently of the AP.

The mesh STA shall define a series of TBTTs exactly dot11BeaconPeriod TUs apart. Time zero is defined to be a TBTT with the Beacon frame containing a DTIM. At each TBTT, the mesh STA shall schedule a Beacon frame as the next frame for transmission according to the medium access rules specified in Clause 10. The Address 1 field of the Beacon frame shall be set to the broadcast address.

NOTE—To achieve this requirement, the mesh STA suspends any pending transmissions until the beacon has been transmitted. In the case of a DTIM, the mesh STA also suspends any pending individually addressed transmissions until any pending group addressed transmissions have been performed (see 14.14.5).

The beacon period is included in Beacon and Probe Response frames.

The mesh STA shall start beaconing upon the receipt of the MLME-START.request primitive.

14.13.3.2 Beacon reception for mesh STA

A mesh STA shall use information from the Timestamp field without regard to the BSSID or Mesh ID in order to obtain information necessary for synchronization, if the mesh STA maintains synchronization with the transmitter of the Beacon frame. A mesh STA may use information from the Beacon Interval field and the Beacon Timing element without regard for the Mesh ID in order to obtain information necessary for MBCA, if the mesh STA maintains synchronization with the transmitter of the Beacon frame and dot11MBCAActivated is true. A mesh STA may use information from the MCCAOP Advertisement Overview element and MCCAOP Advertisement element without regard for the Mesh ID in order to obtain

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information necessary for MCCA, if the mesh STA maintains synchronization with the transmitter of the Beacon frame and dot11MCCAActivated is true.

A mesh STA in a mesh BSS shall use information in the Timestamp field, the Beacon Interval field, the Beacon Timing element, the MCCAOP Advertisement Overview element, or the MCCAOP Advertisement element in received Beacon frames only if the mesh STA maintains a mesh peering with the transmitter of the Beacon frame.

14.13.4 Mesh beacon collision avoidance (MBCA)

14.13.4.1 Overview

Mesh STAs use the mesh beacon collision avoidance (MBCA) protocol to detect and mitigate collisions among Beacon frames transmitted by other STAs (including mesh STAs, IBSS APs, and IBSS STAs) on the same channel within the range of 2 hops. MBCA mitigates hidden node problems with respect to Beacon frames.

NOTE—Beacon frames are transmitted without acknowledgment and might collide with other frames. In a mesh BSS, multiple STAs transmit Beacon frames periodically, and mesh STAs might be located out of range of each other. This implies that Beacon frames might suffer from the so-called hidden node problem and might not be received by neighbor STAs. Once Beacon frames from hidden STAs start to collide, Beacon frames keep on colliding if these hidden STAs transmit Beacon frames at the same beacon interval that is a typical operation. MBCA provides a set of rules to mitigate this problem.

When dot11MBCAActivated is true, the mesh STA shall set the MBCA Enabled subfield in the Mesh Capability field of the Mesh Configuration element to 1.

MBCA is composed of beacon timing advertisements, TBTT selection, and TBTT adjustment. When dot11MBCAActivated is true, the mesh STA advertises the TBTT and beacon interval of its neighbor STAs through the Beacon Timing element as described in 14.13.4.2. Upon reception of the Beacon Timing element, the mesh STA obtains the beacon timing information of its neighbor mesh STAs and uses this information for its TBTT selection and TBTT adjustment as described in 14.13.4.3 and 14.13.4.4. The mesh STA may also perform additional procedures described in 14.13.4.5 and 14.13.4.6.

When dot11MBCAActivated is true, the mesh STA that alternates awake state and doze state should listen to Beacon frames from its neighbor STAs, with which it maintains synchronization, often, in order to advertise and obtain the recent TBTT information.

14.13.4.2 Beacon timing advertisement

14.13.4.2.1 General

When dot11MBCAActivated is true, the mesh STA shall contain Beacon Timing element in Beacon and Probe Response frames in order to advertise its beacon timing information. The mesh STA calculates the TBTT of its neighbor STAs with which it maintains synchronization as described in 14.13.4.2.2, and composes beacon timing information as described in 14.13.4.2.3. The mesh STA collects the beacon timing information from each neighbor STA with which it maintains synchronization. The collection of the beacon timing information is termed “beacon timing information set.” The mesh STA contains whole or part of the beacon timing information set in the Beacon Timing element as described in 14.13.4.2.5. The mesh STA also maintains the status number of the beacon timing information set and contains the status number in the Beacon Timing element as described in 14.13.4.2.4. The receiver of the Beacon Timing element uses the received beacon timing information as described in 14.13.4.2.6.

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14.13.4.2.2 Calculation of neighbor STA's TBTT

When a Beacon frame is received from one of its neighbor STAs with which the mesh STA maintains synchronization, the mesh STA shall calculate the TBTT of the received Beacon frame as follows:

$$T_{TBTT} = T_r - (T_t \bmod (T_{BeaconInterval} \times 1024))$$

where

T_{TBTT}	is the calculated TBTT
T_r	is the frame reception time measured in the TSF timer of the receiving mesh STA
T_t	is the value in the Timestamp field in the received frame
$T_{BeaconInterval}$	is the value in the Beacon Interval field in the received frame

The T_{TBTT} is used as described in 14.13.4.2.3.

Further, the mesh STA shall calculate the time difference between the TBTT of the received Beacon frame and the time predicted from the past TBTT as follows:

$$T_{Delta} = | T_{TBTT,\,c} - (T_{TBTT,\,p} + (T_{BeaconInterval} \times N_{Count})) |$$

where

T_{Delta}	is the time difference
$T_{TBTT,\,c}$	is the TBTT calculated from the received Beacon frame
$T_{TBTT,\,p}$	is the TBTT calculated for the first time after the latest status number update (see 14.13.4.2.4)
$T_{BeaconInterval}$	is the value in the Beacon Interval field in the received Beacon frame
N_{Count}	is the number of TBTTs since $T_{TBTT,\,p}$ has been calculated

T_{Delta} is used to maintain the status number described in 14.13.4.2.4.

14.13.4.2.3 Beacon timing information

The mesh STA shall keep the latest T_{TBTT} together with the beacon interval contained in the received frame and the identifier of the neighbor STA as the beacon timing information with respect to the neighbor STA. When the elapsed time since the latest Beacon frame reception is smaller than 524 288 TU, the beacon timing information is valid.

NOTE—The beacon timing information provides the time reference for a series of the TBTTs of the corresponding STA. Using the beacon timing information, a mesh STA is able to predict future TBTTs by adding the reported beacon interval to the reported TBTT.

The mesh STA shall collect the valid beacon timing information from each neighbor STA with which it maintains synchronization and keep the collection as the beacon timing information set. The beacon timing information set is advertised to its neighbor mesh STAs through the Beacon Timing element as described in 14.13.4.2.5.

When the amount of neighbors, for which valid beacon timing information is kept, is large, the beacon timing information set may be divided into multiple tuples of beacon timing information. In such case, a tuple of beacon timing information is included in the Beacon Timing element (see 14.13.4.2.5).

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14.13.4.2.4 Maintenance of the status number

The mesh STA shall maintain the status number of the beacon timing information set. The status number is set to a value from a single modulo 16 counter, starting at 0 and incrementing by 1 for each transmission of a frame containing the Beacon Timing element after the mesh STA encountered any of the following events:

a) It starts or stops maintaining synchronization with a neighbor STA.

b) It receives a Beacon frame from a neighbor STA with which it maintains synchronization and the calculated T_{Delta} (see 14.13.4.2.2) is larger than 255 µs.

c) It completes the TBTT adjustment procedure described in 14.13.4.4.3.

The mesh STA shall set the Status Number subfield in the Report Control field in the Beacon Timing element to the status number. The Status Number subfield in the Report Control field facilitates the detection of the changes in the beacon timing information set.

14.13.4.2.5 Transmitter's procedure

When dot11MBCAActivated is true, the mesh STA shall report the TBTT and beacon interval of its neighbor STAs through the Beacon Timing element as described in this subclause.

The Beacon Timing element reports on timing information of the Beacon frames that are received from the neighbor STAs with which the mesh STA maintains synchronization on the operating channel. The mesh STA shall include the Beacon Timing element in Probe Response frames and in TBTT Adjustment Request frames. The mesh STA shall also include the Beacon Timing element in Beacon frames as specified by dot11MeshBeaconTimingReportInterval and dot11MeshBeaconTimingReportMaxNum. The Beacon Timing element is present in a Beacon frame when the DTIM Count value in the Beacon frame is zero or equal to an integer multiple of dot11MeshBeaconTimingReportInterval.

The maximum number of Beacon Timing Information fields contained in a Beacon Timing element is limited to dot11MeshBeaconTimingReportMaxNum for Beacon frames, or is limited by the maximum element size for other frames. When the number of neighbors, for which valid beacon timing information is kept, is equal or smaller than the limit, the mesh STA shall include all the beacon timing information in a single Beacon Timing element, setting both Beacon Timing Element Number and More Beacon Timing Elements subfield in the Report Control field to 0. When the number of neighbors, for which valid beacon timing information is kept, exceeds the limit, the mesh STA shall divide the beacon timing information set into multiple tuples and assign each tuple with an index number starting from 0. When the beacon timing information set is divided, the mesh STA shall include the successive tuples of beacon timing information in the Beacon Timing elements. In this case, the mesh STA shall set the Beacon Timing Element Number subfield in the Report Control field to the index number of the tuple. The mesh STA shall set the More Beacon Timing Elements subfield in the Report Control field to 1 when it has one or more beacon timing information tuples with a larger index number. The mesh STA shall divide the beacon timing information set into no more than N_{info} tuples, where

$N_{info} = \lceil N_v / N_{max} \rceil$

N_v is the number of valid beacon timing information fields

N_{max} is the maximum number of Beacon Timing Information fields in the Beacon Timing element

The mesh STA may update the combination of the tuples only when the status number described in 14.13.4.2.4 is updated. The mesh STA shall include newly updated beacon timing information (i.e., beacon timing information that causes an update of the status number as described in 14.13.4.2.4) in the tuple with a smaller index number. When the status number is updated, the mesh STA shall include the tuple of beacon timing information indexed as 0 in the Beacon Timing element in the subsequent Beacon frame. Successive tuples shall be transmitted in ascending order of the index number in the successive Beacon frames.

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NOTE—The standard does not impose mesh STAs to advertise a fragmented beacon timing information set sequentially in its Beacon frames at all times. This implies that the mesh STA might advertise tuples with a smaller index number more frequently, which is useful to notify new beacon timing information efficiently.

When the mesh STA receives a Probe Request frame containing a Beacon Timing element ID in its Request element, it shall respond with a Probe Response frame containing the Beacon Timing element. If all beacon timing information cannot be contained in a Beacon Timing element, the mesh STA shall include multiple Beacon Timing elements containing successive tuples of beacon timing information in the order of the Request element (see Table 9-39) so that all tuples are transmitted.

14.13.4.2.6 Receiver's procedure

A mesh STA with dot11MBCAActivated equal to true that receives a Beacon Timing element obtains the beacon timing information of its neighbor mesh STA and uses it for its TBTT selection and TBTT adjustment as described in 14.13.4.3 and 14.13.4.4.

When a mesh STA receives a Beacon frame with a Beacon Timing element that contains only a subset of the beacon timing information set, the mesh STA may transmit a Probe Request frame containing a Beacon Timing element ID in its Request element to the transmitter of the Beacon Timing element, in order to request the rest of the beacon timing information.

NOTE 1—The Report Control field in the Beacon Timing element facilitates the detection of the missing beacon timing information.

NOTE 2—Once the entire beacon timing information set with a particular Status Number is obtained, the mesh STA does not need to retrieve beacon timing information as long as the Status Number remains the same.

A mesh STA that receives the Beacon Timing element shall record the reported TBTT and its successive TBTTs as neighbor's essential beacon reception timing if the MSB of the Neighbor STA ID field in the corresponding Beacon Timing Information field is 0. The essential beacon reception timing is used to control the transmission of frames as described in 14.13.4.5.

A mesh STA can also check if its neighbor mesh STAs received its Beacon frame successfully by checking whether the Beacon Timing elements received from its neighbor mesh STAs contain beacon timing information of the mesh STA. When the Beacon Timing element is received from one of the peer mesh STAs, the mesh STA checks if the MSB of the Neighbor STA ID subfield is set to 0 and the rest of the field matches with the 7 LSBs of the AID value assigned to the mesh STA through the mesh peering establishment. When the Beacon Timing element is received from a nonpeer mesh STA, the mesh STA checks if the MSB of the Neighbor STA ID subfield is set to 1 and the rest of the field matches with MAC_ADDR[42:47] of its own MAC address. If the matching is verified, the corresponding beacon timing information represents the correct beacon reception by the neighbor mesh STA.

If a Beacon frame is received from a neighbor peer mesh STA that is either in active mode or in light sleep mode, the Beacon Timing element is present in the frame, and all beacon timing information is contained in the Beacon Timing element, the mesh STA shall verify whether the neighbor peer mesh STA received its Beacon frame. If the Beacon Timing element does not contain beacon timing information of the mesh STA or the Neighbor TBTT subfield of the corresponding beacon timing information does not reflect the recent TBTT of the mesh STA, the mesh STA considers the previous Beacon frame was not received by the neighbor peer mesh STA.

14.13.4.3 TBTT selection

When dot11MBCAActivated is true, the mesh STA performs the TBTT selection described herein before it starts beaconing (see 14.2.8). The mesh STA selects its TBTTs and its beacon interval so that its Beacon frames do not collide with Beacon frames transmitted by other STAs in its 2 hop range.

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Before the mesh STA starts beaconing, it performs scanning and discovered neighbor STAs are reported through an MLME-SCAN.confirm primitive (see 14.2.6). Using TimeStamp, Local Time, and Beacon Period in the BSSDescriptionSet parameter provided by the MLME-SCAN.confirm primitive, the mesh STA shall obtain the TBTT and beacon interval of its neighbor STAs operating on the same channel as the mesh STA starts to operate. The mesh STA shall also collect the beacon timing information contained in the Beacon Timing elements received on the channel through Beacon Timing in the BSSDescriptionSet parameter provided by the MLME-SCAN.confirm primitive, in order to obtain the TBTT and beacon interval of STAs in 2 hop range. After obtaining this information, the mesh STA shall look for a timing of its beacon transmissions so that its Beacon frames are likely not to collide with Beacon frames transmitted by other STAs in its 2 hop range. The mesh STA shall update its TSF timer and select its beacon interval to set its TBTTs to the appropriate timing, and then it shall start beaconing using the MLME-START.request primitive.

14.13.4.4 TBTT adjustment

14.13.4.4.1 Self-determined TBTT adjustment

When dot11MBCAActivated is true, the mesh STA checks if it does not transmit Beacon frames during the beacon transmissions of other STAs within its 2 hop range using the Beacon Timing element received from its neighbor peer mesh STA.

When the mesh STA discovers that its Beacon frames repeatedly collide with the Beacon frames of a neighbor or a neighbor's neighbor and its TBTT comes later than the TBTT of the colliding STA at the time of collision, it shall perform the TBTT scanning procedure described in 14.13.4.4.3. If the mesh STA finds an alternative TBTT, it shall start the TBTT adjustment procedure as described in 14.13.4.4.3.

14.13.4.4.2 Requested TBTT adjustment

When a mesh STA discovers that Beacon frames from two or more neighbor STAs are colliding repeatedly or a series of TBTTs are close enough to trigger frequent beacon collisions, the mesh STA may transmit a TBTT Adjustment Request frame to the neighbor mesh STA of which the TBTT comes last at a particular collision timing in order to request this neighbor mesh STA to adjust its TBTT. The TBTT Adjustment Request frame may be transmitted only if the following conditions hold:

— The recipient of the TBTT Adjustment Request frame is a peer mesh STA and has set the MBCA Enabled subfield in the Mesh Capability field of the Mesh Configuration element to 1.

— The other colliding STA does not include the Mesh Configuration element in its Beacon frames or the TBTT Adjusting field in the Mesh Configuration element is 0.

When dot11MBCAActivated is true, the mesh STA that receives a TBTT Adjustment Request frame shall perform the TBTT scanning procedure described in 14.13.4.4.3, and determine if it can find an appropriate alternative timing for its TBTTs. After the completion of the TBTT scanning procedure, the mesh STA that receives the TBTT Adjustment Request frame shall respond with a TBTT Adjustment Response frame containing the result of the TBTT scanning in the Status Code field. If the mesh STA finds an alternative TBTT, it shall agree with the request. If it agrees with the request, the Status Code field is set to SUCCESS in the TBTT Adjustment Response frame, and it shall complete the TBTT adjustment procedure described in 14.13.4.4.3. If it does not agree with the request, it shall indicate the reason in the Status Code field in the TBTT Adjustment Response frame. A mesh STA may set the Status Code to either SUCCESS, REFUSED_REASON_UNSPECIFIED, or CANNOT_FIND_ALTERNATIVE_TBTT in the TBTT Adjustment Response frame.

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14.13.4.4.3 TBTT scanning and adjustment procedures

When a mesh STA is in need of TBTT adjustment, it tries to find an alternative TBTT first. The mesh STA shall perform the TBTT scanning procedure as follows:

— The mesh STA checks if its beacon timing information and collected neighbor's beacon timing information are sufficiently new. If the mesh STA did not receive a Beacon frame from a neighbor STA with which it maintains synchronization at the latest TBTT, it shall receive a Beacon or Probe Response frame from the neighbor STA and obtain the TBTT of the neighbor STA and the beacon timing information contained in the Beacon Timing element.

NOTE 1—This is particularly important if the mesh STA is in deep sleep mode for a neighbor peer mesh STA.

— Using the latest TBTT of its neighbor STAs and the latest beacon timing information of neighbor mesh STAs, the mesh STA shall look for an alternative TBTT that does not cause beacon collision among the STAs in its 2 hop range.

If an alternative TBTT is not available, the mesh STA terminates the procedure. If an alternative TBTT is available, the mesh STA shall start the TBTT adjustment procedure as follows:

— The mesh STA shall set the TBTT Adjusting field in the Mesh Configuration element to 1 in order to announce that the TBTT adjustment procedure is ongoing.

— The mesh STA shall suspend its TSF timer for a period of time, no longer than half of the Group Delivery Idle Time (defined in 14.14.5) within a single beacon period, to slow its TSF.

— The mesh STA shall adjust TBTT information of the neighbor STAs (see 14.13.4.2.3), that are to be contained in the Beacon Timing element, accordingly by subtracting the delay amount.

— When dot11MCCAActivated is true, the mesh STA shall adjust the MCCAOP reservations accordingly by modifying the MCCAOP Offset of each MCCAOP reservation. See 10.24.3.3.

— The mesh STA shall repeat suspending its TSF timer over multiple beacon periods until its TBTT is set to the alternative TBTT.

— Upon completion of the TBTT adjustment, the mesh STA shall update the status number as described in 14.13.4.2.4 and shall set the TBTT Adjusting field in the Mesh Configuration element to 0.

NOTE 2—A mesh STA in deep sleep mode might interpret its neighbor mesh STA's TBTT adjustment as a large TSF jitter. When a mesh STA in deep sleep mode observes a large TSF jitter and the Status Number in the Report Control field in the Beacon Timing element of the received Beacon frame (or Probe Response frame) has been updated, the mesh STA in deep sleep mode should not take this jitter as clock drift and listen to the next Beacon frame to verify if the clock drift is large.

14.13.4.5 Frame transmission across reported TBTT

When dot11MBCAActivated is true, the mesh STA should not extend its transmissions across TBTT of its neighbor STAs with which it maintains synchronization. Further, the mesh STA should not extend its transmissions, other than Beacon frames, across all essential beacon reception timing (see 14.13.4.2.6) reported from its neighbor mesh STAs with which it maintains synchronization. This operation helps in reducing the hidden STA interference with beacon reception at its neighbor mesh STAs. When both dot11MBCAActivated and dot11MCCAActivated are true, the mesh STA shall not extend its transmissions across TBTT of its neighbor STAs with which it maintains synchronization. Further, the mesh STA shall not extend its transmissions, other than Beacon frames, across all beacon reception timing reported from its neighbor mesh STAs with which it maintains synchronization.

After silencing for dot11MeshAverageBeaconFrameDuration μs from the reported neighbor's TBTT, the mesh STA may start transmitting frames again.

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14.13.4.6 Delayed beacon transmissions

A mesh STA may occasionally delay its Beacon frame transmission from its TBTT for a pseudorandom time. This attribute is specified by dot11MeshDelayedBeaconTxInterval, dot11MeshDelayedBeaconTxMinDelay, and dot11MeshDelayedBeaconTxMaxDelay. When dot11MeshDelayedBeaconTxInterval is set to nonzero value, the mesh STA shall delay its Beacon frame transmission from TBTT, once every dot11MeshDelayedBeaconTxInterval. When the mesh STA transmits a Beacon frame with delay from its TBTT, the delay time shall be randomly selected between dot11MeshDelayedBeaconTxMinDelay and dot11MeshDelayedBeaconTxMaxDelay μs.

NOTE—Delayed beacon transmission allows mesh STAs to discover Beacon frames that are transmitted from multiple mesh STAs with TBTTs close to each other. It is recommended to set dot11MeshDelayedBeaconTxMaxDelay to a time longer than the typical duration of Beacon frames.

14.14 Power save in a mesh BSS

14.14.1 General

A mesh STA may use mesh power management modes to reduce its power consumption. A mesh STA manages each of its mesh peerings with a peer-specific mesh power management mode as described in 14.14.2.2. A mesh STA may set the mesh power management mode for a mesh peering independently of the mesh power management modes for its other mesh peerings. A mesh STA also manages a nonpeer mesh power management mode as described in 14.14.2.3. When a mesh STA is in light sleep mode or in deep sleep mode for a mesh peering, the mesh STA shall maintain its mesh awake window as described in 14.14.6.

A mesh STA shall have the capability to buffer frames and to perform mesh power management mode tracking for the peer-specific mesh power management modes of its peer mesh STAs, as described in 14.14.7. A mesh STA shall use mesh peer service periods for individually addressed frame transmissions to neighbor peer mesh STAs that are either in light sleep mode or in deep sleep mode toward this mesh STA, as described in 14.14.9. A mesh STA transmits group addressed frames after the Beacon frame containing DTIM when any of its peer mesh STAs is in light sleep mode or deep sleep mode for the mesh peering with the mesh STA (see 14.14.4 and 14.14.5). These capabilities are referred to as *support for power save*.

14.14.2 Mesh power management modes

14.14.2.1 General

The manner in which a mesh STA transitions between power states is determined by its peer-specific mesh power management modes and its nonpeer mesh power management mode. A mesh STA shall be in awake state if any of the conditions specified in 14.14.8.6 is not fulfilled. A mesh STA maintains peer-specific mesh power management modes for each of its mesh peerings as described in 14.14.2.2. A mesh STA may have a different peer-specific mesh power management mode for each mesh peering. A mesh STA maintains a nonpeer mesh power management mode for nonpeer mesh STAs that is described in 14.14.2.3. An example illustration of the use of peer specific and nonpeer mesh power management modes is shown in Figure 14-5.

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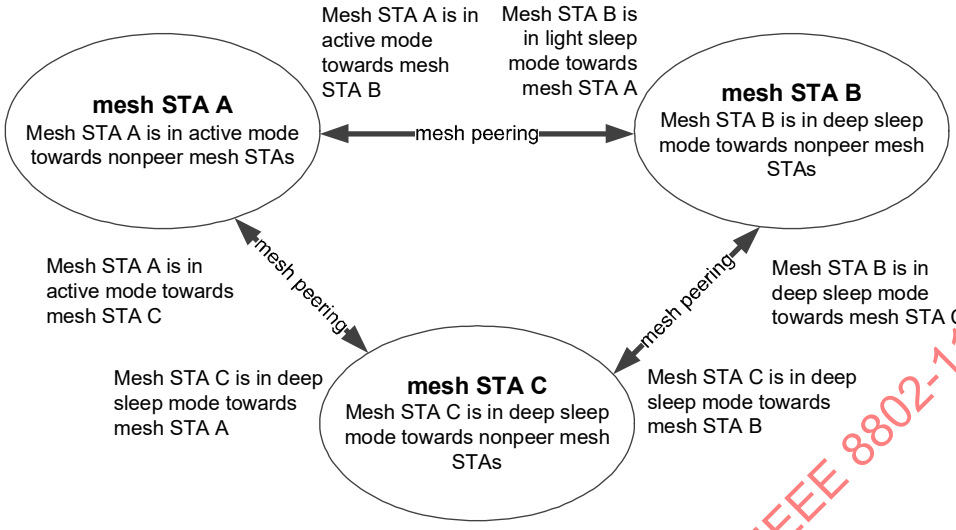

Figure 14-5—Example of mesh power management mode usage

14.14.2.2 Peer-specific mesh power management modes

The peer-specific mesh power management mode specifies the activity level of the mesh STA for the corresponding mesh peering. Three mesh power management modes are defined: active mode, light sleep mode, and deep sleep mode. The peer-specific mesh power management modes are defined as follows:

— *Active mode:* The mesh STA shall be in awake state all the time.

— *Light sleep mode:* The mesh STA alternates between awake state and doze state, as specified in 14.14.8.4. The mesh STA shall listen to all of the Beacon frames from the corresponding peer mesh STA.

— *Deep sleep mode:* The mesh STA alternates between awake state and doze state, as specified in 14.14.8.5. The mesh STA may choose not to listen to the Beacon frames from the corresponding peer mesh STA.

The combination of the Power Management subfield in the Frame Control field and the Mesh Power Save Level subfield in the QoS Control field contained in mesh Data frames indicates the peer-specific mesh power management mode as shown in the Table 14-32.

Table 14-32—Peer-specific mesh power management mode definition

Activity level	Peer-specific mesh power management mode	Power Management subfield	Mesh Power Save Level subfield
Highest ↑ Lowest	Active mode	0	Reserved
	Light sleep mode	1	0
	Deep sleep mode	1	1

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14.14.2.3 Nonpeer mesh power management modes

The nonpeer mesh power management mode indicates the mesh power management mode of the mesh STA toward the nonpeer mesh STAs. Two nonpeer mesh power management modes are defined: active mode and deep sleep mode. The nonpeer mesh power management mode is indicated by the Power Management subfield in the Frame Control field in group addressed frames, Management frames transmitted to nonpeer neighbor STAs, and in Probe Response frames. When the Power Management subfield in the Frame Control field is set to 1, the nonpeer mesh power management mode is deep sleep mode. When the Power Management subfield in the Frame Control field is set to 0, the nonpeer mesh power management mode is active mode.

A mesh STA may send Probe Request and Mesh Peering Open Request frames to a nonpeer mesh STA that sets its nonpeer mesh power management mode to deep sleep mode only during the mesh awake window of the mesh STA.

14.14.3 Mesh power management mode indications and transitions

14.14.3.1 General

When a mesh STA is in active mode for a mesh peering, it shall set the Power Management subfield in the Frame Control field to 0 in all individually addressed Mesh Data or QoS Null frames transmitted to the corresponding peer mesh STA.

When a mesh STA is in light sleep mode for a mesh peering, it shall set the Power Management subfield in the Frame Control field to 1 and the Mesh Power Save Level subfield in the QoS Control field to 0 in all individually addressed Mesh Data or QoS Null frames transmitted to the corresponding peer mesh STA.

When a mesh STA is in deep sleep mode for a mesh peering, it shall set the Power Management subfield in the Frame Control field to 1 and the Mesh Power Save Level subfield in the QoS Control field to 1 in all individually addressed Mesh Data or QoS Null frames transmitted to the corresponding mesh STA.

When a mesh STA is in deep sleep mode for any of its mesh peerings, the Mesh Power Save Level subfield in the QoS Control field in group addressed mesh Data frames and the Mesh Power Save Level subfield in the Mesh Capability field in the Mesh Configuration element shall be set to 1. When a mesh STA is not in deep sleep mode for any of its mesh peerings, these subfields shall be set to 0.

To change peer-specific mesh power management modes, a mesh STA shall inform its peer mesh STAs through a successful frame exchange initiated by the mesh STA. The Power Management subfield in the Frame Control field and the Mesh Power Save Level subfield in the QoS Control field of the frame sent by the mesh STA in this exchange indicates the peer-specific mesh power management mode that the STA shall adopt upon successful completion of the entire frame exchange.

The algorithm to trigger the change of a peer-specific mesh power management mode is beyond the scope of this standard.

The nonpeer mesh power management mode is determined by the peer-specific mesh power management modes of the mesh STA. When a mesh STA is in light sleep mode or deep sleep mode for at least one mesh peering, it shall set the nonpeer mesh power management mode to deep sleep mode.

When a mesh STA is in active mode for nonpeer STAs, it shall set the Power Management subfield in the Frame Control field to 0 in group addressed frames, in Management frames transmitted to nonpeer mesh STAs, and in Probe Response frames.

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When a mesh STA is in deep sleep mode for nonpeer STAs, it shall set the Power Management subfield in the Frame Control field to 1 in group addressed frames, in Management frames transmitted to nonpeer mesh STAs, and in Probe Response frames.

14.14.3.2 Transition to a higher activity level

A mesh STA may use group addressed or individually addressed Mesh Data or QoS Null frames to change its mesh power management mode to a higher activity level, for example; from deep sleep to light sleep or to active mode; or from light sleep to active mode.

Individually addressed frames may be used to temporarily raise the activity level of the mesh STA for a mesh peering.

NOTE—This is useful in cases when a link temporarily requires efficient data transmission with the peer mesh STA and the mesh STA is attempting to transit back to lower activity level without performing the mesh power management mode transition signaling with all peer mesh STAs.

14.14.3.3 Transition to a lower activity level

A mesh STA shall use acknowledged individually addressed Mesh Data or QoS Null frames to change its peer-specific mesh power management mode to a lower activity level, for example; from active mode to light or deep sleep mode; or from light sleep to deep sleep mode.

14.14.4 TIM transmissions in an MBSS

The TIM element identifies the peer mesh STAs for which traffic is pending and buffered in the reporting mesh STA. This information is coded in a partial virtual bitmap, as described in 9.4.2.5. In addition, the TIM contains an indication whether group addressed traffic is pending. Every neighbor peer mesh STA is assigned an AID by the reporting mesh STA as part of the mesh peering establishment process (see 14.3.1). The mesh STA shall identify those peer mesh STAs for which it is prepared to deliver[43] buffered MSDUs and MMPDUs by setting bits in the TIM's partial virtual bitmap that correspond to the appropriate AIDs.

14.14.5 TIM types

There are two different TIM types: TIM and DTIM. A mesh STA shall transmit a TIM with every Beacon frame. Every DTIMPeriod, a TIM of type DTIM is transmitted with a Beacon frame. After transmitting a Beacon frame containing a DTIM, the mesh STA shall send the buffered group addressed MSDUs and MMPDUs, before transmitting any individually addressed frames. The More Data subfield of each group addressed frame shall be set to indicate the presence of further buffered group addressed MSDUs and MMPDUs. The mesh STA sets the More Data subfield to 0 in the last transmitted group addressed frame following the transmission of the DTIM Beacon frame.

While waiting to receive a group addressed frame that was previously indicated in a TIM element or More Data subfield, a mesh STA that detects CCA is IDLE for the duration of the PHY specific Group Delivery Idle Time may assume that no more frames destined to group addresses will be transmitted and may return to doze state. The Group Delivery Idle Time is identical to the TXOP limit for AC_VI specified by the default EDCA Parameter Set shown in Table 9-155.

[43] How the AP or mesh STA determines the traffic is prepared to deliver is outside the scope of this standard.

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14.14.6 Mesh awake window

A mesh STA shall be in awake state when its mesh awake window is active. A mesh awake window is active after the Beacon and Probe Response frames containing the Mesh Awake Window element. A mesh STA shall include the Mesh Awake Window element in its DTIM Beacon frames and may include the Mesh Awake Window element in its TIM Beacon and Probe Response frames. A mesh STA that operates in light sleep mode or deep sleep mode for any of its mesh peerings shall include the Mesh Awake Window element in its Beacon frame if the Beacon frame indicates buffered traffic for at least one peer mesh STA. The start of the mesh awake window is measured from the end of the Beacon or Probe Response frame transmission. The duration of the mesh awake window period is specified by dot11MeshAwakeWindowDuration. A mesh STA shall set the Mesh Awake Window field in the Mesh Awake Window element to dot11MeshAwakeWindowDuration. If the Mesh Awake Window element is not contained in the Beacon frame of a mesh STA, the duration of the mesh awake window period following this beacon is zero.

If the mesh STA that has its mesh awake window active transmits frames destined to group addresses, the duration of the mesh awake window is extended by an additional PostAwakeDuration. The PostAwakeDuration follows the group address frame, and the mesh STA that has its mesh awake window active shall stay in awake state until it has transmitted all of its group addressed frames and the PostAwakeDuration has expired. The PostAwakeDuration is equal to duration of the mesh awake window.

A mesh STA may send a frame to a peer mesh STA that is in light sleep mode or deep sleep mode for the corresponding mesh peering during the mesh awake window of this peer mesh STA. When a peer trigger frame is successfully transmitted it initiates a mesh peer service period as described in 14.14.9.

A mesh STA may send Class 1 or Class 2 frames, such as Probe Request or Mesh Peering Open frames, to a nonpeer mesh STA that is in deep sleep mode for nonpeer mesh STAs during the mesh awake window of this nonpeer mesh STA.

14.14.7 Power save support

As described in 14.14.2, a mesh STA indicates its peer-specific mesh power management modes and performs mesh power management mode tracking of the peer-specific mesh power management modes of its peer mesh STAs. A mesh STA shall not arbitrarily transmit frames to mesh STAs operating in a light or deep sleep mode, but shall buffer frames and only transmit them at designated times.

A mesh STA may transmit frames to a mesh STA operating in a light or deep sleep mode if the recipient mesh STA is in the awake state as defined in 14.14.8.4, 14.14.8.5, and 14.14.9; otherwise, the mesh STA shall not transmit frames and shall buffer frames.

As described in 14.14.4, a mesh STA indicates the presence of buffered traffic in TIM elements for all peer mesh STAs that operate in light or deep sleep mode toward the mesh STA. The mesh STA sets the bit for AID 0 (zero) in the Bitmap Control field of the TIM element to 1 when group addressed traffic is buffered, according to 9.4.2.5. As described in 14.14.5, a mesh STA transmits its group addressed frames after its DTIM beacon if any of its peer mesh STA is in light or deep sleep mode toward the mesh STA.

As described in 14.14.9, mesh peer service periods are used for frame transmissions toward a mesh STA that operates in light or deep sleep mode. Mesh peer service periods are not used in frame exchanges toward active mode mesh STAs.

A mesh STA may initiate a mesh peer service period with a peer mesh STA in deep or light sleep mode by transmitting a peer trigger frame when the mesh awake window of the peer mesh STA is active.

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14.14.8 Operation in peer-specific and nonpeer mesh power management modes

14.14.8.1 General

Detailed operations of mesh STA in each mesh power management mode are described in the following subclauses. Figure 14-6 depicts example power state transitions of mesh STAs, when three mesh STAs are in the mesh power management modes shown in the Figure 14-5.

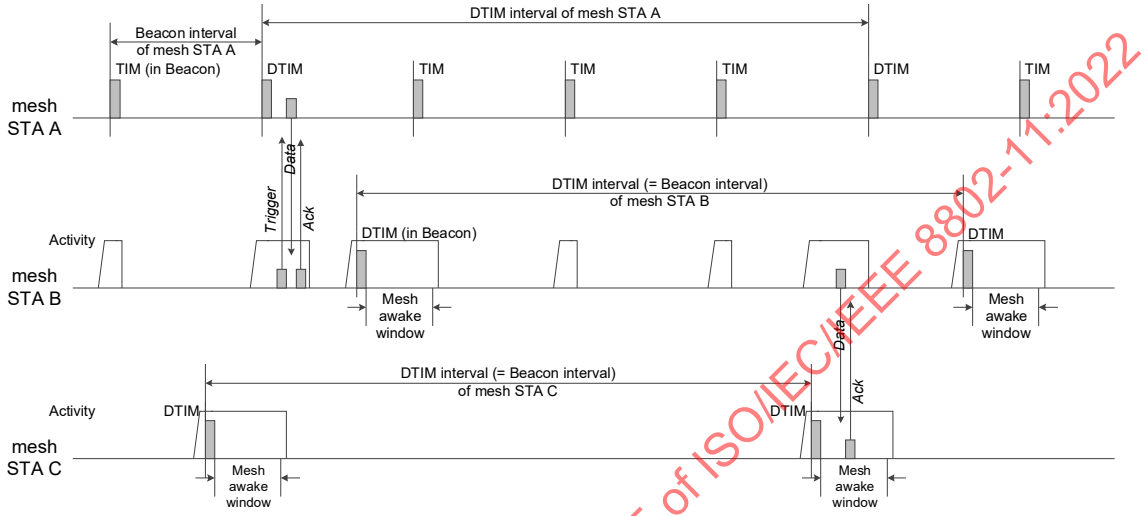

Figure 14-6—Mesh power management operation

14.14.8.2 Operation in active mode

When a mesh STA is in active mode for a mesh peering or for nonpeer mesh STAs, it shall be in awake state. Mesh peer service periods are not used in frame exchanges toward mesh STAs that are in active mode.

An active mode mesh STA may receive peer trigger frames from a peer mesh STA in light or deep sleep mode when there is no mesh peer service period ongoing between the peer mesh STAs.

14.14.8.3 Operation in deep sleep mode for nonpeer mesh STAs

If a mesh STA is in deep sleep mode for nonpeer mesh STAs, it shall enter the awake state prior to every TBTT of its own and shall remain in awake state after the beacon transmission for the duration of the mesh awake window and the duration of its group addressed frame transmissions. The mesh STA may receive frames during its mesh awake window as described in 14.14.6.

When receiving a frame initiating a mesh peering management procedure, an authentication procedure, or a passive scanning procedure, a mesh STA in deep sleep mode for nonpeer mesh STAs shall operate in awake state at least until the completion of the mesh peering management procedure (see 14.3 and 14.5), until the completion of the authentication procedure (see 14.3.1 and 14.3.3), or the transmission of the Probe Response frame.

If a mesh STA receives a peer trigger frame initiating a mesh peer service period from a peer mesh STA, the mesh STA shall remain in awake state until the mesh peer service period is terminated as defined in 14.14.9.4.

A mesh STA may return to doze state after its mesh awake window if no frame initiating a response transaction or a mesh peer service period is received during the mesh awake window.

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14.14.8.4 Operation in light sleep mode for a mesh peering

If a mesh STA is in light sleep mode for a mesh peering, it shall enter the awake state prior to every TBTT of the corresponding peer mesh STA to receive the Beacon frame from the peer mesh STA. The mesh STA may return to the doze state after the beacon reception from this peer mesh STA, if the peer mesh STA did not indicate buffered individually addressed or group addressed frames. If an indication of buffered individually addressed frames is received, the light sleep mode mesh STA shall send a peer trigger frame with the RSPI field set to 1 to initiate a mesh peer service period with the mesh STA that transmitted the Beacon frame (see 14.14.9.2). If an indication of buffered group addressed frames is received, the light sleep mode mesh STA shall remain in awake state after the DTIM Beacon reception to receive group addressed frames The mesh STA shall remain awake state until the More Data subfield of a received group addressed frame is set to 0 or if no group addressed frame is received within the PHY specific Group Delivery Idle Time. (See 14.14.5.)

NOTE—When a mesh STA is in light sleep mode for a mesh peering, it sets its nonpeer mesh power management mode to deep sleep mode. This implies that a mesh STA operating in light sleep mode a mesh peering is required to comply with the rules described in 14.14.8.3.

14.14.8.5 Operation in deep sleep mode for a mesh peering

A mesh STA operating in deep sleep mode for a mesh peering might not receive Beacon frames from the corresponding peer mesh STA. The logic of how the mesh STA in deep sleep mode maintains synchronization among neighbors is beyond the scope of this standard. Guidance for the synchronization maintenance by the mesh STA in deep sleep mode is given in S.3.6.

NOTE—When a mesh STA is in deep sleep mode for a mesh peering, it sets its nonpeer mesh power management mode to deep sleep mode. This implies that a mesh STA operating in deep sleep mode for a mesh peering is required to comply with the rules described in 14.14.8.3.

14.14.8.6 Conditions for doze state

A mesh STA may enter doze state if all of the following conditions are fulfilled:

- The mesh STA operates in light sleep mode or deep sleep mode for all of its mesh peerings, as described in 14.14.8.4 or 14.14.8.5
- The mesh STA has no mesh peer service period ongoing, as described in 14.14.9
- The mesh STA has no pending transaction of mesh peering management, authentication, nor passive scanning (see 14.14.8.3)
- The mesh awake window indicated by the mesh STA has expired, as described in 14.14.6
- The mesh STA has terminated its group addressed frames delivery sequence after its DTIM Beacon frame, as described in 14.14.5

Guidance for using the power save in mesh BSS and default parameter values are given in S.3.

14.14.9 Mesh peer service periods

14.14.9.1 General

Mesh peer service periods are used for individually addressed frame exchanges between neighbor peer mesh STAs in which at least one of the mesh STAs is in light or deep sleep mode for the corresponding mesh peering. A mesh peer service period is a period of time during which one or more individually addressed frames are transmitted between two peer mesh STAs. Within a mesh peer service period, a mesh STA may obtain multiple TXOPs. A mesh peer service period is directional. One mesh STA is the owner of the mesh peer service period. It obtains TXOPs in order to transmit Data frames or Management frames to the

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recipient in the mesh peer service period. At the end of the frame transmissions, the owner of the mesh peer service period terminates the mesh peer service period. The other mesh STA operates as the recipient of the mesh peer service period and does not obtain TXOPs for transmitting Data frames or Management frames to the owner of the mesh peer service period. A mesh STA may have multiple mesh peer service periods concurrently toward multiple neighbor peer mesh STAs. At most, one mesh peer service period is set up in each direction with each peer mesh STA.

A mesh peer service period is initiated by a peer trigger frame. A peer trigger frame may initiate two mesh peer service periods. This enables both the transmitter and the receiver of the peer trigger frame to become the owner of a mesh peer service period. An example mesh peer service period between two mesh STAs in light or deep sleep mode is shown in Figure 14-7. The numbering on the left-hand-side describes the phase of the operation: 1 indicates the Initiation phase, 2 indicates the data transmission phase, and 3 indicates the termination phase of the mesh peer service period.

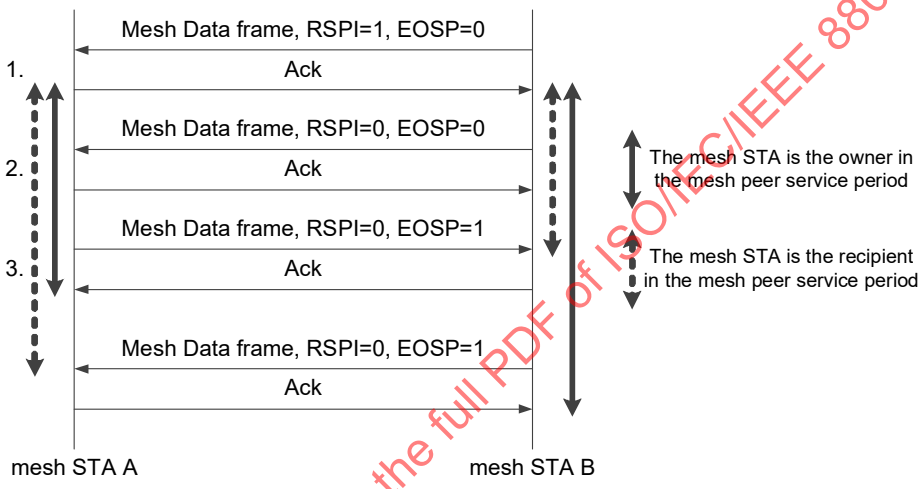

Figure 14-7—Mesh peer service period

14.14.9.2 Initiation of a mesh peer service period

A mesh Data frame or a QoS Null frame that requires immediate acknowledgment are used as a peer trigger frame. The RSPI and the EOSP subfields in the QoS Control field control the initiation of a mesh peer service period. Table 14-33 lists how mesh peer service periods shall be initiated with different combinations of RSPI and EOSP subfield values.

Table 14-33—Mesh peer service period triggering with RSPI and EOSP subfield combinations in peer trigger frame

RSPI	EOSP	Mesh peer service period triggering
0	0	One mesh peer service period is initiated. The transmitter of the trigger frame is the owner in the mesh peer service period.
0	1	No mesh peer service period is initiated.
1	0	Two mesh peer service periods are initiated. Both mesh STAs are owners in a mesh peer service period.
1	1	One mesh peer service period is initiated. The receiver of the trigger frame is the owner in the mesh peer service period.

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Mesh peer service periods are not used in frame transmissions toward active mode mesh STAs.

The mesh peer service period may be initiated in the following cases:

— A mesh STA in light or deep sleep mode receives a peer trigger frame during its mesh awake window as described in 14.14.6

— A mesh STA in active mode receives a peer trigger frame from the peer mesh STA in light or deep sleep mode as described in 14.14.8.2

— A mesh STA receives a peer trigger frame from the peer mesh STA in light sleep mode as described in 14.14.8.4

In addition, when a mesh STA uses MCCA with a neighbor peer mesh STA while in a light sleep mode for the corresponding mesh peering, a scheduled service period begins at the each MCCAOP start time as described in 14.14.10. A mesh STA in a light or deep sleep mode shall enter the awake state prior to the start time of scheduled service period.

14.14.9.3 Operation during a mesh peer service period

During the mesh peer service period, the owner and the recipient of the mesh peer service period shall operate in awake state. The mesh peer service period may contain one or more TXOPs.

Reverse direction grant (RDG) shall not be used when the receiver of the TXOP operates in light or deep sleep mode for the link and there is no mesh peer service period ongoing toward the TXOP holder.

14.14.9.4 Termination of a mesh peer service period

The mesh peer service period is terminated after a successfully acknowledged QoS Null or mesh Data frame with the EOSP subfield set to 1 from the owner of the mesh peer service period.

If the mesh STA does not receive an acknowledgment to a frame that requires an acknowledgment and that is sent with the EOSP subfield set to 1, the mesh STA shall retransmit that frame at least once within the same mesh peer service period, subject to applicable retry or lifetime limits. The maximum number of retransmissions within the same mesh peer service period is the lesser of the Max Retry Limit and dot11MeshSTAMissingAckRetryLimit.

NOTE—If an acknowledgment to the retransmission of this last frame in the same mesh peer service period is not received, the mesh STA might use the next mesh peer service period to further retransmit that frame subject to the applicable retry or lifetime limit.

14.14.10 MCCA use by power saving mesh STA

When dot11MCCAActivated is true and the mesh STA establishes MCCAOPs, the mesh STA shall be in active mode or light sleep mode toward the neighbor peer mesh STAs with which it has established MCCAOPs.

A scheduled mesh peer service period begins at the MCCAOP start time, if the MCCAOP responder operates in light sleep mode for the MCCAOP owner. The MCCAOP owner is the owner of the scheduled mesh peer service period. The MCCAOP responder is the recipient of the scheduled mesh peer service period. Scheduled mesh peer service periods are not used if the MCCAOP responder is in active mode for the MCCAOP owner.

The scheduled mesh peer service period continues until it is successfully terminated by the acknowledged QoS Null or mesh Data frame with the EOSP subfield set to 1 from the owner of the mesh peer service period to the recipient of the mesh peer service period as described in 14.14.9.

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15. DSSS PHY specification for the 2.4 GHz band designated for ISM applications

15.1 Overview

15.1.1 General

The PHY for the DSSS system is described in this clause. The RF LAN system is aimed for the 2.4 GHz band designated for ISM applications.

The DSSS system provides a WLAN with both a 1 Mb/s and a 2 Mb/s data payload communication capability. The DSSS system uses baseband modulations of differential binary phase shift keying (DBPSK) and differential quadrature phase shift keying (DQPSK) to provide the 1 Mb/s and 2 Mb/s data rates, respectively.

15.1.2 Scope of DSSS PHY services

The PHY services provided to the IEEE 802.11 WLAN MAC by the 2.4 GHz DSSS system are described in this clause. The DSSS PHY consists of the following protocol functions:

a) A function that defines a method of mapping the IEEE 802.11 MPDUs into a framing format suitable for sending and receiving user data and management information between two or more STAs.

b) A function that defines the characteristics of, and method of transmitting and receiving data through, a WM between two or more STAs each using the DSSS system.

15.1.3 DSSS PHY functions

15.1.3.1 General

The 2.4 GHz DSSS PHY architecture is depicted in the reference model shown in Figure 4-24 (in 4.9). The DSSS PHY contains two functional entities: the PHY function and the layer management function. Each of these functions is described in detail in the following subclauses.

The DSSS PHY service shall be provided to the MAC through the PHY service primitives described in Clause 8.

15.1.3.2 PLME

The PLME performs management of the local PHY functions in conjunction with the MLME.

15.1.4 Service specification method and notation

The models represented by figures and state diagrams are intended to be illustrations of functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, but do not necessarily reflect any particular implementation.

The service of a layer or sublayer is a set of capabilities that it offers to a user in the next-higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

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15.2 DSSS PHY specific service parameter list

15.2.1 Introduction

The architecture of the IEEE 802.11 MAC is intended to be PHY independent. Some PHY implementations require medium management state machines running in the MAC sublayer in order to meet certain PHY requirements. These PHY-dependent MAC state machines reside in a sublayer defined as the MLME. In certain PHY implementations, the MLME may need to interact with the PLME as part of the normal PHY SAP primitives. These interactions are defined by the PLME parameter list currently defined in the PHY service primitives as TXVECTOR and RXVECTOR. The list of these parameters, and the values they may represent, are defined in the specific PHY specifications for each PHY. Subclause 15.2 addresses the TXVECTOR and RXVECTOR for the DSSS PHY.

15.2.2 TXVECTOR parameters

15.2.2.1 General

The parameters in Table 15-1 are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive.

Table 15-1—TXVECTOR parameters

Parameter	Value
LENGTH	0 to $2^{12} - 1$
DATARATE	1, 2 Mb/s
SERVICE	Null
TXPWR_LEVEL_INDEX	1 to 8
TIME_OF_DEPARTURE_REQUESTED	false, true. When true, the MAC entity requests that the PHY entity measures and reports time of departure parameters corresponding to the time when the first frame energy is sent by the transmitting port; when false, the MAC entity requests that the PHY entity neither measures nor reports time of departure parameters.
TX_ANTENNA	1 to 255

15.2.2.2 TXVECTOR LENGTH

The LENGTH parameter provided in the TXVECTOR is in octets and is converted to microseconds for inclusion in the PHY LENGTH field.

15.2.2.3 TXVECTOR DATARATE

The DATARATE parameter describes the bit rate at which the PHY shall transmit the PSDU. Its value takes any of the rates defined in Table 15-1.

15.2.2.4 TXVECTOR SERVICE

The SERVICE parameter shall be null.

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15.2.2.5 TXVECTOR TXPWR_LEVEL_INDEX

The allowed values for the TXPWR_LEVEL_INDEX parameter are in the range 1 to 8. This parameter is used to indicate which of the available TxPowerLevel attributes defined in the MIB shall be used for the current transmission.

15.2.2.6 TXVECTOR TIME_OF_DEPARTURE_REQUESTED

The allowed values are false or true. A parameter value of true indicates that the MAC sublayer is requesting that the PHY entity provides measurement of when the first frame energy is sent by the transmitting port and reporting within the PHY-TXSTART.confirm primitive. A parameter value of false indicates that the MAC sublayer is requesting that the PHY entity not provide time of departure measurement nor reporting in the PHY-TXSTART.confirm primitive.

15.2.2.7 TXVECTOR TX_ANTENNA

Selects the antenna used by the PHY for transmission (when diversity is disabled), in the range 1 to 255.

15.2.3 RXVECTOR parameters

15.2.3.1 General

The parameters listed in Table 15-2 are defined as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive.

Table 15-2—RXVECTOR parameters

Parameter	Value
LENGTH	0 to 2^{12} – 1
RSSI	0–255
SIGNAL	1, 2 Mb/s
SERVICE	1, 2 Mb/s
SQ	0–255
RX_ANTENNA	0–255
RX_START_OF_FRAME_OFFSET	0 to 2^{32} – 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble corresponding to the incoming frame arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC.

15.2.3.2 RXVECTOR LENGTH

The MPDU length in octets (calculated from the LENGTH field in microseconds).

15.2.3.3 RXVECTOR RSSI

This parameter is a measure by the PHY of the energy observed at the antenna connector used to receive the current PPDU. RSSI shall be measured during the reception of the PHY preamble. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power.

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15.2.3.4 RXVECTOR SIGNAL

SIGNAL shall represent the data rate at which the current PPDU was received.

15.2.3.5 RXVECTOR SERVICE

The SERVICE parameter shall be null.

15.2.3.6 PHY-RXEND.indication parameter RCPI

The allowed values for the RCPI are in the range 0 to 255, as defined in 9.4.2.37. This parameter is a measure by the PHY of the received channel power. The performance requirements for the measurement of RCPI are defined in 15.4.6.6.

15.2.3.7 RXVECTOR SQ

SQ provides to the MAC entity the signal quality of the DSSS PHY PN code correlation. The SQ shall be sampled when the DSSS PHY achieves code lock and shall be held until the next code lock acquisition.

The SQ may be used in conjunction with RSSI as part of a CCA scheme.

15.2.3.8 RXVECTOR RX_ANTENNA

RX_ANTENNA reports the antenna used by the PHY for reception of the most recent PPDU.

15.2.4 TXSTATUS parameters

15.2.4.1 General

The parameters listed in Table 15-3 are defined as part of the TXSTATUS parameter list in the PHY-TXSTART.confirm primitive.

Table 15-3—TXSTATUS parameters

Parameter	Value
TIME_OF_DEPARTURE	0 to 2^{32}– 1. The locally measured time when the first frame energy is sent by the transmitting port, in units equal to 1/ TIME_OF_DEPARTURE_ClockRate. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request.
TIME_OF_DEPARTURE_ClockRate	0 to 2^{16}– 1. The clock rate, in units of MHz, is used to generate the TIME_OF_DEPARTURE value. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request.
TX_START_OF_FRAME_OFFSET	0 to 2^{32}– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble corresponding to the frame was transmitted at the transmit antenna connector to the point in time at which this primitive is issued to the MAC.

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15.2.4.2 TXSTATUS TIME_OF_DEPARTURE

The allowed values for the TIME_OF_DEPARTURE parameter are integers in the range 0 to $2^{32} - 1$. This parameter is used to indicate when the first frame energy is sent by the transmitting port in units equal to 1/TIME_OF_DEPARTURE_ClockRate. TIME_OF_DEPARTURE may be included in the transmitted frame in order for recipients on multiple channels to determine the time differences of air propagation times between transmitter and recipients and hence to compute the location of the transmitter.

15.2.4.3 TXSTATUS TIME_OF_DEPARTURE_ClockRate

TIME_OF_DEPARTURE_ClockRate indicates the clock rate used for TIME_OF_DEPARTURE.

15.3 DSSS PHY

15.3.1 Overview

Subclause 15.3 provides a convergence procedure in which MPDUs are converted to and from PPDUs. During transmission, the MPDU shall be prepended with a PHY preamble and header to create the PPDU. At the receiver, the PHY preamble and header are processed to aid in demodulation and delivery of the MPDU.

15.3.2 PPDU format

Figure 15-1 shows the format for the PPDU including the DSSS PHY preamble, the DSSS PHY header, and the MPDU. The PHY preamble contains the following fields: SYNC and SFD. The PHY header contains the following fields: Signaling (SIGNAL), Service (SERVICE), length (LENGTH), and CRC-16 (CRC). Each of these fields is described in detail in 15.3.3.

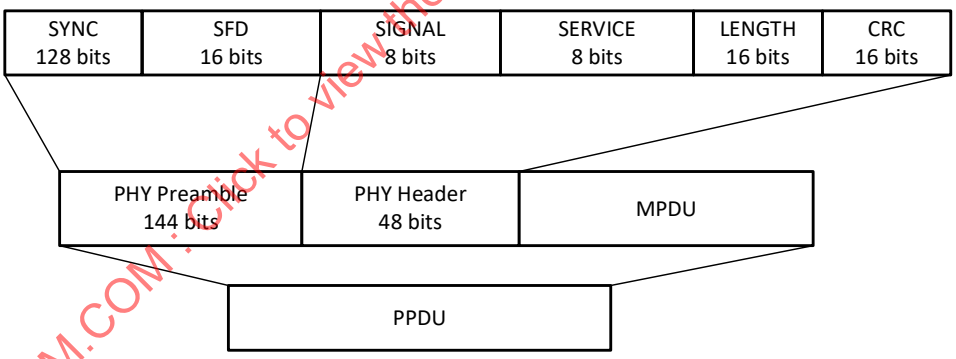

Figure 15-1—PPDU format

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15.3.3 PHY field definitions

15.3.3.1 General

The entire PHY preamble and header shall be transmitted using the 1 Mb/s DBPSK modulation described in 15.4.5. All transmitted bits shall be scrambled using the feedthrough scrambler described in 15.3.4.

15.3.3.2 PHY SYNC field

The SYNC field shall consist of scrambled 1s. This field shall be provided so that the receiver can perform the necessary operations for synchronization.

15.3.3.3 PHY SFD

The SFD shall be provided to indicate the start of PHY-dependent parameters within the PHY preamble. The SFD shall be X'F3A0' (MSB to LSB). The LSB shall be transmitted first in time.

15.3.3.4 PHY SIGNAL field

The SIGNAL field indicates to the PHY the modulation that shall be used for transmission (and reception) of the MPDU. The data rate shall be equal to the signal field value multiplied by 100 kb/s. The DSSS PHY currently supports two mandatory modulation services given by the following 8-bit words, where the LSB shall be transmitted first in time:

a) X'0A' (MSB to LSB) for 1 Mb/s DBPSK
b) X'14' (MSB to LSB) for 2 Mb/s DQPSK

The DSSS PHY rate change capability is described in 15.3.5. This field shall be protected by the CRC-16 FCS described in 15.3.3.7.

15.3.3.5 PHY SERVICE field

The SERVICE field is reserved for future use; it shall be set to 0 on transmission and ignored on reception. The LSB shall be transmitted first in time. This field shall be protected by the CRC-16 FCS described in 15.3.3.7.

15.3.3.6 PHY LENGTH field

The PHY LENGTH field shall be an unsigned integer that indicates the number of microseconds required to transmit the MPDU. The transmitted value shall be determined from the LENGTH parameter in the TXVECTOR issued with the PHY-TXSTART.request primitive described in 8.3.5.5. The LENGTH field provided in the TXVECTOR is in octets and is converted to microseconds for inclusion in the PHY LENGTH field. The LSB shall be transmitted first in time. This field shall be protected by the CRC-16 FCS described in 15.3.3.7.

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15.3.3.7 PHY CRC field

The SIGNAL, SERVICE, and LENGTH fields shall be protected with a CRC-16 FCS. The CRC-16 FCS shall be the 1s complement of the remainder generated by the modulo 2 division of the protected PHY fields by the polynomial:

$$x^{16} + x^{12} + x^5 + 1$$

The protected bits shall be processed in transmit order. All FCS calculations shall be made prior to data scrambling.

As an example, the SIGNAL, SERVICE, and LENGTH fields for a DBPSK signal with an MPDU length of 192 μs (24 octets) would be given by the following:

0101 0000 0000 0000 0000 0011 0000 0000 (leftmost bit transmitted first in time)

The 1s complement FCS for these protected PHY preamble bits would be the following:

0101 1011 0101 0111 (leftmost bit transmitted first in time)

Figure 15-2 depicts this example.

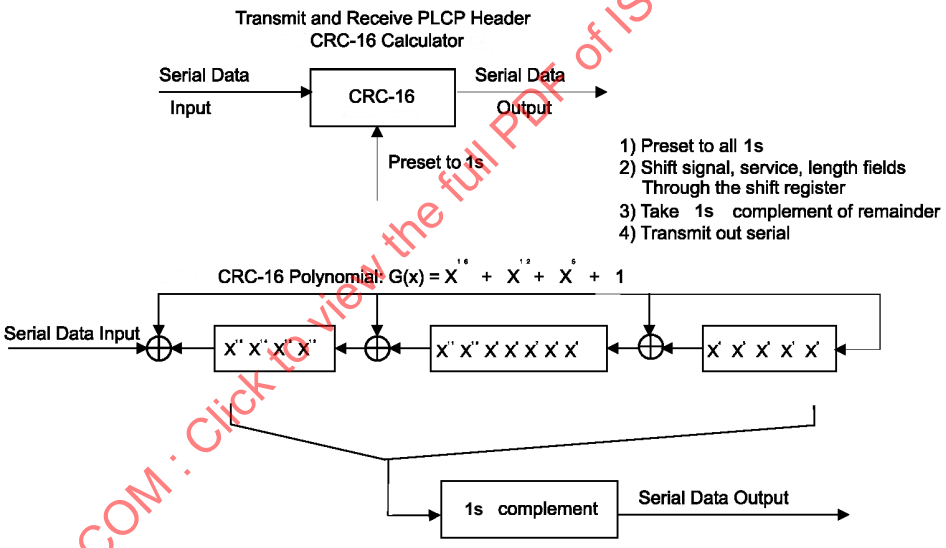

Figure 15-2—CRC-16 implementation

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An illustrative example of the CRC-16 FCS using the information from Figure 15-2 follows in Figure 15-3.

Data	CRC registers MSB LSB	
	1111111111111111	; initialize preset to 1s
0	1110111111011111	
1	1101111110111110	
0	1010111101011101	
1	0101111010111010	
0	1011110101110100	
0	0110101011001001	
0	1101010110010010	
0	1011101100000101	
0	0110011000101011	
0	1100110001010110	
0	1000100010001101	
0	0000000100111011	
0	0000001001110110	
0	0000010011101100	
0	0000100111011000	
0	0001001110110000	
0	0010011101100000	
0	0100111011000000	
0	1001110110000000	
0	0010101100100001	
0	0101011001000010	
0	1010110010000100	
1	0101100100001000	
1	1010001000110001	
0	0101010001000011	
0	1010100010000110	
0	0100000100101101	
0	1000001001011010	
0	0001010010010101	
0	0010100100101010	
0	0101001001010100	
0	1010010010101000	
	0101101101010111	; 1s complement, result = CRC FCS parity

Figure 15-3—Example CRC calculation

15.3.4 PHY/DSSS PHY data scrambler and descrambler

The polynomial $G(z) = z^{-7} + z^{-4} + 1$ shall be used to scramble all bits transmitted by the DSSS PHY. The feedthrough configuration of the scrambler and descrambler is self-synchronizing, which requires no prior knowledge of the transmitter initialization of the scrambler for receive processing. Figure 15-4 and Figure 15-5 show typical implementations of the data scrambler and descrambler, but other implementations are possible.

The scrambler should be initialized to any state except all 1s when transmitting.

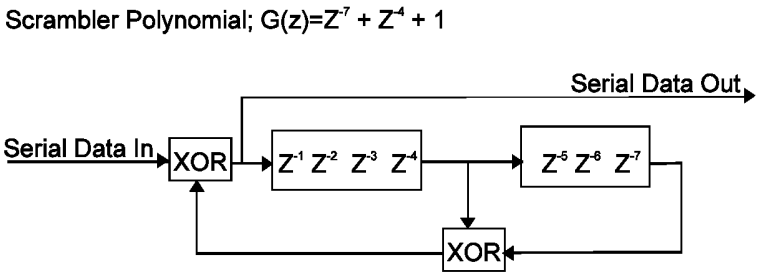

Figure 15-4—Data scrambler

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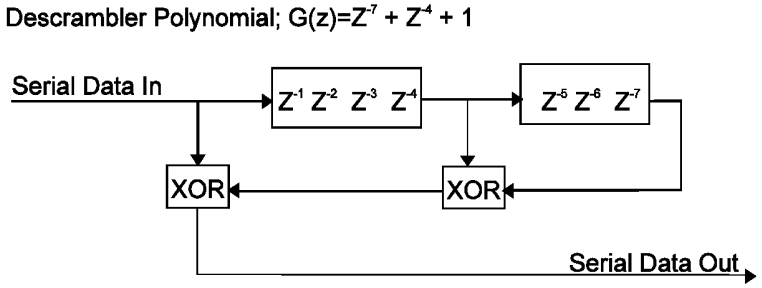

Figure 15-5—Data descrambler

15.3.5 PHY data modulation and modulation rate change

The PHY preamble shall be transmitted using the 1 Mb/s DBPSK modulation. The SIGNAL field shall indicate the modulation that shall be used to transmit the MPDU. The transmitter and receiver shall initiate the modulation indicated by the SIGNAL field starting with the first symbol (1 bit for DBPSK or 2 bits for DQPSK) of the MPDU. The MPDU transmission rate shall be set by the DATARATE parameter in the TXVECTOR issued with the PHY-TXSTART.request primitive described in 15.2.2.

15.3.6 Transmit PHY

The transmit PHY is shown in Figure 15-6.

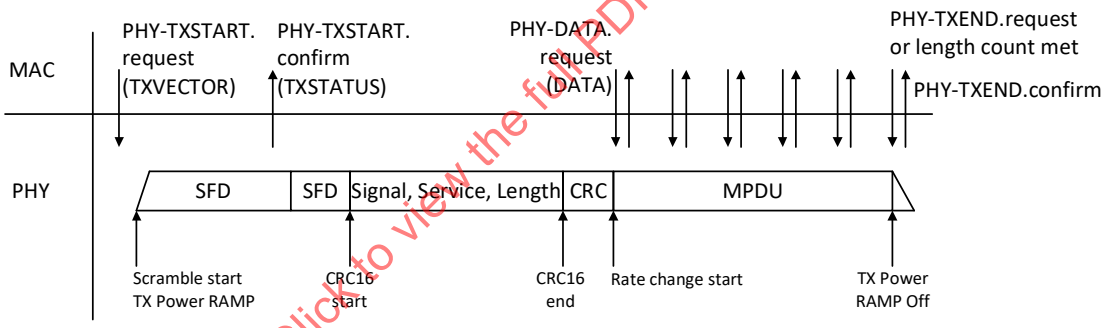

Figure 15-6—Transmit PHY

In order to transmit data, PHY-TXSTART.request primitive shall be issued so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate channel through STA management via the PLME. Other transmit parameters such as DATARATE, TX antenna, and TX power are set via the PHY SAP with the PHY-TXSTART.request(TXVECTOR) primitive as described in 15.2.2.

Based on the state of CCA indicated by the PHY-CCA.indication primitive, the MAC assesses that the channel is clear. A clear channel shall be indicated by a PHY-CCA.indication(IDLE) primitive. If the channel is clear, transmission of the PPDU shall be initiated by issuing the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request primitive are the PHY header parameters SIGNAL (DATARATE), SERVICE, LENGTH, TX_ANTENNA, TXPWR_LEVEL_INDEX, and TIME_OF_DEPARTURE_REQUESTED. The PHY header parameter LENGTH is calculated from the TXVECTOR element by multiplying by 8 for 1 Mb/s and by 4 for 2 Mb/s.

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The PHY is configured with the TXVECTOR elements TX_ANTENNA, DATARATE, and TXPWR_LEVEL_INDEX. The PHY entity shall immediately initiate data scrambling and transmission of the PHY preamble based on the parameters passed in the PHY-TXSTART.request primitive. The time required for transmit power-on ramp described in 15.4.5.8 shall be included in the PHY SYNC field.

Once the PHY preamble transmission is complete, data shall be exchanged between the MAC and the PHY by a series of PHY-DATA.request(DATA) primitives issued by the MAC and PHY-DATA.confirm primitives issued by the PHY. The modulation rate change, if any, shall be initiated with the first data symbol of the MPDU as described in 15.3.5. The PHY proceeds with MPDU transmission through a series of data octet transfers from the MAC. Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. Normal termination occurs after the transmission of the final bit of the last MPDU octet according to the number supplied in the TXVECTOR LENGTH field. The PPDU transmission shall be completed and the PHY entity shall enter the receive state. It is recommended that chipping continue during power-down. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

A typical state machine implementation of the transmit PHY is provided in Figure 15-7.

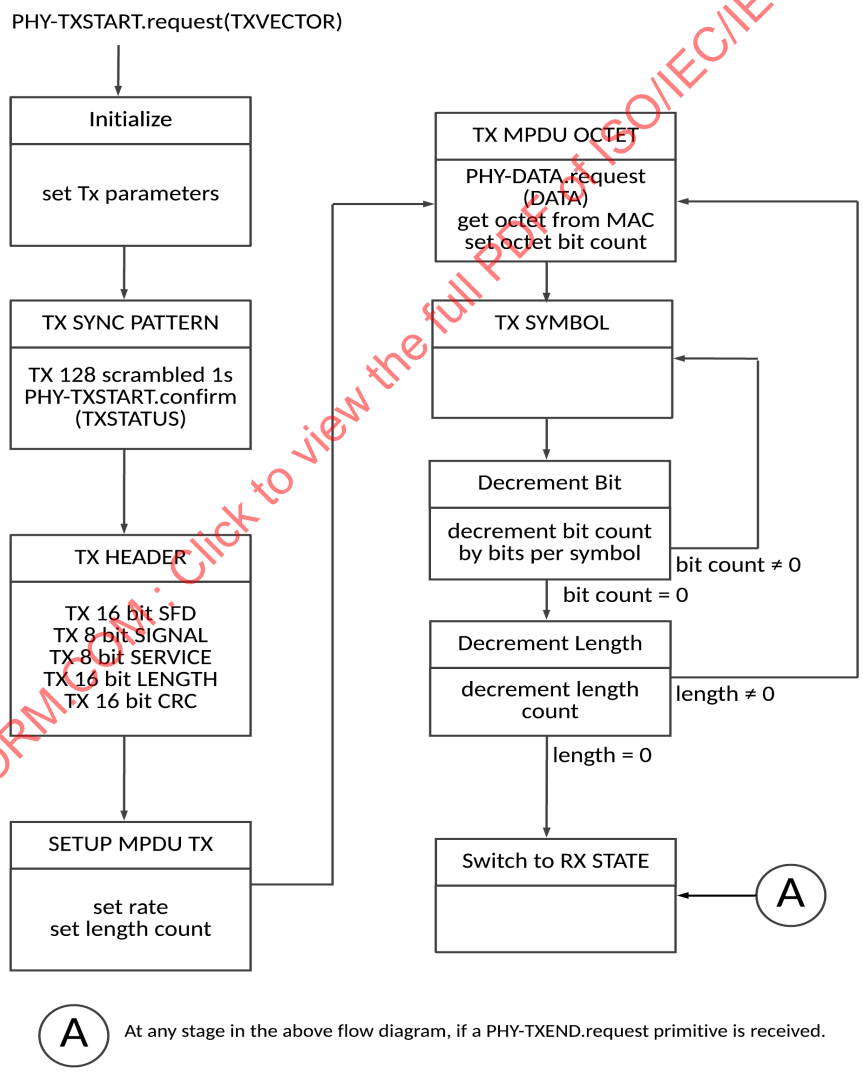

Figure 15-7—PHY transmit state machine

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15.3.7 Receive PHY

The receive PHY is shown in Figure 15-8.

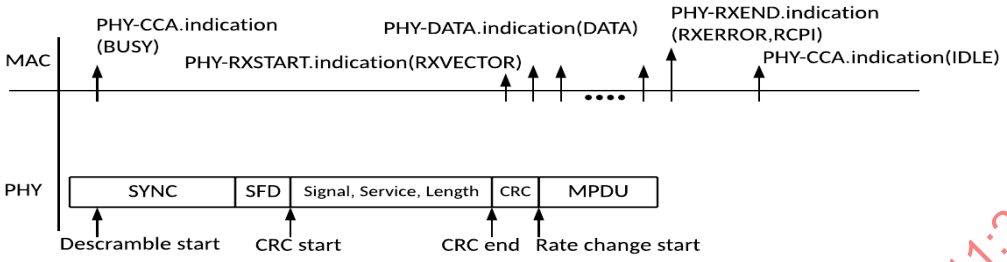

Figure 15-8—Receive PHY

In order to receive data, PHY-TXSTART.request primitive shall be disabled so that the PHY entity is in the receive state. Further, through STA management via the PLME, the PHY is set to the appropriate channel and the CCA method is chosen. Other receive parameters such as RSSI, RCPI, signal quality (SQ), and indicated DATARATE may be accessed via the PHY SAP.

Upon receiving the transmitted energy, according to the selected CCA mode, A PHY-CCA.indication(BUSY) primitive shall be issued for energy detection (ED) and/or code lock prior to correct reception of the PHY header. The PHY measures the RSSI and SQ and the parameters are reported to the MAC in the RXVECTOR.

After a PHY-CCA.indication primitive is issued, the PHY entity shall begin searching for the SFD field. Once the SFD field is detected, CRC-16 processing shall be initiated and the PHY SIGNAL, SERVICE and LENGTH fields are received. The CRC-16 FCS shall be processed. If the CRC-16 FCS check fails, the PHY receiver shall return to the RX IDLE state as depicted in Figure 15-9. Should the status of CCA return to the IDLE state during reception prior to completion of the full PPDU processing, the PHY receiver shall return to the RX IDLE state.

If the PHY header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. If dot11TimingMsmtActivated is true, the PHY shall do the following:

— Complete receiving the PHY header and verify the validity of the PHY Header.
— If the PHY header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued and RX_START_OF_FRAME_OFFSET parameter within the RXVECTOR shall be forwarded (see 15.2.3).

NOTE—The RX_START_OF_FRAME_OFFSET value is used as described in 6.3.55 in order to estimate when the start of the preamble for the incoming frame was detected on the medium at the receive antenna connector.

The RXVECTOR associated with this primitive includes the SIGNAL field, the SERVICE field, the MPDU length in octets (calculated from the LENGTH field in microseconds), the antenna used for receive (RX_ANTENNA), RSSI, and SQ.

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The received MPDU bits are assembled into octets and presented to the MAC using a series of PHY-DATA.indication(DATA) primitive exchanges. The rate change indicated in the SIGNAL field shall be initiated with the first symbol of the MPDU as described in 15.3.5. The PHY proceeds with MPDU reception. After the reception of the final bit of the last MPDU octet, as indicated by the PHY preamble LENGTH field, the receiver shall be returned to the RX IDLE state as shown in Figure 15-9. A PHY-RXEND.indication(NoError) primitive shall be issued. A PHY-CCA.indication(IDLE) primitive shall be issued following a change in PHY carrier sense (PHYCS) and/or PHY energy detection (PHYED) according to the selected CCA method.

In the event that a change in PHYCS or PHYED would cause the status of CCA to return to the IDLE state before the complete reception of the MPDU, as indicated by the PHY LENGTH field, the error condition shall be reported to the MAC using a PHY-RXEND.indication(CarrierLost) primitive. The CCA of the DSSS PHY shall indicate a busy medium for the intended duration of the transmitted PPDU.

If the PHY header is successful, but the indicated rate in the SIGNAL field is not receivable, a PHY-RXSTART.indication primitive shall not be issued. The PHY shall indicate the error condition by issuing a PHY-RXEND.indication(UnsupportedRate) primitive. If the PHY header is successful, but the SERVICE field is out of IEEE 802.11 DSSS specification, a PHY-RXSTART.indication primitive shall not be issued. The PHY shall indicate the error condition by issuing a PHY-RXEND.indication(FormatViolation) primitive. Also, in both cases, the CCA of the DSSS PHY shall indicate a busy medium for the intended duration of the transmitted frame as indicated by the LENGTH field. The intended duration is indicated by the LENGTH field (length × 1 μs).

If dot11RadioMeasurementActiviated is true and RXERROR equals NoError or UnsupportedRate, the PHY-RXEND.indication primitive also includes RCPI as a parameter.

Figure 15-9 shows the flow of a typical state machine implementation of the receive PHY.

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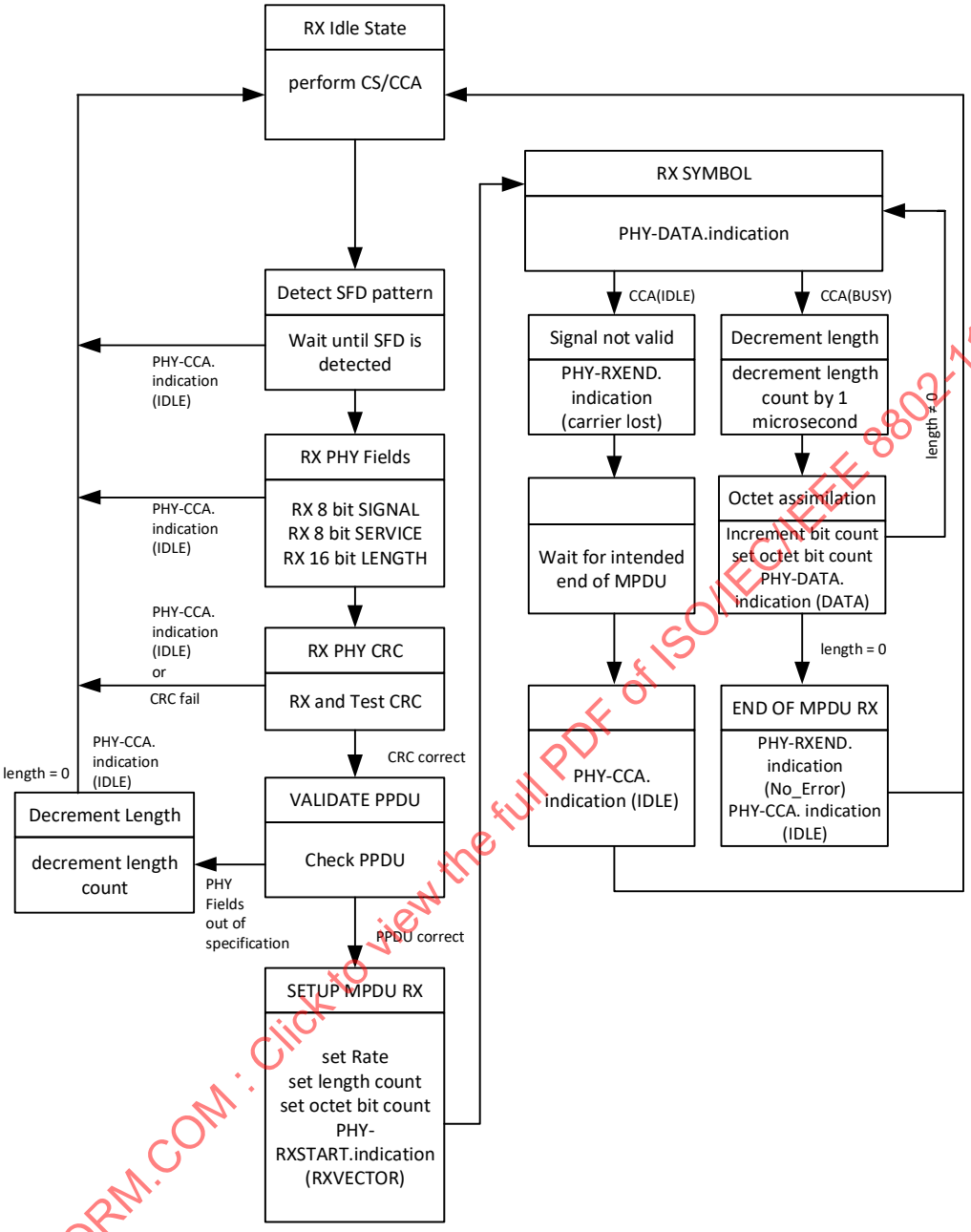

Figure 15-9—PHY receive state machine

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15.4 DSSS PLME

15.4.1 PLME SAP sublayer management primitives

Table 15-4 lists the MIB attributes that may be accessed by the PHY entities and intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, and PLME-RESET primitives defined in Clause 6.

Table 15-4—MIB attribute default values/ranges

Managed object	Default value/range	Operational semantics
dot11PhyOperationComplianceGroup		
dot11PHYType	DSSS–2.4 (02)	Static
dot11RegDomainsSupported	Implementation dependent	Static
dot11CurrentRegDomain	Implementation dependent	Static
dot11PhyRateGroup		
dot11SupportedDataRatesTx	X'02', X'04'	Static
dot11SupportedDataRatesRx	X'02', X'04'	Static
dot11PhyAntennaComplianceGroup		
dot11CurrentTxAntenna	Implementation dependent	Dynamic
dot11DiversitySupportImplemented	Implementation dependent	Static
dot11CurrentRxAntenna	Implementation dependent	Dynamic
dot11PhyTxPowerComplianceGroup		
dot11NumberSupportedPowerLevelsImplemented	Implementation dependent	Static
dot11TxPowerLevel1	Implementation dependent	Static
dot11TxPowerLevel2	Implementation dependent	Static
dot11TxPowerLevel3	Implementation dependent	Static
dot11TxPowerLevel4	Implementation dependent	Static
dot11TxPowerLevel5	Implementation dependent	Static
dot11TxPowerLevel6	Implementation dependent	Static
dot11TxPowerLevel7	Implementation dependent	Static
dot11TxPowerLevel8	Implementation dependent	Static
dot11CurrentTxPowerLevel	Implementation dependent	Dynamic
dot11PhyDSSSComplianceGroup		
dot11CurrentChannel	Implementation dependent	Dynamic
dot11CCAModeSupported	Implementation dependent	Static
dot11CurrentCCAMode	Implementation dependent	Dynamic
dot11EDThreshold	Implementation dependent	Dynamic

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Table 15-4—MIB attribute default values/ranges *(continued)*

Managed object	Default value/range	Operational semantics
dot11AntennasListEntry		
dot11TxAntennaImplemented	Implementation dependent	Static
dot11RxAntennaImplemented	Implementation dependent	Static
dot11DiversitySelectionRxImplemented	Implementation dependent	Dynamic
NOTE—The column titled "Operational semantics" contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. MIB attributes defined as dynamic can be modified by some management entities.		

15.4.2 DSSS PHY MIB

All DSSS PHY MIB attributes are defined in Clause 8, with specific values defined in Table 15-4.

When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.

15.4.3 DSSS PHY

The static DSSS PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 15-5. The definitions for these characteristics are given in 6.5.4.

Table 15-5—DSSS PHY characteristics

Characteristic	Value
aSlotTime	If dot11OperatingClassesRequired is false, 20 μs If dot11OperatingClassesRequired is true, 20 μs plus any coverage-class-dependent aAirPropagationTime (see Table 9-95)
aSIFSTime	10 μs
aCCATime	Implementation dependent, see 10.3.7.
aRxPHYStartDelay	192 μs
aRxTxTurnaroundTime	Implementation dependent, see 10.3.7.
aTxPHYDelay	Implementation dependent, see 10.3.7.
aRxPHYDelay	Implementation dependent, see 10.3.7.
aRxTxSwitchTime	Implementation dependent, see 10.3.7.
aTxRampOnTime	Implementation dependent, see 10.3.7.
aAirPropagationTime	As indicated by the coverage class (see 10.22.5).

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Table 15-5—DSSS PHY characteristics *(continued)*

Characteristic	Value
aMACProcessingDelay	Implementation dependent, see 10.3.7.
aPSDUMaxLength	$2^{12} - 1$ octets
aCWmin	31
aCWmax	1023

15.4.4 PHY operating specifications, general

15.4.4.1 General

Subclause 15.4.4 provides general specifications for the DSSS PHY sublayer. These specifications apply to both the Receive and the Transmit functions and general operation of a DSSS PHY.

15.4.4.2 Operating frequency range

The DSSS PHY shall operate in the frequency range of 2.4 GHz to 2.4835 GHz as allocated by regulatory bodies in the China, United States and Europe or in the 2.471 GHz to 2.497 GHz frequency band as allocated by regulatory authority in Japan.

15.4.4.3 Channel Numbering of operating channels

When dot11OperatingClassesRequired is true, channel numbering shall be as specified in 17.3.8.4.2 and channelization shall be as specified in 17.3.8.4.3. When dot11OperatingClassesDefined is false or not defined, the channel center frequencies and CHNL_ID numbers shall be as shown in Table 15-6.

In a multiple cell network topology, overlapping and/or adjacent cells using different channels can operate simultaneously without interference if the distance between the center frequencies is at least 30 MHz.

Table 15-6—DSSS PHY frequency channel plan

CHNL_ID	Frequency (MHz)
1	2412
2	2417
3	2422
4	2427
5	2432
6	2437
7	2442
8	2447
9	2452

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Table 15-6—DSSS PHY frequency channel plan *(continued)*

CHNL_ID	Frequency (MHz)
10	2457
11	2462
12	2467
13	2472
14	2484

15.4.4.4 Spreading sequence

The following 11-chip Barker sequence shall be used as the PN code sequence:

+1, –1, +1, +1, –1, +1, +1, +1, –1, –1, –1

The leftmost chip shall be output first in time. The first chip shall be aligned at the start of a transmitted symbol. The symbol duration shall be exactly 11 chips long.

15.4.4.5 Modulation and channel data rates

Two modulation formats and data rates are specified for the DSSS PHY: a *basic access rate* and an *enhanced access rate*. The basic access rate shall be based on 1 Mb/s DBPSK modulation. The DBPSK encoder is specified in Table 15-7. The enhanced access rate shall be based on 2 Mb/s DQPSK. The DQPSK encoder is specified in Table 15-8. (In the tables, +jω shall be defined as counterclockwise rotation.)

Table 15-7—1 Mb/s DBPSK encoding table

Bit input	Phase change (+jω)
0	0
1	π

Table 15-8—2 Mb/s DQPSK encoding table

Dibit pattern (d0,d1) d0 is first in time	Phase change (+jω)
00	0
01	π/2
11	π
10	3π/2 (–π/2)

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15.4.4.6 Transmit and receive in-band and out-of-band spurious emissions

The DSSS PHY shall comply with in-band and out-of-band spurious emissions as set by the appropriate regulatory bodies.

15.4.4.7 TX-to-RX turnaround time

The TX-to-RX turnaround time shall be less than 10 μs, including the power-down ramp specified in 15.4.5.8.

The TX-to-RX turnaround time shall be measured on the WM from the trailing edge of the last transmitted symbol to valid CCA detection of the incoming signal.

15.4.4.8 RX-to-TX turnaround time

The RX-to-TX turnaround time shall be measured at the MAC/PHY interface, using the PHY-TXSTART.request primitive and shall be ≤ 5 μs. This includes the transmit power-on ramp described in 15.4.5.8.

15.4.4.9 Slot time

The value of the slot time is found in Table 15-5.

15.4.4.10 Transmit and receive antenna connector impedance

The impedance at the transmit antenna connector and receive antenna connector shall be 50 Ω if that connector is exposed.

15.4.5 PHY transmit specifications

15.4.5.1 Introduction

The transmit functions and parameters associated with the PHY sublayer are described in 15.4.5.2 to 15.4.5.10.

15.4.5.2 Transmit power levels

The maximum allowable output power is measured in accordance with practices specified by the appropriate regulatory bodies.

15.4.5.3 Minimum transmitted power level

The minimum transmitted power shall be no less than 1 mW.

15.4.5.4 Transmit power level control

Power control shall be provided for transmitted power greater than 100 mW. A maximum of four power levels may be provided. At a minimum, a radio capable of transmission greater than 100 mW shall be capable of switching power back to 100 mW or less.

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15.4.5.5 Transmit spectrum mask

The transmitted spectral products shall be less than –30 dBr (decibel relative to the SINx/x peak) for $f_c - 22$ MHz $< f < f_c - 11$ MHz, $f_c + 11$ MHz $< f < f_c + 22$ MHz, –50 dBr for $f < f_c - 22$ MHz, and $f > f_c + 22$ MHz, where f_c is the channel center frequency. The transmit spectral mask is shown in Figure 15-10. The measurements shall be made using 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

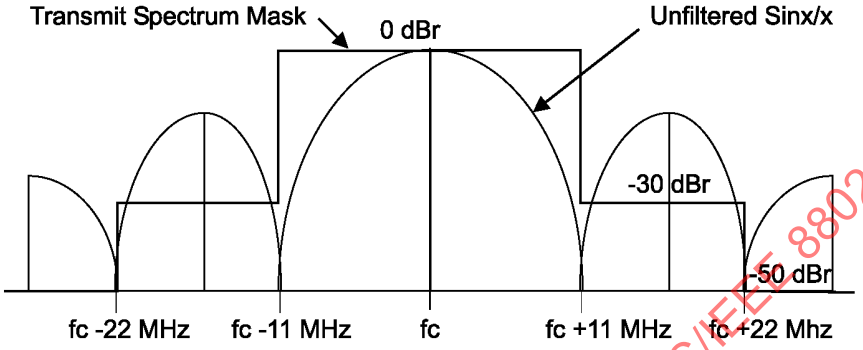

Figure 15-10—Transmit spectrum mask

Channel 14 is unique. The Japanese standard ARIB RCR-STD 33 (5.0) [B5] states that B90/2π normalized to the 'transmission speed of modulation signal' shall be > 10, where B90 is the 90% occupied channel bandwidth. Therefore, for channel 14, B90/2π > 13.75 MHz for CCK spreading and >10.0 MHz for Barker spreading.

15.4.5.6 Transmit center frequency tolerance

The transmitted center frequency tolerance shall be ± 25 ppm.

15.4.5.7 Chip clock frequency tolerance

The PN code chip clock frequency tolerance shall be ± 25 ppm.

15.4.5.8 Transmit power-on and power-down ramp

The transmit power-on ramp for 10% to 90% of maximum power shall be no greater than 2 µs. The transmit power-on ramp is shown in Figure 15-11.

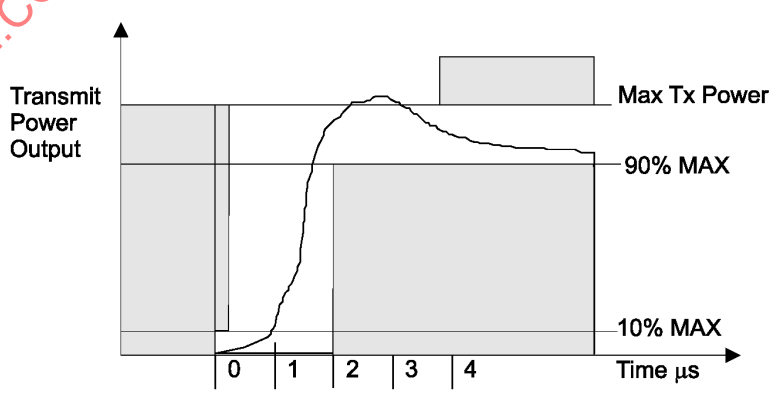

Figure 15-11—Transmit power-on ramp

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The transmit power-down ramp for 90% to 10% maximum power shall be no greater than 2 µs. The transmit power-down ramp is shown in Figure 15-12.

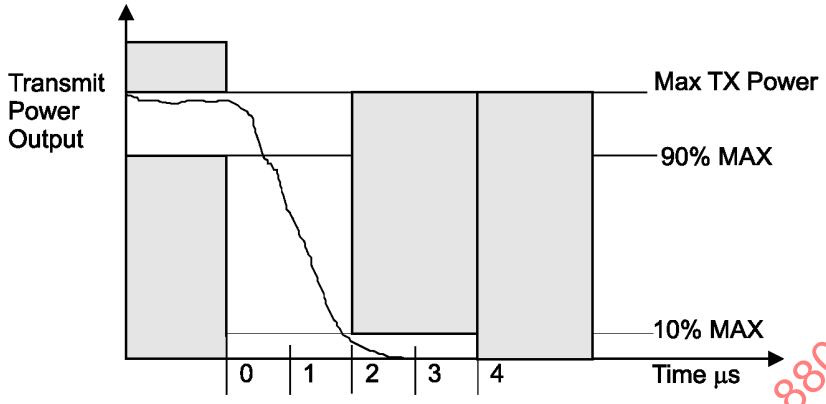

Figure 15-12—Transmit power-down ramp

The transmit power ramps shall be constructed such that the DSSS PHY emissions comply with the spurious frequency product specification defined in 15.4.4.6.

15.4.5.9 RF carrier suppression

The RF carrier suppression, measured at the channel center frequency, shall be at least 15 dB below the peak sin(x)/x power spectrum. The RF carrier suppression shall be measured while transmitting a repetitive 01 data sequence with the scrambler disabled using DQPSK modulation. A 100 kHz resolution bandwidth shall be used to perform this measurement.

15.4.5.10 Transmit modulation accuracy

The transmit modulation accuracy requirement for the DSSS PHY shall be based on the difference between the actual transmitted waveform and the ideal signal waveform. Modulation accuracy shall be determined by measuring the peak vector error magnitude measured during each chip period. Worst-case vector error magnitude shall not exceed 0.35 for the normalized sampled chip data. The ideal complex I and Q constellation points associated with DQPSK modulation (0.707, 0.707), (0.707, –0.707), (–0.707, 0.707), (–0.707, –0.707) shall be used as the reference. These measurements shall be from baseband I and Q sampled data after recovery through a reference receiver system.

Figure 15-13 illustrates the ideal DQPSK constellation points and range of worst-case error specified for modulation accuracy.

Error vector measurement requires a reference receiver capable of carrier lock. All measurements shall be made under carrier lock conditions. The distortion induced in the constellation by the reference receiver shall be calibrated and measured. The test data error vectors described below shall be corrected to compensate for the reference receiver distortion.

The IEEE 802.11 vendor compatible radio shall provide an exposed TX chip clock, which shall be used to sample the I and Q outputs of the reference receiver.

The measurement shall be made under the conditions of continuous DQPSK transmission using scrambled all 1s.

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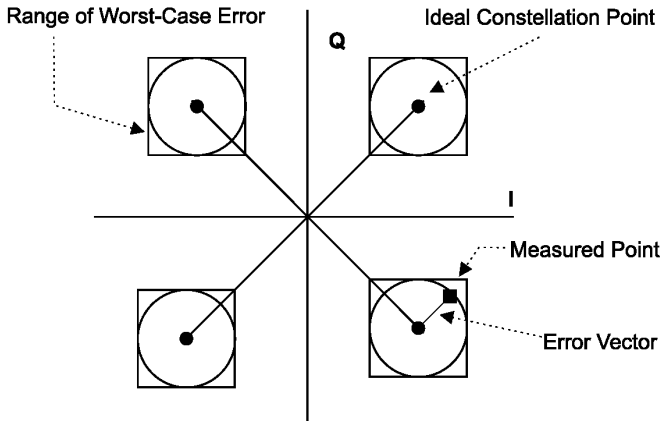

Figure 15-13—Modulation accuracy measurement example

The eye pattern of the I channel shall be used to determine the *I* and *Q* sampling point. The chip clock provided by the vendor radio shall be time delayed such that the samples fall at a 1/2 chip period offset from the mean of the zero crossing positions of the eye (see Figure 15-14). This is the ideal center of the eye and might not be the point of maximum eye opening.

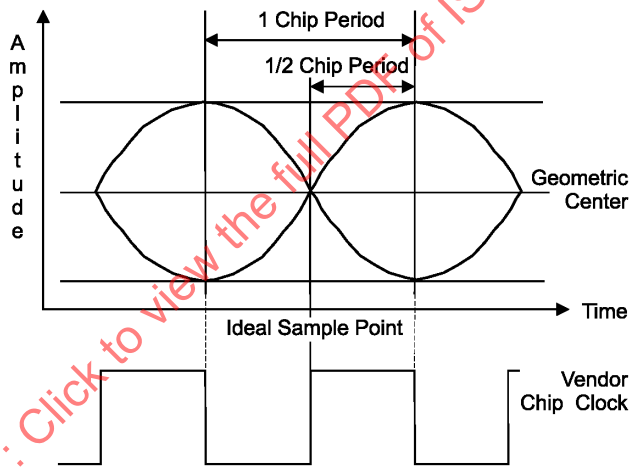

Figure 15-14—Chip clock alignment with baseband eye pattern

Using the aligned chip clock, 1000 samples of the *I* and *Q* baseband outputs from the reference receiver are captured. The vector error magnitudes shall be calculated as follows:

Calculate the dc offsets for *I* and *Q* samples.

$$I_{\text{mean}} = \sum_{n=1}^{1000} I(n)/1000$$

$$Q_{\text{mean}} = \sum_{n=1}^{1000} Q(n)/1000$$

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Calculate the dc corrected I and Q samples for all n =1000 sample pairs.

$$I_{dc}(n) = I(n) - I_{mean}$$

$$Q_{dc}(n) = Q(n) - Q_{mean}$$

Calculate the average magnitude of I and Q samples.

$$I_{mag} = \sum_{n=1}^{1000} |I_{dc}(n)| / 1000$$

$$Q_{mag} = \sum_{n=1}^{1000} |Q_{dc}(n)| / 1000$$

Calculate the normalized error vector magnitude for the $I_{dc}(n)/Q_{dc}(n)$ pairs.

$$V_{err}(n) = [\{|I_{dc}(n)| - I_{mag}\}^2 + \{|Q_{dc}(n)| - Q_{mag}\}^2]^{1/2}$$

where
the average power of the constellation is 1

NOTE—A correction factor might be needed to compensate for the error induced by a test reference receiver system.

For all n =1000 samples, the following condition shall be met:

$$V_{err}(n) < 0.35$$

15.4.5.11 Time of Departure accuracy

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is $22 \times 10^6 \left(1 + \left\lceil \frac{f_H - f_L}{22\ \text{MHz}} \right\rceil\right)$ sample/s

where
f_H is the nominal center frequency in Hz of the highest channel in the channel set
f_L is the nominal center frequency in Hz of the lowest channel in the channel set, the channel set is the set of channels upon which frames providing measurements are transmitted, the channel set comprises channels uniformly spaced across $f_H - f_L \geq 50$ MHz

— FIRST_TRANSITION_FIELD is the SYNC field.
— SECOND_TRANSITION_FIELD is the SFD field.
— TRAINING_FIELD is the concatenation of the SYNC and SFD fields, using a chip pulse that should approximate a rectangular pulse of duration 1/ 11 MHz convolved with a brick-wall low pass filter of bandwidth 11 MHz.
— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns.

NOTE—The indicated chip pulse applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

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15.4.6 PHY receiver specifications

15.4.6.1 Introduction

The receive functions and parameters associated with the PHY sublayer are described in 15.4.6.2 to 15.4.6.5.

15.4.6.2 Receiver minimum input level sensitivity

The FER shall be less than 8×10^{-2} at an MPDU length of 1024 octets for an input level of –80 dBm measured at the antenna connector. This FER shall be specified for 2 Mb/s DQPSK modulation. The test for the minimum input level sensitivity shall be conducted with the ED threshold set ≤ –80 dBm.

15.4.6.3 Receiver maximum input level

If the STA is non-ERP, the receiver shall provide a maximum FER of 8×10^{-2} at an MPDU length of 1024 octets for a maximum input level of –4 dBm measured at the antenna connector. This FER shall be specified for 2 Mb/s DQPSK modulation.

15.4.6.4 Receiver adjacent channel rejection

Adjacent channel rejection is defined between any two channels with ≥ 30 MHz separation in each channel group defined in 15.4.4.3.

The adjacent channel rejection shall be ≥ 35 dB with an FER of 8×10^{-2} using 2 Mb/s DQPSK modulation described in 15.4.4.5 and an MPDU length of 1024 octets.

The adjacent channel rejection shall be measured using the following method:

Input a 2 Mb/s DQPSK modulated signal at a level 6 dB greater than specified in 15.4.6.2. In an adjacent channel (≥ 30 MHz separation as defined by the channel numbering), input a signal modulated in a similar fashion that adheres to the transmit mask specified in 15.4.5.5 to a level 41 dB above the level specified in 15.4.6.2. The adjacent channel signal shall be derived from a separate signal source. It shall not be a frequency shifted version of the reference channel. Under these conditions, the FER shall be less than or equal to 8×10^{-2}.

15.4.6.5 CCA

Requirements in this subclause are applicable to non-ERP DSSS STAs.

The non-ERP DSSS PHY shall provide the capability to perform CCA according to both:

A — at least one of the following options:

- — *CCA Mode 1:* Energy above threshold. CCA shall report a busy medium upon detection of any energy above the ED threshold.
- — *CCA Mode 2:* CS only. CCA shall report a busy medium only upon detection of a DSSS signal. This signal may be above or below the ED threshold.
- — *CCA Mode 3:* CS with energy above threshold. CCA shall report a busy medium upon detection of a DSSS signal with energy above the ED threshold.

and

B — *CCA Mode 6:* CCA shall report a busy medium upon detection of any energy above –62 dBm.

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A busy channel shall be indicated by issuing a PHY-CCA.indication(BUSY) primitive.

A clear channel shall be indicated by issuing a PHY-CCA.indication(IDLE) primitive.

For a non-ERP DSSS STA, the value of dot11CCAModeSupported shall indicate the appropriate operation modes. The PHY shall be configured according to dot11CurrentCCAMode.

The CCA parameters are subject to the following criteria:

a) The ED threshold shall be ≤ –80 dBm for TX power > 100 mW, –76 dBm for 50 mW < TX power ≤ 100 mW, and –70 dBm for TX power ≤ 50 mW. The ED threshold is the value contained in dot11EDThreshold.

b) With a valid signal (according to the CCA mode of operation) present at the receiver antenna within 5 µs of the start of a MAC slot boundary, the PHY-CCA.indication(BUSY) primitive shall be generated before the end of the slot time if aSlotTime is 20 µs. Refer to Figure 10-21 (in 10.3.7) and Figure 10-25 for a definition of slot boundary.

c) In the event that a correct PHY header is received, the DSSS PHY shall not generate a PHY-CCA.indication (IDLE) primitive until the end of the PPDU as determined by TXTIME in 15.4.6.7.

Compliance to DSSS PHY CCA shall be demonstrated by applying a DSSS signal, above the appropriate ED threshold (item a), so that all conditions described in item b and item c are demonstrated.

15.4.6.6 Received channel power indicator (RCPI) measurement

The RCPI is a measure of the received RF power in the selected channel for a received frame. This parameter shall be a measure by the PHY of the received RF power in the channel measured over the entire received frame or by other equivalent means that meet the specified accuracy.

The RCPI encoding is defined in 9.4.2.37.

RCPI shall equal the received RF power within an accuracy of ± 5 dB (95% confidence interval) within the specified dynamic range of the receiver. The received RF power shall be determined assuming a receiver noise equivalent bandwidth equal to the channel bandwidth multiplied by 1.1.

15.4.6.7 DSSS PHY TXTIME calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated according to the following equations:

$$\text{TXTIME} = \text{PreambleLength} + \text{PHYHeaderTime} + \left\lceil \frac{\text{LENGTH} \times 8}{\text{DATARATE}} \right\rceil$$

where

LENGTH and DATARATE	are values from the TXVECTOR parameter of the corresponding PLME-TXTIME.request primitive
LENGTH	is in units of octets
DATARATE	is in units of Mb/s
The value of PreambleLength	is 144 µs
The value of PHYHeaderTime	is 48 µs

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16. High rate direct sequence spread spectrum (HR/DSSS) PHY specification

16.1 Overview

16.1.1 General

This clause specifies the high rate extension of the PHY for the DSSS system (see Clause 15), hereinafter known as the HR/DSSS PHY for the 2.4 GHz band designated for ISM applications.

This extension of the DSSS system builds on the data rate capabilities, as described in Clause 15, to provide 5.5 Mb/s and 11 Mb/s payload data rates in addition to the 1 Mb/s and 2 Mb/s rates. To provide the higher rates, 8-chip complementary code keying (CCK) is employed as the modulation scheme. The chipping rate is 11 MHz, which is the same as the DSSS system described in Clause 15, thus providing the same occupied channel bandwidth. The basic new capability described in this clause is called *HR/DSSS*. One mode of the HR/DSSS PHY uses the same PHY preamble and header as the DSSS PHY, so both PHYs can coexist in the same BSS and can use the rate switching mechanism as provided.

In addition to providing higher speed extensions to the DSSS system, a number of optional features allow the performance of the RF LAN system to be improved as technology allows the implementation of these options to become cost effective.

Another optional mode is provided that allows data throughput at the higher rates (2, 5.5, and 11 Mb/s) to be significantly increased by using a shorter PHY preamble. This mode is called *HR/DSSS/short*. This short preamble mode can coexist with DSSS, HR/DSSS under limited circumstances, such as on different channels or with appropriate CCA mechanisms.

16.1.2 Scope of HR/DSSS PHY services

This clause specifies the PHY entity for the HR/DSSS extension and explains how this standard accommodates the HR/DSSS PHY.

The HR/DSSS PHY consists of the following two protocol functions:

a) A PHY function that defines a method for mapping the MPDUs into a framing format suitable for sending and receiving user data and management information between two or more STAs. The PHY exchanges PPDUs that contain PSDUs. The MAC uses the PHY service, so each MPDU corresponds to a PSDU that is carried in a PPDU.

b) A function that defines the characteristics of, and method of transmitting and receiving data through, a WM between two or more STAs, each using the HR/DSSS PHY system.

16.1.3 HR/DSSS PHY functions

16.1.3.1 General

The HR/DSSS PHY contains two functional entities: the PHY function and the layer management function. Each of these functions is described in detail in 16.2 and 16.3.

The HR/DSSS PHY service shall be provided to the MAC through the PHY service primitives described in Clause 8.

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16.1.3.2 PLME

The PLME performs management of the local PHY functions in conjunction with the MLME.

16.1.4 Service specification method and notation

The models represented by figures and state diagrams are intended to be illustrations of functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, but do not necessarily reflect any particular implementation.

The service of a layer or sublayer is a set of capabilities that it offers to a user in the next-higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

16.2 HR/DSSS PHY

16.2.1 Overview

Subclause 16.2 provides a convergence procedure for the 2 Mb/s, 5.5 Mb/s, and 11 Mb/s specification, in which PSDUs are converted to and from PPDUs. During transmission, the PSDU shall be appended to a PHY preamble and header to create the PPDU. Two different preambles and headers are defined: the mandatory supported long preamble and header, which interoperates with the current 1 Mb/s and 2 Mb/s DSSS specification, and an optional short preamble and header. At the receiver, the PHY preamble and header are processed to aid in demodulation and delivery of the PSDU.

The optional short preamble and header provides maximum throughput when interoperability with legacy and nonshort-preamble-capable STAs is not a consideration. That is, it is expected to be used only in networks of STAs that support the optional mode.

16.2.2 PPDU format

16.2.2.1 General

Two different preambles and headers are defined: the mandatory supported long preamble and header, which is interoperable with the current 1 Mb/s and 2 Mb/s DSSS specification, and an optional short preamble and header.

16.2.2.2 Long PPDU format

Figure 16-1 shows the format for the interoperable (long) PPDU, including the HR/DSSS PHY preamble, the HR/DSSS PHY header, and the PSDU. The PHY preamble contains the following fields: SYNC and SFD. The PHY header contains the following fields: signaling (SIGNAL), service (SERVICE), length (LENGTH), and CRC-16. Each of these fields is described in detail in 16.2.3. The format for the PPDU, including the long HR/DSSS PHY preamble, the long HR/DSSS PHY header, and the PSDU, does not differ from the format for 1 Mb/s and 2 Mb/s. The only exceptions are:

a) The encoding of the rate in the SIGNAL field;
b) The use of a bit in the SERVICE field to resolve an ambiguity in PSDU length in octets, when the length is expressed in whole microseconds;
c) The use of a bit in the SERVICE field to indicate that the transit frequency and bit clocks are locked.

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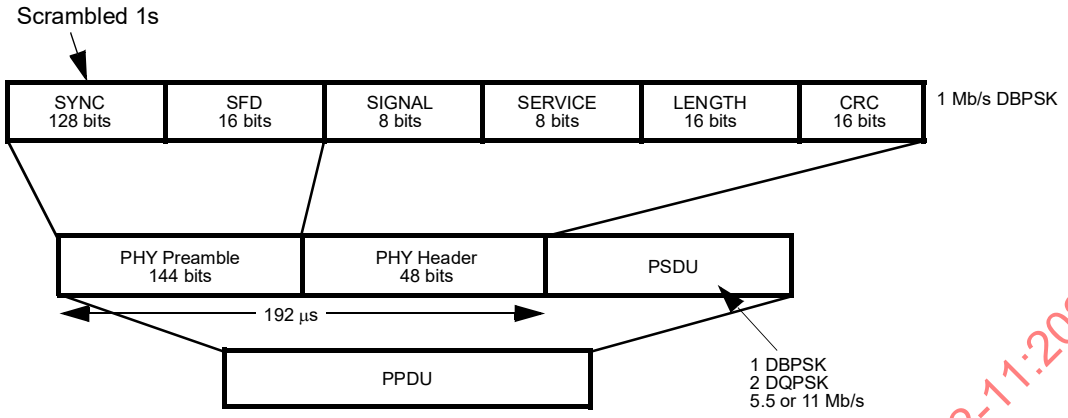

Figure 16-1—Long PPDU format

16.2.2.3 Short PPDU format

The short PHY preamble and header (HR/DSSS/short) is optional. The short preamble and header may be used to minimize overhead and, thus, maximize the network data throughput. The format of the PPDU, with HR/DSSS/short, is shown in Figure 16-2. A Clause 18 STA shall support the short PPDU format.

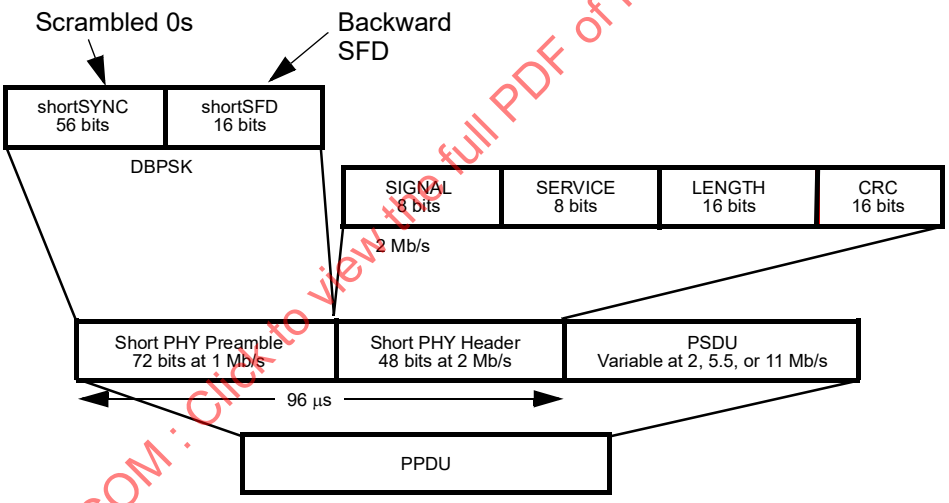

Figure 16-2—Short PPDU format

A transmitter using the short PPDU is interoperable with only another receiver that is also capable of receiving this short PPDU. To interoperate with a receiver that is not capable of receiving a short preamble and header, the transmitter shall use the long PHY preamble and header. The short PHY preamble uses the 1 Mb/s Barker code spreading with DBPSK modulation. The short PHY header uses the 2 Mb/s Barker code spreading with DQPSK modulation, and the PSDU is transmitted at 2 Mb/s, 5.5 Mb/s, or 11 Mb/s.

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16.2.3 PPDU field definitions

16.2.3.1 General

In the PHY field definition subclauses (16.2.3.2 to 16.2.3.15), the definitions of the long (Clause 15) PHY fields are given first, followed by the definitions of the short PHY fields. The names for the short PHY fields are preceded by the term *short*.

16.2.3.2 Long PHY SYNC field

The SYNC field shall consist of scrambled 1 bits. This field is provided so the receiver can perform the necessary synchronization operations. The initial state of the scrambler (seed) shall be [1101100], where the bit specifies the value to put in the first delay element (Z^1) in Figure 16-5 (in 16.2.4), and the rightmost bit specifies the value to put in the last delay element in the scrambler.

To support the reception of DSSS signals generated with implementations based on Clause 15, the receiver shall also be capable of synchronization on a SYNC field derived from any nonzero scrambler initial state.

16.2.3.3 Long PHY SFD

The SFD shall be provided to indicate the start of PHY-dependent parameters within the PHY preamble. The SFD shall be [1111 0011 1010 0000], where the rightmost bit shall be transmitted first in time.

16.2.3.4 Long PHY SIGNAL field

The SIGNAL field indicates to the PHY the modulation that shall be used for transmission (and reception) of the PSDU. The data rate shall be equal to the SIGNAL field value multiplied by 100 kb/s. The high rate PHY supports four mandatory rates given by the following 8-bit words, which represent the rate in units of 100 kb/s, where the LSB shall be transmitted first in time:

a) X'0A' (MSB to LSB) for 1 Mb/s
b) X'14' (MSB to LSB) for 2 Mb/s
c) X'37' (MSB to LSB) for 5.5 Mb/s
d) X'6E' (MSB to LSB) for 11 Mb/s

The HR/DSSS PHY rate change capability is described in 16.2.3.15. This field shall be protected by the CRC-16 FCS described in 16.2.3.7.

16.2.3.5 Long PHY SERVICE field

Two bits have been defined in the SERVICE field to support the high rate extension; see Table 16-1. The rightmost bit (bit 7) shall be used to supplement the LENGTH field described in 16.2.3.6. Bit 2 shall be used to indicate that the transmit frequency and symbol clocks are derived from the same oscillator. This locked clocks bit shall be set by the PHY based on its implementation configuration. The SERVICE field shall be transmitted B0 first in time, and shall be protected by the CRC-16 FCS described in 16.2.3.7. B0, B1, B3, B4, B5, and B6 are reserved and shall be set to 0 on transmission and ignored on reception.

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Table 16-1—SERVICE field definitions

B0	B1	B2	B3	B4	B5	B6	B7
Reserved	Reserved	Locked clocks bit 0 = not locked 1 = locked	Reserved	Reserved	Reserved	Reserved	Length extension bit

16.2.3.6 Long PHY LENGTH field

The PHY LENGTH field shall contain an unsigned integer that indicates the number of microseconds required to transmit the PSDU. The transmitted value shall be determined from the LENGTH and DATARATE parameters in the TXVECTOR issued with the PHY-TXSTART.request primitive described in 16.3.5.

The LENGTH field provided in the TXVECTOR is in octets and is converted to microseconds for inclusion in the PHY LENGTH field. The LENGTH field is calculated as follows. Because there is an ambiguity in the number of octets that is described by a length in integer microseconds for any data rate over 8 Mb/s, a length extension bit is present in the SERVICE field to indicate when the smaller potential number of octets is correct as follows:

— 5.5 Mb/s CCK LENGTH = $\left\lceil \text{number of octets} \times \frac{8}{5.5} \right\rceil$.

— 11 Mb/s CCK LENGTH = $\left\lceil \text{number of octets} \times \frac{8}{11} \right\rceil$; the length extension bit shall be set to 0 if (LENGTH – (number of octets × 8/11)) < 8/11 and shall be set to 1 otherwise.

The length extension bit is reserved when the data rate is not 11 Mb/s.

At the receiver, the number of octets in the MPDU is calculated as follows:

— 5.5 Mb/s CCK number of octets = $\left\lfloor \text{LENGTH} \times \frac{5.5}{8} \right\rfloor$.

— 11 Mb/s CCK number of octets = $\left\lfloor \text{LENGTH} \times \frac{11}{8} \right\rfloor$, minus 1 if the length extension bit is a 1.

An example for an 11 Mb/s calculation described in pseudocode form is shown below. At the transmitter, the values of the LENGTH field and length extension bit are calculated as follows:

LENGTH' = (number of octets × 8) / R

LENGTH = ⌈LENGTH'⌉

If

(R = 11) and ((LENGTH–LENGTH') ≥ 8/11)

then

length extension = 1

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else

length extension = 0

where
R is the data rate (Mb/s)

At the receiver, the number of octets in the MPDU is calculated as follows:

$$\text{number of octets} = \left\lfloor \frac{\text{LENGTH} \times R}{8} \right\rfloor - \text{length extension}$$

where
R is the data rate (Mb/s)

Table 16-2 shows an example calculation for several LENGTH values of CCK at 11 Mb/s.

Table 16-2—Example of LENGTH calculations for CCK

TX octets	$\frac{\text{Octets} \times 8}{11}$	LENGTH	Length extension bit	$\frac{\text{LENGTH} \times 11}{8}$	$\left\lfloor \frac{\text{LENGTH} \times 11}{8} \right\rfloor$	RX octets
1023	744	744	0	1023	1023	1023
1024	744.7273	745	0	1024.375	1024	1024
1025	745.4545	746	0	1025.75	1025	1025
1026	746.1818	747	1	1027.125	1027	1026

This example illustrates why normal rounding or truncation of the number does produce the right result. The LENGTH field is defined in units of microseconds and corresponds to the actual length, and the number of octets is exact.

The LSB shall be transmitted first in time. This field shall be protected by the CRC-16 FCS described in 16.2.3.7.

16.2.3.7 PHY CRC (CRC-16) field

The SIGNAL, SERVICE, and LENGTH fields shall be protected with a CRC-16 FCS. The CRC-16 FCS shall be the 1s complement of the remainder generated by the modulo 2 division of the protected PHY fields by the polynomial

$$x^{16} + x^{12} + x^5 + 1$$

The protected bits shall be processed in transmit order. All FCS calculations shall be made prior to data scrambling. A schematic of the processing is shown in Figure 16-3.

As an example, the SIGNAL, SERVICE, and LENGTH fields for a DBPSK signal with a PPDU length of 192 μs (24 octets) would be given by the following:

0101 0000 0000 0000 0000 0011 0000 0000 [leftmost bit (B0) transmitted first in time]
B0.....B48

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The 1s complement FCS for these protected PHY preamble bits would be the following:

0101 1011 0101 0111 [leftmost bit (B0) transmitted first in time]
B0.....B16

Figure 16-3 depicts this example.

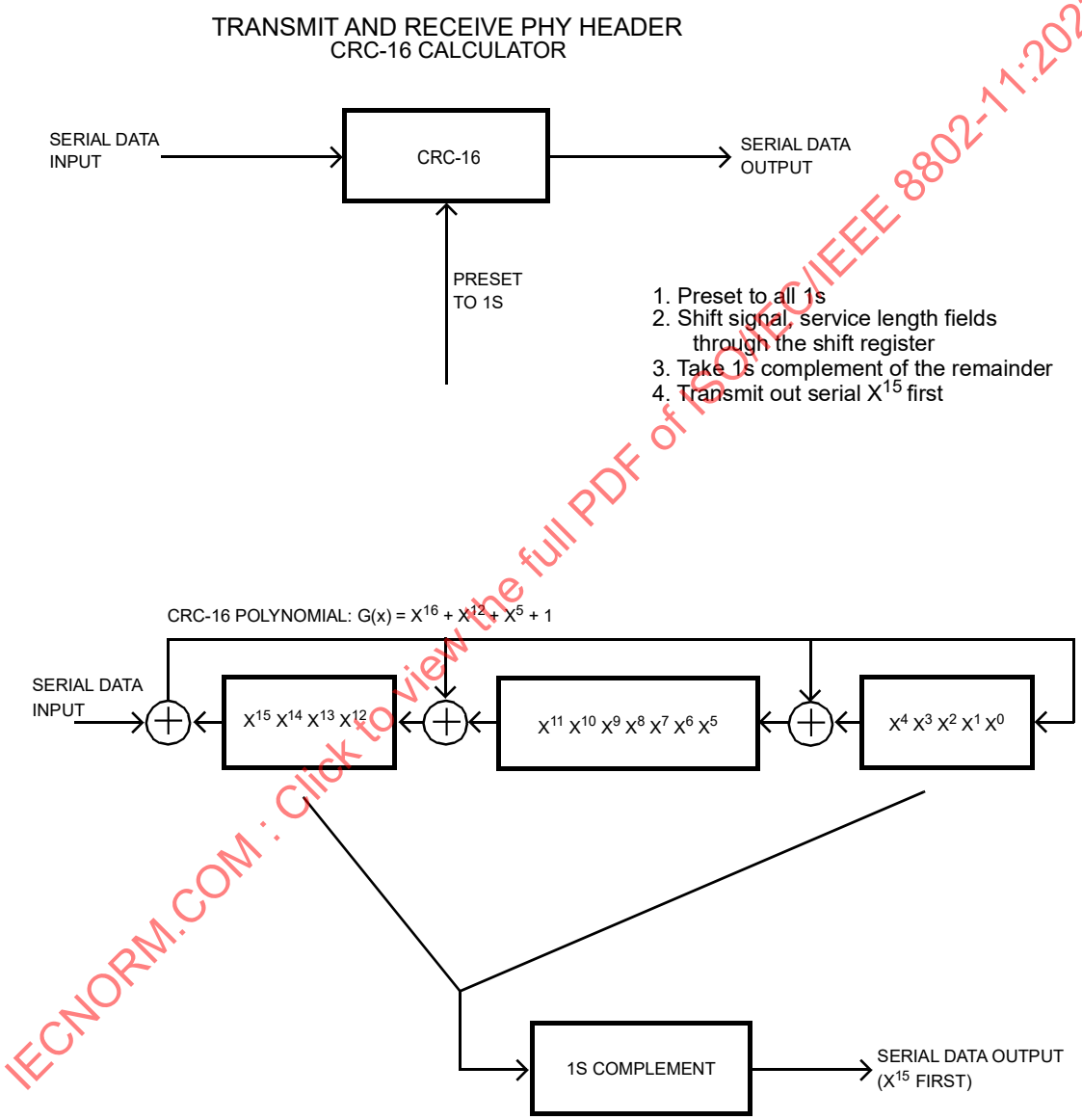

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Figure 16-3—CRC-16 implementation

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An illustrative example of the CRC-16 FCS using the information from Figure 16-3 is shown in Figure 16-4.

Data	CRC Registers MSB LSB	
	1111111111111111	; Initialize preset to 1s
0	1110111111011111	
1	1101111110111110	
0	1010111101011101	
1	0101111010111010	
0	1011110101110100	
0	0110101011001001	
0	1101010110010010	
0	1011101100000101	
0	0110011000101011	
0	1100110001010110	
0	1000100010001101	
0	0000000100111011	
0	0000001001110110	
0	0000010011101100	
0	0000100111011000	
0	0001001110110000	
0	0010011101100000	
0	0100111011000000	
0	1001110110000000	
0	0010101100100001	
0	0101011001000010	
0	1010110010000100	
1	0101100100001000	
1	1010001000110001	
0	0101010001000011	
0	1010100010000110	
0	0100000100101101	
0	1000001001011010	
0	0001010010010101	
0	0010100100101010	
0	0101001001010100	
0	1010010010101000	
	0101101101010111	; 1s complement, result = CRC FCS parity

Figure 16-4—Example of CRC calculation

16.2.3.8 Long PHY data modulation and modulation rate change

The long PHY preamble and header shall be transmitted using the 1 Mb/s DBPSK modulation. The SIGNAL field indicates the rate that is used to transmit the PSDU. The transmitter and receiver shall initiate the rate indicated by the SIGNAL field, starting with the first octet of the PSDU. The PSDU transmission rate shall be set by the DATARATE parameter in the TXVECTOR, issued with the PHY-TXSTART.request primitive described in 16.3.5.

16.2.3.9 Short PHY synchronization (shortSYNC)

The shortSYNC field shall consist of scrambled 0 bits. This field is provided so the receiver can perform the necessary synchronization operations. The initial state of the scrambler (seed) shall be [001 1011], where the left end bit specifies the value to place in the first delay element (Z^1) in Figure 16-5 (in 16.2.4), and the right end bit specifies the value to place in the last delay element (Z^7).

16.2.3.10 Short PHY SFD field (shortSFD)

The shortSFD shall be the time reverse of the field of the SFD in the long PHY preamble (16.2.3.3). The field is the bit pattern 0000 0101 1100 1111. The right end bit shall be transmitted first in time. A receiver not configured to use the short header option does not detect this SFD.

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16.2.3.11 Short PHY SIGNAL field (shortSIGNAL)

The SIGNAL field of the short header indicates to the PHY the data rate that shall be used for transmission (and reception) of the PSDU. A PHY operating with the HR/DSSS/short option supports three mandatory rates given by the following 8-bit words, where the LSB shall be transmitted first in time and the number represents the rate in units of 100 kb/s:

a) X'14' (MSB to LSB) for 2 Mb/s
b) X'37' (MSB to LSB) for 5.5 Mb/s
c) X'6E' (MSB to LSB) for 11 Mb/s

16.2.3.12 Short PHY SERVICE field (shortSERVICE)

The SERVICE field in the short header shall be the same as the SERVICE field described in 16.2.3.5.

16.2.3.13 Short PHY LENGTH field (shortLENGTH)

The LENGTH field in the short header shall be the same as the LENGTH field described in 16.2.3.6.

16.2.3.14 Short CRC-16 field (shortCRC)

The CRC in the short header shall be the same as the CRC field defined in 16.2.3.7. The CRC-16 is calculated over the shortSIGNAL, shortSERVICE, and shortLENGTH fields.

16.2.3.15 Short PHY data modulation and modulation rate change

The short PHY preamble shall be transmitted using the 1 Mb/s DBPSK modulation. The short PHY header shall be transmitted using the 2 Mb/s modulation. The SIGNAL field indicates the rate that is used to transmit the PSDU. The transmitter and receiver shall initiate the rate indicated by the SIGNAL field, starting with the first octet of the PSDU. The PSDU transmission rate shall be set by the DATARATE parameter in the TXVECTOR, issued with the PHY-TXSTART.request primitive described in 16.3.5.

16.2.4 PHY/HR/DSSS PHY data scrambler and descrambler

The polynomial $G(z) = z^{-7} + z^{-4} + 1$ shall be used to scramble all bits transmitted. The feedthrough configuration of the scrambler and descrambler is self-synchronizing, which requires no prior knowledge of the transmitter initialization of the scrambler for receive processing. Figure 16-5 and Figure 16-6 show typical implementations of the data scrambler and descrambler, but other implementations are possible.

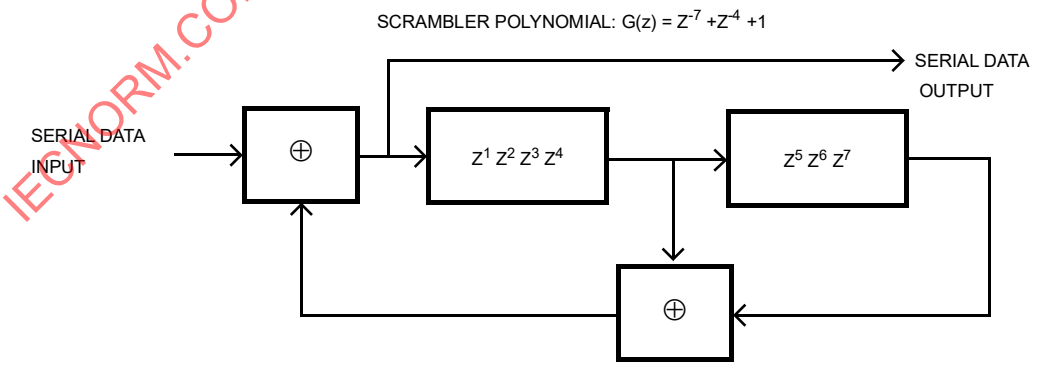

Figure 16-5—Data scrambler

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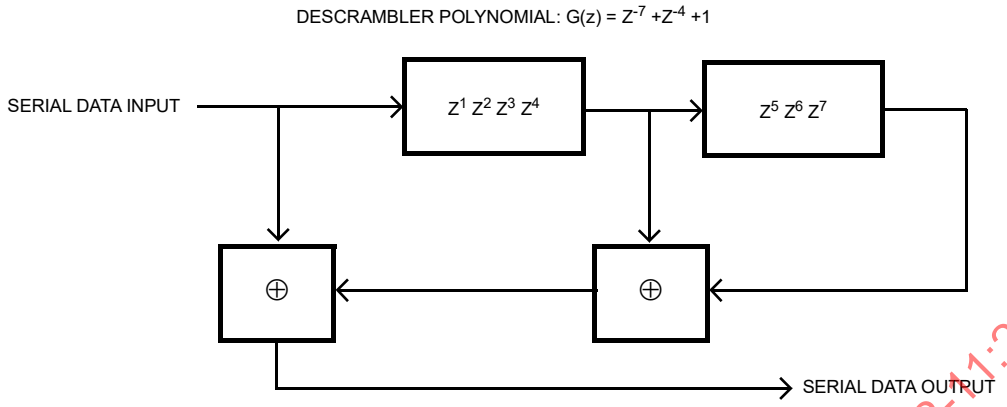

Figure 16-6—Data descrambler

The scrambler shall be initialized as specified in 16.2.3.9 for the short PPDU format and 16.2.3.2 for the long PPDU format. For a long preamble, this shall result in the scrambler registers Z^1 to Z^7 in Figure 16-5 having the data pattern [1101100] (i.e., Z^1= 1... Z^7= 0) when the scrambler is first started. The scrambler shall be initialized with the reverse pattern [0011011] when transmitting the optional short preamble.

16.2.5 Transmit PHY

The transmit procedures for a HR/DSSS PHY using the long PPDU format are the same as the transmit procedures described in 15.3.6 and 15.3.7 and do not change apart from the ability to transmit 5.5 Mb/s and 11 Mb/s.

The procedures for a transmitter employing HR/DSSS/short are the same except for length and rate changes. The decision to use the long or short PPDU format is beyond the scope of this standard.

The transmit PHY is shown in Figure 16-7.

A PHY-TXSTART.request(TXVECTOR) primitive is issued by the MAC to start the transmission of a PPDU. In addition to parameters DATARATE and LENGTH, other transmit parameters such as PREAMBLE_TYPE are set via the PHY SAP with the PHY-TXSTART.request(TXVECTOR) primitive, as described in 16.3.5. The SIGNAL, SERVICE, and LENGTH fields of the PHY header are calculated as described in 16.2.3.

The PHY is configured with the TXVECTOR elements TX_ANTENNA, DATARATE, and TXPWR_LEVEL_INDEX. The PHY entity shall immediately initiate data scrambling and transmission of the PHY preamble based on the parameters passed in the PHY-TXSTART.request primitive. The time required for transmit power-on ramp, described in 16.3.7.7, shall be included in the PHY SYNC field.

Once the PHY preamble transmission is complete, data shall be exchanged between the MAC and the PHY by a series of PHY-DATA.request(DATA) primitives issued by the MAC and PHY-DATA.confirm primitives issued by the PHY. The modulation and rate change, if any, shall be initiated with the first data symbol of the PSDU, as described in 16.2.3.8 and 16.2.3.15. The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. Normal termination occurs after the transmission of the final bit of the last PSDU octet, calculated from the number supplied in the PHY preamble LENGTH and SERVICE fields using the equations specified in 16.2.3.6. The PPDU transmission shall be completed and the PHY entity shall enter the receive state. It is recommended that modulation continue during power-down

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to prevent radiating a continuous wave carrier. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

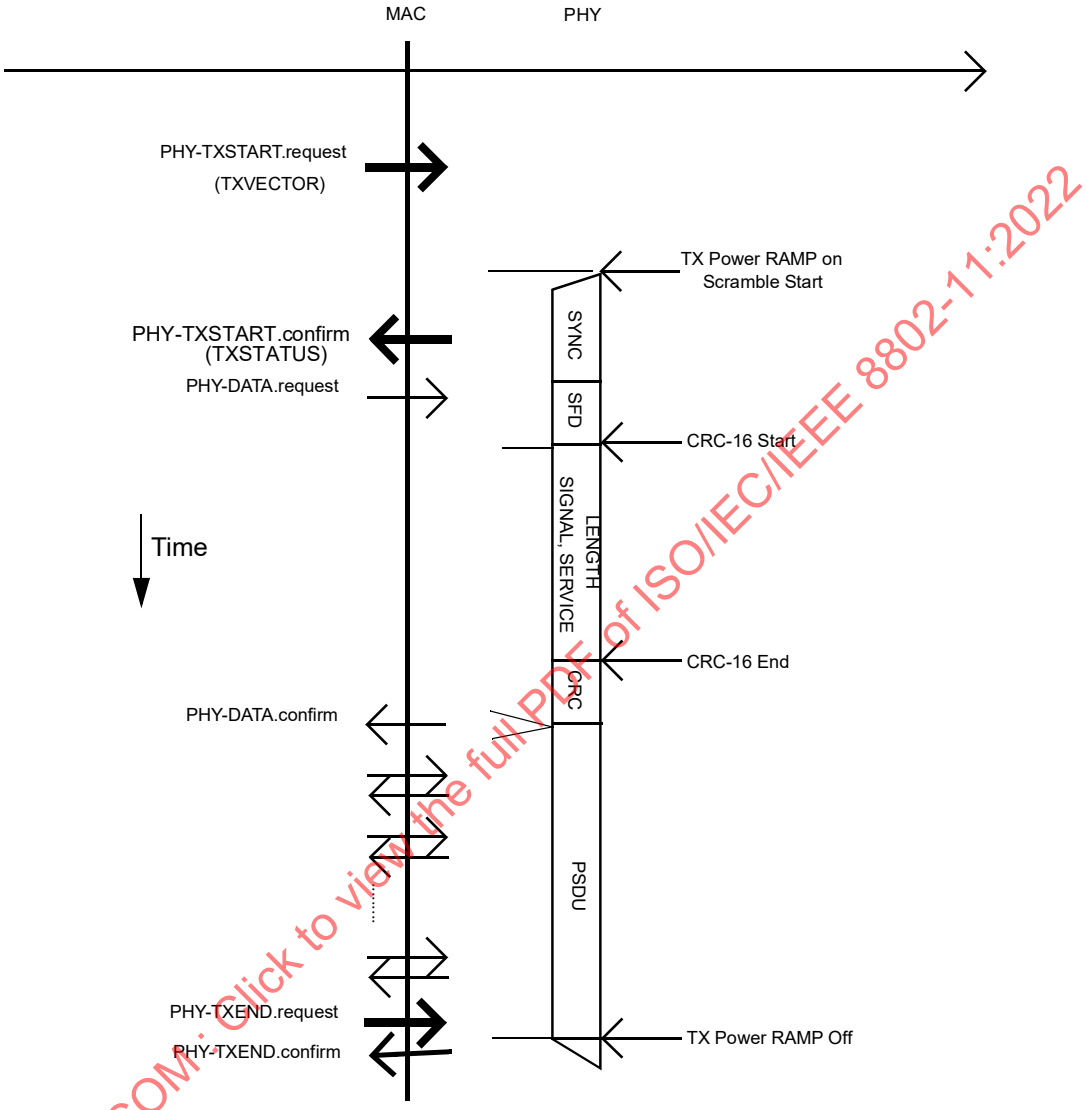

Figure 16-7—Transmit PHY

16.2.6 Receive PHY

The receive procedures for receivers configured to receive the mandatory and optional PHYs, rates, and modulations are described in this subclause. A receiver that supports this high rate extension of the standard is capable of receiving 5.5 Mb/s and 11 Mb/s, in addition to 1 Mb/s and 2 Mb/s. If the PHY implements the short preamble option, it shall detect both short and long preamble formats and indicate which type of preamble was received in the RXVECTOR. The receiver shall implement the CCA procedure as defined in 16.3.8.5. Upon receiving a PPDU, the receiver shall distinguish between a long and short

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header format by the value of the SFD, as specified in 16.2.2. The receiver shall demodulate a long PHY header using BPSK at 1 Mb/s. The receiver shall demodulate a short PHY header using QPSK at 2 Mb/s. The receiver shall use the SIGNAL and SERVICE fields of the PHY header to determine the data rate and modulation of the PSDU.

The receive PHY is shown in Figure 16-8. In order to receive data, the PHY-TXSTART.request primitive shall be disabled so that the PHY entity is in the receive state. Further, through station management via the PLME, the PHY shall be set to the appropriate channel and the CCA method chosen. Other receive parameters, such as RSSI, RCPI, SQ, and indicated DATARATE, may be accessed via the PHY SAP.

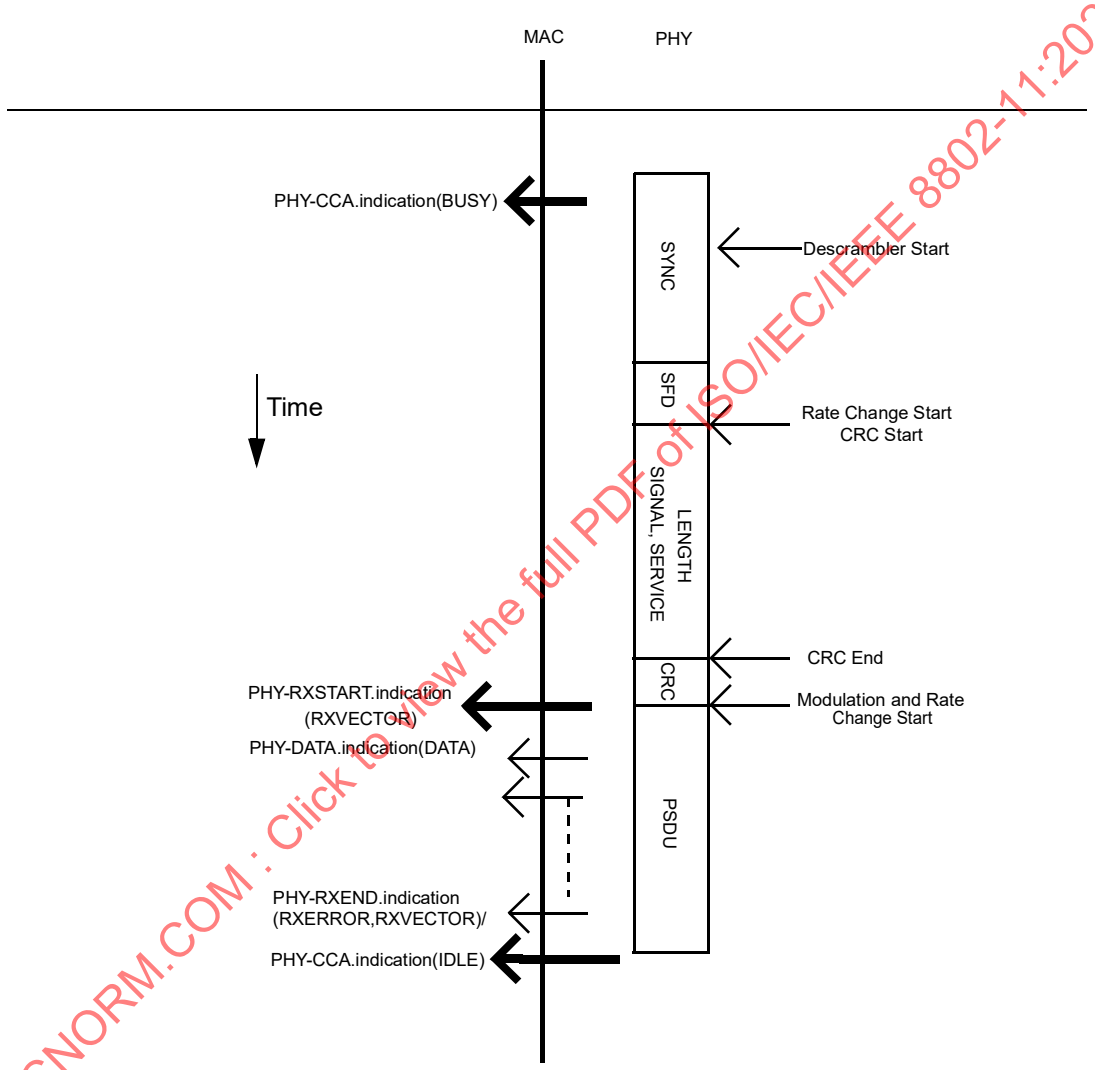

Figure 16-8—Receive PHY

Upon receiving the transmitted energy, according to the selected CCA mode a PHY-CCA.indication(BUSY) primitive shall be issued for ED and/or code lock prior to correct reception of the PHY header. The PHY measures the SQ and RSSI parameters and these are reported to the MAC in the RXVECTOR.

After a PHY-CCA.indication primitive is issued, the PHY entity shall begin searching for the SFD field. Once the SFD field is detected, CRC-16 processing shall be initiated and the PHY SIGNAL, SERVICE, and LENGTH fields shall be received. The CRC-16 FCS shall be processed. If the CRC-16 FCS check fails, the

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PHY receiver shall return to the RX IDLE state, as depicted in Figure 16-9. Should the status of CCA return to the IDLE state during reception prior to completion of the full PPDU processing, the PHY receiver shall return to the RX IDLE state.

If the PHY header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. The RXVECTOR associated with this primitive includes:

a) The SIGNAL field
b) The SERVICE field
c) The PSDU length in octets (calculated from the LENGTH field in microseconds and the DATARATE in Mb/s, in accordance with the formula in 16.2.3.6)
d) RXPREAMBLE_TYPE (which is an enumerated type taking on values SHORTPREAMBLE or LONGPREAMBLE)
e) RX_ANTENNA, RSSI, and SQ

If dot11TimingMsmtActivated is true, the PHY shall do the following:

— Complete receiving the PHY header and verify the validity of the PHY Header.
— If the PHY header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued and RX_START_OF_FRAME_OFFSET parameter within the RXVECTOR shall be forwarded (see 16.3.5).

NOTE—The RX_START_OF_FRAME_OFFSET value is used as described in 6.3.55 in order to estimate when the start of the preamble for the incoming frame was detected on the medium at the receive antenna connector.

The received PSDU bits are assembled into octets and presented to the MAC using a series of PHY-DATA.indication(DATA) primitive exchanges. The rate and modulation change indicated in the SIGNAL field shall be initiated with the first symbol of the PSDU, as described in 16.2.5. The PHY proceeds with PSDU reception. After reception of the final bit of the last PSDU octet, as indicated by the PHY preamble LENGTH field, the receiver shall be returned to the RX IDLE state shown in Figure 16-9.

A PHY-RXEND.indication(NoError) primitive shall be issued. A PHY-CCA.indication(IDLE) primitive shall be issued following a change in PHYCS and/or PHYED according to the selected CCA method.

In the event that a change in PHYCS or PHYED would cause the status of CCA to return to the IDLE state before the complete reception of the PSDU, as indicated by the PHY LENGTH field, the error condition shall be reported to the MAC using a PHY-RXEND.indication(CarrierLost) primitive. The CCA of the HR/DSSS PHY shall indicate a busy medium for the intended duration of the transmitted PPDU.

If the PHY header is successful, but the indicated rate or modulation in the SIGNAL and SERVICE fields is not within the capabilities of the receiver, a PHY-RXSTART.indication primitive shall not be issued. The PHY shall indicate the error condition by issuing a PHY-RXEND.indication(UnsupportedRate) primitive. If the PHY header is invalid, a PHY-RXSTART.indication primitive shall not be issued, and the PHY shall indicate the error condition using a PHY-RXEND.indication(FormatViolation) primitive. Also, in both cases, the CCA of the HR/DSSS PHY shall indicate a busy medium for the intended duration of the transmitted PSDU, as indicated by the LENGTH field. The intended duration is indicated by the LENGTH field (LENGTH × 1 μs).

If dot11RadioMeasurementActiviated is true and RXERROR equals NoError or UnsupportedRate, the PHY-RXEND.indication primitive also includes RCPI as a parameter.

A typical state machine implementation of the receive PHY is shown in Figure 16-9.

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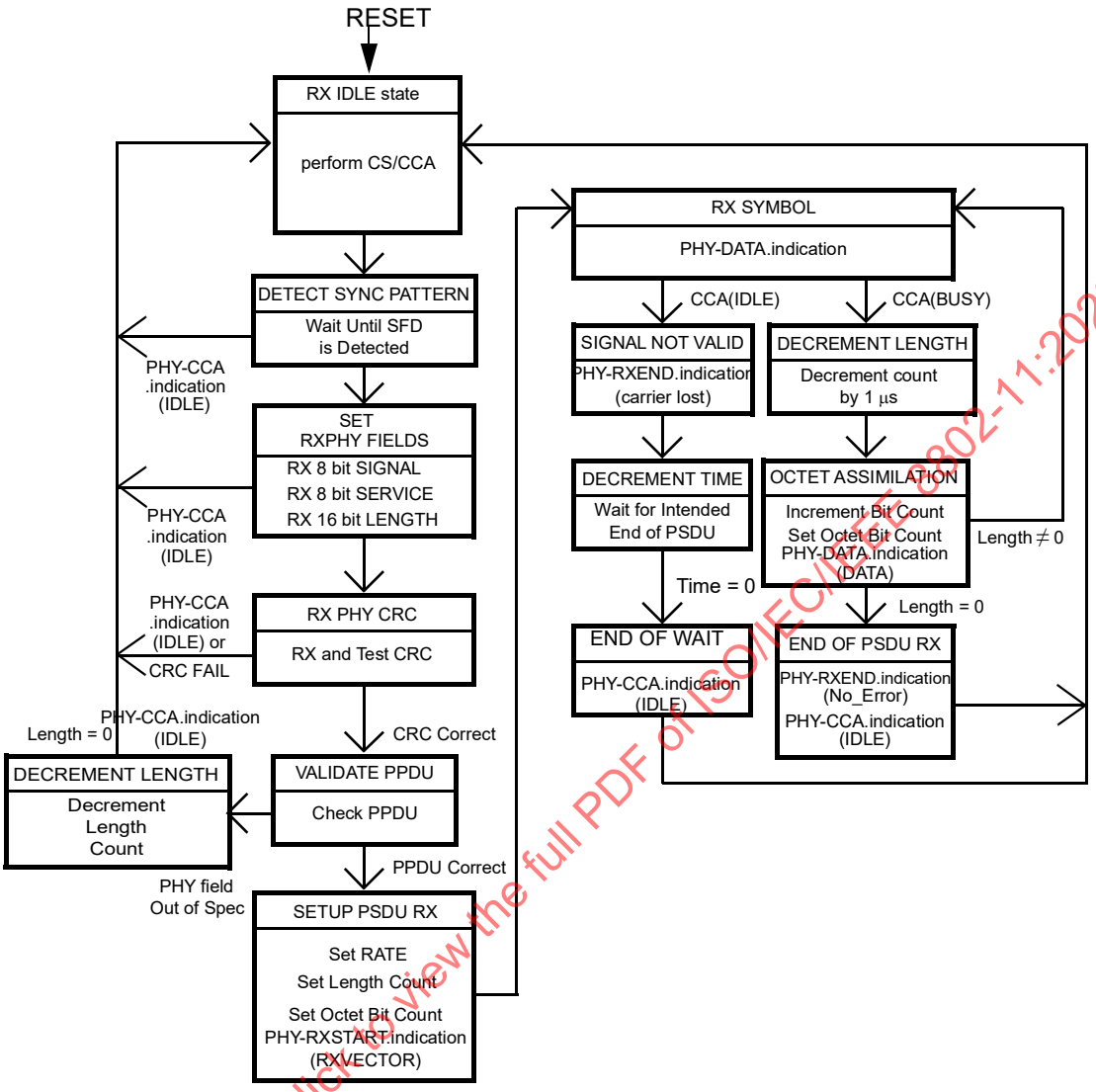

Figure 16-9—PHY receive state machine

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16.3 HR/DSSS PLME

16.3.1 PLME SAP sublayer management primitives

Table 16-3 lists the MIB attributes that may be accessed by the PHY entities and intralayer or higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, and PLME-RESET primitives defined in Clause 6.

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Table 16-3—MIB attribute default values/ranges

Managed object	Default value/range	Operational semantics
dot11PhyOperationTable		
dot11PHYType	High rate–2.4 (X'05')	Static
dot11CurrentRegDomain	Implementation dependent	Static
dot11PhyHRDSSSEntryTable		
dot11ShortPreambleOptionImplemented	Implementation dependent	Static
dot11PhyAntennaTable		
dot11CurrentTxAntenna	Implementation dependent	Dynamic
dot11DiversitySupportImplemented	Implementation dependent	Static
dot11CurrentRxAntenna	Implementation dependent	Dynamic
dot11PhyTxPowerTable		
dot11NumberSupportedPowerLevelsImplemented	Implementation dependent	Static
dot11TxPowerLevel1	Implementation dependent	Static
dot11TxPowerLevel2	Implementation dependent	Static
dot11TxPowerLevel3	Implementation dependent	Static
dot11TxPowerLevel4	Implementation dependent	Static
dot11TxPowerLevel5	Implementation dependent	Static
dot11TxPowerLevel6	Implementation dependent	Static
dot11TxPowerLevel7	Implementation dependent	Static
dot11TxPowerLevel8	Implementation dependent	Static
dot11CurrentTxPowerLevel	Implementation dependent	Dynamic
dot11PhyDSSSTable		
dot11CurrentChannel	Implementation dependent	Dynamic
dot11HRCCAModeSupported	Implementation dependent	Static
dot11CurrentCCAMode	Implementation dependent	Dynamic
dot11EDThreshold	Implementation dependent	Dynamic
dot11AntennasListTable		
dot11SupportedTxAntenna	Implementation dependent	Static
dot11SupportedRxAntenna	Implementation dependent	Static
dot11DiversitySelectionRxImplemented	Implementation dependent	Dynamic
dot11RegDomainsSupportedTable		
dot11RegDomainsImplementedValue	Implementation dependent	Static
dot11SupportedDataRatesTx	Table Tx X'02', X'04', X'0B', X'16'	Static
dot11SupportedDataRatesRx	Table Rx X'02', X'04', X'0B', X'16'	Static

NOTE—The column titled "Operational semantics" contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. Dynamic MIB attributes can be modified by some management entities.

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16.3.2 HR/DSSS PHY MIB

All HR/DSSS PHY MIB attributes are defined in Annex C, with specific values defined in Table 16-3.

When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.

16.3.3 HR/DSSS PHY

The static HR/DSSS PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 16-4. The definitions for these characteristics are given in 6.5.4.

Table 16-4—HR/DSSS PHY characteristics

Characteristic	Value
aSlotTime	If dot11OperatingClassesRequired is false, 20 μs If dot11OperatingClassesRequired is true, 20 μs plus any coverage-class-dependent aAirPropagationTime (see Table 9-95)
aSIFSTime	10 μs
aCCATime	Implementation dependent, see 10.3.7.
aRxPHYStartDelay	192 μs for long preamble and 96 μs for short preamble
aRxTxTurnaroundTime	Implementation dependent, see 10.3.7.
aTxPHYDelay	Implementation dependent, see 10.3.7.
aRxPHYDelay	Implementation dependent, see 10.3.7.
aRxTxSwitchTime	Implementation dependent, see 10.3.7.
aTxRampOnTime	Implementation dependent, see 10.3.7.
aAirPropagationTime	As indicated by the coverage class (see 10.22.5).
aMACProcessingDelay	Implementation dependent, see 10.3.7.
aPSDUMaxLength	$2^{12} - 1$ octets
aCWmin	31
aCWmax	1023

16.3.4 HR/DSSS TXTIME calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated according to the following equation:

$$\text{TXTIME} = \text{PreambleLength} + \text{PHYHeaderTime} + \left\lceil \frac{\text{LENGTH} \times 8}{\text{DATARATE}} \right\rceil$$

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where

LENGTH and DATARATE	are values from the TXVECTOR parameter of the corresponding PLME-TXTIME.request primitive
LENGTH	is in units of octets
DATARATE	is in units of Mb/s
The value of PreambleLength	is 144 μs if the TXPREAMBLE_TYPE value from the TXVECTOR parameter indicates "LONGPREAMBLE," or 72 μs if the TXPREAMBLE_TYPE value from the TXVECTOR parameter indicates "SHORTPREAMBLE"
The value of PHYHeaderTime	is 48 μs if the TXPREAMBLE_TYPE value from the TXVECTOR parameter indicates "LONGPREAMBLE," or 24 μs if the TXPREAMBLE_TYPE value from the TXVECTOR parameter indicates "SHORTPREAMBLE"

16.3.5 Vector descriptions

Several service primitives include a parameter vector. These vectors are a list of parameters as described in Table 16-5. DATARATE and LENGTH are described in 8.3.4.4. The remaining parameters are considered to be management parameters and are specific to this PHY.

Table 16-5—Parameter vectors

Parameter	Associated vector	Value
DATARATE	RXVECTOR, TXVECTOR	The rate used to transmit the PSDU in Mb/s.
LENGTH	RXVECTOR, TXVECTOR	The length of the PSDU in octets.
PREAMBLE_TYPE	RXVECTOR, TXVECTOR	The preamble used for the transmission of this PPDU. This is an enumerated type that takes the value SHORTPREAMBLE or LONGPREAMBLE.
RX_ANTENNA	RXVECTOR	1–254
TX_ANTENNA	TXVECTOR	Selects which of the available antennas should be used for transmit, in the range 1 to 255.
RSSI	RXVECTOR	255
SQ	RXVECTOR	0–8 bits of SQ
TIME_OF_DEPARTURE_REQUESTED	TXVECTOR	false, true. When true, the MAC entity requests that the PHY entity measures and reports time of departure parameters corresponding to the time when the first frame energy is sent by the transmitting port; when false, the MAC entity requests that the PHY entity neither measures nor reports time of departure parameters.
TIME_OF_DEPARTURE	TXSTATUS	0 to 2^{32}– 1. The time when the first frame energy is sent by the transmitting port, measured by the local PHY entity, in units equal to 1/TIME_OF_DEPARTURE_ClockRate. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request.

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Table 16-5—Parameter vectors *(continued)*

Parameter	Associated vector	Value
TIME_OF_DEPARTURE_ ClockRate	TXSTATUS	0 to 2^{16}– 1. The clock rate, in units of MHz, is used to generate the TIME_OF_DEPARTURE value. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request.
TX_START_OF_FRAME_ OFFSET	TXSTATUS	0 to 2^{32}– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble corresponding to the frame was transmitted at the transmit antenna connector to the point in time at which this primitive is issued to the MAC.
RX_START_OF_FRAME_ OFFSET	RXVECTOR	0 to 2^{32}– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble corresponding to the incoming frame arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC.

16.3.6 PHY operating specifications, general

16.3.6.1 General

General specifications for the HR/DSSS PHY sublayer are provided in 16.3.6.2 to 16.3.6.11. These specifications apply to both the receive and transmit functions and general operation of a HR/DSSS PHY.

WLANs implemented in accordance with this standard are subject to equipment certification and operation requirements established by regional and national regulatory administrations. The PHY specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regulations are subject to revision, or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PHY specification. Regulatory requirements that do not affect interoperability are not addressed in this standard. Implementers are referred to the following regulatory source for further information. Operation in countries within defined regulatory domains may be subject to additional regulations.

16.3.6.2 Operating frequency range

The HR/DSSS PHY shall operate in the 2.4–2.4835 GHz frequency range, as allocated by regulatory bodies in the China, United States, Europe, and Japan, or in the 2.471–2.497 GHz frequency range, as allocated by regulatory authority in Japan.

16.3.6.3 Channel Numbering of operating channels

When dot11OperatingClassesRequired is true, channel numbering shall be as specified in 17.3.8.4.2 and channelization shall be as specified in 17.3.8.4.3. When dot11OperatingClassesDefined is false or not defined, the channel center frequencies and CHNL_ID numbers shall be as shown in Table 16-6.

In a multiple cell network topology, overlapping and/or adjacent cells using different channels can operate simultaneously without interference if the distance between the center frequencies is at least 25 MHz. Channel 14 shall be designated specifically for operation in Japan.

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Table 16-6—HR/DSSS PHY frequency channel plan

CHNL_ID	Frequency (MHz)
1	2412
2	2417
3	2422
4	2427
5	2432
6	2437
7	2442
8	2447
9	2452
10	2457
11	2462
12	2467
13	2472
14	2484

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16.3.6.4 Modulation and channel data rates

Four modulation formats and data rates are specified for the HR/DSSS PHY. The basic access rate shall be based on 1 Mb/s DBPSK modulation. The enhanced access rate shall be based on 2 Mb/s DQPSK. The extended direct sequence specification defines two additional data rates. The HR/DSSS access rates shall be based on the CCK modulation scheme for 5.5 Mb/s and 11 Mb/s.

16.3.6.5 Spreading sequence and modulation for 1 Mb/s and 2 Mb/s

The following 11-chip Barker sequence shall be used as the PN code sequence for the 1 Mb/s and 2 Mb/s modulation:

+1, –1, +1, +1, –1, +1, +1, +1, –1, –1, –1

The leftmost chip shall be output first in time. The first chip shall be aligned at the start of a transmitted symbol. The symbol duration shall be exactly 11 chips long.

The DBPSK encoder for the basic access rate is specified in Table 16-7. The DQPSK encoder is specified in Table 16-8. (In these tables, +jω shall be defined as counterclockwise rotation.)

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Table 16-7—1 Mb/s DBPSK encoding table

Bit input	Phase change (+jω)
0	0
1	π

Table 16-8—2 Mb/s DQPSK encoding table

Dibit pattern (d0,d1) (d0 is first in time)	Phase change (+jω)
00	0
01	π/2
11	π
10	3π/2 (–π/2)

16.3.6.6 Spreading sequences and modulation for CCK modulation at 5.5 Mb/s and 11 Mb/s

16.3.6.6.1 General

For the CCK modulation modes, the spreading code length is 8 and is based on complementary codes. The chipping rate is 11 Mchip/s. The symbol duration shall be exactly 8 complex chips long.

Equation (16-1) shall be used to derive the CCK codewords that shall be used for spreading both 5.5 Mb/s and 11 Mb/s.

$$c = \{e^{j(\varphi_1+\varphi_2+\varphi_3+\varphi_4)}, e^{j(\varphi_1+\varphi_3+\varphi_4)}, e^{j(\varphi_1+\varphi_2+\varphi_4)}, -e^{j(\varphi_1+\varphi_4)}, e^{j(\varphi_1+\varphi_2+\varphi_3)}, e^{j(\varphi_1+\varphi_3)}, -e^{j(\varphi_1+\varphi_2)}, e^{j\varphi_1}\} \quad (16\text{-}1)$$

where C is the codeword

C = {c0 to c7}

The terms φ1, φ2, φ3, and φ4 are defined in 16.3.6.6.3 for 5.5 Mb/s and 16.3.6.6.4 for 11 Mb/s.

This formula creates 8 complex chips (c0 to c7), where c0 is transmitted first in time.

This is a form of the generalized Hadamard transform encoding, where φ1 is added to all code chips, φ2 is added to all odd code chips, φ3 is added to all odd pairs of code chips, and φ4 is added to all odd groups of four code chips.

The term φ1 modifies the phase of all code chips of the sequence and shall be DQPSK encoded for 5.5 Mb/s and 11 Mb/s. This shall take the form of rotating the whole symbol by the appropriate amount relative to the phase of the preceding symbol. Note that the chip c7 of the symbol defined above is the chip that indicates the symbol's phase and is transmitted last.

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16.3.6.6.2 Cover code for CCK

The fourth and seventh chips are rotated 180° by a cover sequence to optimize the sequence correlation properties and minimize dc offsets in the codes. This explains the minus sign on the fourth and seventh terms in Equation (16-1).

16.3.6.6.3 CCK 5.5 Mb/s modulation

At 5.5 Mb/s, 4 bits (d0 to d3; d0 first in time) are transmitted per symbol.

The data bits d0 and d1 encode φ1 based on DQPSK. The DQPSK encoder is specified in Table 16-8. (In the table, +jω shall be defined as counterclockwise rotation.) The phase change for φ1 is relative to the phase φ1 of the preceding symbol. For the header to PSDU transition, the phase change for φ1 is relative to the phase of the preceding DQPSK (2 Mb/s) symbol. That is, the phase of the last symbol of the CRC-16 is the reference phase for the first symbol generated from the PSDU octets. (See the definition in 16.3.6.5 for the reference phase of this Barker coded symbol.) A "+1" chip in the Barker code shall represent the same carrier phase as a "+1" chip in the CCK code.

All odd-numbered symbols generated from the PSDU octets shall be given an extra 180° (π) rotation, in addition to the standard DQPSK modulation as shown in Table 16-9. The symbols of the PSDU shall be numbered starting with 0 for the first symbol, for the purposes of determining odd and even symbols. That is, the PSDU transmission starts on an even-numbered symbol.

Table 16-9—DQPSK encoding table

Dibit pattern (d0, d1) (d0 is first in time)	Even symbols phase change (+jω)	Odd symbols phase change (+jω)
00	0	π
01	π/2	3π/2 (–π/2)
11	π	0
10	3π/2 (–π/2)	π/2

The data dibits d2 and d3 CCK encode the basic symbol, as specified in Table 16-10. This table is derived from the formula above by setting φ2 = (d2 × π) + π /2, φ3 = 0, and φ4 = d3 × π. In this table, d2 and d3 are in the order shown, and the complex chips are shown c0 to c7 (left to right), with c0 transmitted first in time.

Table 16-10—5.5 Mb/s CCK encoding table

d2, d3	c1	c2	c3	c4	c5	c6	c7	c8
00	1j	1	1j	–1	1j	1	–1j	1
01	–1j	–1	–1j	1	1j	1	–1j	1
10	–1j	1	–1j	–1	–1j	1	1j	1
11	1j	–1	1j	1	–1j	1	1j	1

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16.3.6.6.4 CCK 11 Mb/s modulation

At 11 Mb/s, 8 bits (d0 to d7; d0 first in time) are transmitted per symbol.

The first dibit (d0, d1) encodes φ1 based on DQPSK. The DQPSK encoder is specified in Table 16-8. The phase change for φ1 is relative to the phase φ1 of the preceding symbol. In the case of header to PSDU transition, the phase change for φ1 is relative to the phase of the preceding DQPSK symbol. All odd-numbered symbols of the PSDU are given an extra 180° (π) rotation, in accordance with the DQPSK modulation shown in Table 16-8. Symbol numbering starts with 0 for the first symbol of the PSDU.

The data dibits (d2, d3), (d4, d5), and (d6, d7) encode φ2, φ3, and φ4, respectively, based on QPSK as specified in Table 16-11. Note that this table is binary (not Gray) coded.

Table 16-11—QPSK encoding table

Dibit pattern [di, d(i+1)] (di is first in time)	Phase
00	0
01	π/2
10	π
11	3π/2 (–π/2)

16.3.6.7 Transmit and receive in-band and out-of-band spurious emissions

The HR/DSSS PHY shall comply with in-band and out-of-band spurious emissions as set by the appropriate regulatory bodies.

16.3.6.8 TX-to-RX turnaround time

The TX-to-RX turnaround time shall be less than 10 μs, including the power-down ramp specified in 16.3.7.7.

The TX-to-RX turnaround time shall be measured on the WM from the trailing edge of the last transmitted symbol to the valid CCA detection of the incoming signal.

16.3.6.9 RX-to-TX turnaround time

The RX-to-TX turnaround time shall be measured at the MAC/PHY interface using the PHY-TXSTART.request primitive, and shall be 5 μs. This includes the transmit power-on ramp described in 16.3.7.7.

16.3.6.10 Slot time

The value of the slot time is found in Table 16-4.

16.3.6.11 Transmit and receive impedance at the antenna connector

The impedance at the transmit antenna connector and receive antenna connector shall be 50 Ω if that connector is exposed.

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16.3.7 PHY transmit specifications

16.3.7.1 Introduction

The transmit functions and parameters associated with the PHY sublayer are described in 16.3.7.2 to 16.3.7.9.

16.3.7.2 Transmit power levels

The maximum allowable output power is measured in accordance with practices specified by the appropriate regulatory bodies.

16.3.7.3 Transmit power level control

Power control shall be provided for transmitted power greater than 100 mW. A maximum of four power levels may be provided. As a minimum, a radio capable of transmission greater than 100 mW shall be capable of switching power back to 100 mW or less.

16.3.7.4 Transmit spectrum mask

The transmitted spectral products shall be less than –30 dBr (decibel relative to the SINx/x peak) for

$f_c - 22\ \text{MHz} < f < f_c - 11\ \text{MHz}$ and
$f_c + 11\ \text{MHz} < f < f_c + 22\ \text{MHz}$

and shall be less than –50 dBr for

$f < f_c - 22\ \text{MHz}$ and
$f > f_c + 22\ \text{MHz}$

where
f_c is the channel center frequency

The transmit spectral mask is shown in Figure 16-10. The measurements shall be made using a 100 kHz resolution bandwidth and a 100 kHz video bandwidth.

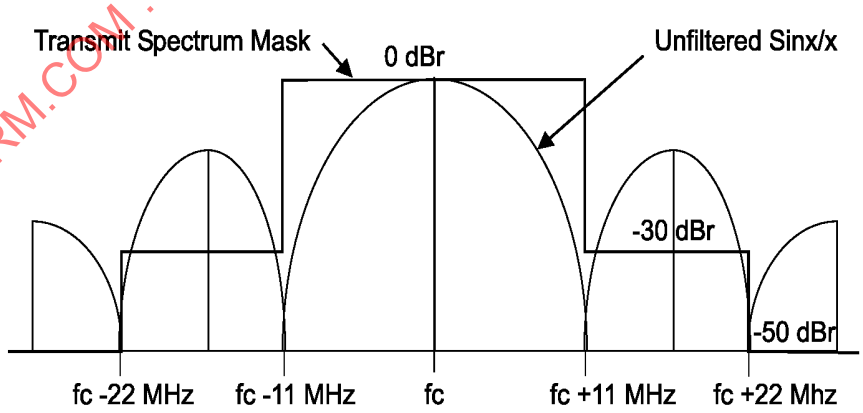

Figure 16-10—Transmit spectrum mask

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16.3.7.5 Transmit center frequency tolerance

The transmitted center frequency tolerance shall be ± 25 ppm.

16.3.7.6 Chip clock frequency tolerance

The PN code chip clock frequency tolerance shall be ± 25 ppm. It is highly recommended that the chip clock and the transmit frequency be locked (coupled) for optimum demodulation performance. If these clocks are locked, it is recommended that bit 2 of the SERVICE field be set to 1, as indicated in 16.2.3.5.

16.3.7.7 Transmit power-on and power-down ramp

The transmit power-on ramp for 10% to 90% of maximum power shall be no greater than 2 µs. The transmit power-on ramp is shown in Figure 16-11.

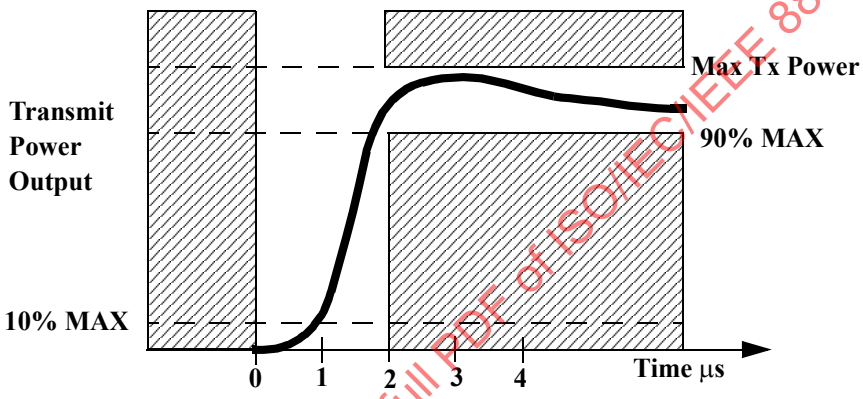

Figure 16-11—Transmit power-on ramp

The transmit power-down ramp for 90% to 10% maximum power shall be no greater than 2 µs. The transmit power-down ramp is shown in Figure 16-12.

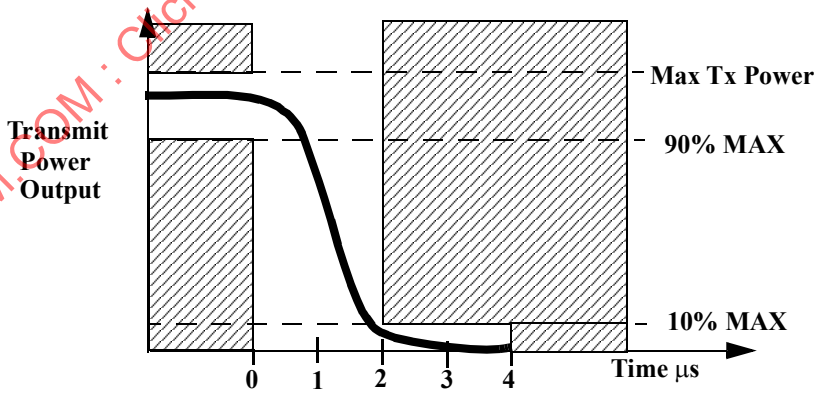

Figure 16-12—Transmit power-down ramp

The transmit power ramps shall be constructed such that the HR/DSSS PHY emissions comply with spurious frequency product specification defined in 16.3.6.7.

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16.3.7.8 RF carrier suppression

The RF carrier suppression, measured at the channel center frequency, shall be at least 15 dB below the peak sin(x)/x power spectrum. The RF carrier suppression shall be measured while transmitting a repetitive 01 data sequence with the scrambler disabled using DQPSK modulation. A 100 kHz resolution bandwidth shall be used to perform this measurement.

16.3.7.9 Transmit modulation accuracy

The transmit modulation accuracy requirement for the HR/DSSS PHY shall be based on the difference between the actual transmitted waveform and the ideal signal waveform. Modulation accuracy shall be determined by measuring the peak vector error magnitude during each chip period. Worst-case vector error magnitude shall not exceeded 0.35 for the normalized sampled chip data. The ideal complex I and Q constellation points associated with DQPSK modulation, (0.707, 0.707), (0.707, –0.707), (–0.707, 0.707), (–0.707, –0.707), shall be used as the reference. These measurements shall be from baseband I and Q sampled data after recovery through a reference receiver system.

Figure 16-13 illustrates the ideal DQPSK constellation points and range of worst-case error specified for modulation accuracy.

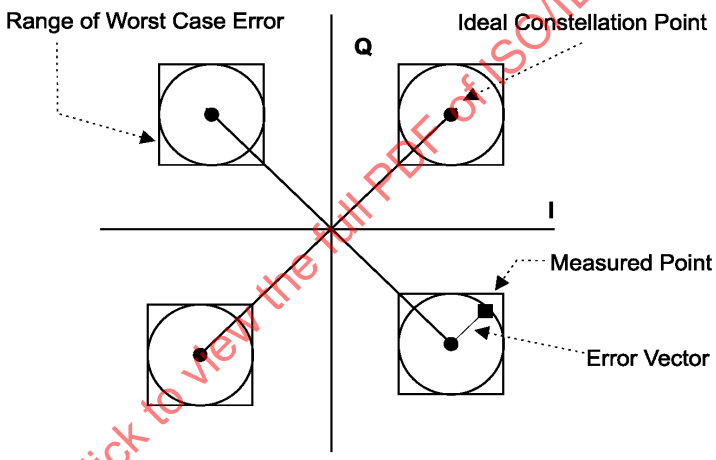

Figure 16-13—Modulation accuracy measurement example

Error vector measurement requires a reference receiver capable of carrier lock. All measurements shall be made under carrier lock conditions. The distortion induced in the constellation by the reference receiver shall be calibrated and measured. The test data error vectors described below shall be corrected to compensate for the reference receiver distortion.

The IEEE Std 802.11-compatible radio shall provide an exposed TX chip clock, which shall be used to sample the I and Q outputs of the reference receiver.

The measurement shall be made under the conditions of continuous DQPSK transmission using scrambled all 1s.

The eye pattern of the I channel shall be used to determine the I and Q sampling point. The chip clock provided by the vendor radio shall be time delayed, such that the samples fall at a 1/2 chip period offset from the mean of the zero crossing positions of the eye (see Figure 16-14). This is the ideal center of the eye and might not be the point of maximum eye opening.

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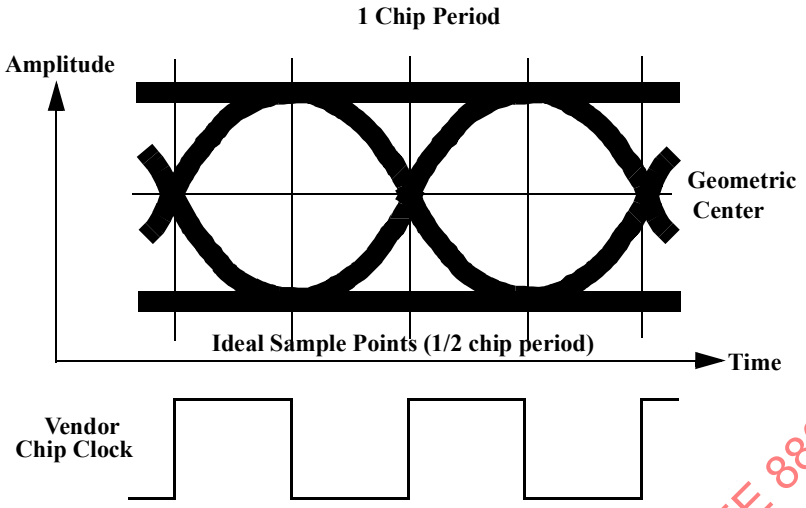

Figure 16-14—Chip clock alignment with baseband eye pattern

Using the aligned chip clock, 1000 samples of the I and Q baseband outputs from the reference receiver are captured. The vector error magnitudes shall be calculated as follows:

Calculate the dc offsets for I and Q samples

$$I_{mean} = \sum_{n=0}^{999} I(n)/1000$$

$$Q_{mean} = \sum_{n=0}^{999} Q(n)/1000$$

Calculate the dc corrected I and Q samples for all $n = 1000$ sample pairs

$$I_{dc}(n) = I(n) - I_{mean}$$

$$Q_{dc}(n) = Q(n) - Q_{mean}$$

Calculate the average magnitude of I and Q samples

$$I_{mag} = \sum_{n=0}^{999} |I_{dc}(n)|/1000$$

$$Q_{mag} = \sum_{n=0}^{999} |Q_{dc}(n)|/1000$$

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Calculate the normalized error vector magnitude for the $I_{dc}(n)/Q_{dc}(n)$ pairs

$$V_{err}(n) = [\{|I_{dc}(n)| - I_{mag}\}^2 + \{|Q_{dc}(n)| - Q_{mag}\}^2]^{\frac{1}{2}} - V_{correction}$$

where

the average power of the constellation	is 1
$V_{correction}$	is the error induced by the reference receiver system

For all $n = 1000$ samples, the following condition shall be met:

$V_{err}(n) < 0.35$

16.3.7.10 Time of Departure accuracy

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is $22 \times 10^6 \left(1 + \left\lceil \frac{f_H - f_L}{22\ \text{MHz}} \right\rceil\right)$ sample/s

where

f_H is the nominal center frequency in Hz of the highest channel in the channel set

f_L is the nominal center frequency in Hz of the lowest channel in the channel set, the channel set is the set of channels upon which frames providing measurements are transmitted, the channel set comprises channels uniformly spaced across $f_H - f_L \geq 50$ MHz

— FIRST_TRANSITION_FIELD is the SYNC field.

— SECOND_TRANSITION_FIELD is the SFD field.

— TRAINING_FIELD is the concatenation of the appropriate short or long SYNC and SFD fields, using a chip pulse which should approximate a rectangular pulse of duration 1/ 11 MHz convolved with a brick-wall low pass filter of bandwidth 11 MHz.

— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns.

NOTE—The indicated chip pulse applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

16.3.8 PHY receiver specifications

16.3.8.1 Introduction

The receive functions and parameters associated with the PHY sublayer are described in 16.3.8.2 to 16.3.8.5.

16.3.8.2 Receiver minimum input level sensitivity

The FER shall be less than 8×10^{-2} at a PSDU length of 1024 octets for an input level of –76 dBm measured at the antenna connector. This FER shall be specified for 11 Mb/s CCK modulation. The test for the minimum input level sensitivity shall be conducted with the ED threshold set less than or equal to –76 dBm.

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16.3.8.3 Receiver maximum input level

If the STA is non-ERP, the receiver shall provide a maximum FER of 8×10^{-2} at a PSDU length of 1024 octets for a maximum input level of –10 dBm measured at the antenna connector. This FER shall be specified for 11 Mb/s CCK modulation.

16.3.8.4 Receiver adjacent channel rejection

Adjacent channel rejection is defined between any two channels with ≥ 25 MHz separation in each channel group, as defined in 16.3.6.3.

The adjacent channel rejection shall be greater than or equal to than 35 dB, with an FER of 8×10^{-2} using 11 Mb/s CCK modulation described in 16.3.6.4 and a PSDU length of 1024 octets.

The adjacent channel rejection shall be measured using the following method.

Input an 11 Mb/s CCK modulated signal at a level 6 dB greater than specified in 16.3.8.2. In an adjacent channel (≥ 25 MHz separation as defined by the channel numbering), input a signal modulated in a similar fashion, which adheres to the transmit mask specified in 16.3.7.4, to a level 41 dB above the level specified in 16.3.8.2. The adjacent channel signal shall be derived from a separate signal source. It shall not be a frequency shifted version of the reference channel. Under these conditions, the FER shall be less than or equal to 8×10^{-2}.

16.3.8.5 CCA

Requirements in this subclause are applicable to non-ERP HR/DSSS STAs.

The non-ERP HR/DSSS PHY shall provide the capability to perform CCA according to both:

A — At least one of the following options:

- *CCA Mode 1*: Energy above threshold. CCA shall report a busy medium upon detecting any energy above the ED threshold.
- *CCA Mode 4*: CS with timer. CCA shall start a timer whose duration is 3.65 ms and report a busy medium only upon the detection of a HR/DSSS PHY signal. CCA shall report an IDLE medium after the timer expires and no HR/DSSS PHY signal is detected. The 3.65 ms timeout is the duration of the longest possible 5.5 Mb/s PSDU.
- *CCA Mode 5*: A combination of CS and energy above threshold. CCA shall report busy at least while a HR/DSSS PPDU is being received with energy above the ED threshold at the antenna connector.

and

B — *CCA Mode 6*: CCA shall report a busy medium upon detection of any energy above –62 dBm.

A busy channel shall be indicated by issuing a PHY-CCA.indication(BUSY) primitive. A clear channel shall be indicated by issuing a PHY-CCA.indication(IDLE) primitive.

For a non-ERP HR/DSSS STA, dot11HRCCAModeSupported shall indicate the appropriate operation modes. The PHY shall be configured through dot11CurrentCCAMode.

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The CCA parameters are subject to the following criteria:

a) If a valid HR/DSSS signal is detected during its preamble within the CCA window, the ED threshold shall be less than or equal to –76 dBm for TX power > 100 mW; –73 dBm for 50 mW < TX power ≤ 100 mW; and –70 dBm for TX power ≤ 50 mW. The ED threshold is the value contained in dot11EDThreshold.

b) With a valid signal (according to the CCA mode of operation) present at the receiver antenna within 5 µs of the start of a MAC slot boundary, the PHY-CCA.indication(BUSY) primitive shall be generated before the end of the slot time if aSlotTime is 20 µs. Refer to Figure 10-21 (in 10.3.7) and Figure 10-25 for a definition of slot boundary.

c) In the event that a correct PHY header is received, the HR/DSSS PHY shall not generate a PHY-CCA.indication (IDLE) primitive until the end of the PPDU as determined by TXTIME in 16.3.4. Upon reception of a correct PHY header, the timer of CCA Mode 4 shall be overridden by this requirement.

Compliance to the HR/DSSS PHY CCA shall be demonstrated by applying an equivalent HR/DSSS signal above the appropriate ED threshold [item a)] so that all conditions described in item b) and item c) are demonstrated.

16.3.8.6 Received channel power indicator (RCPI) measurement

The RCPI is a measure of the received RF power in the selected channel for a received frame. This parameter shall be a measure by the PHY of the received RF power in the channel measured over the entire received frame or by other equivalent means that meet the specified accuracy.

The RCPI encoding is defined in 9.4.2.37.

RCPI shall equal the received RF power within an accuracy of ± 5 dB (95% confidence interval) within the specified dynamic range of the receiver. The received RF power shall be determined assuming a receiver noise equivalent bandwidth equal to the channel bandwidth multiplied by 1.1.

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17. Orthogonal frequency division multiplexing (OFDM) PHY specification

17.1 Introduction

17.1.1 General

This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.

The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The half-clocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM PHY are in Annex D and Annex E.

The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarter-clocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM PHY are in Annex D and Annex E.

17.1.2 Scope of OFDM services

Subclause 17.1 describes the PHY services provided to the IEEE 802.11 WLAN MAC by the OFDM PHY. The OFDM PHY consists of the following protocol functions:

a) A function that defines a method of mapping the IEEE 802.11 PSDUs into a framing format suitable for sending and receiving user data and management information between two or more STAs.

b) A function that defines the characteristics and method of transmitting and receiving data through a WM between two or more STAs, each using the OFDM system.

17.1.3 OFDM PHY functions

17.1.3.1 General

The OFDM PHY architecture is depicted in the reference model shown in Figure 4-24 (in 4.9). The OFDM PHY contains two functional entities: the PHY function and the layer management function. Each of these functions is described in detail in 17.3 and 17.4.

The OFDM PHY service is provided to the MAC through the PHY service primitives described in Clause 8.

17.1.3.2 PLME

The PLME performs management of the local PHY functions in conjunction with the MLME.

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17.1.3.3 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, but do not necessarily reflect any particular implementation.

The service of a layer or sublayer is the set of capabilities that it offers to a user in the next higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

17.2 OFDM PHY specific service parameter list

17.2.1 Introduction

The architecture of the IEEE 802.11 MAC is intended to be PHY independent. Some PHY implementations require medium management state machines running in the MAC sublayer in order to meet certain PHY requirements. These PHY-dependent MAC state machines reside in a sublayer defined as the MLME. In certain PHY implementations, the MLME may need to interact with the PLME as part of the normal PHY SAP primitives. These interactions are defined by the PLME parameter list currently defined in the PHY service primitives as TXVECTOR and RXVECTOR. The list of these parameters, and the values they may represent, are defined in the specific PHY specifications for each PHY. Subclause 17.2 addresses the TXVECTOR and RXVECTOR for the OFDM PHY.

17.2.2 TXVECTOR parameters

17.2.2.1 General

The parameters in Table 17-1 are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive.

Table 17-1—TXVECTOR parameters

Parameter	Associated primitive	Value
LENGTH	PHY-TXSTART.request (TXVECTOR)	1–4095
DATATRATE	PHY-TXSTART.request (TXVECTOR)	6, 9, 12, 18, 24, 36, 48, and 54 Mb/s for 20 MHz channel spacing (Support of 6, 12, and 24 Mb/s data rates is mandatory.) 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s for 10 MHz channel spacing (Support of 3, 6, and 12 Mb/s data rates is mandatory.) 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s for 5 MHz channel spacing (Support of 1.5, 3, and 6 Mb/s data rates is mandatory.)
SERVICE	PHY-TXSTART.request (TXVECTOR)	Null
TXPWR_LEVEL_INDEX	PHY-TXSTART.request (TXVECTOR)	1–8

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Table 17-1—TXVECTOR parameters *(continued)*

Parameter	Associated primitive	Value
TIME_OF_ DEPARTURE_ REQUESTED	PHY-TXSTART.request (TXVECTOR)	false, true. When true, the MAC entity requests that the PHY entity measures and reports time of departure parameters corresponding to the time when the first frame energy is sent by the transmitting port; when false, the MAC entity requests that the PHY entity neither measures nor reports time of departure parameters.
CH_BANDWIDTH_ IN_NON_HT	PHY-TXSTART.request (TXVECTOR)	If present, CBW20, CBW40, CBW80, CBW160, or CBW80+80
DYN_BANDWIDTH _IN_NON_HT	PHY-TXSTART.request (TXVECTOR)	If present, Static or Dynamic
SCRAMBLER_RESET	PHY-TXSTART.request (TXVECTOR)	Indicates whether the scrambler is reset before the start of the PPDU Enumerated Type: RESET_SCRAMBLER: The scrambler is reset NO_SCRAMBLER_RESET: The scrambler is not reset.

17.2.2.2 TXVECTOR LENGTH

The allowed values for the LENGTH parameter are in the range 1 to 4095. This parameter is used to indicate the number of octets in the MPDU which the MAC is currently requesting the PHY to transmit. This value is used by the PHY to determine the number of octet transfers that will occur between the MAC and the PHY after receiving a request to start the transmission.

17.2.2.3 TXVECTOR DATARATE

The DATARATE parameter describes the bit rate at which the PHY shall transmit the PSDU. Its value takes any of the rates defined in Table 17-1. Data rates of 6, 12, and 24 Mb/s shall be supported for 20 MHz channel spacing, data rates of 3, 6, and 12 Mb/s shall be supported for 10 MHz channel spacing, and data rates of 1.5, 3, and 6 Mb/s shall be supported for 5 MHz channel spacing; other rates may also be supported.

17.2.2.4 TXVECTOR SERVICE

The SERVICE parameter shall be null.

17.2.2.5 TXVECTOR TXPWR_LEVEL_INDEX

The allowed values for the TXPWR_LEVEL_INDEX parameter are in the range 1 to 8. This parameter is used to indicate which of the available TxPowerLevel attributes defined in the MIB shall be used for the current transmission.

17.2.2.6 TXVECTOR TIME_OF_DEPARTURE_REQUESTED

The allowed values are false or true. A parameter value of true indicates that the MAC sublayer is requesting that the PHY entity provides measurement of when the first frame energy is sent by the transmitting port and reporting within the PHY-TXSTART.confirm primitive. A parameter value of false indicates that the MAC sublayer is requesting that the PHY entity not provide time of departure measurement nor reporting in the PHY-TXSTART.confirm primitive.

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17.2.2.7 TXVECTOR CH_BANDWIDTH_IN_NON_HT

If present, the allowed values for CH_BANDWIDTH_IN_NON_HT are CBW20, CBW40, CBW80, CBW160, and CBW80+80. If present, this parameter is used to modify the first 7 bits of the scrambling sequence to indicate the bandwidth of the non-HT duplicate PPDU.

NOTE—The CH_BANDWIDTH_IN_NON_HT parameter is not present when the frame is transmitted by a non-VHT STA. The CH_BANDWIDTH_IN_NON_HT parameter is not present when the frame is transmitted by a VHT STA to a non-VHT STA. See 10.6.12.

17.2.2.8 TXVECTOR DYN_BANDWIDTH_IN_NON_HT

If present, the allowed values for DYN_BANDWIDTH_IN_NON_HT are Static and Dynamic. If present, this parameter is used to modify the first 7 bits of the scrambling sequence to indicate if the transmitter is capable of Static or Dynamic bandwidth operation. If DYN_BANDWIDTH_IN_NON_HT is present, then CH_BANDWIDTH_IN_NON_HT is also present.

NOTE—The DYN_BANDWIDTH_IN_NON_HT parameter is not present when the frame is transmitted by a non-VHT STA. The DYN_BANDWIDTH_IN_NON_HT parameter is not present when the frame is transmitted by a VHT STA to a non-VHT STA. See 10.6.12.

17.2.3 RXVECTOR parameters

17.2.3.1 General

The parameters listed in Table 17-2 are defined as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive.

Table 17-2—RXVECTOR parameters

Parameter	Associated primitive	Value
LENGTH	PHY-RXSTART.indication	1–4095
RSSI	PHY-RXSTART.indication (RXVECTOR)	255
DATARATE	PHY-RXSTART.request (RXVECTOR)	6, 9, 12, 18, 24, 36, 48, and 54 Mb/s for 20 MHz channel spacing (Support of 6, 12, and 24 Mb/s data rates is mandatory.) 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s for 10 MHz channel spacing (Support of 3, 6, and 12 Mb/s data rates is mandatory.) 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s for 5 MHz channel spacing (Support of 1.5, 3, and 6 Mb/s data rates is mandatory.)
SERVICE	PHY-RXSTART.request (RXVECTOR)	Null
RCPI (see NOTE)	PHY-RXEND.indication	0–255

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Table 17-2—RXVECTOR parameters *(continued)*

Parameter	Associated primitive	Value
RX_ANTENNA (see NOTE)	PHY-RXSTART.indication (RXVECTOR) PHY-RXEND.indication (RXVECTOR)	0–255
RX_START_OF_FRAME_OFFSET	PHY-RXSTART.indication (RXVECTOR)	0 to 2^{32}– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble corresponding to the incoming frame arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC.
CH_BANDWIDTH_IN_NON_HT	PHY-RXSTART.request (RXVECTOR)	If present, CBW20, CBW40, CBW80, CBW160, or CBW80+80
DYN_BANDWIDTH_IN_NON_HT	PHY-RXSTART.request (RXVECTOR)	If present, Static or Dynamic
NOTE—Parameter is present only when dot11RadioMeasurementActivated is true.		

17.2.3.2 RXVECTOR LENGTH

The allowed values for the LENGTH parameter are in the range 1–4095. This parameter is used to indicate the value contained in the LENGTH field which the PHY has received in the PHY header. The MAC and PHY use this value to determine the number of octet transfers that will occur between the two sublayers during the transfer of the received PSDU.

17.2.3.3 RXVECTOR RSSI

The allowed values for the RSSI parameter are in the range 0 to 255. This parameter is a measure by the PHY of the energy observed at the antenna connector used to receive the current PPDU. RSSI shall be measured during the reception of the PHY preamble. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power.

17.2.3.4 RXVECTOR DATARATE

DATARATE shall represent the data rate at which the current PPDU was received. The allowed values of the DATARATE are 6, 9, 12, 18, 24, 36, 48, or 54 Mb/s for 20 MHz channel spacing; 3, 4.5, 6, 9, 12, 18, 24, or 27 Mb/s for 10 MHz channel spacing; and 1.5, 2.25, 3, 4.5, 6, 9, 12, or 13.5 Mb/s for 5 MHz channel spacing.

17.2.3.5 RXVECTOR SERVICE

The SERVICE parameter shall be null.

17.2.3.6 PHY-RXEND.indication parameter RCPI

The allowed values for the RCPI are in the range 0 to 255, as defined in 17.3.10.7. This parameter is a measure by the PHY of the received channel power. RCPI indications of 8 bits are supported. RCPI shall be measured over the entire received frame or by other equivalent means that meet the specified accuracy.

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17.2.3.7 RXVECTOR CH_BANDWIDTH_IN_NON_HT

If present, the allowed values for CH_BANDWIDTH_IN_NON_HT are CBW20, CBW40, CBW80, CBW160, and CBW80+80. If present and valid, this parameter indicates the bandwidth of the non-HT duplicate PPDU. This parameter is used by the MAC only when valid (see 10.3.2.9 and 10.6.6.6).

NOTE—The CH_BANDWIDTH_IN_NON_HT parameter is not present when the frame is received by a non-VHT STA (see 10.6.12).

17.2.3.8 RXVECTOR DYN_BANDWIDTH_IN_NON_HT

If present, the allowed values for DYN_BANDWIDTH_IN_NON_HT are Static and Dynamic. If present and valid, this parameter indicates whether the transmitter is capable of Static or Dynamic bandwidth operation. This parameter is used by the MAC only when valid (see 10.3.2.9 and 10.6.6.6). If DYN_BANDWIDTH_IN_NON_HT is present, then CH_BANDWIDTH_IN_NON_HT is also present.

NOTE—The DYN_BANDWIDTH_IN_NON_HT parameter is not present when the frame is received by a non-VHT STA (see 10.6.12).

17.2.4 TXSTATUS parameters

17.2.4.1 General

The parameters listed in Table 17-3 are defined as part of the TXSTATUS parameter list in the PHY-TXSTART.confirm primitive.

Table 17-3—TXSTATUS parameters

Parameter	Associated primitive	Value
TIME_OF_DEPARTURE	PHY-TXSTART.confirm	0 to 2^{32}– 1. The locally measured time when the first frame energy is sent by the transmitting port, in units equal to 1/ TIME_OF_DEPARTURE_ClockRate. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request.
TIME_OF_DEPARTURE_ClockRate	PHY-TXSTART.confirm	0 to 2^{16}– 1. The clock rate, in units of MHz, is used to generate the TIME_OF_DEPARTURE value. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request.
TX_START_OF_FRAME_OFFSET	PHY-TXSTART.confirm	0 to 2^{32}– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble corresponding to the frame was transmitted at the transmit antenna connector to the point in time at which this primitive is issued to the MAC.

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17.2.4.2 TXSTATUS TIME_OF_DEPARTURE

The allowed values for the TIME_OF_DEPARTURE parameter are integers in the range 0 to 2^{32}– 1. This parameter is used to indicate when the first frame energy is sent by the transmitting port in units equal to 1/TIME_OF_DEPARTURE_ClockRate. TIME_OF_DEPARTURE may be included in the transmitted frame in order for recipients on multiple channels to determine the time differences of air propagation times between transmitter and recipients and hence to compute the location of the transmitter.

17.2.4.3 TXSTATUS TIME_OF_DEPARTURE_ClockRate

TIME_OF_DEPARTURE_ClockRate indicates the clock rate used for TIME_OF_DEPARTURE.

17.3 OFDM PHY

17.3.1 Introduction

Subclause 17.3 provides a convergence procedure in which PSDUs are converted to and from PPDUs. During transmission, the PSDU shall be provided with a PHY preamble and header to create the PPDU. At the receiver, the PHY preamble and header are processed to aid in demodulation and delivery of the PSDU.

17.3.2 PPDU format

17.3.2.1 General

Figure 17-1 shows the format for the PPDU including the OFDM PHY preamble, OFDM PHY header, PSDU, tail bits, and pad bits. The PHY header contains the following fields: LENGTH, RATE, a reserved bit, an even parity bit, and the SERVICE field. In terms of modulation, the LENGTH, RATE, reserved bit, and parity bit (with 6 zero tail bits appended) constitute a separate single OFDM symbol, denoted SIGNAL, which is transmitted with the most robust combination of BPSK modulation and a coding rate of R = 1/2. The SERVICE field of the PHY header and the PSDU (with 6 zero tail bits and pad bits appended), denoted as DATA, are transmitted at the data rate described in the RATE field and may constitute multiple OFDM symbols. The tail bits in the SIGNAL symbol enable decoding of the RATE and LENGTH fields immediately after the reception of the tail bits. The RATE and LENGTH fields are required for decoding the DATA field of the PPDU. In addition, the CCA mechanism is augmented by predicting the duration of the PPDU from the contents of the RATE and LENGTH fields, even if the data rate is not supported by the STA. Each of these fields is described in detail in 17.3.3, 17.3.4, and 17.3.5.

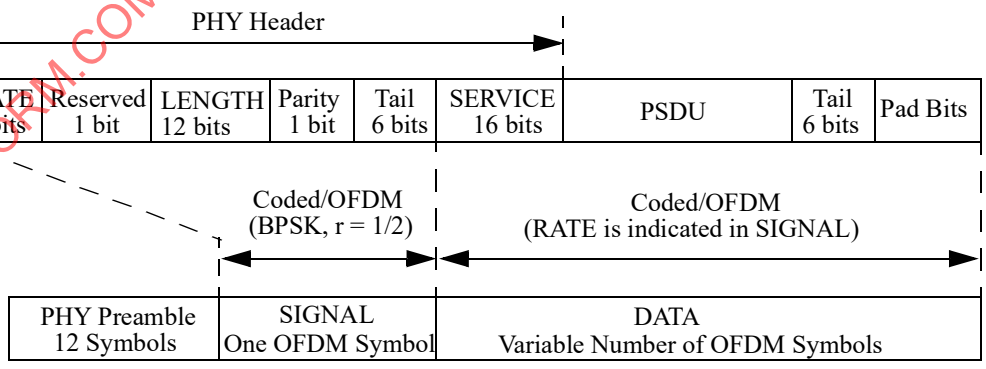

Figure 17-1—PPDU format

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17.3.2.2 Overview of the PPDU encoding process

The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:

a) Produce the PHY Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details.

b) Produce the PHY header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PHY header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PHY header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details.

c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (N_{DBPS}), the coding rate (R), the number of bits in each OFDM subcarrier (N_{BPSC}), and the number of coded bits per OFDM symbol (N_{CBPS}). Refer to 17.3.2.3 for details.

d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length is a multiple of N_{DBPS}. The resulting bit string constitutes the DATA field of the PPDU. Refer to 17.3.5.4 for details.

e) If the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT is not present, initiate the scrambler with a pseudorandom nonzero seed and generate a scrambling sequence. If the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT is present, construct the first 7 bits of the scrambling sequence from CH_BANDWIDTH_IN_NON_HT, DYN_BANDWIDTH_IN_NON_HT (if present), and a pseudorandom integer constrained such that the first 7 bits of the scrambling sequence are not all 0s; then set the scrambler state to these 7 bits and generate the remainder of the scrambling sequence. XOR the scrambling sequence with the extended string of data bits. Refer to 17.3.5.5 for details.

f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.3 for details.

g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the "coding rate" corresponding to the TXVECTOR parameter RATE. Refer to 17.3.5.6 for details.

h) Divide the encoded bit string into groups of N_{CBPS} bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the TXVECTOR parameter RATE. Refer to 17.3.5.7 for details.

i) Divide the resulting coded and interleaved data string into groups of N_{BPSC} bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.8 for details.

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j) Divide the complex number string into groups of 48 complex numbers. Each such group is associated with one OFDM symbol. In each group, the complex numbers are numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with the value 0. Refer to 17.3.5.10 for details.

k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.9 for details.

l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.10 for details.

m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.10 for details.

n) Upconvert the resulting “complex baseband” waveform to an RF according to the center frequency of the operating channel and transmit. Refer to 17.3.2.5 and 17.3.8.2 for details.

An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3).

17.3.2.3 Modulation-dependent parameters

The modulation parameters dependent on the data rate used shall be set according to Table 17-4.

Table 17-4—Modulation-dependent parameters

Modulation	Coding rate (R)	Coded bits per subcarrier (N_{BPSC})	Coded bits per OFDM symbol (N_{CBPS})	Data bits per OFDM symbol (N_{DBPS})	Data rate (Mb/s) (20 MHz channel spacing)	Data rate (Mb/s) (10 MHz channel spacing)	Data rate (Mb/s) (5 MHz channel spacing)
BPSK	1/2	1	48	24	6	3	1.5
BPSK	3/4	1	48	36	9	4.5	2.25
QPSK	1/2	2	96	48	12	6	3
QPSK	3/4	2	96	72	18	9	4.5
16-QAM	1/2	4	192	96	24	12	6
16-QAM	3/4	4	192	144	36	18	9
64-QAM	2/3	6	288	192	48	24	12
64-QAM	3/4	6	288	216	54	27	13.5

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17.3.2.4 Timing-related parameters

Table 17-5 is the list of timing parameters associated with the OFDM PHY.

Table 17-5—Timing-related parameters

Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.156 25 MHz (= 10 MHz/64)	0.078 125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs ($1/\Delta_F$)	6.4 μs ($1/\Delta_F$)	12.8 μs ($1/\Delta_F$)
$T_{PREAMBLE}$: PHY preamble duration	16 μs ($T_{SHORT} + T_{LONG}$)	32 μs ($T_{SHORT} + T_{LONG}$)	64 μs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 μs ($T_{GI} + T_{FFT}$)	8.0 μs ($T_{GI} + T_{FFT}$)	16.0 μs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 μs ($T_{FFT}/4$)	1.6 μs ($T_{FFT}/4$)	3.2 μs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 μs ($T_{FFT}/2$)	3.2 μs ($T_{FFT}/2$)	6.4 μs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 μs ($T_{GI} + T_{FFT}$)	8 μs ($T_{GI} + T_{FFT}$)	16 μs ($T_{GI} + T_{FFT}$)
T_{SHORT}: Short training sequence duration	8 μs ($10 \times T_{FFT}/4$)	16 μs ($10 \times T_{FFT}/4$)	32 μs ($10 \times T_{FFT}/4$)
T_{LONG}: Long training sequence duration	8 μs ($T_{GI2} + 2 \times T_{FFT}$)	16 μs ($T_{GI2} + 2 \times T_{FFT}$)	32 μs ($T_{GI2} + 2 \times T_{FFT}$)

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17.3.2.5 Mathematical conventions in the signal descriptions

The transmitted signals are described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)}\langle t\rangle = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\} \quad (17\text{-}1)$$

where

f_c denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \quad (17\text{-}2)$$

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The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.10. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

All of the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 to 17.3.5.

$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \quad (17\text{-}3)$$

The parameters Δ_F and N_{ST} are described in Table 17-5. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-5.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

$$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t-T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$$

In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. This standard describes transmitted waveforms using a rectangular pulse shape. In a typical implementation, a higher T_{TR} is used in order to smooth the transitions between consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.3 and 17.3.9.7. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering.

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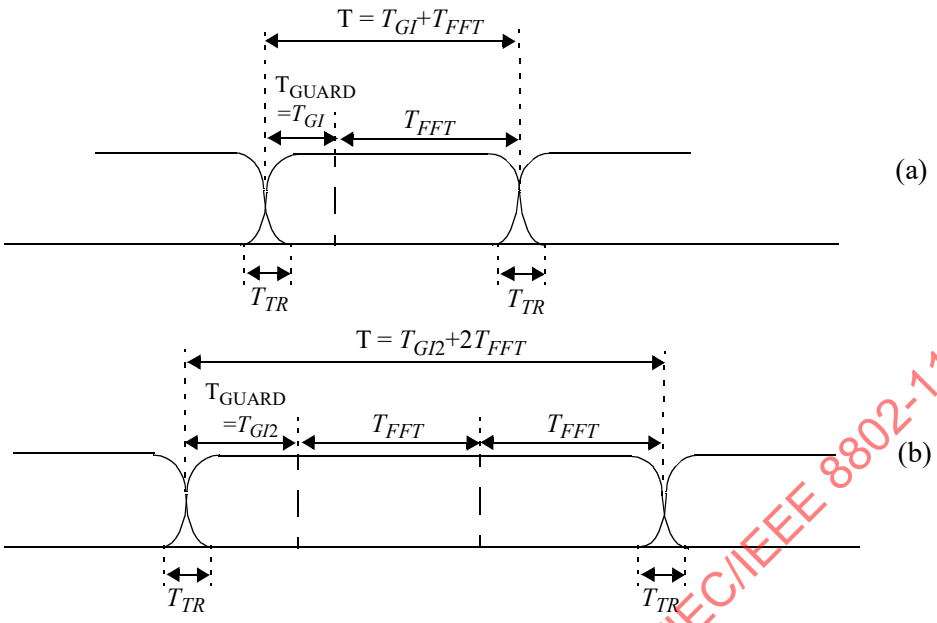

Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period

17.3.2.6 Discrete time implementation considerations

The following descriptions of the discrete time implementation are informational.

In a typical implementation, the windowing function is represented in discrete time. As an example, when a windowing function with parameters T = 4.0 μs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

$$w_T[n] = w_T(nT_S) = \begin{Bmatrix} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{Bmatrix} \quad (17\text{-}5)$$

The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended and the resulting waveform is windowed to the required OFDM symbol length.

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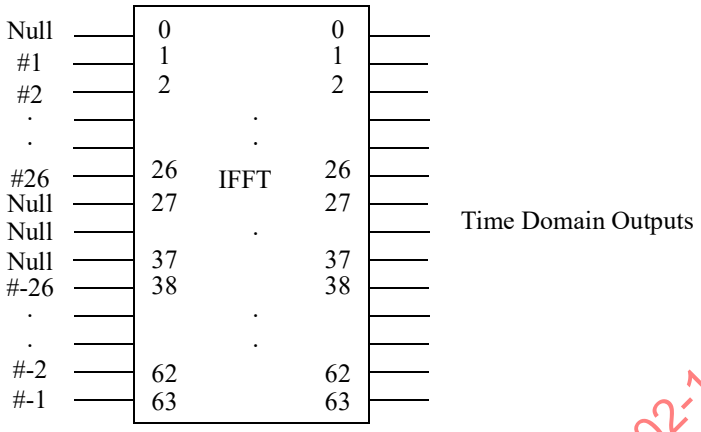

Figure 17-3—Inputs and outputs of inverse Fourier transform

17.3.3 PHY preamble (SYNC)

The PHY Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.

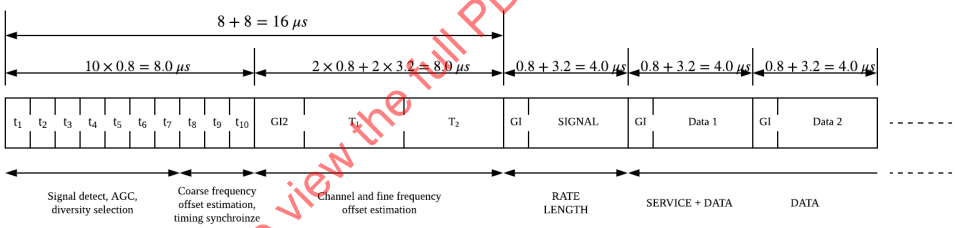

Figure 17-4—OFDM training structure

Figure 17-4 shows the OFDM training structure (PHY preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PHY preamble is followed by the SIGNAL field and DATA. The total training length is 16 μs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0,$$

$$0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

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The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table I-2.

A long OFDM training symbol consists of 53 subcarriers (including the value 0 at dc), which are modulated by the elements of the sequence L, given by

$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 0,$

$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\}$ (17-8)

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G\,12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table I-5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

17.3.4 SIGNAL field

17.3.4.1 General

The OFDM training symbols shall be followed by the SIGNAL field, which contains the RATE and the LENGTH fields of the TXVECTOR. The RATE field conveys information about the type of modulation and the coding rate as used in the rest of the PPDU. The encoding of the SIGNAL single OFDM symbol shall be performed with BPSK modulation of the subcarriers and using convolutional coding at R = 1/2. The encoding procedure, which includes convolutional encoding, interleaving, modulation mapping processes, pilot insertion, and OFDM modulation, follows the steps described in 17.3.5.6, 17.3.5.7, and 17.3.5.9, as used for transmission of data with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled.

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The SIGNAL field shall be composed of 24 bits, as shown in Figure 17-5. The four bits 0 to 3 shall encode the RATE. Bit 4 shall be reserved for future use. Bits 5–16 shall encode the LENGTH field of the TXVECTOR, with the LSB being transmitted first.

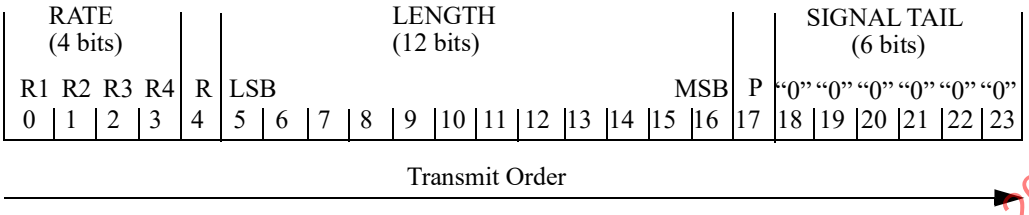

Figure 17-5—SIGNAL field bit assignment

The process of generating the SIGNAL OFDM symbol is illustrated in I.1.4.

17.3.4.2 RATE field

The bits R1–R4 shall be set, dependent on RATE, according to the values in Table 17-6.

Table 17-6—Contents of the SIGNAL field

R1–R4	Rate (Mb/s) (20 MHz channel spacing)	Rate (Mb/s) (10 MHz channel spacing)	Rate (Mb/s) (5 MHz channel spacing)
1101	6	3	1.5
1111	9	4.5	2.25
0101	12	6	3
0111	18	9	4.5
1001	24	12	6
1011	36	18	9
0001	48	24	12
0011	54	27	13.5

17.3.4.3 PHY LENGTH field

The PHY LENGTH field shall be an unsigned 12-bit integer that indicates the number of octets in the PSDU that the MAC is currently requesting the PHY to transmit. This value is used by the PHY to determine the number of octet transfers that will occur between the MAC and the PHY after receiving a request to start transmission. The transmitted value shall be determined from the LENGTH parameter in the TXVECTOR issued with the PHY-TXSTART.request primitive described in 8.3.5.5. The LSB shall be transmitted first in time. This field shall be encoded by the convolutional encoder described in 17.3.5.6.

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17.3.4.4 Parity (P), Reserved (R), and SIGNAL TAIL fields

Bit 4 is reserved. It shall be set to 0 on transmit and ignored on receive. Bit 17 shall be a positive parity (even parity) bit for bits 0–16. The bits 18–23 constitute the SIGNAL TAIL field, and all 6 bits shall be set to 0.

17.3.5 DATA field

17.3.5.1 General

The DATA field contains the SERVICE field, the PSDU, the TAIL bits, and the PAD bits, if needed, as described in 17.3.5.3 and 17.3.5.4. All bits in the DATA field are scrambled, as described in 17.3.5.5.

17.3.5.2 SERVICE field

The SERVICE field has 16 bits, which shall be denoted as bits 0–15. The bit 0 shall be transmitted first in time. The bits from 0–6 of the SERVICE field, which are transmitted first, are set to 0s and are used to synchronize the descrambler in the receiver. The remaining 9 bits (7–15) of the SERVICE field shall be reserved for future use. All reserved bits shall be set to 0 on transmission and ignored on reception. Refer to Figure 17-6.

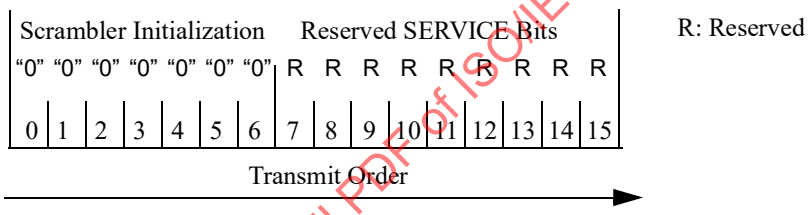

Figure 17-6—SERVICE field bit assignment

17.3.5.3 PPDU TAIL field

The PPDU TAIL field shall be six bits of 0, which are required to return the convolutional encoder to the zero state. This procedure improves the error probability of the convolutional decoder, which relies on future bits when decoding and which may be not be available past the end of the message. The PPDU TAIL field shall be produced by replacing six scrambled zero bits following the message end with six nonscrambled zero bits.

17.3.5.4 Pad bits (PAD)

The number of bits in the DATA field shall be a multiple of N_{CBPS}, the number of coded bits in an OFDM symbol (48, 96, 192, or 288 bits). To achieve that, the length of the message is extended so that it becomes a multiple of N_{DBPS}, the number of data bits per OFDM symbol. At least 6 bits are appended to the message, in order to accommodate the TAIL bits, as described in 17.3.5.3. The number of OFDM symbols, N_{SYM}; the number of bits in the DATA field, N_{DATA}; and the number of pad bits, N_{PAD}, are computed from the length of the PSDU (LENGTH) as follows:

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$$N_{SYM} = \left\lceil \frac{16 + 8 \times \text{LENGTH} + 6}{N_{DBPS}} \right\rceil \quad (17\text{-}11)$$

$$N_{DATA} = N_{SYM} \times N_{DBPS} \quad (17\text{-}12)$$

$$N_{PAD} = N_{DATA} - (16 + 8 \times \text{LENGTH} + 6) \quad (17\text{-}13)$$

The appended bits ("pad bits") are set to 0 and are subsequently scrambled with the rest of the bits in the DATA field.

An example of a DATA field that contains the SERVICE field, DATA, tail, and pad bits is given in I.1.5.1.

17.3.5.5 PHY DATA scrambler and descrambler

The DATA field, composed of SERVICE, PSDU, tail, and pad parts, shall be scrambled with a length-127 PPDU-synchronous scrambler. The octets of the PSDU are placed in the transmit serial bit stream, bit 0 first and bit 7 last. The PPDU synchronous scrambler uses the generator polynomial $S(x)$ as follows and is illustrated in Figure 17-7:

$$S(x) = x^7 + x^4 + 1 \quad (17\text{-}14)$$

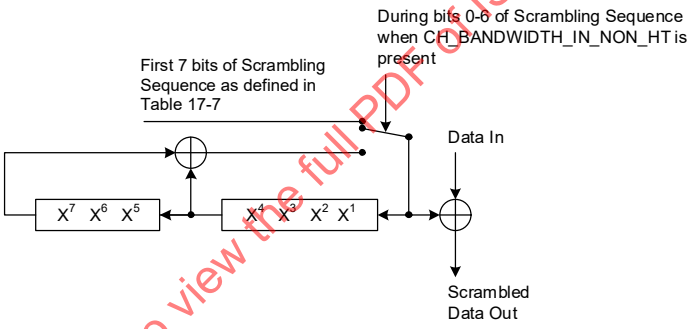

Figure 17-7—Data scrambler

NOTE 1—The 127-bit sequence generated repeatedly by the scrambler is (leftmost used first) 00001110 11110010 11001001 00000010 00100110 00101110 10110110 00001100 11010100 11100111 10110100 00101010 11111010 01010001 10111000 1111111, when the all 1s initial state is used.

The same scrambler is used to scramble transmit data and to descramble receive data. If the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT is not present, when transmitting, the initial state of the scrambler shall be set to a pseudorandom nonzero state. If the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT is present,

— The first 7 bits of the scrambling sequence shall be set as shown in Table 17-7 (with field values defined in Table 17-8 and Table 17-10) and shall be also used to initialize the state of the scrambler.
— The scrambler with this initialization shall generate the remainder (i.e., after the first 7 bits) of the scrambling sequence as shown in Figure 17-7.
— CH_BANDWIDTH_IN_NON_HT is transmitted LSB first. For example, if CBW80 has a value of 2, which is 10 in binary representation, then B5=0 and B6=1.

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If the TXVECTOR parameter SCRAMBLER_RESET is set to RESET_SCRAMBLER and dot11MACPrivacyActivated is true, the initial state of the scrambler shall be set to a nonzero random value not based on the scrambler value at the end of the last transmitted PPDU, before changes based on CH_BANDWIDTH_IN_NON_HT defined above are applied.

During reception by a VHT STA, RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT shall be determined from selected bits in the scrambling sequence as shown in Table 17-7 and Table 17-9. During reception by a VHT STA, the RXVECTOR parameter DYN_BANDWIDTH_IN_NON_HT shall be set to selected bits in the scrambling sequence as shown in Table 17-7. The fields shall be interpreted as being sent LSB-first.

Table 17-7—Contents of the first 7 bits of the scrambling sequence

Parameter	Condition	First 7 bits of scrambling sequence		
		B0 B3	B4	B5 B6
		Transmit order →		
TXVECTOR	CH_BANDWIDTH_IN_NON_HT is present and DYN_BANDWIDTH_IN_NOT_HT is not present in TXVECTOR	5-bit pseudorandom nonzero integer if CH_BANDWIDTH_IN_NON_HT equals CBW20 and a 5-bit pseudorandom integer otherwise		CH_BANDWIDTH_IN_NON_HT
TXVECTOR	CH_BANDWIDTH_IN_NON_HT is present and DYN_BANDWIDTH_IN_NOT_HT is present in TXVECTOR	4-bit pseudorandom nonzero integer if CH_BANDWIDTH_IN_NON_HT equals CBW20 and DYN_BANDWIDTH_IN_NON_HT equals Static, and a 4-bit pseudorandom integer otherwise	DYN_BANDWIDTH_IN_NON_HT	
RXVECTOR	CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NOT_HT are present in RXVECTOR	—	DYN_BANDWIDTH_IN_NON_HT	CH_BANDWIDTH_IN_NON_HT_INDICATOR (see Table 17-9)

Table 17-8—TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT values

Enumerated value	Value
CBW20	0
CBW40	1
CBW80	2
CBW160 or CBW80+80	3

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Table 17-9—RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT values

CH_BANDWIDTH_IN_NON_HT_INDICATOR field of first 7 bits of scrambling sequence	dot11CurrentChannelCenterFrequencyIndex1	RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT
0	0	CBW20
1	0	CBW40
2	0	CBW80
3	0	CBW160
3	1 to 200	CBW80+80

Table 17-10—DYN_BANDWIDTH_IN_NON_HT values

Enumerated value	Value
Static	0
Dynamic	1

NOTE 2—The receiving PHY cannot determine whether the CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT parameters were present in the TXVECTOR of the transmitting PHY; therefore, the receiving PHY in a VHT STA always includes values for the CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT parameters in the RXVECTOR if the PPDU is a non-HT PPDU. It is the responsibility of the MAC to determine the validity of the RXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT.

NOTE 3—The receiving PHY cannot determine whether the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT was present, but it does not matter since descrambling the DATA field is the same either way.

The seven LSBs of the SERVICE field shall be set to all 0s prior to scrambling to enable estimation of the initial state of the scrambler in the receiver.

An example of the scrambler output is illustrated in I.1.5.2 with CH_BANDWIDTH_IN_NON_HT not present.

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17.3.5.6 Convolutional encoder

The DATA field, composed of SERVICE, PSDU, tail, and pad parts, shall be coded with a convolutional encoder of coding rate R = 1/2, 2/3, or 3/4, corresponding to the TXVECTOR parameter RATE. The convolutional encoder shall use the industry-standard generator polynomials, $g_0 = 133_8$ and $g_1 = 171_8$, of rate R = 1/2, as shown in Figure 17-8. The bit denoted as "A" shall be output from the encoder before the bit denoted as "B." Higher rates are derived from it by employing "puncturing." Puncturing is a procedure for omitting some of the encoded bits in the transmitter (thus reducing the number of transmitted bits and increasing the coding rate) and inserting a dummy "zero" metric into the convolutional decoder on the receive side in place of the omitted bits. The puncturing patterns are illustrated in Figure 17-9. Decoding by the Viterbi algorithm is recommended.

An example of encoding operation is shown in I.1.6.1.

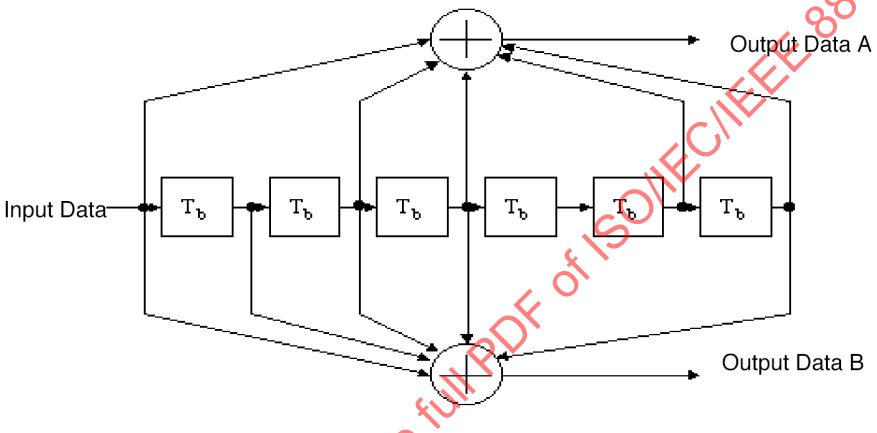

Figure 17-8—Convolutional encoder (k = 7)

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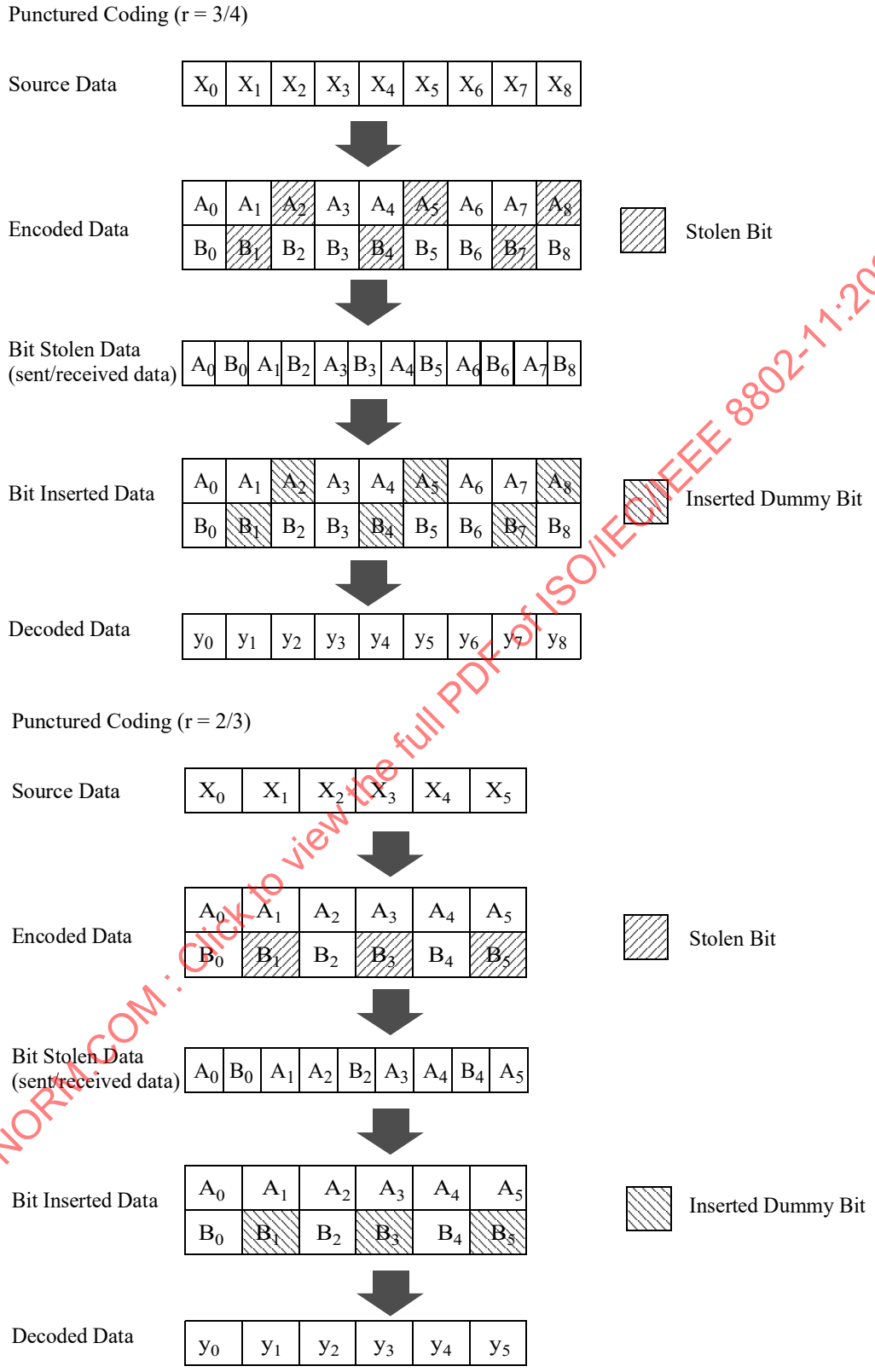

Figure 17-9—Example of the bit-stealing and bit-insertion procedure (r = 3/4, 2/3)

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17.3.5.7 Data interleaving

All encoded data bits shall be interleaved by a block interleaver with a block size corresponding to the number of bits in a single OFDM symbol, N_{CBPS}. The interleaver is defined by a two-step permutation. The first permutation causes adjacent coded bits to be mapped onto nonadjacent subcarriers. The second causes adjacent coded bits to be mapped alternately onto less and more significant bits of the constellation and, thereby, long runs of low reliability (LSB) bits are avoided.

The index of the coded bit before the first permutation shall be denoted by k; i shall be the index after the first and before the second permutation; and j shall be the index after the second permutation, just prior to modulation mapping.

The first permutation is defined by the rule

$$i = (N_{CBPS}/16) \times (k \bmod 16) + \lfloor k/16 \rfloor \qquad k = 0,1,\ldots,N_{CBPS}-1 \tag{17-15}$$

The second permutation is defined by the rule

$$j = s \times \left\lfloor \frac{i}{s} \right\rfloor + \left(i + N_{CBPS} - \left\lfloor \frac{16 \times i}{N_{CBPS}} \right\rfloor \right) \bmod s \qquad i = 0,1,\ldots N_{CBPS}-1 \tag{17-16}$$

The value of s is determined by the number of coded bits per subcarrier, N_{BPSC}, according to

$$s = \max(N_{BPSC}/2,1) \tag{17-17}$$

The deinterleaver, which performs the inverse relation, is also defined by two permutations.

Here the index of the original received bit before the first permutation shall be denoted by j; i shall be the index after the first and before the second permutation; and k shall be the index after the second permutation, just prior to delivering the coded bits to the convolutional (Viterbi) decoder.

The first permutation is defined by the rule

$$i = s \times \lfloor j/s \rfloor + \left(j + \left\lfloor \frac{16 \times j}{N_{CBPS}} \right\rfloor \right) \bmod s \qquad j = 0,1,\ldots N_{CBPS}-1 \tag{17-18}$$

where

s is defined in Equation (17-17).

This permutation is the inverse of the permutation described in Equation (17-16).

The second permutation is defined by the rule

$$k = 16 \times i - (N_{CBPS}-1) \times \left\lfloor \frac{16 \times i}{N_{CBPS}} \right\rfloor, \qquad i = 0,1,\ldots N_{CBPS}-1 \tag{17-19}$$

This permutation is the inverse of the permutation described in Equation (17-15).

An example of interleaving operation is illustrated in I.1.6.2.

17.3.5.8 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM

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constellation points. The conversion shall be performed according to Gray-coded constellation mappings, shown in Figure 17-10, with the input bit, B_0, being the earliest in the stream.

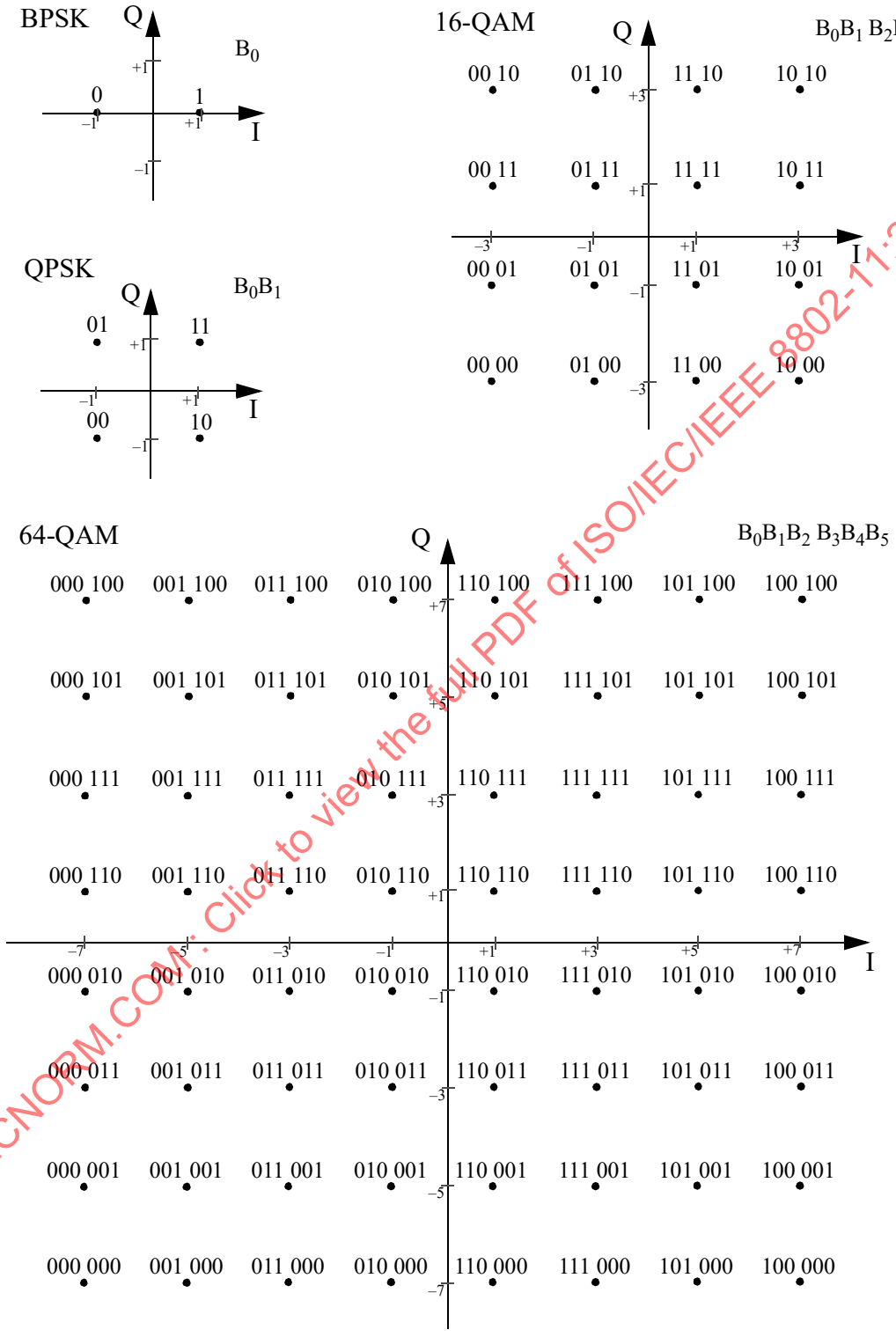

Figure 17-10—BPSK, QPSK, 16-QAM, and 64-QAM constellation bit encoding

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The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \quad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-11. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor may be used, as long as the device complies with the modulation accuracy requirements described in 17.3.9.7.

Table 17-11—Modulation-dependent normalization factor K_{MOD}

Modulation	K_{MOD}
BPSK	1
QPSK	$1/\sqrt{2}$
16-QAM	$1/\sqrt{10}$
64-QAM	$1/\sqrt{42}$

For BPSK, B_0 determines the I value, as illustrated in Table 17-12. For QPSK, B_0 determines the I value and B_1 determines the Q value, as illustrated in Table 17-13. For 16-QAM, B_0B_1 determines the I value and B_2B_3 determines the Q value, as illustrated in Table 17-14. For 64-QAM, $B_0B_1B_2$ determines the I value and $B_3B_4B_5$ determines the Q value, as illustrated in Table 17-15.

Table 17-12—BPSK encoding table

Input bit (B_0)	I-out	Q-out
0	–1	0
1	1	0

Table 17-13—QPSK encoding table

Input bit (B_0)	I-out
0	–1
1	1

Input bit (B_1)	Q-out
0	–1
1	1

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Table 17-14—16-QAM encoding table

Input bits (B_0 B_1)	I-out
00	–3
01	–1
11	1
10	3

Input bits (B_2 B_3)	Q-out
00	–3
01	–1
11	1
10	3

Table 17-15—64-QAM encoding table

Input bits (B_0 B_1 B_2)	I-out
000	–7
001	–5
011	–3
010	–1
110	1
111	3
101	5
100	7

Input bits (B_3 B_4 B_5)	Q-out
000	–7
001	–5
011	–3
010	–1
110	1
111	3
101	5
100	7

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17.3.5.9 Pilot subcarriers

In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-random binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.10.

17.3.5.10 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.4.

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An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,\,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,\,n}\exp((j2\pi M(k)\Delta_F(t-T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t-T_{GI}))\right) \quad (17\text{-}22)$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index –26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k-26 & 0 \le k \le 4 \\ k-25 & 5 \le k \le 17 \\ k-24 & 18 \le k \le 23 \\ k-23 & 24 \le k \le 29 \\ k-22 & 30 \le k \le 42 \\ k-21 & 43 \le k \le 47 \end{cases} \quad (17\text{-}23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$P_{-26,\,26} = \{0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0,$$

$$0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, –1, 0, 0, 0, 0, 0\} \quad (17\text{-}24)$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ –1,–1,–1,1,\ –1,–1,–1,–1,\ 1,1,–1,1,\ –1,–1,1,1,\ –1,1,1,–1,\ 1,1,1,1,\ 1,1,–1,1,$$
$$1,1,–1,1,\ 1,–1,–1,1,\ 1,1,–1,1,\ –1,–1,–1,1,\ –1,1,–1,–1,\ 1,–1,–1,1,\ 1,1,1,1,\ –1,–1,1,1,$$
$$–1,–1,1,–1,\ 1,–1,1,1,\ –1,–1,–1,1,\ 1,–1,–1,–1,\ –1,1,–1,–1,\ 1,–1,1,1,\ 1,1,–1,1,\ –1,1,–1,1,$$
$$–1,–1,–1,–1,\ –1,1,–1,1,\ 1,–1,1,–1,\ 1,1,1,–1,\ –1,1,–1,–1,\ –1,1,1,1,\ –1,–1,–1,–1,\ –1,–1,–1\} \quad (17\text{-}25)$$

The sequence p_n is generated by the scrambler defined by Figure 17-7 when the all 1s initial state is used, and by replacing all 1s with –1 and all 0s with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

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The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

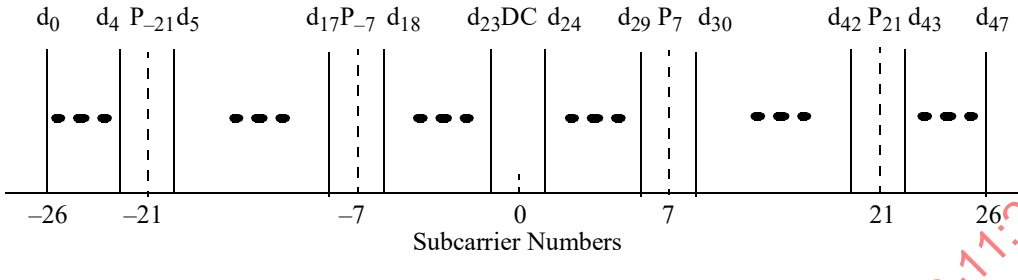

Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols is written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in I.1.6.3, as well as the scrambling of the pilot signals (see I.1.7). The final output of these operations is also shown in I.1.8.

17.3.6 CCA

The PHY shall provide the capability to perform CCA and report the result to the MAC. The CCA mechanism shall detect a “medium busy” condition with requirements specified in 17.3.10.6 and 17.3.12. The PHY issues the PHY-CCA.indication primitive to provide this medium status report to the MAC.

17.3.7 PHY data modulation and modulation rate change

The SIGNAL field, which follows the non-HT preamble, shall indicate the modulation and coding rate that shall be used to transmit the MPDU. The transmitter (receiver) shall initiate the modulation (demodulation) constellation and the coding rate according to the RATE indicated in the SIGNAL field. The MPDU transmission rate shall be set by the DATARATE parameter in the TXVECTOR, issued with the PHY-TXSTART.request primitive described in 17.2.2.

17.3.8 PHY operating specifications (general)

17.3.8.1 General

General specifications for the BPSK OFDM, QPSK OFDM, 16-QAM OFDM, and 64-QAM OFDM PHY sublayers are provided in 17.3.8.2 to 17.3.8.7. These specifications apply to both the receive and transmit functions and general operation of the OFDM PHY.

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17.3.8.2 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-16.

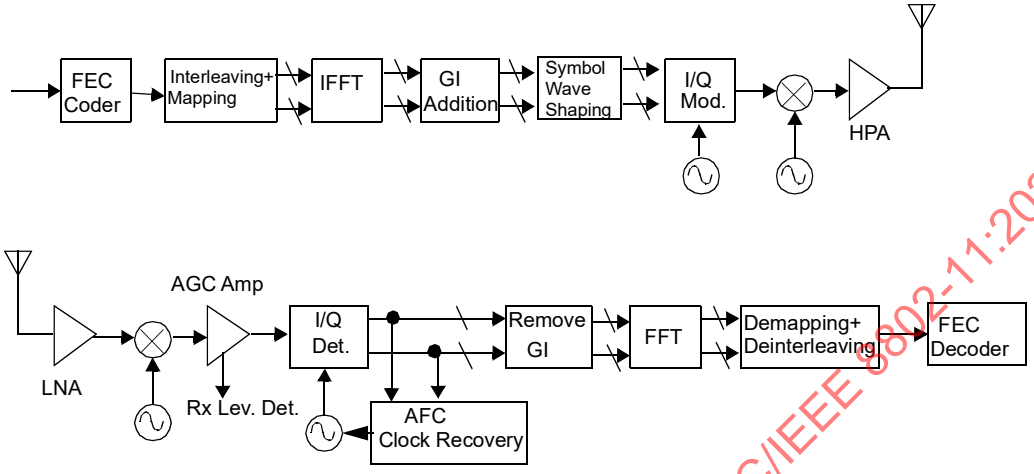

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

Table 17-16—Major parameters of the OFDM PHY

Information data rate	6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)	3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)	1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 µs	8.0 µs	16.0 µs
GI	0.8 µs[a] (T_{GI})	1.6 µs (T_{GI})	3.2 µs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

[a]Refer to 17.3.2.5.

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17.3.8.3 Regulatory requirements

WLANs implemented in accordance with this standard are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The PHY specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regulations are subject to revision, or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PHY specification. Regulatory requirements that do not affect interoperability are not addressed in this standard. Implementers are referred to the regulatory sources in Annex D for further information. Operation in countries within defined regulatory domains may be subject to additional or alternative national regulations.

17.3.8.4 Operating channel frequencies

17.3.8.4.1 Operating frequency range

The OFDM PHY shall not operate in frequency bands not allocated by a regulatory body in its operational region. Regulatory requirements for a given frequency band are set by the regulatory authority responsible for spectrum management in a given geographic region or domain. The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.

In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. An OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsImplementedValue and dot11FrequencyBandsImplemented.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for an OFDM PHY contains an OPERATING_CHANNEL parameter, which identifies the operating channel. The PHY shall set dot11CurrentFrequency to the value of this parameter.

17.3.8.4.2 Channel numbering

Channel center frequencies are defined at every integer multiple of 5 MHz above the channel starting frequency. The relationship between center frequency and channel number is given by Equation (17-27):

$$\text{Channel center frequency} = \text{Channel starting frequency} + 5 \times n_{ch} \text{ (MHz)} \quad (17\text{-}27)$$

where

n_{ch} = 1,…200

Channel starting frequency is defined as dot11ChannelStartingFactor × 500 kHz or
is defined as 5 GHz where dot11OperatingClassesRequired is false or not defined.

A channel center frequency of 5 GHz shall be indicated by dot11ChannelStartingFactor = 8000 and n_{ch} = 200.

This definition provides a unique numbering system for all channels with 5 MHz between center frequencies, as well as the flexibility to define channelization sets for all current and future regulatory domains.

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17.3.8.4.3 Channelization

The set of valid operating channel numbers by regulatory domain is defined in Annex E. As shown in Figure 17-11, no subcarrier is allocated on the channel center frequency.

17.3.8.5 Transmit and receive in-band and out-of-band spurious emissions

The OFDM PHY shall comply with in-band and out-of-band spurious emissions as set by regulatory bodies.

17.3.8.6 Slot time

The value of the slot time is found in Table 17-21 (in 17.4.4).

17.3.8.7 Transmit and receive impedance at the antenna connector

The impedance at the transmit antenna connector and receive antenna connector shall be 50 Ω if that connector is exposed.

17.3.9 PHY transmit specifications

17.3.9.1 General

The transmit specifications associated with the PHY sublayer are described in 17.3.9.2 to 17.3.9.8.

17.3.9.2 Transmit power levels

The maximum allowable output power is measured in accordance with practices specified by the appropriate regulatory bodies.

17.3.9.3 Transmit spectrum mask

The transmit spectrum mask by regulatory domain is defined in Annex D and Annex E.

NOTE—In the presence of additional regulatory restrictions, the device needs to meet both the regulatory requirements and the mask defined here, i.e., its emissions need to be no higher at any frequency offset than the minimum of the values specified in the regulatory and default masks.

For rules regarding TX center frequency leakage levels by VHT STAs, see 21.3.17.4.2.

For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and the maximum of –40 dBr and –53 dBm/MHz at 30 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 17-13. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

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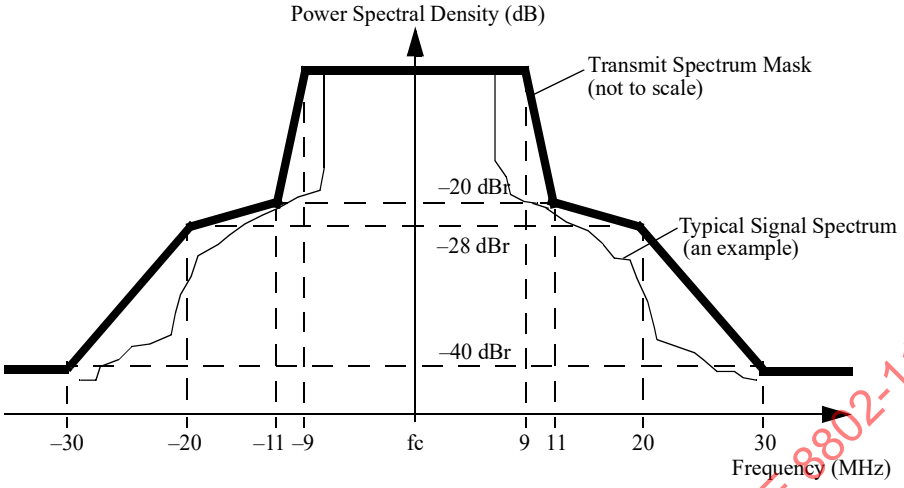

Figure 17-13—Transmit spectrum mask for 20 MHz transmission

For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and the maximum of –40 dBr and –50 dBm/MHz at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 17-14. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

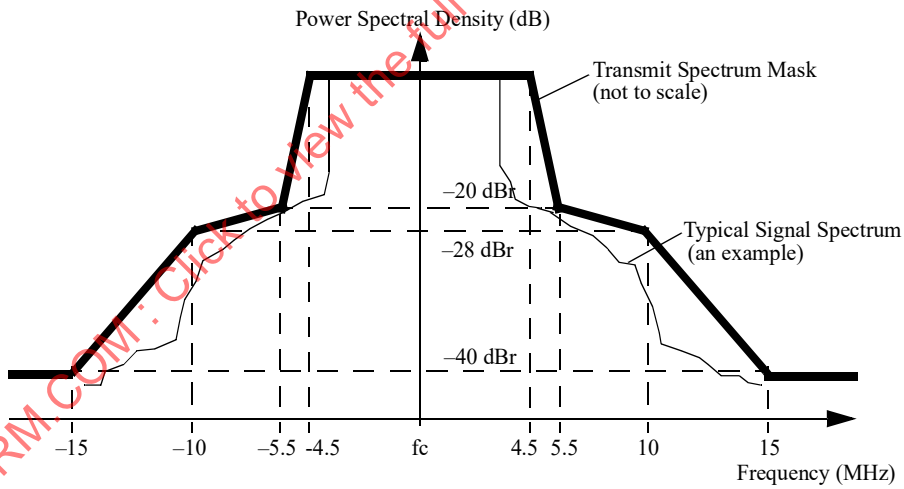

Figure 17-14—Transmit spectrum mask for 10 MHz transmission

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For operation using 5 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 4.5 MHz, –20 dBr at 2.75 MHz frequency offset, –28 dBr at 5 MHz frequency offset, and the maximum of –40 dBr and –47 dBm/MHz at 7.5 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 17-15. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

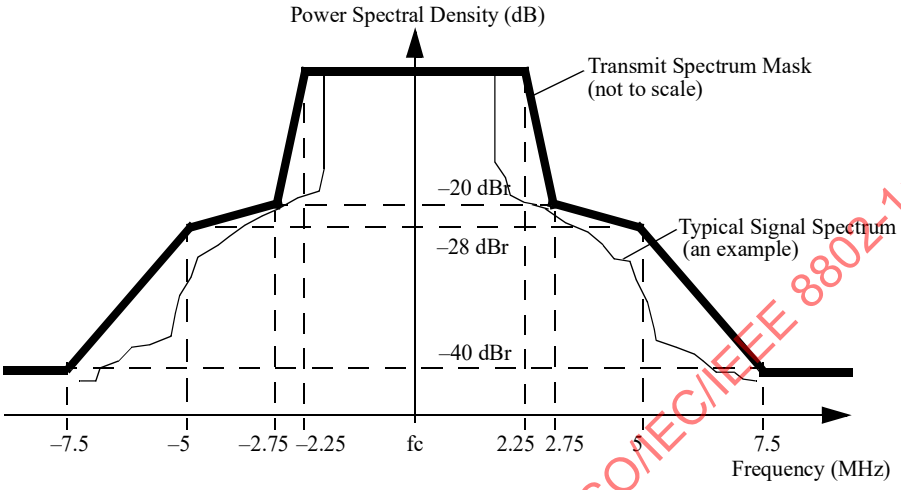

Figure 17-15—Transmit spectrum mask for 5 MHz transmission

17.3.9.4 Transmission spurious

Spurious transmissions shall comply with national regulations.

17.3.9.5 Transmit center frequency tolerance

The transmitted center frequency tolerance shall be ± 20 ppm for 20 MHz and 10 MHz channels and shall be ± 10 ppm for 5 MHz channels. The transmit center frequency and the symbol clock frequency shall be derived from the same reference oscillator.

17.3.9.6 Symbol clock frequency tolerance

The symbol clock frequency tolerance shall be ± 20 ppm for 20 MHz and 10 MHz channels, and shall be ± 10 ppm for 5 MHz channels. The transmit center frequency and the symbol clock frequency shall be derived from the same reference oscillator.

17.3.9.7 Modulation accuracy

17.3.9.7.1 Introduction

Transmit modulation accuracy specifications are described in 17.3.9.7. The test method is described in 17.3.9.8.

17.3.9.7.2 Transmitter center frequency leakage

For VHT STAs, the requirements on transmitter center frequency leakage are defined in 21.3.17.4.2; otherwise, the requirements are defined in this subclause.

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Certain transmitter implementations might cause leakage of the center frequency component. Such leakage (which manifests itself in a receiver as energy in the center frequency component) shall not exceed $max(P - 15, -20)$ dBm or, equivalently, +2 dB relative to the average energy of the rest of the subcarriers. The data for this test shall be derived from the channel estimation phase.

17.3.9.7.3 Transmitter spectral flatness

The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 shall deviate no more than ± 4 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 shall deviate no more than +4/–6 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step.

17.3.9.7.4 Transmitter constellation error

The relative constellation RMS error, averaged over subcarriers and OFDM PPDUs, shall not exceed a data-rate dependent value according to Table 17-17.

Table 17-17—Allowed relative constellation error versus data rate

Relative constellation error (dB)	Modulation	Coding rate (R)
–5	BPSK	1/2
–8	BPSK	3/4
–10	QPSK	1/2
–13	QPSK	3/4
–16	16-QAM	1/2
–19	16-QAM	3/4
–22	64-QAM	2/3
–25	64-QAM	3/4

17.3.9.8 Transmit modulation accuracy test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples at 20 Msample/s or more, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc. A possible embodiment of such a setup is converting the signal to a low IF with a microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components.

The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or an equivalent procedure:

a) Start of frame shall be detected.

b) Transition from short sequences to channel estimation sequences shall be detected, and fine timing (with one sample resolution) shall be established.

c) Coarse and fine frequency offsets shall be estimated.

d) The PPDU shall be derotated according to estimated frequency offset.

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e) The complex channel response coefficients shall be estimated for each of the subcarriers.

f) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, derotate the subcarrier values according to estimated phase, and divide each subcarrier value with a complex estimated channel response coefficient.

g) For each data-carrying subcarrier, find the closest constellation point and compute the Euclidean distance from it.

h) Compute the RMS average of all errors in a PPDU. It is given by

$$Error_{RMS} = \frac{\sum_{i=1}^{N_f} \sqrt{\sum_{j=1}^{L_P} \left[\sum_{k=1}^{52} \{(I(i,j,k) - I_0(i,j,k))^2 + (Q(i,j,k) - Q_0(i,j,k))^2\} \right]}}{52 L_P \times P_0} \Big/ N_f \quad (17\text{-}28)$$

where

L_P is the length of the packet

N_f is the number of frames for the measurement

$(I_0(i,j,k), Q_0(i,j,k))$ denotes the ideal symbol point of the i^{th} frame, j^{th} OFDM symbol of the frame, k^{th} subcarrier of the OFDM symbol in the complex plane

$(I(i,j,k), Q(i,j,k))$ denotes the observed point of the i^{th} frame, j^{th} OFDM symbol of the frame, k^{th} subcarrier of the OFDM symbol in the complex plane (see Figure 17-16)

P_0 is the average power of the constellation

The vector error on a phase plane is shown in Figure 17-16.

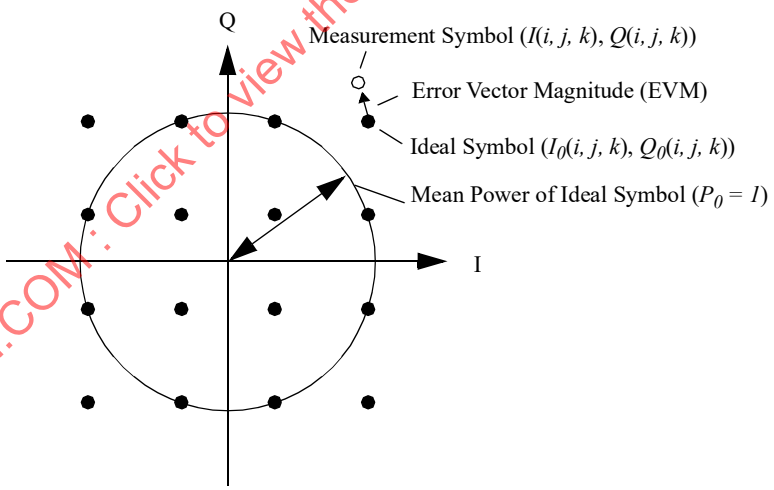

Figure 17-16—Constellation error

The test shall be performed over at least 20 frames (N_f), and the RMS average shall be taken. The packets under test shall be at least 16 OFDM symbols long. Random data shall be used for the symbols.

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17.3.9.9 Time of Departure accuracy

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is $20 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{20\ \text{MHz}} \right\rceil\right)$ sample/s

where

f_H is the nominal center frequency in Hz of the highest channel in the channel set

f_L is the nominal center frequency in Hz of the lowest channel in the channel set, the channel set is the set of channels upon which frames providing measurements are transmitted, the channel set comprises channels uniformly spaced across $f_H - f_L \geq 50$ MHz

— FIRST_TRANSITION_FIELD is the Short symbols.

— SECOND_TRANSITION_FIELD is the Long symbols.

— TRAINING_FIELD is the Long symbols windowed in a manner which should approximate the windowing described in 17.3.2.5 with T_{TR} = 100 ns for 20 MHz channel spacing, T_{TR} = 200 ns for 10 MHz channel spacing and T_{TR} = 400 ns for 5 MHz channel spacing.

— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns.

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

17.3.10 PHY receiver specifications

17.3.10.1 Introduction

The receive specifications associated with the PHY sublayer are described in 17.3.10.2 to 17.3.10.6.

17.3.10.2 Receiver minimum input sensitivity

The packet error ratio (PER) shall be 10% or less when the PSDU length is 1000 octets and the rate-dependent input level is as shown in Table 17-18. The minimum input levels are measured at the antenna connector (noise factor of 10 dB and 5 dB implementation margins are assumed).

Table 17-18—Receiver performance requirements

Modulation	Coding rate (R)	Adjacent channel rejection (dB)	Alternate adjacent channel rejection (dB)	Minimum sensitivity (dBm) (20 MHz channel spacing)	Minimum sensitivity (dBm) (10 MHz channel spacing)	Minimum sensitivity (dBm) (5 MHz channel spacing)
BPSK	1/2	16	32	–82	–85	–88
BPSK	3/4	15	31	–81	–84	–87
QPSK	1/2	13	29	–79	–82	–85
QPSK	3/4	11	27	–77	–80	–83
16-QAM	1/2	8	24	–74	–77	–80
16-QAM	3/4	4	20	–70	–73	–76
64-QAM	2/3	0	16	–66	–69	–72
64-QAM	3/4	–1	15	–65	–68	–71

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17.3.10.3 Adjacent channel rejection

The adjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 17-18 and raising the power of the interfering signal until 10% PER is caused for a PSDU length of 1000 octets. The difference in power between the signals in the interfering channel and the desired channel is the corresponding adjacent channel rejection. The interfering signal in the adjacent channel shall be a signal compliant with the OFDM PHY, unsynchronized with the signal in the channel under test. In an OFDM PHY the corresponding rejection shall be no less than specified in Table 17-18.

An optional enhanced performance specification is provided for systems requiring improved immunity to out-of-channel interfering emissions. If a STA has dot11ACRType equal to 2, the adjacent channel rejection shall be no less than specified in Table 17-19. The interfering signal in the adjacent channel shall be a signal compliant with the OFDM PHY, using transmit mask M (see D.2.4), unsynchronized with the signal in the channel under test. The corresponding minimum receiver sensitivities for each modulation and coding rate are the same as in Table 17-18.

NOTE—Transmit mask M is equivalent to class C (see D.2.2).

Table 17-19—Optional enhanced receiver performance requirements

Modulation	Coding rate (R)	Adjacent channel rejection (dB)	Nonadjacent channel rejection (dB)
BPSK	1/2	28	42
BPSK	3/4	27	41
QPSK	1/2	25	39
QPSK	3/4	23	37
16-QAM	1/2	20	34
16-QAM	3/4	16	30
64-QAM	2/3	12	26
64-QAM	3/4	11	25

17.3.10.4 Nonadjacent channel rejection

The nonadjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 17-18, and raising the power of the interfering signal until a 10% PER occurs for a PSDU length of 1000 octets. The difference in power between the signals in the interfering channel and the desired channel is the corresponding nonadjacent channel rejection. The interfering signal in the nonadjacent channel shall be a signal compliant with the OFDM PHY, unsynchronized with the signal in the channel under test. In an OFDM PHY, the corresponding rejection shall be no less than specified in Table 17-18.

An optional enhanced performance specification is provided for systems requiring improved immunity to out-of-channel interfering emissions. If a STA has dot11ACRType equal to 2, the nonadjacent channel rejection shall be no less than specified in Table 17-19. The interfering signal in the nonadjacent channel shall be a signal compliant with the OFDM PHY, using transmit mask M (see D.2.4), unsynchronized with the signal in the channel under test. The corresponding minimum receiver sensitivities for each modulation and coding rate are the same as in Table 17-18.

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17.3.10.5 Receiver maximum input level

The receiver shall provide a maximum PER of 10% at a PSDU length of 1000 octets, for a maximum input level of –30 dBm measured at the antenna connector for any baseband modulation.

17.3.10.6 CCA requirements

The PHY shall indicate a medium busy condition by issuing a PHY-CCA.indication primitive when the carrier sense/clear channel assessment (CS/CCA) mechanism detects a channel busy condition.

For the operating classes requiring CCA-Energy Detect (CCA-ED), the PHY shall also indicate a medium busy condition when CCA-ED detects a channel busy condition.

The start of an OFDM transmission at a receive level greater than or equal to the minimum modulation and coding rate sensitivity (–82 dBm for 20 MHz channel spacing, –85 dBm for 10 MHz channel spacing, and –88 dBm for 5 MHz channel spacing) shall cause CS/CCA to detect a channel busy condition with a probability > 90% within 4 μs for 20 MHz channel spacing, 8 μs for 10 MHz channel spacing, and 16 μs for 5 MHz channel spacing.

NOTE 1—CS/CCA detect time is based on finding the short sequences in the preamble, so when T_{SYM} doubles, so does CS/CCA detect time.

Additionally, the CS/CCA mechanism shall detect a medium busy condition within 4 μs of any signal with a received energy that is 20 dB above the minimum modulation and coding rate sensitivity (minimum modulation and coding rate sensitivity + 20 dB resulting in –62 dBm for 20 MHz channel spacing, –65 dBm for 10 MHz channel spacing, and –68 dBm for 5 MHz channel spacing).

For improved spectrum sharing, CCA-ED is required in some bands. The behavior class indicating CCA-ED is given in Table D-2. The operating classes requiring the corresponding CCA-ED behavior class are given in E.1. The PHY of a STA that is operating within an operating class that requires CCA-ED shall operate with CCA-ED.

CCA-ED shall detect a channel busy condition when the received signal strength exceeds the CCA-ED threshold as given by dot11OFDMEDThreshold. The CCA-ED thresholds for the operating classes requiring CCA-ED are subject to the criteria in D.2.5.

NOTE 2—The requirement to detect a channel busy condition for any signal 20 dB above the minimum modulation and coding rate sensitivity (minimum modulation and coding rate sensitivity + 20 dB resulting in –62 dBm for 20 MHz channel spacing, –65 dBm for 10 MHz channel spacing, and –68 dBm for 5 MHz channel spacing) is a mandatory energy detect requirement on all Clause 17 receivers. Support for CCA-ED is an additional requirement that relates specifically to the sensitivities described in D.2.5.

17.3.10.7 Received channel power indicator (RCPI) measurement

The RCPI is a measure of the received RF power in the selected channel for a received frame. This parameter shall be a measure by the PHY of the received RF power in the channel measured over the entire received frame or by other equivalent means that meet the specified accuracy.

The RCPI encoding is defined in 9.4.2.37.

RCPI shall equal the received RF power within an accuracy of ± 5 dB (95% confidence interval) within the specified dynamic range of the receiver. The received RF power shall be determined assuming a receiver noise equivalent bandwidth equal to the channel bandwidth multiplied by 1.1.

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17.3.11 Transmit PHY

The transmit PHY is shown in Figure 17-17. In order to transmit data, the PHY-TXSTART.request primitive shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate frequency through STA management via the PLME. Other transmit parameters, such as DATARATE and TX power, are set via the PHY SAP with the PHY-TXSTART.request(TXVECTOR) primitive, as described in 17.2.2.

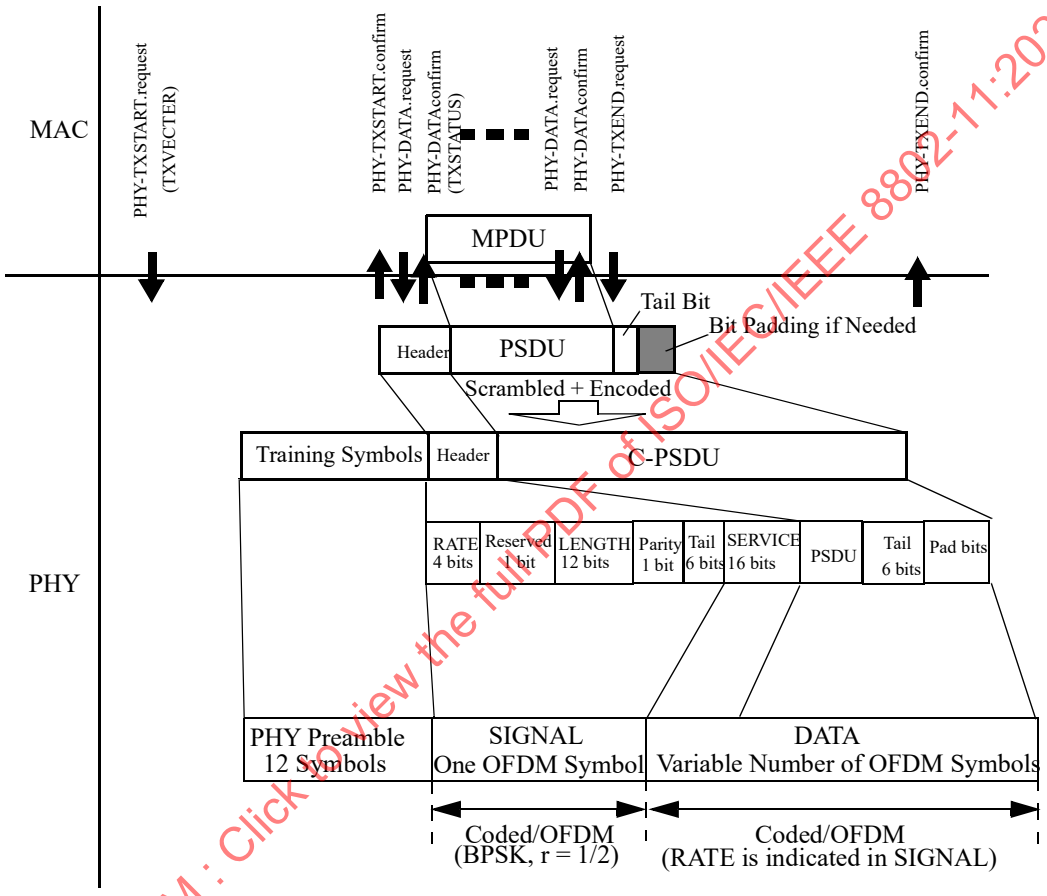

Figure 17-17—Transmit PHY

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The PHY shall indicate a clear channel by issuing a PHY-CCA.indication(IDLE) primitive. The MAC considers this indication before issuing the PHY-TXSTART.request primitive. Transmission of the PPDU shall be initiated after receiving the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request primitive are the PHY header parameters DATARATE, SERVICE, and LENGTH and the PHY parameters TXPWR_LEVEL_INDEX and TIME_OF_DEPARTURE_REQUESTED.

The PHY is configured with the TXVECTOR elements DATARATE and TXPWR_LEVEL_INDEX. Transmission of the PHY preamble and PHY header, based on the parameters passed in the PHY-TXSTART.request primitive, shall be immediately initiated.

Once PHY preamble transmission is started, the PHY entity shall immediately initiate PHY header encoding then data scrambling and data encoding, where the data shall be exchanged between the MAC and the PHY through a series of PHY-DATA.request(DATA) primitives issued by the MAC, and PHY-DATA.confirm primitives issued by the PHY. The modulation rate change, if any, shall be initiated from the SERVICE field data of the PHY header, as described in 17.3.2.

The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. The PHY header parameter, SERVICE, and PSDU are encoded by the convolutional encoder with the bit-stealing function described in 17.3.5.6. Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. Normal termination occurs after the transmission of the final bit of the last PSDU octet, according to the number supplied in the LENGTH field of the SIGNAL field.

The packet transmission shall be completed and the PHY entity shall enter the receive state. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY. If the coded PSDU (C-PSDU) length is not a multiple of the OFDM symbol length N_{CBPS}, the PSDU is padded prior to scrambling and coding (see 17.3.5.4).

In the PHY, the GI shall be inserted in every OFDM symbol as a countermeasure against severe delay spread.

A typical state machine implementation of the transmit PHY is provided in Figure 17-18. Requests (.request) and confirmations (.confirm) are issued once with designated states.

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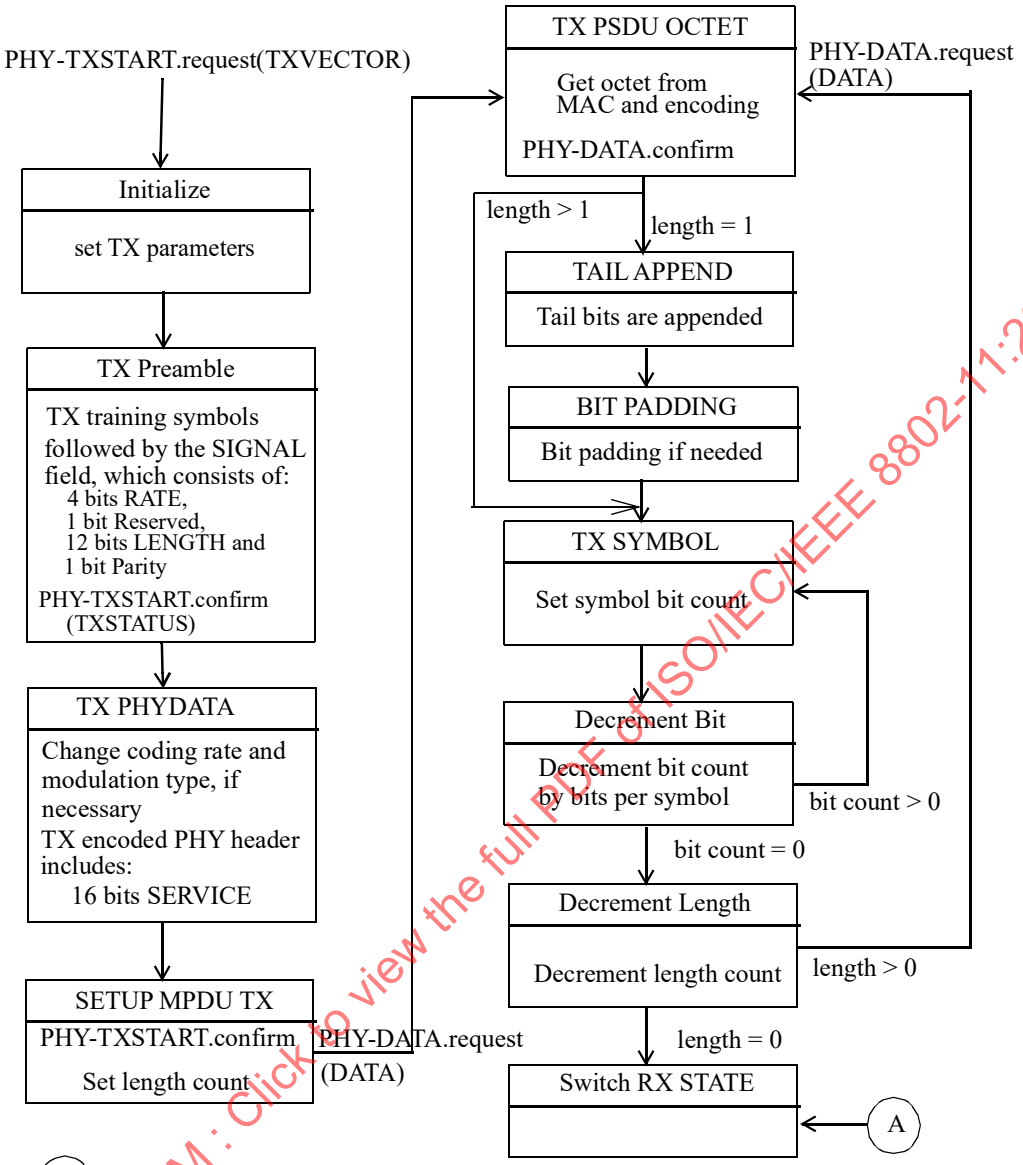

Figure 17-18—PHY transmit state machine

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17.3.12 Receive PHY

The receive PHY is shown in Figure 17-19. In order to receive data, the PHY-TXSTART.request primitive shall be disabled so that the PHY entity is in the receive state. Further, through STA management (via the PLME) the PHY is set to the appropriate frequency. Other receive parameters, such as RSSI, RCPI, and indicated DATARATE, may be accessed via the PHY SAP.

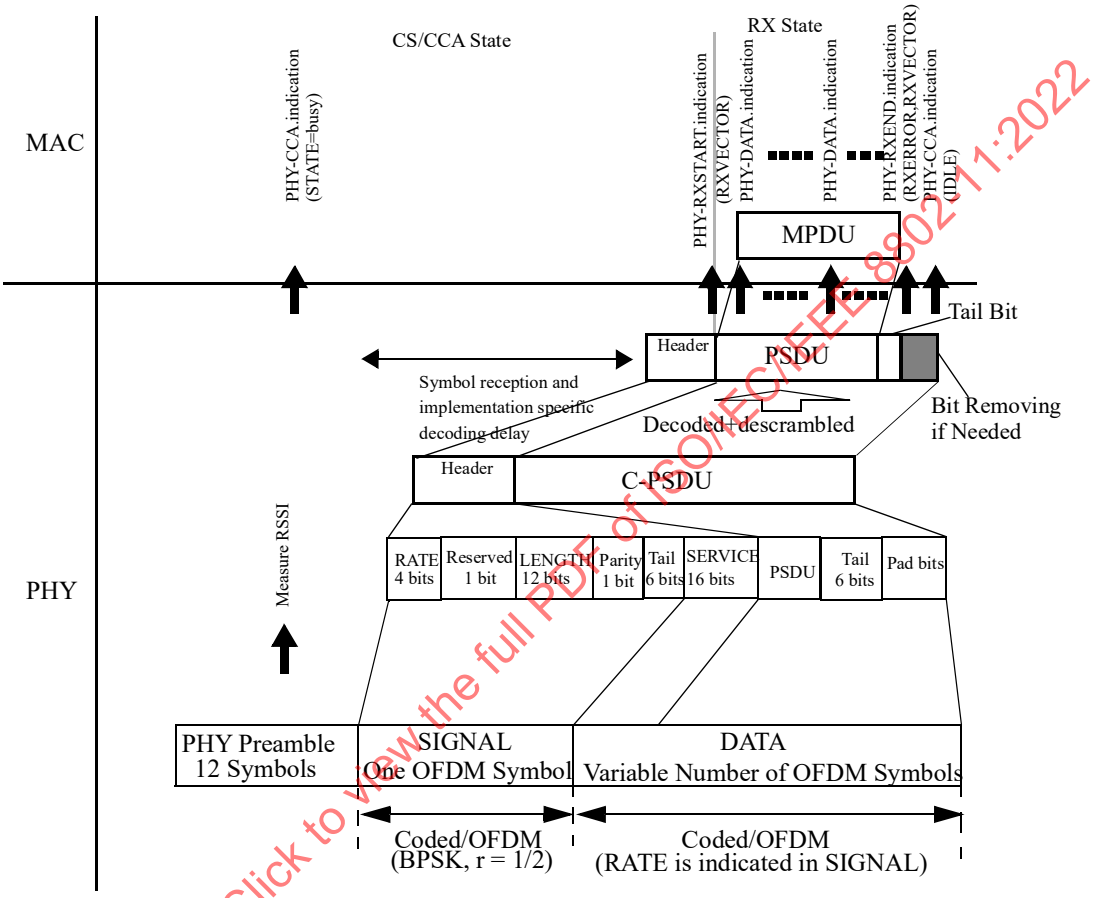

Figure 17-19—Receive PHY

Upon receiving the transmitted PHY preamble, the PHY measures the received signal strength level. This indicates activity to the MAC via PHY-CCA.indication primitive. A PHY-CCA.indication(BUSY) primitive shall be issued for reception of a signal prior to correct reception of the PPDU. The RSSI parameter reported to the MAC in the RXVECTOR.

After a PHY-CCA.indication primitive is issued, the PHY entity shall begin receiving the training symbols and searching for the SIGNAL in order to set the length of the data stream, the demodulation type, and the decoding rate.

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If the PHY header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. If dot11TimingMsmtActivated is true, the PHY shall do the following:

— Complete receiving the PHY header and verify the validity of the PHY Header.
— If the PHY header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued and RX_START_OF_FRAME_OFFSET parameter within the RXVECTOR shall be forwarded (see 17.2.3).

A VHT STA shall include the CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT parameters in the RXVECTOR within the PHY-RXSTART.indication(RXVECTOR) primitive.

NOTE—The RX_START_OF_FRAME_OFFSET value is used as described in 6.3.55 in order to estimate when the start of the preamble for the incoming frame was detected on the medium at the receive antenna connector.

The RXVECTOR associated with this primitive includes the SIGNAL field, the SERVICE field, the PSDU length in octets, and the RSSI. Also, in this case, the CCA of the OFDM PHY shall indicate a busy medium for the intended duration of the transmitted frame, as indicated by the LENGTH field.

The received PSDU bits are assembled into octets, decoded, and presented to the MAC using a series of PHY-DATA.indication(DATA) primitive exchanges. The rate change indicated in the SIGNAL field shall be initiated from the SERVICE field data of the PHY header, as described in 17.3.2. The PHY shall proceed with PSDU reception. After the reception of the final bit of the last PSDU octet indicated by the LENGTH field of the SIGNAL field, the receiver shall be returned to the RX IDLE state, as shown in Figure 17-19. A PHY-RXEND.indication(NoError) primitive shall be issued.

In the event that a change in the RSSI causes the status of the CCA to return to the IDLE state before the complete reception of the PSDU, as indicated by the PHY LENGTH field, the error condition shall be reported to the MAC using a PHY-RXEND.indication(CarrierLost) primitive and the PHY receiver shall return to the RX IDLE state. The CCA of the OFDM PHY shall indicate a busy medium for the intended duration of the transmitted packet.

If the indicated rate in the SIGNAL field is not receivable, a PHY-RXSTART.indication primitive shall not be issued. The PHY shall indicate the error condition by issuing a PHY-RXEND.indication(UnsupportedRate) primitive and hold CCA busy for the calculated duration of the PPDU. If the PHY header is receivable, but the parity check of the PHY header is not valid, a PHY-RXSTART.indication primitive shall not be issued. The PHY shall indicate the error condition using a PHY-RXEND.indication(FormatViolation) primitive.

Any data received after the indicated data length are considered pad bits (to fill out an OFDM symbol) and should be discarded.

A typical state machine implementation of the receive PHY is given in Figure 17-20.

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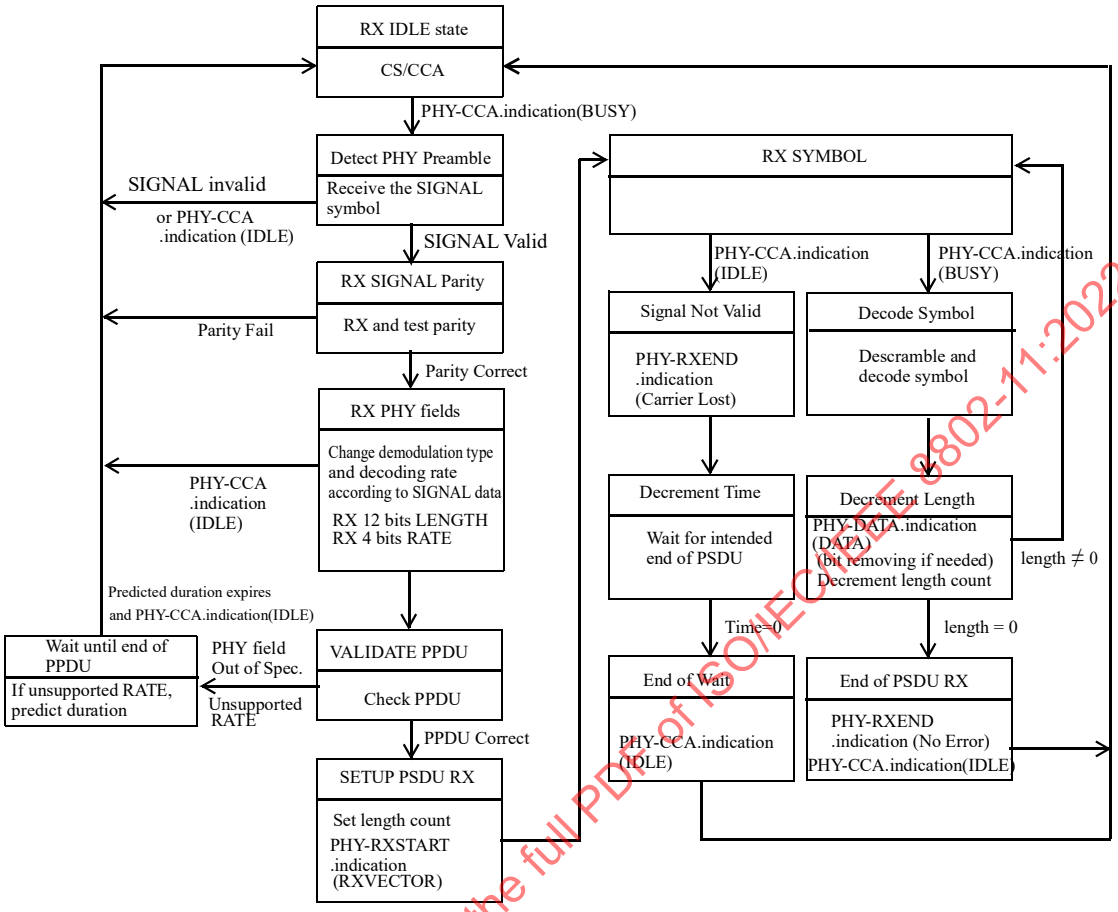

Figure 17-20—PHY receive state machine

17.4 OFDM PLME

17.4.1 PLME SAP sublayer management primitives

Table 17-20 lists the MIB attributes that may be accessed by the PHY entities and the intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.5.

Table 17-20—MIB attribute default values/ranges

Managed object	Default value/range	Operational semantics
dot11 PHY Operation Table		
dot11PHYType	OFDM-5. (04)	Static
dot11CurrentRegDomain	Implementation dependent	Dynamic

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Table 17-20—MIB attribute default values/ranges *(continued)*

Managed object	Default value/range	Operational semantics
dot11 PHY Antenna Table		
dot11CurrentTxAntenna	Implementation dependent	Dynamic
dot11DiversitySupportImplemented	Implementation dependent	Static
dot11CurrentRxAntenna	Implementation dependent	Dynamic
dot11 PHY Tx Power Table		
dot11NumberSupportedPowerLevelsImplemented	Implementation dependent	Static
dot11TxPowerLevel1	Implementation dependent	Static
dot11TxPowerLevel2	Implementation dependent	Static
dot11TxPowerLevel3	Implementation dependent	Static
dot11TxPowerLevel4	Implementation dependent	Static
dot11TxPowerLevel5	Implementation dependent	Static
dot11TxPowerLevel6	Implementation dependent	Static
dot11TxPowerLevel7	Implementation dependent	Static
dot11TxPowerLevel8	Implementation dependent	Static
dot11CurrentTxPowerLevel	Implementation dependent	Dynamic
dot11 Reg Domains Supported Table		
dot11RegDomainsImplementedValue	Implementation dependent	Static
dot11FrequencyBandsSupported	Implementation dependent	Static
dot11 PHY Antennas List Table		
dot11SupportedTxAntenna	Implementation dependent	Static
dot11SupportedRxAntenna	Implementation dependent	Static
dot11DiversitySelectionRx	Implementation dependent	Dynamic
dot11 Supported Data Rates Tx Table		
dot11ImplementedDataRatesTxValue	6, 9, 12, 18, 24, 36, 48, and 54 Mb/s for 20 MHz channel spacing (Mandatory rates: 6, 12, and 24) 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s for 10 MHz channel spacing (Mandatory rates: 3, 6, and 12) 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s for 5 MHz channel spacing (Mandatory rates: 1.5, 3, and 6)	Static

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Table 17-20—MIB attribute default values/ranges *(continued)*

Managed object	Default value/range	Operational semantics
dot11 Supported Data Rates Rx Table		
dot11ImplementedDataRatesRxValue	6, 9, 12, 18, 24, 36, 48, and 54 Mb/s for 20 MHz channel spacing (Mandatory rates: 6, 12, and 24) 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s for 10 MHz channel spacing (Mandatory rates: 3, 6, and 12) 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s for 5 MHz channel spacing (Mandatory rates: 1.5, 3, and 6)	Static
dot11 PHY OFDM Table		
dot11CurrentFrequency	Implementation dependent	Dynamic
dot11TIThreshold	Implementation dependent	Dynamic
dot11ChannelStartingFactor	Implementation dependent	Dynamic
dot11OFDMEDThreshold	Implementation dependent	Dynamic
dot11ACRType	Implementation dependent	Dynamic

17.4.2 OFDM PHY MIB

All OFDM PHY MIB attributes are defined in Annex C, with specific values defined in Table 17-20. The column titled "Operational semantics" in Table 17-20 contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. Dynamic MIB attributes can be modified by some management entity.

When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.

17.4.3 OFDM TXTIME calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated according to the following equation:

$$\text{TXTIME} = T_{PREAMBLE} + T_{SIGNAL} + T_{SYM} \times N_{SYM} \quad (17\text{-}29)$$

where

$T_{PREAMBLE}$ is defined in Table 17-5
T_{SIGNAL} is defined in Table 17-5
T_{SYM} is defined in Table 17-5
N_{SYM} is given by Equation (17-11)

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17.4.4 OFDM PHY

The static OFDM PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 17-21. The definitions for these characteristics are given in 6.5.4.

Table 17-21—OFDM PHY characteristics

Characteristics	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
aSlotTime	If dot11OperatingClassesRequired is false, 9 µs If dot11OperatingClassesRequired is true, 9 µs plus any coverage-class-dependent aAirPropagationTime (see Table 9-95)	If dot11OperatingClassesRequired is false, 13 µs If dot11OperatingClassesRequired is true, 13 µs plus any coverage-class-dependent aAirPropagationTime (see Table 9-95)	If dot11OperatingClassesRequired is false, 21 µs If dot11OperatingClassesRequired is true, 21 µs plus any coverage-class-dependent aAirPropagationTime (see Table 9-95)
aSIFSTime	16 µs	32 µs	64 µs
aCCATime	Implementation dependent, see 10.3.7.		
aRxPHYStartDelay	20 µs	40 µs	80 µs
aRxTxTurnaroundTime	Implementation dependent, see 10.3.7.		
aTxPHYDelay	Implementation dependent, see 10.3.7.		
aRxPHYDelay	Implementation dependent, see 10.3.7.		
aRxTxSwitchTime	Implementation dependent, see 10.3.7.		
aTxRampOnTime	Implementation dependent, see 10.3.7.		
aAirPropagationTime	As indicated by the coverage class (see 10.22.5).		
aMACProcessingDelay	Implementation dependent, see 10.3.7.		
aPSDUMaxLength	4095 octets	4095 octets	4095 octets
aCWmin	15	15	15
aCWmax	1023	1023	1023

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18. Extended Rate PHY (ERP) specification

18.1 Overview

18.1.1 General

This clause specifies further rate extension of the PHY for the DSSS system of Clause 15 and the extensions of Clause 16. Hereinafter the PHY defined in this clause is known as the ERP. This PHY operates in the 2.4 GHz ISM band. In addition, a variant capability PHY based on the ERP ("Class 2 ERP") is defined in this clause.

18.1.2 Introduction

The ERP builds on the payload data rates of 1 and 2 Mb/s, as described in Clause 15, that use DSSS modulation and builds on the payload data rates of 1, 2, 5.5, and 11 Mb/s, as described in Clause 16, that use DSSS and CCK. An ERP STA shall comply with all normative requirements of Clause 16. The ERP draws from Clause 17 to provide additional payload data rates of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. Of these rates, transmission and reception capability for 1, 2, 5.5, 6, 11, 12, and 24 Mb/s data rates is mandatory.

A non-AP STA is a Class 2 ERP STA if it satisfies all of the following requirements and is not an ERP STA:

1) The STA shall operate in the 2.4 GHz band, and shall have operating channel width 20 MHz.
2) The STA shall support transmission and reception of DSSS 1 Mb/s and 2 Mb/s.
3) The STA shall support transmission and reception of ERP-OFDM 6 Mb/s.
4) If the STA supports HR/DSSS 11 Mb/s, then it shall support HR/DSSS 5.5 Mb/s.
5) If the STA supports ERP-OFDM 24 Mb/s, then it shall support ERP-OFDM 12 Mb/s.
6) Subject to 4) and 5), each (non-DSSS) HR/DSSS, (non-6 Mb/s) ERP-OFDM, and HT data rate is optional.
7) The STA shall support transmission and reception of DSSS long preamble and short preamble.
8) The STA shall support short slot time.
9) The CCA functionality for ERP-OFDM in 18.4.6 a), b) and for HT in 19.3.19.5.4 shall be supported.
10) The minimum receiver sensitivity requirements of Clause 15, Clause 16, Clause 18, and Clause 19 shall apply to all supported modes.
11) A class 2 ERP STA shall indicate support in the Supported Rates and BSS Membership Selectors element, and if applicable, the Extended Supported Rates and BSS Membership Selectors element, during association and reassociation, and in probe requests, for
    - 1, 2, 5.5, 11, 6, 12, and 24 Mb/s (whether it supports all of these rates of not), and
    - all ERP rates from the set 9, 18, 36, 48, and 54 Mb/s that the Class 2 ERP STA supports, and shall not indicate support for other ERP rates.
12) A class 2 ERP STA shall transmit the Supplemental Class 2 Capabilities element.
13) In all other respects the STA shall follow the requirements of the ERP.

NOTE—A Class 2 ERP STA will not be able to operate in a BSS whose AP includes in the basic rate set, and uses for transmission of group-addressed frames, only rates that the STA does not support.

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18.1.3 Operational modes

The radio portion of all Clause 18 systems implements all mandatory modes of Clause 17 and Clause 16, except it uses the 2.4 GHz frequency band and channelization plan specified in 16.3.6. The ERP has the capability to decode Clause 15, Clause 16 and ERP PPDUs. An ERP shall be capable of sending and receiving the short preamble that is (and remains) optional for Clause 16 PHYs.

The ERP has the capability to detect ERP and Clause 16 preambles whenever a CCA is requested. Because protection mechanisms are not required in all cases, the ERP CCA mechanisms for all preamble types shall be active at all times.

An ERP BSS is capable of operating in any combination of available ERP modes (Clause 18 PHYs) and non-ERP modes (Clause 15 or Clause 16 PHYs). For example, a BSS could operate in an ERP-OFDM-only mode, a mixed mode of ERP-OFDM and ERP-DSSS/CCK, or a mixed mode of ERP-DSSS/CCK and non-ERP. When options are enabled, combinations are also allowed.

The changes to other parts of this standard required to implement the ERP are summarized as follows:

a) ERP-DSSS/CCK
   1) The PHY uses the capabilities of Clause 16 with the following exceptions:
      i) Support of the short PPDU header format capability of 16.2.2.3 is mandatory.
      ii) CCA (see 16.3.8.5) has a mechanism that detects all mandatory Clause 18 sync symbols.
      iii) The maximum input signal level (see 16.3.8.3) is –20 dBm.
      iv) Locking the transmit center frequency and the symbol clock frequency to the same reference oscillator is mandatory.
b) ERP-OFDM
   1) The PHY uses the capabilities of Clause 17 with the following exceptions:
      i) The frequency plan is in accordance with 16.3.6.2 and 16.3.6.3 instead of 17.3.8.4.
      ii) CCA has a mechanism that detects all mandatory Clause 18 sync symbols.
      iii) The frequency accuracy (see 17.3.9.5 and 17.3.9.6) is ± 25 ppm.
      iv) The maximum input signal level (see 17.3.10.5) is –20 dBm.
      v) The value of the slot time is found in Table 18-5.
      vi) SIFS is 10 μs in accordance with 16.3.3. See 18.3.2.4 for more detail.

The 2.4 GHz ISM band is a shared medium, and coexistence with other devices such as Clause 15 and Clause 16 STAs is an important issue for maintaining high performance in Clause 18 (ERP) STAs. The ERP modulation (ERP-OFDM) has been designed to coexist with existing Clause 15 and Clause 16 STAs. This coexistence is achieved by several means, including virtual CS (RTS/CTS or CTS-to-self), CSMA/CA protocols, and MSDU fragmentation.

18.1.4 Scope of ERP PHY services

This clause specifies the ERP entity and the deviations from earlier clauses to accommodate it. It is organized by reference to the relevant earlier clauses to avoid excessive duplication.

The ERP consists of the following protocol functions:

a) A function that defines a method for mapping the MPDUs into a framing format suitable for sending and receiving user data and management information between two or more STAs using the associated PHY system. The PHY exchanges PPDUs that contain PSDUs. The MAC uses the PHY service, so each MPDU corresponds to a PSDU that is carried in a PPDU.
b) A function that defines the characteristics and method of transmitting and receiving data through a WM between two or more STAs; each using the ERP.

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18.1.5 ERP functions

The ERP contains two functional entities: the PHY function and the layer management function.

The ERP service is provided to the MAC through the PHY service primitives described in Clause 8. Interoperability is addressed by use of the CS mechanism specified in 10.3.2.1 and the protection mechanism in 10.27. This mechanism allows non-ERP STAs to know of ERP traffic that they cannot demodulate so that they may defer the medium to that traffic.

18.2 PHY-specific service parameter list

The architecture of the IEEE 802.11 MAC is intended to be PHY independent. Some PHY implementations require PHY-dependent MAC state machines running in the MAC sublayer in order to meet certain PHY requirements. The PHY-dependent MAC state machine resides in a sublayer defined as the MLME. In certain PHY implementations, the MLME may need to interact with the PLME as part of the normal PHY SAP primitives. These interactions are defined by the PLME parameter list currently defined in the PHY service primitives as TXVECTOR, TXSTATUS, and RXVECTOR. The list of these parameters and the values they may represent are defined in the specific PHY specifications for each PHY. This subclause addresses the TXVECTOR, TXSTATUS, and RXVECTOR for the ERP.

Several service primitives include a parameter vector. DATARATE and LENGTH are described in 8.3.4.4. The remaining parameters are considered to be management parameters and are specific to this PHY.

The parameters in Table 18-1 are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request and PLME-TXTIME.request primitives.

Table 18-1—TXVECTOR parameters

Parameter	Value
DATARATE	The rate used to transmit the PSDU in Mb/s. Allowed value depends on value of MODULATION parameter: ERP-DSSS: 1 and 2 ERP-CCK: 5.5 and 11 ERP-OFDM: 6, 9, 12, 18, 24, 36, 48, and 54
LENGTH	The length of the PSDU in octets. Range: 1–4095
PREAMBLE_TYPE	The preamble used for the transmission of the PPDU. Enumerated type for which the allowed value depends on value of MODULATION parameter: ERP-OFDM: null ERP-DSSS, ERP-CCK: SHORTPREAMBLE, LONGPREAMBLE
MODULATION	The modulation used for the transmission of this PSDU. Enumerated type: ERP-DSSS, ERP-CCK, ERP-OFDM
SERVICE	The scrambler initialization vector. Null.

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Table 18-1—TXVECTOR parameters *(continued)*

Parameter	Value
TXPWR_LEVEL_INDEX	The transmit power level index. The definition of these levels is up to the implementer. 1–8
TIME_OF_DEPARTURE_REQUESTED	false, true. When true, the MAC entity requests that the PHY entity measures and reports time of departure parameters corresponding to the time when the first frame energy is sent by the transmitting port; when false, the MAC entity requests that the PHY entity neither measures nor reports time of departure parameters.

The parameters in Table 18-2 are defined as part of the TXSTATUS parameter list in the PHY-TXSTART.confirm service primitive.

Table 18-2—TXSTATUS parameters

Parameter	Value
TIME_OF_DEPARTURE	0 to 2^{32}– 1. The locally measured time when the first frame energy is sent by the transmitting port, in units equal to 1/ TIME_OF_DEPARTURE_ClockRate. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request.
TIME_OF_DEPARTURE_ClockRate	0 to 2^{16}– 1. The clock rate, in units of MHz, is used to generate the TIME_OF_DEPARTURE value. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request.
TX_START_OF_FRAME_OFFSET	0 to 2^{32}– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble corresponding to the frame was transmitted at the transmit antenna connector to the point in time at which this primitive is issued to the MAC.

The parameters in Table 18-3 are defined as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive. When implementations require the use of these vectors, some or all of these parameters may be used in the vectors.

Table 18-3—RXVECTOR parameters

Parameter	Value
DATARATE	The rate at which the PSDU was received in Mb/s. Allowed value depends on value of MODULATION parameter: ERP-DSSS: 1 and 2 ERP-CCK: 5.5 and 11 ERP-OFDM: 6, 9, 12, 18, 24, 36, 48, and 54
LENGTH	The length of the PSDU in octets. Range: 1–4095

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Table 18-3—RXVECTOR parameters *(continued)*

Parameter	Value
PREAMBLE_TYPE	The preamble type detected during reception of the PPDU. Enumerated type for which the allowed value depends on value of MODULATION parameter: ERP-OFDM: null ERP-DSSS, ERP-CCK: SHORTPREAMBLE, LONGPREAMBLE.
MODULATION	The modulation used for the reception of this PSDU. Enumerated types: ERP-DSSS, ERP-CCK, ERP-OFDM
SERVICE	Null.
RSSI	The RSSI is a measure of the RF energy received by the ERP. The 8-bit value is in the range 0 to RSSI maximum as described in 17.2.3.3.
RX_START_OF_FRAME_OFFSET	0 to 2^{32}– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble corresponding to the incoming frame arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC.

18.3 Extended Rate PHY sublayer

18.3.1 Introduction

Subclause 18.3 provides a PHY for the ERP. The convergence procedure specifies how PSDUs are converted to and from PPDUs at the transmitter and receiver. The PPDU is formed during data transmission by appending the PSDU to the Extended Rate PHY preamble and header. At the receiver, the PHY preamble and header are processed to aid in the demodulation and delivery of the PSDU.

18.3.2 PPDU format

18.3.2.1 General

An ERP STA shall support three different preamble and header formats. The first is the long preamble and header described in 18.3.2.2 (and based on 16.2.2.2 with redefinition of reserved bits defined therein). This PPDU provides interoperability with Clause 16 STAs when using the 1, 2, 5.5, and 11 Mb/s data rates. The second is the short preamble and header described in 18.3.2.3 (and based on 16.2.2.3 where it is optional). The short preamble supports the rates 2, 5.5, and 11 Mb/s. The third is the ERP-OFDM preamble and header specified in 18.3.2.4 (and based on 17.3.2).

18.3.2.2 Long preamble PPDU format

Figure 16-1 of 16.2.2.2 shows the basic format for the long preamble PPDU. This preamble is appropriate for use with the 1, 2, 5.5, and 11 Mb/s (Clause 16) modes and is compatible with BSSs using these modes.

The SERVICE field is defined in 16.2.3.5. An ERP STA shall set the Locked clocks bit to 1, when transmitting at a data rate described in Clause 16.

18.3.2.3 Short preamble PPDU format

Figure 16-2 of 16.2.2.3 shows the basic format for the short preamble PPDU. For the ERP, support for this preamble is mandatory. The short preamble is appropriate for use with 2, 5.5, and 11 Mb/s modes. The bits of the Short PHY SERVICE field and RATE field are the same as for the Long PHY SERVICE field and RATE field and are defined in 18.3.2.2.

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18.3.2.4 ERP-OFDM PPDU format

The format, preamble, and headers for the ERP-OFDM PPDU are described in 17.3.2 to 17.3.5. For the ERP-OFDM modes, the DATA field that contains the SERVICE field, the PSDU, the TAIL bits, and the PAD bits shall follow 17.3.5.

For ERP-OFDM modes, an ERP PPDU is terminated by a period of no transmission with a duration of aSignalExtension called the signal extension. The purpose of this extension is to make the TXTIME calculation in 18.5.3 result in a transmission duration interval that includes an additional duration of aSignalExtension. The SIFS for Clause 17 packets is 16 µs, and the SIFS for Clause 16 packets is 10 µs. The longer SIFS in Clause 17 is to allow extra time for the convolutional decode process to finish. As Clause 18 packets use a SIFS of 10 µs, this extra aSignalExtension length extension causes the transmitter to compute the Duration field in the MAC header incorporating the aSignalDuration of "idle time" following each ERP-OFDM transmission, which causes the NAV value of Clause 16 STAs to be set correctly.

The "CS mechanism" described in 10.3.2.1 combines the NAV state and the STA's transmitter status with physical CS to determine the busy/idle state of the medium. The time interval between frames is called the *IFS*. A STA shall determine that the medium is idle through the use of the CCA mechanism for the interval specified. The starting reference of slot boundaries is the end of the last symbol of the previous frame on the medium. For ERP-OFDM frames, this includes the length extension. For ERP-OFDM frames, a STA shall generate the PHY-RXEND.indication aSignalDuration after the end of the last symbol of the previous frame on the medium. This adjustment shall be performed by the STA based on local configuration information set using the PLME SAP.

18.3.3 PHY data modulation and rate change

18.3.3.1 Long and short preamble formats

The long and short PHY preamble and the long PHY header shall be transmitted using the 1 Mb/s DBPSK modulation. The short PHY header shall be transmitted using the 2 Mb/s modulation. The SIGNAL and SERVICE fields combined shall indicate the modulation and rate that shall be used to transmit the PSDU. The transmitter and receiver shall initiate the modulation and rate indicated by the SIGNAL and SERVICE fields, starting with the first octet of the PSDU. The PSDU transmission rate shall be set by the DATARATE parameter in the TXVECTOR, issued with the PHY-TXSTART.request primitive described in 16.3.5.

Four modulation formats are mandatory, 1 Mb/s and 2 Mb/s ERP-DSSS and 5.5 Mb/s and 11 Mb/s ERP-CCK, and they are specified in 16.3.6.4.

18.3.3.2 ERP-OFDM format

PHY modulation and rate change for the ERP-OFDM frame format follows 17.3.7.

18.3.4 CCA

The PHY shall provide the capability to perform a CCA and report the results of the assessment to the MAC. The CCA mechanism shall detect a "medium busy" condition for all supported preamble and header types. That is, the CCA mechanism shall detect that the medium is busy for the PPDUs specified in 18.3.2 and 16.2.2. The CCA mechanism performance requirements are given in 18.4.6.

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The ERP shall provide the capability to perform CCA according to the following method:

> **CCA Mode** (ED and CS): A combination of CS and energy above threshold. CCA shall have a mechanism for CS that detects all mandatory Clause 18 sync symbols. This CCA's mode's CS shall include both Barker code sync detection and OFDM sync symbol detection. CCA shall report busy at least while a PPDU is being received with energy above the ED threshold at the antenna connector.

The PHY shall indicate a busy channel by issuing a PHY-CCA.indication(BUSY) primitive and shall indicate a clear channel by issuing a PHY-CCA.indication(IDLE) primitive.

18.3.5 PHY receive procedure

This subclause describes the procedure used by receivers of the ERP. An ERP receiver shall be capable of receiving 1, 2, 5.5, and 11 Mb/s PPDUs using either the long or short preamble formats described in Clause 16 and shall be capable of receiving the ERP-OFDM modulations at rates of 6, 12, and 24 Mb/s using the modulation and preamble described in Clause 17. The PHY may also be capable of receiving the ERP-OFDM modulations at rates of 9, 18, 36, 48, and 54 Mb/s using this modulation and preamble. The receiver shall be capable of detecting the preamble type (ERP-OFDM, short preamble, or long preamble) and the modulation type. These values shall be reported in the RXVECTOR (see 18.2).

Upon the receipt of a PPDU, the receiver shall first distinguish between the ERP-OFDM preamble and the single carrier modulations (long or short preamble). In the case where the preamble is an ERP-OFDM preamble, the PHY receive procedure shall follow the procedure described in 17.3.12. Otherwise, the receiver shall then distinguish between the long preamble and short preamble as specified in 16.2.2, except that the issuance of the PHY-RXEND.indication (and the following PHY-CCA.indication) is delayed by the signal extension (see 18.3.2.4). The receiver shall then demodulate the SERVICE field to determine the modulation type as specified in 18.3.2.2 or 18.3.2.3. For short preamble and long preamble using ERP-DSSS or ERP-CCK, the receiver shall then follow the receive procedure described in 16.2.6.

18.4 ERP operating specifications (general)

18.4.1 Introduction

Subclauses 18.4.2 to 18.4.7 provide general specifications for the ERP sublayers. These specifications are based on 17.3.8 except where noted.

18.4.2 Regulatory requirements

All systems shall comply with the appropriate regulatory requirements for operation in the 2.4 GHz band.

18.4.3 Operating channel frequencies

The ERP shall operate in the frequency ranges specified in 16.3.6.3, as allocated by regulatory bodies in the United States, Europe, and Japan. The channel numbering and the number of operating channels shall follow Table 16-6 of 16.3.6.3.

18.4.4 Transmit and receive in-band and out-of-band spurious emissions

The ERP shall comply with in-band and out-of-band spurious emissions as set by the appropriate regulatory bodies for the 2.4 GHz band.

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18.4.5 SIFS

The ERP shall use a SIFS of 10 μs.

18.4.6 CCA performance

The CCA parameters are subject to the following criteria:

a) When the start of an ERP-OFDM signal or DSSS, HR-DSSS, ERP-DSSS or ERP-CCK sync symbols at a receive level greater than or equal to –82 dBm at the receiver antenna connector are present at the start of the MAC slot, the receiver's CCA indicator shall report the channel busy with probability CCA_Detect_Probability within a aCCATime. CCA_Detect_Probabilty is the probability that the CCA does respond correctly to a signal and shall be at least 99% for long slot time and at least 90% for short slot time. The values for the other parameters are found in Table 18-5. Note that the CCA Detect Probability and the power level are performance requirements.

b) In the event that a correct PHY header is received, the ERP shall hold the CCA signal inactive (channel busy) for the full duration, as indicated by the PHY LENGTH field. Should a loss of CS occur in the middle of reception, the CCA shall indicate a busy medium for the intended duration of the transmitted PPDU.

c) CCA shall report a busy medium upon detection of any energy above –62 dBm.

18.4.7 PHY transmit specifications

18.4.7.1 General

The PHY transmit specifications shall follow 17.3.9 with the exception of the transmit power level (17.3.9.2), the transmit center frequency tolerance (17.3.9.5), the symbol clock frequency tolerance (17.3.9.6), and the time of departure accuracy (17.3.9.9). Regulatory requirements may have an effect on the combination of maximum transmit power and spectral mask if the resulting signals violate restricted band emission limits.

18.4.7.2 Transmit power levels

The maximum transmit power level shall meet the requirements of the local regulatory body.

18.4.7.3 Transmit spectral mask

The transmit spectral mask for the ERP-OFDM modes shall follow 17.3.9.3 and is shown in Figure 17-13 therein. The transmit spectral mask for the ERP-DSSS modes shall follow 16.3.7.4 and is shown in Figure 16-10 therein.

18.4.7.4 Transmit center frequency tolerance

The transmit center frequency tolerance shall be ± 25 ppm. The transmit center frequency and symbol clock frequency shall be derived from the same reference oscillator (locked).

18.4.7.5 Symbol clock frequency tolerance

The symbol clock frequency tolerance shall be ± 25 ppm. The transmit center frequency and symbol clock frequency shall be derived from the same reference oscillator (locked oscillators). This means that the error in ppm for the carrier and the symbol timing shall be the same.

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18.4.7.6 Time of Departure accuracy

The time of departure specifications shall follow 17.3.9.9 for PPDUs transmitted using ERP-OFDM format and 16.3.7.10 for PPDUs transmitted using ERP-DSSS/CCK.

18.4.8 PHY receive specifications

18.4.8.1 General

Subclause 18.4.8 describes the receive specifications for the PHY sublayer. The receive specification for the ERP-OFDM modes shall follow 17.3.10 with the exception of the receiver maximum input level (17.3.10.5) and the adjacent channel rejection (17.3.10.3). The receive specifications for the ERP-DSSS modes shall follow 16.3.8 with the exception of the receiver maximum input level (16.3.8.3).

18.4.8.2 Receiver minimum input level sensitivity

The PER of the ERP-OFDM modes shall be less than 10% at a PSDU length of 1000 octets for the input levels of Table 17-18 of 17.3.10. Input levels are specific for each data rate and are measured at the antenna connector. A noise figure of 10 dB and an implementation loss of 5 dB are assumed. The PER of the ERP-DSSS modes shall be as specified in 16.3.8.2.

18.4.8.3 Adjacent channel rejection

Adjacent channels at 2.4 GHz are defined to be at ± 25 MHz spacing. The adjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 17-18 of 17.3.10 and raising the power of the interfering signal until 10% PER is caused for a PSDU length of 1000 octets. The difference in power between the signals in the interfering channel and the desired channel is the corresponding adjacent channel rejection. The interfering signal in the adjacent channel shall be a signal compliant with the ERP, unsynchronized with the signal in the channel under test. In an ERP the corresponding rejection shall be no less than specified in Table 17-18 of 17.3.10.

The alternative adjacent channel rejection of Table 17-18 shall not be required for the ERP.

The adjacent channel rejection of the ERP-DSSS modes shall follow 16.3.8.4.

18.4.8.4 Receive maximum input level capability

The PER shall be less than 10% at a PSDU length of 1000 octets for an input level of –20 dBm measured at the antenna connector for any supported modulation signal or data rate (i.e., 1, 2, 5.5, 6, 9, 11, 12, 18, 22, 24, 33, 36, 48, 54 Mb/s).

18.5 ERP PLME

18.5.1 PLME SAP

Table 18-4 lists the additional MIB attributes that may be accessed by the PHY entities and the intralayer of higher LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.5.

18.5.2 MIB

HR/DSSS PHY MIB attributes are defined in Annex C with additions from this supplement and with specific values defined in Table 18-4.

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Table 18-4—MIB attribute default values/ranges

Managed object	Default value/range	Operational semantics
dot11 PHY Operation Table		
dot11PHYType	ERP (X'06')	Static
dot11CurrentRegDomain	Implementation dependent	Static
dot11 PHY Antenna Table		
dot11CurrentTxAntenna	Implementation dependent	Dynamic
dot11DiversitySupportImplemented	Implementation dependent	Static
dot11CurrentRxAntenna	Implementation dependent	Dynamic
dot11 PHY Tx Power Table		
dot11NumberSupportedPowerLevelsImplemented	Implementation dependent	Static
dot11TxPowerLevel1	Implementation dependent	Static
dot11TxPowerLevel2	Implementation dependent	Static
dot11TxPowerLevel3	Implementation dependent	Static
dot11TxPowerLevel4	Implementation dependent	Static
dot11TxPowerLevel5	Implementation dependent	Static
dot11TxPowerLevel6	Implementation dependent	Static
dot11TxPowerLevel7	Implementation dependent	Static
dot11TxPowerLevel8	Implementation dependent	Static
dot11CurrentTxPowerLevel	Implementation dependent	Dynamic
dot11 Phy DSSS Table		
dot11CurrentChannel	Implementation dependent	Dynamic
dot11 Reg Domains Supported Table		
dot11RegDomainsImplementedValue(s)	Implementation dependent	Static
dot11 PHY Antennas List Table		
dot11TxAntennaImplemented	Implementation dependent	Static
dot11RxAntennaImplemented	Implementation dependent	Static
dot11DiversitySelectionRxImplemented	Implementation dependent	Dynamic
dot11 Supported Data Rates Tx Table		
dot11SupportedDataratesTxValue	X'02' = 1 Mb/s X'04' = 2 Mb/s X'0B' = 5.5 Mb/s X'16' = 11 Mb/s X'0C' = 6 Mb/s X'12' = 9 Mb/s X'18' = 12 Mb/s X'24' = 18 Mb/s X'30' = 24 Mb/s X'48' = 36 Mb/s X'60' = 48 Mb/s X'6C' = 54 Mb/s	Static

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Table 18-4—MIB attribute default values/ranges *(continued)*

Managed object	Default value/range	Operational semantics
dot11 Supported Data Rates Rx Table		
dot11ImplementedDataRatesRxValue	X'02' = 1 Mb/s X'04' = 2 Mb/s X'0B' = 5.5 Mb/s X'16' = 11 Mb/s X'0C' = 6 Mb/s X'12' = 9 Mb/s X'18' = 12 Mb/s X'24' = 18 Mb/s X'30' = 24 Mb/s X'48' = 36 Mb/s X'60' = 48 Mb/s X'6C' = 54 Mb/s	Static
dot11 HRDSSS PHY Table		
dot11ShortPreambleOptionImplemented	true/Boolean	Static
dot11 PHY ERP Table		
dot11ShortSlotTimeOptionImplemented	false/Boolean	Static
dot11ShortSlotTimeOptionActivated	false/Boolean	Dynamic

When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.

18.5.3 TXTIME

18.5.3.1 General

The value of TXTIME is calculated for each modulation type based on parameters in the TXVECTOR. For the 1, 2, 5.5, and 11 Mb/s modes with DSSS and CCK modulation formats, the value shall be calculated as described in 16.3.4.

18.5.3.2 ERP-OFDM TXTIME calculations

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated using the ERP-OFDM TXTIME calculation as shown in Equation (18-1).

$$\text{TXTIME} = T_{PREAMBLE} + T_{SIGNAL} + T_{SYM} \times \left\lceil \frac{16 + 8 \times \text{LENGTH} + 6}{N_{DBPS}} \right\rceil + T_{SE} \quad (18\text{-}1)$$

where

$T_{PREAMBLE}$, T_{SIGNAL}, and T_{SYM} are defined in Table 17-5 in 17.3.2.4

N_{DBPS} is the number of data bits per symbol and is derived from the DATARATE parameter in Table 17-4 in 17.3.2.3

T_{SE} is aSignalExtension

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18.5.4 ERP

The ERP characteristics in Table 18-5 shall be used for the ERP for the purposes of MAC timing calculations. The definitions for these characteristics are given in 6.5.4.

Table 18-5—ERP characteristics

Characteristic	Value
aSlotTime	If dot11OperatingClassesRequired is false: Long slot time = 20 µs Short slot time = 9 µs If dot11OperatingClassesRequired is true: Long slot time = 20 µs plus any coverage-class-dependent aAirPropagationTime (see Table 9-95) Short slot time = 9 µs plus any coverage-class-dependent aAirPropagationTime (see Table 9-95)
aSIFSTime	10 µs
aSignalExtension	6 µs
aCCATime	Implementation dependent, see 10.3.7.
aRxPHYStartDelay	20 µs for ERP-OFDM, 192 µs for ERP-DSSS/CCK with long preamble, and 96 µs for ERP-DSSS/CCK with short preamble
aRxTxTurnaroundTime	Implementation dependent, see 10.3.7.
aTxPHYDelay	Implementation dependent, see 10.3.7.
aRxPHYDelay	Implementation dependent, see 10.3.7.
aRxTxSwitchTime	Implementation dependent, see 10.3.7.
aTxRampOnTime	Implementation dependent, see 10.3.7.
aAirPropagationTime	As indicated by the coverage class (see 10.22.5).
aMACProcessingDelay	Implementation dependent, see 10.3.7.
aPSDUMaxLength	4095 octets
aCWmin(0)	31
aCWmin(1)	15
ACWmin	The set aCWmin()
aCWmax	1023

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The long slot time indicated in Table 18-5 shall be used unless the BSS consists only of STAs that support short slot time. STAs indicate support for short slot time by setting the Short Slot Time subfield to 1 when transmitting Association Request and Reassociation Request frames. If the BSS consists of only ERP STAs that support short slot time, an optional short slot time may be used. APs indicate usage of the short slot time indicated in Table 18-5 by setting the Short Slot Time subfield to 1 in all Beacon, Probe Response, Association Response, and Reassociation Response frame transmissions as described in 9.4.1.4.

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19. High-throughput (HT) PHY specification

19.1 Introduction

19.1.1 Introduction to the HT PHY

Clause 19 specifies the PHY entity for a high-throughput (HT) orthogonal frequency division multiplexing (OFDM) system. In addition, a variant capability PHY based on the HT PHY ("Class 2 HT PHY") is defined in this clause.

In addition to the requirements found in Clause 19, an HT STA shall be capable of transmitting and receiving frames that are compliant with the mandatory PHY specifications defined as follows:

— In Clause 17 when the HT STA is operating in a 20 MHz channel width in the 5 GHz band
— In Clause 16 and Clause 18 when the HT STA is operating in a 20 MHz channel width in the 2.4 GHz band

An HT STA that operates in the 5 GHz band shall comply with all normative requirements of Clause 17. An HT STA that operates in the 2.4 GHz band shall comply with all normative requirements of Clause 18.

The HT PHY is based on the OFDM PHY defined in Clause 17, with extensibility up to four spatial streams, operating in 20 MHz bandwidth. Additionally, transmission using one to four spatial streams is defined for operation in 40 MHz bandwidth. These features are capable of supporting data rates up to 600 Mb/s (four spatial streams, 40 MHz bandwidth).

The HT PHY data subcarriers are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), or 64-QAM. Forward error correction (FEC) coding (convolutional coding) is used with a coding rate of 1/2, 2/3, 3/4, or 5/6. LDPC codes are added as an optional feature.

Other optional features at both transmit and receive sides are 400 ns (short) guard interval (GI), transmit beamforming, HT-greenfield format, and STBC.

The maximum HT PSDU length is 65 535 octets.

A non-AP STA is a Class 2 HT STA if it satisfies all of the following requirements and is not an HT STA:

1) The STA shall operate in the 2.4 GHz band, and shall have operating channel width 20 MHz.
2) The STA shall support transmission and reception of DSSS 1 Mb/s and 2 Mb/s.
3) The STA shall support transmission and reception of ERP-OFDM 6 Mb/s.
4) If the STA supports HR/DSSS 11 Mb/s, then it shall support HR/DSSS 5.5 Mb/s.
5) If the STA supports ERP-OFDM 24 Mb/s, then it shall support ERP-OFDM 12 Mb/s.
6) If the STA supports any N_{SS} = 1 HT-MCS > 0, then it shall support all N_{SS} = 1 HT lower HT-MCSs and all lower ERP rates.
7) Except as noted in 4), 5), and 6), each (non-DSSS) HR/DSSS and ERP-OFDM data rate and each HT-MCS is optional.
8) The STA shall support DSSS long preamble and short preamble.
9) The STA shall support short slot time.
10) The CCA functionality for ERP-OFDM in 18.4.6 a) and b) and for HT in 19.3.19.5.4 shall be supported.
11) The minimum receiver sensitivity requirements of Clause 15, Clause 16, Clause 18, and Clause 19 shall apply to all supported modes.

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12) A Class 2 HT STA shall indicate support in the Supported Rates and BSS Membership Selectors element, and, if applicable, the Extended Supported Rates and BSS Membership Selectors element, during association and reassociation, and in probe requests, for
    - 1, 2, 5.5, 11, 6, 12, and 24 Mb/s (whether it supports all of these rates of not), and
    - All ERP rates from the set 9, 18, 36, 48, and 54 Mb/s that the Class 2 HT STA supports, and shall not indicate support for other ERP rates.
13) A Class 2 HT STA shall transmit the HT Capabilities element during association and reassociation, and in probe requests, and shall indicate in the Supported MCS Set field support for HT-MCSs 0-7 (whether it supports all of these HT-MCSs or not).
14) A Class 2 HT STA shall transmit the Supplemental Class 2 Capabilities element.
15) In all other respects the STA shall follow the requirements of the ERP and the HT PHY.

NOTE—A Class 2 HT STA will not be able to operate in a BSS whose AP includes in the basic rate/HT-MCS set, and uses for transmission of group-addressed frames, only rates/HT-MCSs that the STA does not support.

19.1.2 Scope of HT PHY services

The services provided to the MAC by the HT PHY consist of the following protocol functions:

a) A function that defines a method of mapping the PSDUs into a framing format (PPDU) suitable for sending and receiving PSDUs between two or more STAs.
b) A function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. Depending on the PPDU format, these STAs support a mixture of HT PHY and Clause 15, Clause 17, Clause 16, or Clause 18 PHYs.

19.1.3 HT PHY functions

19.1.3.1 General

The HT PHY contains two functional entities: the PHY and the layer management function (i.e., the PLME). Both of these functions are described in detail in 19.3 and 19.4.

The HT PHY service is provided to the MAC through the PHY service primitives defined in Clause 8.

19.1.3.2 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.

19.1.3.3 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, but do not necessarily reflect any particular implementation. The service of a layer or sublayer is the set of capabilities that it offers to a user in the next higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

19.1.4 PPDU formats

The structure of the PPDU transmitted by an HT STA is determined by the TXVECTOR FORMAT, CH_BANDWIDTH, CH_OFFSET, and MCS parameters as defined in Table 19-1. The effect of the CH_BANDWIDTH, CH_OFFSET, and MCS parameters on PPDU format is described in 19.2.4.

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The FORMAT parameter determines the overall structure of the PPDU as follows:

— *Non-HT format* **(NON_HT):** Packets of this format are structured according to the Clause 17 (OFDM) or Clause 18 (ERP) specification. Support for non-HT format is mandatory.

— *HT-mixed format* **(HT_MF):** Packets of this format contain a preamble compatible with Clause 17 and Clause 18 receivers. The non-HT-STF (L-STF), the non-HT-LTF (L-LTF), and the non-HT SIGNAL field (L-SIG) are defined so they can be decoded by non-HT Clause 17 and Clause 18 STAs. The rest of the packet cannot be decoded by Clause 17 or Clause 18 STAs. Support for HT-mixed format is mandatory.

— *HT-greenfield format* **(HT_GF):** HT packets of this format do not contain a non-HT compatible part. Support for HT-greenfield format is optional. An HT STA that does not support the reception of an HT-greenfield format packet shall be able to detect that an HT-greenfield format packet is an HT transmission (as opposed to a non-HT transmission). In this case, the receiver shall decode the HT-SIG and determine whether the HT-SIG cyclic redundancy check (CRC) passes.

19.2 HT PHY service interface

19.2.1 Introduction

The PHY interfaces to the MAC through the TXVECTOR, TXSTATUS, RXVECTOR, and PHYCONFIG_VECTOR. Using the TXVECTOR, the MAC supplies the PHY with per-PPDU transmit parameters. Status of the transmission is reported from PHY to MAC by parameters within TXSTATUS. Using the RXVECTOR, the PHY informs the MAC of the received packet parameters. Using the PHYCONFIG_VECTOR, the MAC configures the PHY for operation, independent of frame transmission or reception.

This interface is an extension of the generic PHY service interface defined in 8.3.4.

19.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 19-1 are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive and/or as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive.

Table 19-1—TXVECTOR and RXVECTOR parameters

Parameter	Condition	Value	TXVECTOR	RXVECTOR
			See NOTE 1	
FORMAT		Determines the format of the PPDU. Enumerated type: NON_HT indicates DSSS, HR/DSSS, OFDM or ERP PPDU formats or non-HT duplicates PPDU format. In this case, the modulation is determined by the NON_HT_MODULATION parameter. HT_MF indicates HT-mixed format. HT_GF indicates HT-greenfield format.	Y	Y

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Table 19-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
			See NOTE 1	
NON_HT_MODULATION	FORMAT is NON_HT	Enumerated type: ERP-DSSS ERP-CCK ERP-OFDM OFDM NON_HT_DUP_OFDM	Y	Y
	Otherwise	Not present		
L_LENGTH	FORMAT is NON_HT	Indicates the length of the PSDU in octets in the range 1 to 4095. This value is used by the PHY to determine the number of octet transfers that occur between the MAC and the PHY.	Y	Y
	FORMAT is HT_MF	Indicates the value in the Length field of the L-SIG in the range 1 to 4095. This use is defined in 10.27.4.	Y	Y
	FORMAT is HT_GF	Not present	N	N
L_DATARATE	FORMAT is NON_HT	Indicates the rate used to transmit the PSDU in megabits per second. Allowed values depend on the value of the NON_HT_MODULATION parameter as follows: ERP-DSSS: 1 and 2 ERP-CCK: 5.5 and 11 ERP-OFDM,NON_HT_DUP_OFDM: 6, 9, 12, 18, 24, 36, 48, and 54 OFDM: 6, 9, 12, 18, 24, 36, 48, and 54	Y	Y
	FORMAT is HT_MF	Indicates the data rate value that is in the L-SIG. This use is defined in 10.27.4.	Y	Y
	FORMAT is HT_GF	Not present	N	N
LSIGVALID	FORMAT is HT_MF	true if L-SIG Parity is valid false if L-SIG Parity is not valid	N	Y
	Otherwise	Not present	N	N
SERVICE	FORMAT is NON_HT and NON_HT_MODULATION is one of — ERP-OFDM — OFDM	Scrambler initialization, null	Y	N
	FORMAT is HT_MF or HT_GF	Scrambler initialization, null	Y	N
	Otherwise	Not present	N	N

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Table 19-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
			See NOTE 1	
TXPWR_LEVEL_INDEX		The allowed values for the TXPWR_LEVEL_INDEX parameter are in the range 1 to 8. This parameter is used to indicate which of the available TxPowerLevel attributes defined in the MIB shall be used for the current transmission.	Y	N
RSSI		The allowed values for the RSSI parameter are in the range 0 to 255. This parameter is a measure by the PHY of the power observed at the antenna connector used to receive the current PPDU. RSSI shall be measured during the reception of the PHY preamble. In HT-mixed format, the reported RSSI shall be measured during the reception of the HT-LTFs. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power.	N	Y
PREAMBLE_TYPE	FORMAT is NON_HT and NON_HT_MODULATION is one of — ERP-DSSS — ERP-CCK	Enumerated type: SHORTPREAMBLE LONGPREAMBLE	Y	Y
	Otherwise	Not present	N	N
MCS	FORMAT is HT_MF or HT_GF	Selects the modulation and coding scheme used in the transmission of the packet. The value used in each MCS is the index defined in 19.5. Integer: range 0 to 76. Values of 77 to 127 are reserved. The interpretation of the MCS index is defined in 19.5.	Y	Y
	Otherwise	Not present	N	N
REC_MCS	FORMAT is HT_MF or HT_GF	Indicates the MCS that the STA's receiver recommends.	N	O
	Otherwise	Not present	N	N
CH_BANDWIDTH	FORMAT is HT_MF or HT_GF	Indicates whether the packet is transmitted using 40 MHz or 20 MHz channel width. Enumerated type: HT_CBW20 for 20 MHz and 40 MHz upper and 40 MHz lower modes HT_CBW40 for 40 MHz	Y	Y
	FORMAT is NON_HT	Enumerated type: NON_HT_CBW40 for non-HT duplicate format NON_HT_CBW20 for all other non-HT formats	Y	Y

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Table 19-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
			See NOTE 1	
CH_OFFSET		Indicates which portion of the channel is used for transmission. Refer to Table 19-2 for valid combinations of CH_OFFSET and CH_BANDWIDTH. Enumerated type: CH_OFF_20 indicates the use of a 20 MHz channel (that is not part of a 40 MHz channel). CH_OFF_40 indicates the entire 40 MHz channel. CH_OFF_20U indicates the upper 20 MHz of the 40 MHz channel CH_OFF_20L indicates the lower 20 MHz of the 40 MHz channel.	Y	N
LENGTH	FORMAT is HT_MF or HT_GF	Indicates the length of an HT PSDU in the range 0 to 65 535 octets. A value of 0 indicates a NDP that contains no data symbols after the HT preamble (see 19.3.9).	Y	Y
	Otherwise	Not present	N	N
SMOOTHING	FORMAT is HT_MF or HT_GF	Indicates whether frequency domain smoothing is recommended as part of channel estimation. (See NOTE 2.) Enumerated type: SMOOTHING_REC indicates that smoothing is recommended. SMOOTHING_NOT_REC indicates that smoothing is not recommended.	Y	Y
	Otherwise	Not present	N	N
SOUNDING	FORMAT is HT_MF or HT_GF	Indicates whether this packet is a sounding PPDU. Enumerated type: SOUNDING indicates this is a sounding PPDU. NOT_SOUNDING indicates this is not a sounding PPDU.	Y	Y
	Otherwise	Not present	N	N
AGGREGATION	FORMAT is HT_MF or HT_GF	Indicates whether the PSDU contains an A-MPDU. Enumerated type: AGGREGATED indicates this PSDU has A-MPDU aggregation. NOT_AGGREGATED indicates this PSDU does not have A-MPDU aggregation.	Y	Y
	Otherwise	Not present	N	N
STBC	FORMAT is HT_MF or HT_GF	Indicates the difference between the number of space-time streams (N_{STS}) and the number of spatial streams (N_{SS}) indicated by the MCS as follows: 0 indicates no STBC ($N_{STS} = N_{SS}$). 1 indicates $N_{STS} - N_{SS} = 1$. 2 indicates $N_{STS} - N_{SS} = 2$. Value of 3 is reserved.	Y	Y
	Otherwise	Not present	N	N

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Table 19-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR See NOTE 1	RXVECTOR
FEC_CODING	FORMAT is HT_MF or HT_GF	Indicates which FEC encoding is used. Enumerated type: BCC_CODING indicates binary convolutional code. LDPC_CODING indicates low-density parity check code.	Y	Y
	Otherwise	Not present	N	N
GI_TYPE	FORMAT is HT_MF or HT_GF	Indicates whether a short guard interval is used in the transmission of the packet. Enumerated type: LONG_GI indicates short GI is not used in the packet. SHORT_GI indicates short GI is used in the packet.	Y	Y
	Otherwise	Not present	N	N
NUM_EXTEN_SS	FORMAT is HT_MF or HT_GF	Indicates the number of extension spatial streams that are sounded during the extension HT-LTFs in the range 0 to 3.	Y	Y
	Otherwise	Not present	N	N
ANTENNA_SET	FORMAT is HT_MF or HT_GF	Indicates which antennas of the available antennas are used in the transmission. The length of the field is 8 bits. A 1 in bit position *n*, relative to the LSB, indicates that antenna *n* is used. At most 4 bits out of 8 may be set to 1. This field is present only if ASEL is applied.	O	N
	Otherwise	Not present	N	N
N_TX	FORMAT is HT_MF or HT_GF	The N_TX parameter indicates the number of transmit chains.	Y	N
	Otherwise	Not present	N	N
EXPANSION_MAT	EXPANSION_MAT_TYPE is COMPRESSED_SV	Contains a set of compressed beamforming feedback matrices as defined in 19.3.12.3.6. The number of elements depends on the number of spatial streams and the number of transmit chains.	Y	N
	EXPANSION_MAT_TYPE is NON_COMPRESSED_SV	Contains a set of noncompressed beamforming feedback matrices as defined in 19.3.12.3.5. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	Y	N
	EXPANSION_MAT_TYPE is CSI_MATRICES	Contains a set of CSI matrices as defined in 19.3.12.3.2. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	Y	N
	Otherwise	Not present	N	N

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Table 19-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
			See NOTE 1	
EXPANSION_MAT_TYPE	EXPANSION_MAT is present	Enumerated type: COMPRESSED_SV indicates that EXPANSION_MAT is a set of compressed beamforming feedback matrices. NON_COMPRESSED_SV indicates that EXPANSION_MAT is a set of noncompressed beamforming feedback matrices. CSI_MATRICES indicates that EXPANSION_MAT is a set of channel state matrices.	Y	N
	Otherwise	Not present	N	N
CHAN_MAT	CHAN_MAT_TYPE is COMPRESSED_SV	Contains a set of compressed beamforming feedback matrices as defined in 19.3.12.3.6 based on the channel measured during the training symbols of the received PPDU. The number of elements depends on the number of spatial streams and the number of transmit chains.	N	Y
	CHAN_MAT_TYPE is NON_COMPRESSED_SV	Contains a set of noncompressed beamforming feedback matrices as defined in 19.3.12.3.5 based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	N	Y
	CHAN_MAT_TYPE is CSI_MATRICES	Contains a set of CSI matrices as defined in 19.3.12.3.2 based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	N	Y
	Otherwise	Not present	N	N
CHAN_MAT_TYPE	FORMAT is HT_MF or HT_GF	Enumerated type: COMPRESSED_SV indicates that CHAN_MAT is a set of compressed beamforming vector matrices. NON_COMPRESSED_SV indicates that CHAN_MAT is a set of noncompressed beamforming vector matrices. CSI_MATRICES indicates that CHAN_MAT is a set of channel state matrices.	N	Y
	Otherwise	Not present	N	N
SNR	CHAN_MAT_TYPE is CSI_MATRICES	Is a measure of the received SNR per chain. SNR indications of 8 bits are supported. SNR shall be the decibel representation of linearly averaged values over the tones represented in each receive chain as described in 9.4.1.27	N	Y
	CHAN_MAT_TYPE is COMPRESSED_SV or NON_COMPRESSED_SV	Is a measure of the received SNR per stream. SNR indications of 8 bits are supported. SNR shall be the sum of the decibel values of SNR per tone divided by the number of tones represented in each stream as described in 9.4.1.28 and 9.4.1.29	N	Y

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Table 19-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
			See NOTE 1	
NO_SIG_EXTN	FORMAT is HT_MF or HT_GF Or FORMAT is NON_HT and NON_HT_MODULATION is NON_HT_DUP_OFDM	Indicates whether signal extension needs to be applied at the end of transmission. Boolean values: true indicates no signal extension is present. false indicates signal extension may be present depending on other TXVECTOR parameters (see 19.2.2).	Y	N
	Otherwise	Not present	N	N
TIME_OF_DEPARTURE_REQUESTED		Enumerated type: true indicates that the MAC entity requests that the PHY entity measures and reports time of departure parameters corresponding to the time when the first frame energy is sent by the transmitting port. false indicates that the MAC entity requests that the PHY entity neither measures nor reports time of departure parameters.	O	N
RX_START_OF_FRAME_OFFSET		0 to 2^{32} – 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble corresponding to the incoming frame arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC.	N	O

NOTE 1—In the TXVECTOR and RXVECTOR columns, the following apply:
Y = Present; N = Not present; O = Optional.

NOTE 2—Setting the Smoothing bit is defined in 19.3.11.11.2.

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19.2.3 PHYCONFIG_VECTOR parameters

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for an HT PHY contains an OPERATING_CHANNEL parameter, which identifies the operating or primary channel. The PHY shall set dot11CurrentPrimaryChannel to the value of this parameter.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for an HT PHY contains a SECONDARY_CHANNEL_OFFSET parameter, which takes one of the following values:

— SECONDARY_CHANNEL_NONE if no secondary channel is present; in this case the PHY shall set dot11CurrentSecondaryChannel to 0.

— SECONDARY_CHANNEL_ABOVE if the secondary channel is above the primary channel; in this case the PHY shall set dot11CurrentSecondaryChannel to dot11CurrentPrimaryChannel + 4.

— SECONDARY_CHANNEL_BELOW if the secondary channel is below the primary channel; in this case the PHY shall set dot11CurrentSecondaryChannel to dot11CurrentPrimaryChannel – 4.

19.2.4 Effect of CH_BANDWIDTH, CH_OFFSET, and MCS parameters on PPDU format

The structure of the PPDU transmitted by an HT STA is determined by the TXVECTOR FORMAT, CH_BANDWIDTH, CH_OFFSET, and MCS parameters as defined in Table 19-1. The effect of the FORMAT parameter is described in 19.1.4.

The operation of the PHY in the frequency domain is determined by the FORMAT, CH_BANDWIDTH, and CH_OFFSET parameters. Table 19-2 shows the valid combinations of FORMAT, CH_BANDWIDTH, and CH_OFFSET and the corresponding PPDU format. Other combinations are reserved.

Table 19-2—Interpretation of FORMAT, CH_BANDWIDTH, and CH_OFFSET parameters

FORMAT	CH_BANDWIDTH	CH_OFFSET
HF_MF, HF_GF	HT_CBW20	CH_OFF_20: *20 MHz HT format*—The STA has a 20 MHz operating channel width and transmits an HT-mixed or HT-greenfield format PPDU of 20 MHz bandwidth. CH_OFF_20U: *40 MHz HT upper format*—The STA transmits an HT-mixed or HT-greenfield format PPDU of 20 MHz bandwidth in the upper 20 MHz of a 40 MHz channel. CH_OFF_20L: *40 MHz HT lower format*—The STA transmits an HT-mixed or HT-greenfield format PPDU of 20 MHz bandwidth in the lower 20 MHz of a 40 MHz channel.
HT_MF, HT_GF	HT_CBW40	CH_OFF_40: *40 MHz HT format*—The STA transmits an HT-mixed or HT-greenfield format PPDU of 40 MHz bandwidth.
NON_HT	NON_HT_CBW20 and the SECONDARY_CHANNEL_OFFSET parameter of the PHYCONFIG_VECTOR is SECONDARY_CHANNEL_NONE	CH_OFF_20: *20 MHz non-HT format*—The STA has a 20 MHz operating channel width and transmits an ERP-DSSS, ERP-CCK, ERP-OFDM, or OFDM format PPDU.

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Table 19-2—Interpretation of FORMAT, CH_BANDWIDTH, and CH_OFFSET parameters *(continued)*

FORMAT	CH_BANDWIDTH	CH_OFFSET
NON_HT	NON_HT_CBW20 and the SECONDARY_CHANNEL_OFFSET parameter of the PHYCONFIG_VECTOR is SECONDARY_CHANNEL_BELOW	CH_OFF_20U: *40 MHz non-HT upper format*—The STA transmits an ERP-DSSS, ERP-CCK, ERP-OFDM, or OFDM format PPDU, in the upper 20 MHz of a 40 MHz channel.
NON_HT	NON_HT_CBW20 and the SECONDARY_CHANNEL_OFFSET parameter of the PHYCONFIG_VECTOR is SECONDARY_CHANNEL_ABOVE	CH_OFF_20L: *40 MHz non-HT lower format*—The STA transmits an ERP-DSSS, ERP-CCK, ERP-OFDM, or OFDM format PPDU, in the lower 20 MHz of a 40 MHz channel.
NON_HT	NON_HT_CBW40	CH_OFF_40: *Non-HT duplicate format*—The STA transmits an ERP-OFDM or OFDM format PPDU in each of the 20 MHz channels of a 40 MHz channel. The upper channel (higher frequency) is rotated by +90° relative to the lower channel. See 19.3.11.12.

19.2.5 Support for NON_HT formats

When the FORMAT parameter is equal to NON_HT, the behavior of the HT PHY is defined in other clauses as shown in Table 19-3, dependent on the operational band. In this case, the PHY-TXSTART.request primitive is handled by mapping the TXVECTOR parameters as defined in Table 19-3 and following the operation as defined in the referenced clause. Likewise the PHY-RXSTART.indication primitive emitted when a non-HT PPDU is received is defined in the referenced clauses, with mapping of RXVECTOR parameters as defined in Table 19-3.

Table 19-3—Mapping of the HT PHY parameters for NON_HT operation

HT PHY parameter	2.4 GHz operation defined by Clause 15	2.4 GHz operation defined by Clause 16	2.4 GHz operation defined by Clause 18	5.0 GHz operation defined by Clause 17
L_LENGTH	LENGTH	LENGTH	LENGTH	LENGTH
L_DATARATE	DATARATE	DATARATE	DATARATE	DATARATE
LSIGVALID	—	—	—	—
TXPWR_LEVEL_INDEX	TXPWR_LEVEL_INDEX	TXPWR_LEVEL_INDEX	TXPWR_LEVEL_INDEX	TXPWR_LEVEL_INDEX
RSSI	RSSI	RSSI	RSSI	RSSI

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Table 19-3—Mapping of the HT PHY parameters for NON_HT operation *(continued)*

HT PHY parameter	2.4 GHz operation defined by Clause 15	2.4 GHz operation defined by Clause 16	2.4 GHz operation defined by Clause 18	5.0 GHz operation defined by Clause 17
FORMAT	—	—	—	—
PREAMBLE_TYPE	—	—	PREAMBLE_TYPE	—
NON_HT_MODULATION	—	—	MODULATION	—
SERVICE	SERVICE	SERVICE	SERVICE	SERVICE
MCS	—	—	—	—
CH_BANDWIDTH	—	—	—	—
CH_OFFSET	—	—	—	—
LENGTH	—	—	—	—
SMOOTHING	—	—	—	—
SOUNDING	—	—	—	—
AGGREGATION	—	—	—	—
STBC	—	—	—	—
FEC_CODING	—	—	—	—
GI_TYPE	—	—	—	—
NUM_EXTEN_SS	—	—	—	—
ANTENNA_SET	—	—	—	—
EXPANSION_MAT	—	—	—	—
EXPANSION_MAT_TYPE	—	—	—	—
CHAN_MAT	—	—	—	—
CHAN_MAT_TYPE	—	—	—	—
N_TX	—	—	—	—
RCPI	RCPI	RCPI	RCPI	RCPI
REC_MCS	—	—	—	—
NO_SIG_EXTN	—	—	—	—
TIME_OF_DEPARTURE_REQUESTED	TIME_OF_DEPARTURE_REQUESTED	TIME_OF_DEPARTURE_REQUESTED	TIME_OF_DEPARTURE_REQUESTED	TIME_OF_DEPARTURE_REQUESTED
NOTE—A dash (—) in an entry above indicates that the related parameter is not present.				

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Non-HT format PPDUs structured according to Clause 15, Clause 17, Clause 16, or Clause 18 are transmitted

— Within the limits of the transmit spectrum mask specified in the respective clauses, or
— As non-HT duplicate PPDUs within the limits of the 40 MHz transmit spectrum mask defined in 19.3.18.1, or
— As 20 MHz format non-HT PPDUs, within the limits of the 40 MHz transmit spectrum mask defined in 19.3.18.1, in the upper (CH_BANDWIDTH of value NON_HT_CBW20 and CH_OFFSET of value CH_OFF_20U) or lower (CH_BANDWIDTH of value NON_HT_CBW20 and CH_OFFSET of value CH_OFF_20U) 20 MHz of the 40 MHz channel.

Non-HT PPDUs transmitted using the 40 MHz transmit spectrum mask are referred to as *40 MHz mask non-HT PPDUs*. Refer to 11.15.9 for CCA sensing rules for transmission of 40 MHz mask non-HT PPDUs.

19.2.6 TXSTATUS parameters

The parameters listed in Table 19-4 are defined as part of the TXSTATUS parameter list in the PHY-TXSTART.confirm service primitive.

Table 19-4—TXSTATUS parameters

Parameter	Value
TIME_OF_DEPARTURE	0 to 2^{32}– 1. The locally measured time when the first frame energy is sent by the transmitting port, in units equal to 1/ TIME_OF_DEPARTURE_ClockRate. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request.
TIME_OF_DEPARTURE_ClockRate	0 to 2^{16}– 1. The clock rate, in units of MHz, is used to generate the TIME_OF_DEPARTURE value. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request.
TX_START_OF_FRAME_OFFSET	0 to 2^{32}– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble corresponding to the frame was transmitted at the transmit antenna connector to the point in time at which this primitive is issued to the MAC.

19.3 HT PHY

19.3.1 Introduction

Subclause 19.3 provides a procedure in which PSDUs are converted to and from PPDUs. During transmission, the PSDU is processed (i.e., scrambled and coded) and appended to the PHY preamble to create the PPDU. At the receiver, the PHY preamble is processed to aid in demodulation and delivery of the PSDU.

Two preamble formats are defined. For HT-mixed format operation, the preamble has a non-HT portion and an HT portion. The non-HT portion of the HT-mixed format preamble enables detection of the PPDU and acquisition of carrier frequency and timing by both HT STAs and STAs that are compliant with Clause 17 and/or Clause 18. The non-HT portion of the HT-mixed format preamble also consists of the SIGNAL field defined in Clause 17 and is thus decodable by STAs compliant with Clause 17 and Clause 18 as well as HT STAs.

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The HT portion of the HT-mixed format preamble enables estimation of the MIMO channel to support demodulation of the HT data by HT STAs. The HT portion of the HT-mixed format preamble also includes the HT-SIG field, which supports HT operation. The SERVICE field is prepended to the PSDU.

For HT-greenfield operation, compatibility with Clause 17 and Clause 18 STAs is not required. Therefore, the non-HT portions of the preamble are not included in the HT-greenfield format preamble.

19.3.2 PPDU format

Two formats are defined for the PPDU: HT-mixed format and HT-greenfield format. These two formats are called *HT formats*. Figure 19-1 shows the non-HT format[44] and the HT formats. The HT formats can be used for MCS 32 that provides the lowest rate in a 40 MHz channel (see in 19.3.11.11.5). In addition to the HT formats, there is a non-HT duplicate format (specified in 19.3.11.12) that duplicates the 20 MHz non-HT packet in two 20 MHz halves of a 40 MHz channel.

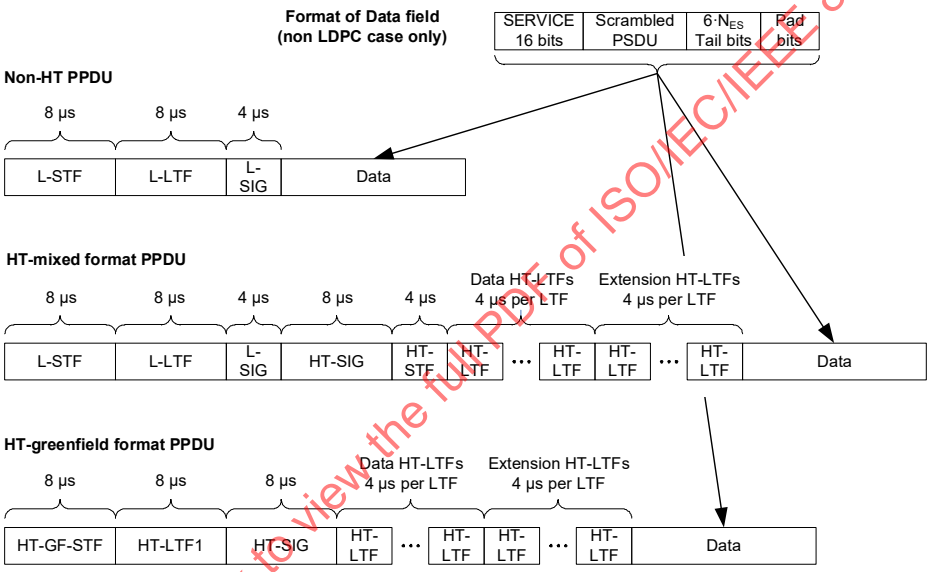

Figure 19-1—PPDU format

The elements of the PPDU are summarized in Table 19-5.

Table 19-5—Elements of the HT PPDU

Element	Description
L-STF	Non-HT Short Training field
L-LTF	Non-HT Long Training field
L-SIG	Non-HT SIGNAL field
HT-SIG	HT SIGNAL field
HT-STF	HT Short Training field

[44] The non-HT format is shown related to the terminology of this subclause. The non-HT PPDU format is defined in 17.3.3 and 17.3.2.

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Table 19-5—Elements of the HT PPDU *(continued)*

Element	Description
HT-GF-STF	HT-Greenfield Short Training field
HT-LTF1	First HT Long Training field (Data)
HT-LTFs	Additional HT Long Training fields (Data and Extension)
Data	The Data field includes the PSDU

The HT-SIG, HT-STF, HT-GF-STF, HT-LTF1, and HT-LTFs exist only in HT packets. In non-HT packets only the L-STF, L-LTF, L-SIG, and Data fields exist.

In both HT-mixed format and HT-greenfield format frames, there are two types of HT-LTFs: Data HT-LTFs (HT-DLTFs) and Extension HT-LTFs (HT-ELTFs). HT-DLTFs are always included in HT PPDUs to provide the necessary reference for the receiver to form a channel estimate that allows it to demodulate the data portion of the frame. The number of HT-DLTFs, $N_{HT\text{-}DLTF}$, may be 1, 2, or 4 and is determined by the number of space-time streams being transmitted in the frame (see Table 19-13). HT-ELTFs provide additional reference in sounding PPDUs so that the receiver can form an estimate of additional dimensions of the channel beyond those that are used by the data portion of the frame. The number of HT-ELTFs, $N_{HT\text{-}ELTF}$, may be 0, 1, 2, or 4 (see Table 19-14). PHY preambles in which HT-DLTFs are followed by HT-ELTFs are referred to as *staggered preambles*. The HT-mixed format and HT-greenfield format frames shown in Figure 19-1 both contain staggered preambles for illustrative purposes.

Transmissions of frames with the TXVECTOR parameter NO_SIG_EXTN equal to false are terminated by a period of no transmission for a duration of aSignalExtension. See 10.3.8.

A signal extension shall be present in a transmitted PPDU, based on the parameters of the TXVECTOR, when the NO_SIG_EXTN parameter is equal to false and either of the following is true:

— The FORMAT parameter is equal to HT_MF or HT_GF.
— The FORMAT parameter is equal to NON_HT, and the NON_HT_MODULATION parameter is equal to ERP-OFDM, or NON_HT_DUP_OFDM.

A signal extension shall be assumed to be present (for the purpose of timing of PHY-RXEND.indication and PHY-CCA.indication primitives, as described below and in 19.3.21) in a received PPDU when either of the following is true, based on the determined parameter values of the RXVECTOR:

— The FORMAT parameter is equal to HT_MF or HT_GF.
— The FORMAT parameter is equal to NON_HT, and the NON_HT_MODULATION parameter is equal to ERP-OFDM, or NON_HT_DUP_OFDM.

A PPDU containing a signal extension is called a *signal extended PPDU*. When transmitting a signal extended PPDU, the PHY-TXEND.indication primitive shall be emitted a period of aSignalExtension after the end of the last symbol of the PPDU. When receiving a signal extended PPDU, the PHY-RXEND.indication primitive shall be emitted a period of aSignalExtension after the end of the last symbol of the PPDU.

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19.3.3 Transmitter block diagram

HT-mixed format and HT-greenfield format transmissions can be generated using a transmitter consisting of the following blocks:

a) *Scrambler* scrambles the data to reduce the probability of long sequences of 0s or 1s; see 19.3.11.3.

b) *Encoder parser*, if binary convolutional code (BCC) encoding is to be used, demultiplexes the scrambled bits among N_{ES} (number of BCC encoders for the Data field) BCC encoders, in a round robin manner.

c) *FEC encoders* encode the data to enable error correction. An FEC encoder may include a binary convolutional encoder followed by a puncturing device, or it may include a low-density parity check (LDPC) encoder.

d) *Stream parser* divides the outputs of the encoders into blocks that are sent to different interleaver and mapping devices. The sequence of the bits sent to an interleaver is called a *spatial stream*.

e) *Interleaver* interleaves the bits of each spatial stream (changes order of bits) to prevent long sequences of adjacent noisy bits from entering the BCC decoder. Interleaving is applied only when BCC encoding is used.

f) *Constellation mapper* maps the sequence of bits in each spatial stream to constellation points (complex numbers).

g) *STBC* encoder spreads constellation points from N_{SS} spatial streams into N_{STS} space-time streams using a space-time block code. STBC is used only when $N_{SS} < N_{STS}$; see 19.3.11.9.2.

h) *Spatial mapper* maps space-time streams to transmit chains. This may include one of the following:

   1) *Direct mapping*: Constellation points from each space-time stream are mapped directly onto the transmit chains (one-to-one mapping).
   2) *Spatial expansion*: Vectors of constellation points from all of the space-time streams are expanded via matrix multiplication to produce the input to all of the transmit chains.
   3) *Beamforming*: Similar to spatial expansion, each vector of constellation points from all of the space-time streams is multiplied by a matrix of steering vectors to produce the input to the transmit chains.

i) *Inverse discrete Fourier transform (IDFT)* converts a block of constellation points to a time domain block.

j) *Cyclic shift (CSD) insertion* is where the insertion of the cyclic shifts prevents unintentional beamforming. CSD insertion may occur before or after the IDFT. There are three cyclic shift types as follows:

   1) A cyclic shift specified per transmitter chain with the values defined in Table 19-9 (a possible implementation is shown in Figure 19-2).
   2) A cyclic shift specified per space-time stream with the values defined in Table 19-10 (a possible implementation is shown in Figure 19-3).
   3) A cyclic shift $M_{CSD}(k)$ that may be applied as a part of the spatial mapper; see 19.3.11.11.2.

k) *GI insertion* prepends to the symbol a circular extension of itself.

l) *Windowing* optionally smooths the edges of each symbol to increase spectral decay.

Figure 19-2 and Figure 19-3 show example transmitter block diagrams. In particular, Figure 19-2 shows the transmitter blocks used to generate the HT-SIG of the HT-mixed format PPDU. These transmitter blocks are also used to generate the non-HT portion of the HT-mixed format PPDU, except that the BCC encoder and interleaver are not used when generating the L-STF and L-LTFs. Figure 19-3 shows the transmitter blocks used to generate the Data field of the HT-mixed format and HT-greenfield format PPDUs. A subset of these transmitter blocks consisting of the constellation mapper and CSD blocks, as well as the blocks to the right

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of, and including, the spatial mapping block, are also used to generate the HT-STF, HT-GF-STF, and HT-LTFs. The HT-greenfield format SIGNAL field is generated using the transmitter blocks shown in Figure 19-2, augmented by additional CSD and spatial mapping blocks.

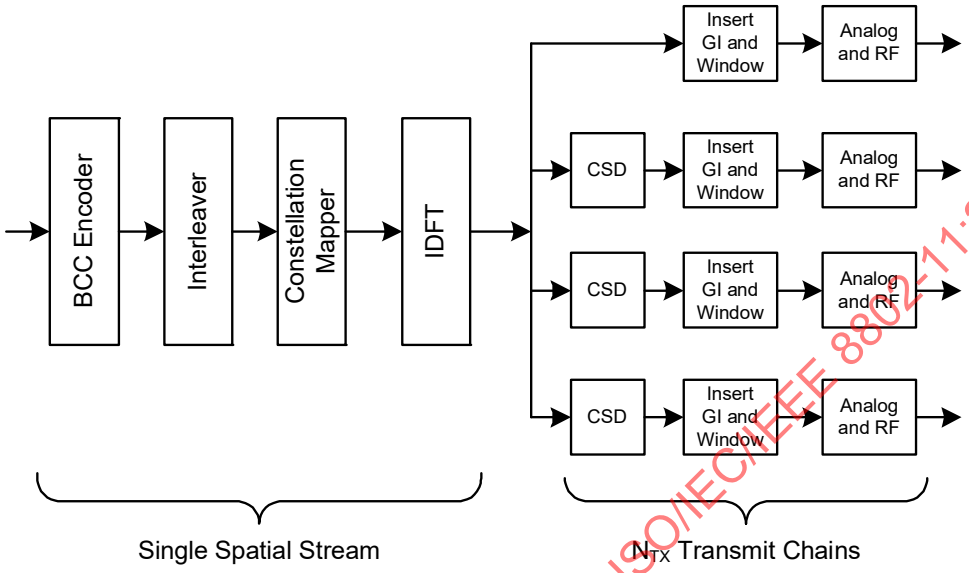
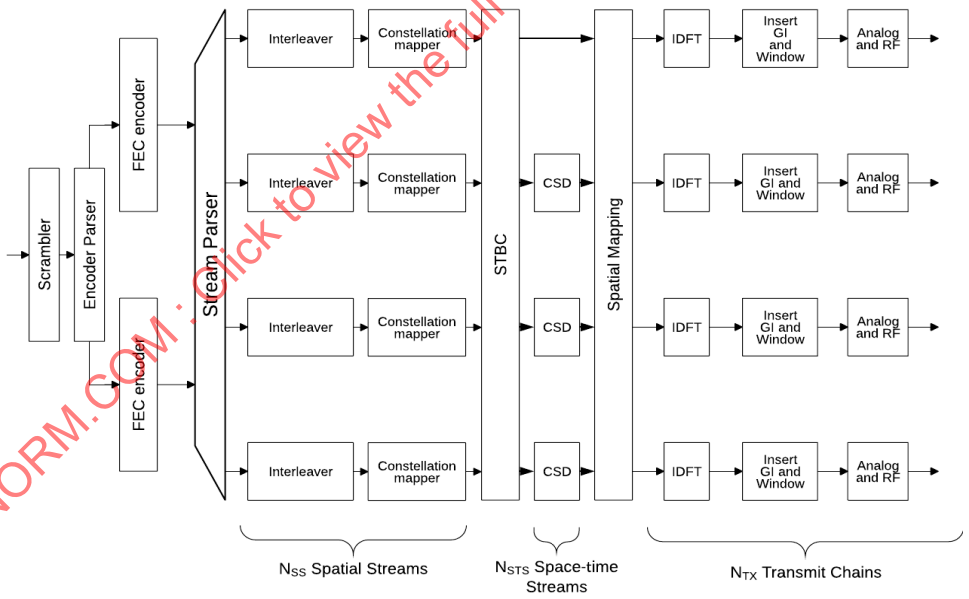


Figure 19-2—Transmitter block diagram 1



NOTE: The particular case shown here has two FEC encoders, four spatial streams, BCC coding, no STBC, and four transmit chains. The actual transmission mode may differ from the one shown here in various ways:
—There might be 1 or 2 FEC encoders when BCC encoding is used.
—The stream parser might have 1, 2, 3 or 4 outputs.
—When LDPC encoding is used, the interleavers are not used.
—When STBC is used, the STBC block has more outputs than inputs (otherwise the ouputs equal the inputs).
—When spatial mapping is used, there might be more transmit chains than space-time streams.
—The number of inputs to the spatial mapper might be 1, 2, 3, or 4.

Figure 19-3—Transmitter block diagram 2

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19.3.4 Overview of the PPDU encoding process

The encoding process is composed of the steps described below. The following overview is intended to facilitate an understanding of the details of the convergence procedure:

a) Determine the number of transmit chains, N_{TX}, from the N_TX field of the TXVECTOR. Produce the PHY preamble training fields for each of the N_{TX} transmit chains based on the FORMAT, NUM_EXTEN_SS, CH_BANDWIDTH, and MCS parameters of the TXVECTOR. The format and relative placement of the PHY preamble training fields vary depending on the frame format being used, as indicated by these parameters. Apply cyclic shifts. Determine spatial mapping to be used for HT-STF and HT-LTFs in HT-mixed format frame and HT-GF-STF and HT-LTFs in HT-greenfield format frame from the EXPANSION_MAT parameter of the TXVECTOR. Refer to 19.3.9 for details.

b) Construct the PHY preamble SIGNAL fields from the appropriate fields of the TXVECTOR by adding tail bits, applying convolutional coding, formatting into one or more OFDM symbols, applying cyclic shifts, applying spatial processing, calculating an inverse Fourier transform for each OFDM symbol and transmit chain, and prepending a cyclic prefix or GI to each OFDM symbol in each transmit chain. The number and placement of the PHY preamble SIGNAL fields depend on the frame format being used. Refer to 19.3.9.3.5, 19.3.9.4.3, and 19.3.9.5.4.

c) Concatenate the PHY preamble training and SIGNAL fields for each transmit chain one field after another, in the appropriate order, as described in 19.3.2 and 19.3.7.

d) Use the MCS and CH_BANDWIDTH parameters of the TXVECTOR to determine the number of data bits per OFDM symbol (N_{DBPS}), the coding rate (R), the number of coded bits in each OFDM subcarrier (N_{BPSC}), and the number of coded bits per OFDM symbol (N_{CBPS}). Determine the number of encoding streams (N_{ES}) from the MCS, CH_BANDWIDTH, and FEC_CODING parameters of the TXVECTOR. Refer to 19.3.11.4 for details.

e) Append the PSDU to the SERVICE field (see 19.3.11.2). If BCC encoding is to be used, as indicated by the FEC_CODING parameter of the TXVECTOR, tail bits are appended to the PSDU. If a single BCC encoder is used (i.e., when the value of N_{ES} is 1), the bit string is extended by 6 zero bits. If two BCC encoders are used (i.e., when the value of N_{ES} is 2), the bit string is extended by 12 zero bits. The number of symbols, N_{SYM}, is calculated according to Equation (19-32), and if necessary, the bit string is further extended with zero bits so that the resulting length is a multiple of $N_{SYM} \times N_{DBPS}$, as described in 19.3.11. If LDPC encoding is to be used, as indicated by the FEC_CODING parameter of the TXVECTOR, the resulting bit string is padded, if needed, by repeating coded bits rather than using zero bits, as given in the encoding procedure of 19.3.11.7.5. The number of resulting symbols is given by Equation (19-41), and the number of repeated coded bits used for padding is given by Equation (19-42). The resulting bit string constitutes the Data field of the packet.

f) Initiate the scrambler with a pseudorandom nonzero seed, generate a scrambling sequence, and exclusive-OR (XOR) it with the string of data bits, as described in 17.3.5.5.

g) If BCC encoding is to be used, replace the scrambled zero bits that served as tail bits (6 bits if the value of N_{ES} is 1, or 12 bits if the value of N_{ES} is 2) following the data with the same number of nonscrambled zero bits, as described in 17.3.5.3. (These bits return the convolutional encoder to the zero state.)

h) If BCC encoding is to be used and the value of N_{ES} is 2, divide the scrambled data bits between two BCC encoders by sending alternating bits to the two different encoders, as described in 19.3.11.5.

i) If BCC encoding is to be used, encode the extended, scrambled data string with a rate 1/2 convolutional encoder (see 17.3.5.6). Omit (puncture) some of the encoder output string (chosen

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according to puncturing pattern) to reach the coding rate, *R*, corresponding to the TXVECTOR parameters MCS or L_DATARATE. Refer to 19.3.11.6 for details. If LDPC encoding is to be used, encode the scrambled data stream according to 19.3.11.7.5.

j) Parse the coded bit stream that results from the BCC encoding or LDPC encoding into N_{SS} spatial streams, where the value of N_{SS} is determined from the MCS parameter of the TXVECTOR. See 19.3.11.8.2 for details.

k) Divide each of the N_{SS} encoded and parsed spatial streams of bits into groups of $N_{CBPSS}(i)$ bits. If BCC encoding is to be used, within each spatial stream and group, perform an interleaving (reordering) of the bits according to a rule corresponding to $N_{BPSCS}(i)$, where i is the index of the spatial stream. Refer to 19.3.6 for details.

l) For each of the N_{SS} encoded, parsed, and interleaved spatial streams, divide the resulting coded and interleaved data string into groups of $N_{BPSCS}(i)$ bits, where i is the index of the spatial stream. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.8 for details.

m) Divide the complex number string for each of the resulting N_{SS} spatial streams into groups of N_{SD} complex numbers, where the value of N_{SD} is determined from the CH_OFFSET parameter of TXVECTOR and the CH_BANDWIDTH parameter of TXVECTOR. Each such group is associated with one OFDM symbol in one spatial stream. In each group, the complex numbers are indexed 0 to $N_{SD}-1$, and these indices have an associated one-to-one correspondence with subcarrier indices via the mapping function $M^{r}(k)$ as described in 19.3.11.11, 19.3.11.11.3, 19.3.11.11.4, 19.3.11.11.5, and 19.3.11.12.

n) If STBC is to be applied, as indicated by the STBC parameter in the TXVECTOR, operate on the complex number associated with each data subcarrier in sequential pairs of OFDM symbols as described in 19.3.11.9.2 to generate N_{STS} OFDM symbols for every N_{SS} OFDM symbols associated with the N_{SS} spatial streams. If STBC is not to be used, the number of space-time streams is the same as the number of spatial streams, and the sequences of OFDM symbols in each space-time stream are composed of the sequences of OFDM symbols in the corresponding spatial stream. In each group of N_{SD} resulting complex numbers in each space-time stream, the complex numbers indexed 0 to $N_{SD}-1$ are mapped onto OFDM subcarriers via the mapping function $M^{r}(k)$ as described in 19.3.11.11, 19.3.11.11.3, 19.3.11.11.4, 19.3.11.11.5, and 19.3.11.12.

o) Determine whether 20 MHz or 40 MHz operation is to be used from the CH_BANDWIDTH parameter of the TXVECTOR. Specifically, when CH_BANDWIDTH is HT_CBW20 or NON_HT_CBW20, 20 MHz operation is to be used. When CH_BANDWIDTH is HT_CBW40 or NON_HT_CBW40, 40 MHz operation is to be used. For 20 MHz operation (with the exception of non-HT formats), insert four subcarriers as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers, N_{ST}, is 56. For 40 MHz operation (with the exception of MCS 32 and non-HT duplicate format), insert six subcarriers as pilots into positions –53, –25, –11, 11, 25, and 53, resulting in a total of N_{ST} = 114 subcarriers. See 19.3.11.11.5 for pilot locations when using MCS 32 and 19.3.11.12 for pilot locations when using non-HT duplicate format. The pilots are modulated using a pseudorandom cover sequence. Refer to 19.3.11.10 for details. For 40 MHz operation, apply a +90° phase shift to the complex value in each OFDM subcarrier with an index greater than 0, as described in 19.3.11.11.4, 19.3.11.11.5, and 19.3.11.12.

p) Map each of the complex numbers in each of the N_{ST} subcarriers in each of the OFDM symbols in each of the N_{STS} space-time streams to the N_{TX} transmit chain inputs. For direct-mapped operation,

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$N_{TX} = N_{STS}$, and there is a one-to-one correspondence between space-time streams and transmit chains. In this case, the OFDM symbols associated with each space-time stream are also associated with the corresponding transmit chain. Otherwise, a spatial mapping matrix associated with each OFDM subcarrier, as indicated by the EXPANSION_MAT parameter of the TXVECTOR, is used to perform a linear transformation on the vector of N_{STS} complex numbers associated with each subcarrier in each OFDM symbol. This spatial mapping matrix maps the vector of N_{STS} complex numbers in each subcarrier into a vector of N_{TX} complex numbers in each subcarrier. The sequence of N_{ST} complex numbers associated with each transmit chain (where each of the N_{ST} complex numbers is taken from the same position in the N_{TX} vector of complex numbers across the N_{ST} subcarriers associated with an OFDM symbol) constitutes an OFDM symbol associated with the corresponding transmit chain. For details, see 19.3.11.11. Spatial mapping matrices may include cyclic shifts, as described in 19.3.11.11.2.

q) If the CH_BANDWIDTH and CH_OFFSET parameters of the TXVECTOR indicate that upper or lower 20 MHz are to be used in 40 MHz, move the complex numbers associated with subcarriers –28 to 28 in each transmit chain to carriers 4 to 60 in the upper channel or –60 to –4 in the lower channel. Note that this shifts the signal in frequency from the center of the 40 MHz channel to +10 MHz or –10 MHz offset from the center of the 40 MHz channel. The complex numbers in the other subcarriers are set to 0.

r) For each group of N_{ST} subcarriers and each of the N_{TX} transmit chains, convert the subcarriers to time domain using IDFT. Prepend to the Fourier-transformed waveform a circular extension of itself, thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Determine the length of the GI according to the GI_TYPE parameter of the TXVECTOR. Refer to 19.3.11.11 and 19.3.11.12 for details. When beamforming is not used, it is sometimes possible to implement the cyclic shifts in the time domain.

s) Append the OFDM symbols associated with each transmit chain one after another, starting after the final field of the PHY preamble. Refer to 19.3.2 and 19.3.7 for details.

t) Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 19.3.7 for details. The transmit chains are connected to antenna elements according to ANTENNA_SET of the TXVECTOR if ASEL is applied.

19.3.5 Modulation and coding scheme (MCS)

The MCS is a value that determines the modulation, coding, and number of spatial channels. It is a compact representation that is carried in the HT-SIG. Rate-dependent parameters for the full set of MCSs are shown in Table 19-27 to Table 19-41 (in 19.5). These tables give rate-dependent parameters for MCSs with indices 0 to 76. MCSs with indices 0 to 7 and 32 have a single spatial stream; MCSs with indices 8 to 31 have multiple spatial streams using equal modulation (EQM) on all of the streams; MCSs with indices 33 to 76 have multiple spatial streams using unequal modulation (UEQM) on the spatial streams. MCS indices 77 to 127 are reserved.

Table 19-27 to Table 19-30 show rate-dependent parameters for EQM MCSs for one, two, three, and four streams for 20 MHz operation. Table 19-31 to Table 19-34 show rate-dependent parameters for EQM MCSs in one, two, three, and four streams for 40 MHz operation. The same EQM MCSs are used for 20 MHz and 40 MHz operation. Table 19-35 shows rate-dependent parameters for the 40 MHz, 6 Mb/s MCS 32 format.

The remaining tables, Table 19-36 to Table 19-41, show rate-dependent parameters for the MCSs with UEQM of the spatial streams for use with $N_{SS} > 1$.

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UEQM MCSs are detailed in the following tables:

— Table 19-36 to Table 19-38 are for 20 MHz operation.

— Table 19-39 to Table 19-41 are for 40 MHz operation.

An HT STA shall support all equal modulation (EQM) rates for one spatial stream (MCSs 0 to 7) using a 20 MHz channel width. An HT AP that is not a VHT AP shall support all EQM rates for two spatial streams (MCSs 8 to 15) using a 20 MHz channel width. All other MCSs and modes are optional, specifically including transmit and receive support of 400 ns GI, operation in 40 MHz, and support of MCSs with indices 16 to 76.

19.3.6 Timing-related parameters

Table 19-6 defines the timing-related parameters.

Table 19-6—Timing-related constants

Parameter	TXVECTOR CH_BANDWIDTH			
	NON_HT_CBW20	HT_CBW20	HT_CBW40 or NON_HT_CBW40	
			HT format	MCS 32 and non-HT duplicate
N_{SD}: Number of complex data numbers	48	52	108	48
N_{SP}: Number of pilot values	4	4	6	4
N_{ST}: Total number of subcarriers See NOTE 1	52	56	114	104
N_{SR}: Highest data subcarrier index	26	28	58	58
Δ_F : Subcarrier frequency spacing	312.5 kHz (20 MHz/64)	312.5 kHz	312.5 kHz (40 MHz/128)	
T_{DFT}: IDFT/DFT period	3.2 µs	3.2 µs	3.2 µs	
T_{GI}: Guard interval duration	0.8 µs= T_{DFT}/4	0.8 µs	0.8 µs	
T_{GI2}: Double guard interval	1.6 µs	1.6 µs	1.6 µs	
T_{GIS}: Short guard interval duration	N/A	0.4 µs = T_{DFT}/8	0.4 µs See NOTE 2	
$T_{L\text{-}STF}$: Non-HT short training sequence duration	8 µs=10× T_{DFT}/4	8 µs	8 µs	
$T_{HT\text{-}GF\text{-}STF}$: HT-greenfield short training field duration	N/A	8 µs=10× T_{DFT}/4	8 µs See NOTE 2	
$T_{L\text{-}LTF}$: Non-HT long training field duration	8 µs=2× T_{DFT}+T_{GI2}	8 µs	8 µs	
T_{SYM}: Symbol interval	4 µs= T_{DFT}+T_{GI}	4 µs	4 µs	

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Table 19-6—Timing-related constants *(continued)*

Parameter	TXVECTOR CH_BANDWIDTH			
	NON_HT_CBW20	HT_CBW20	HT_CBW40 or NON_HT_CBW40	
			HT format	MCS 32 and non-HT duplicate
T_{SYMS}: Short GI symbol interval	N/A	3.6 μs = T_{DFT}+T_{GIS}	3.6 μs See NOTE 2	
$T_{L\text{-}SIG}$: Non-HT SIGNAL field duration	4 μs= T_{SYM}	4 μs	4 μs	
$T_{HT\text{-}SIG}$: HT SIGNAL field duration	N/A	8 μs= 2T_{SYM}	8 μs See NOTE 2	
$T_{HT\text{-}STF}$: HT short training field duration	N/A	4 μs	4 μs See NOTE 2	
$T_{HT\text{-}LTF1}$: First HT long training field duration	N/A	4 μs in HT-mixed format, 8 μs in HT-greenfield format	4 μs in HT-mixed format, 8 μs in HT-greenfield format See NOTE 2	
$T_{HT\text{-}LTFs}$: Second, and subsequent, HT long training fields duration	N/A	4 μs	4 μs See NOTE 2	

NOTE 1—$N_{ST} = N_{SD} + N_{SP}$ except in the cases of MCS 32 and non-HT duplicate, where the number of data subcarriers differs from the number of complex data numbers, and the number of pilot subcarriers differs from the number of pilot values. In those cases, data numbers and pilot values are replicated in upper and lower 20 MHz portions of 40 MHz signal to make a total of 104 subcarriers.

NOTE 2—Not applicable in non-HT formats.

NOTE 3—N/A = Not applicable.

Table 19-7 defines parameters used frequently in Clause 19.

Table 19-7—Frequently used parameters

Symbol	Explanation
N_{CBPS}	Number of coded bits per symbol
$N_{CBPSS}(i)$	Number of coded bits per symbol per the *i*-th spatial stream
N_{DBPS}	Number of data bits per symbol
N_{BPSC}	Number of coded bits per single carrier
$N_{BPSCS}(i)$	Number of coded bits per single carrier for spatial stream *i*
N_{RX}	Number of receive chains
N_{STS}	Number of space-time streams
N_{SS}	Number of spatial streams
N_{ESS}	Number of extension spatial streams
N_{TX}	Number of transmit chains

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Table 19-7—Frequently used parameters *(continued)*

Symbol	Explanation
N_{ES}	Number of BCC encoders for the Data field
$N_{HT\text{-}LTF}$	Number of HT Long Training fields (see 19.3.9.4.6)
$N_{HT\text{-}DLTF}$	Number of Data HT Long Training fields
$N_{HT\text{-}ELTF}$	Number of Extension HT Long Training fields
R	Coding rate

19.3.7 Mathematical description of signals

For the description of the convention on mathematical description of signals, see 17.3.2.5.

In the case of either a 20 MHz non-HT format (TXVECTOR parameter FORMAT equal to NON_HT, MODULATION parameter equal to one of {ERP-OFDM, OFDM}) transmission or a 20 MHz HT format (TXVECTOR parameter FORMAT equal to HT_MF or HT_GF, CH_BANDWIDTH equal to HT_CBW20) transmission, the channel is divided into 64 subcarriers. In the 20 MHz non-HT format, the signal is transmitted on subcarriers –26 to –1 and 1 to 26, with 0 being the center (dc) carrier. In the 20 MHz HT format, the signal is transmitted on subcarriers –28 to –1 and 1 to 28.

In the case of the 40 MHz HT format, a 40 MHz channel is used. The channel is divided into 128 subcarriers. The signal is transmitted on subcarriers –58 to –2 and 2 to 58.

In the case of 40 MHz HT upper format or 40 MHz HT lower format, the upper or lower 20 MHz is divided into 64 subcarriers. The signal is transmitted on subcarriers –60 to –4 in the case of a 40 MHz HT lower format transmission and on subcarriers 4 to 60 in the case of a 40 MHz HT upper format transmission.

In the case of the MCS 32 and non-HT duplicate formats, the same data are transmitted over two adjacent 20 MHz channels. In this case, the 40 MHz channel is divided into 128 subcarriers, and the data are transmitted on subcarriers –58 to –6 and 6 to 58.

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the relation shown in Equation (19-1).

$$r_{RF}(t) = \mathrm{Re}\{r(t)\exp(j2\pi f_c t)\} \tag{19-1}$$

where

f_c is the center frequency of the carrier

The transmitted RF signal is derived by modulating the complex baseband signal, which consists of several fields. The timing boundaries for the various fields are shown in Figure 19-4.

The time offset, t_{Field}, determines the starting time of the corresponding field.

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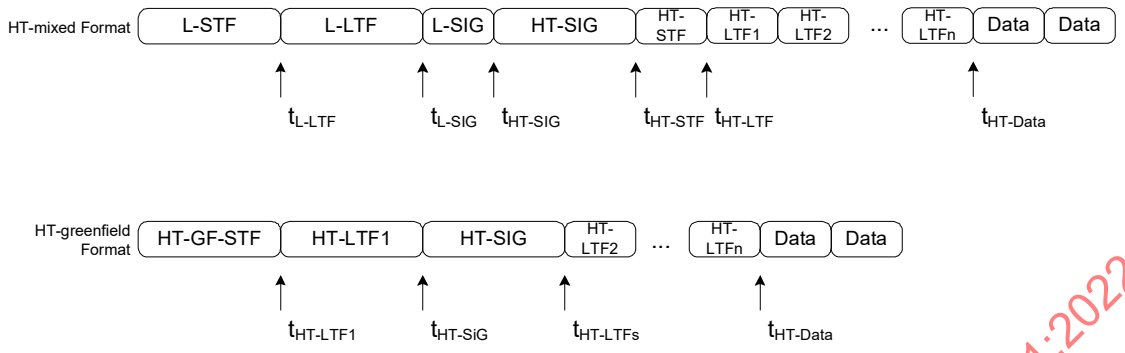

Figure 19-4—Timing boundaries for PPDU fields

In HT-mixed format, the signal transmitted on transmit chain i_{TX} shall be as shown in Equation (19-2).

$$\begin{aligned} r_{PPDU}^{(i_{TX})}(t) &= r_{L\text{-}STF}^{(i_{TX})}(t) + r_{L\text{-}LTF}^{(i_{TX})}(t - t_{L\text{-}LTF}) \\ &+ r_{L\text{-}SIG}^{(i_{TX})}(t - t_{L\text{-}SIG}) + r_{HT\text{-}SIG}^{(i_{TX})}(t - t_{HT\text{-}SIG}) + r_{HT\text{-}STF}^{(i_{TX})}(t - t_{HT\text{-}STF}) \\ &+ \sum_{i_{LTF}=1}^{N_{HTLTF}} r_{HT\text{-}LTF}^{(i_{TX}, i_{LTF})}(t - t_{HT\text{-}LTF} - (i_{LTF} - 1)T_{HT\text{-}LTFs}) + r_{HT\text{-}DATA}^{(i_{TX})}(t - t_{HT\text{-}DATA}) \end{aligned} \tag{19-2}$$

where

$$t_{L\text{-}LTF} = T_{L\text{-}STF}$$
$$t_{L\text{-}SIG} = t_{L\text{-}LTF} + T_{L\text{-}LTF}$$
$$t_{HT\text{-}SIG} = t_{L\text{-}SIG} + T_{L\text{-}SIG}$$
$$t_{HT\text{-}STF} = t_{HT\text{-}SIG} + T_{HT\text{-}SIG}$$
$$t_{HT\text{-}LTF} = t_{HT\text{-}STF} + T_{HT\text{-}STF}$$
$$t_{HT\text{-}Data} = t_{HT\text{-}LTF} + N_{HT\text{-}LTF} \cdot T_{HT\text{-}LTFs}$$

In the case of HT-greenfield format, the transmitted signal on transmit chain i_{TX} shall be as shown in Equation (19-3).

$$\begin{aligned} r_{PPDU}^{(i_{TX})}(t) &= r_{HT-GF-STF}^{(i_{TX})}(t) + r_{HT-LTF1}^{(i_{TX})}(t - t_{HT-LTF1}) \\ &+ r_{HT-SIG}^{(i_{TX})}(t - t_{HT-SIG}) \\ &+ \sum_{i_{LTF}=2}^{N_{HTLTF}} r_{HT-LTF}^{(i_{TX}, i_{LTF})}(t - t_{HT-LTFs} - (i_{LTF} - 2)T_{HT-LTFs}) \\ &+ r_{HT-DATA}^{(i_{TX})}(t - t_{HT-DATA}) \end{aligned} \tag{19-3}$$

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where

$t_{HT-LTF1} = T_{HT-GF-STF}$

$t_{HT\text{-}SIG} = t_{HT\text{-}LTF1} + T_{HT\text{-}LTF1}$

$t_{HT\text{-}LTFs} = t_{HT\text{-}SIG} + T_{HT\text{-}SIG}$

$t_{HT\text{-}Data} = t_{HT\text{-}LTFs} + (N_{HT\text{-}LTF} - 1) \cdot T_{HT\text{-}LTFs}$

Each baseband waveform, $r_{\text{Field}}^{(i_{TX})}(t)$, is defined via the discrete Fourier transform (DFT) per OFDM symbol as shown in Equation (19-4).

$$r_{\text{Field}}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{Field}}^{\text{Tone}} \cdot N_{TX}}} w_{\text{T}_{\text{Field}}}(t) \sum_k \Upsilon_k X_k^{(i_{TX})} \exp(j2\pi k \Delta_F t) \quad (19\text{-}4)$$

This general representation holds for all fields. A suggested definition of the windowing function, $w_{\text{T}_{\text{Field}}}(t)$, is given in 17.3.2.5. The frequency domain symbols $X_k^{(i_{TX})}$ represent the output of any spatial processing in subcarrier k for transmit chain i_{TX} required for the field.

The function Υ_k is used to represent a rotation of the upper tones in a 40 MHz channel as shown in Equation (19-5) and Equation (19-6).

$$\Upsilon_k = \begin{cases} 1, k \le 0, \text{ in a 40 MHz channel} \\ j, k > 0, \text{ in a 40 MHz channel} \end{cases} \quad (19\text{-}5)$$

$$\Upsilon_k = 1, \text{ in a 20 MHz channel} \quad (19\text{-}6)$$

The $1/\sqrt{N_{\text{Field}}^{\text{Tone}} \cdot N_{TX}}$ scale factor in Equation (19-4) causes the total power of the time domain signal as summed over all transmit chains to be either 1 or lower than 1 when required. Table 19-8 summarizes the various values of $N_{\text{Field}}^{\text{Tone}}$.

Table 19-8—Value of tone scaling factor N_{Field}^{Tone}

Field	N_{Field}^{Tone}, see NOTE 1	
	20 MHz	40 MHz
L-STF	12	24
HT-GF-STF	12	24
L-LTF	52	104
L-SIG	52	104
HT-SIG	52/56, see NOTE 2	104/114, see NOTE 2
HT-STF	12	24

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Table 19-8—Value of tone scaling factor N_{Field}^{Tone} *(continued)*

Field	N_{Field}^{Tone}, see NOTE 1	
	20 MHz	40 MHz
HT-LTF	56	114
HT-DATA	56	114
MCS 32	—	104
Non-HT Duplicate	—	104

NOTE 1—The numbers in the table refer only to the value of N_{Field}^{Tone} as it appears in Equation (19-4) and in subsequent specification of various fields. This value might be different from the actual number of tones being transmitted.
NOTE 2—The values 56 and 114 are for HT-greenfield format; the values 52 and 104 are for HT-mixed format.

19.3.8 Transmission in the upper/lower 20 MHz of a 40 MHz channel

When transmitting in the upper/lower 20 MHz portion of a 40 MHz channel, the mathematical definition of transmission shall follow that of a 20 MHz channel with f_c in Equation (19-1) replaced by $f_c \pm 10$ MHz.

This rule applies to 20 MHz HT transmission in the upper/lower 20 MHz of a 40 MHz channel (TXVECTOR primitive CH_BANDWIDTH equal to HT_CBW20 and CH_OFFSET primitive equal to CH_OFF_20U or CH_OFF_20L) and to 20 MHz non-HT transmission in the upper/lower 20 MHz of a 40 MHz channel (TXVECTOR primitive CH_BANDWIDTH equal to NON_HT_CBW20 and CH_OFFSET primitive equal to CH_OFF_20U or CH_OFF_20L).

19.3.9 HT preamble

19.3.9.1 Introduction

The HT preambles are defined in HT-mixed format and in HT-greenfield format to carry the required information to operate in a system with multiple transmit and multiple receive antennas.

In the HT-mixed format, to provide compatibility with non-HT STAs, specific non-HT fields are defined so that they can be received by non-HT STAs compliant with Clause 17 or Clause 18 followed by the fields specific to HT STAs.

In the HT-greenfield format, all of the non-HT fields are omitted. The specific HT fields used are as follows:

— One HT-GF-STF for automatic gain control convergence, timing acquisition, and coarse frequency acquisition,
— One or several HT-LTFs, provided as a way for the receiver to estimate the channel between each spatial mapper input and receive chain. The first HT-LTFs (HT-DLTFs) are necessary for demodulation of the HT-Data portion of the PPDU and are followed, for sounding PPDUs only, by optional HT-LTFs (HT-ELTFs) to sound extra spatial dimensions of the MIMO channel,
— HT-SIG, which provides all the information required to interpret the HT packet format.

In the case of multiple transmit chains, the HT preambles use cyclic shift techniques to prevent unintentional beamforming.

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19.3.9.2 HT-mixed format preamble

In HT-mixed format frames, the preamble has fields that support compatibility with Clause 17 and Clause 18 STAs and fields that support HT operation. The non-HT portion of the HT-mixed format preamble enables detection of the PPDU and acquisition of carrier frequency and timing by both HT STAs and STAs that are compliant with Clause 17 or Clause 18. The non-HT portion of the HT-mixed format preamble contains the SIGNAL field (L-SIG) defined in Clause 17 and is thus decodable by STAs compliant with Clause 17 and Clause 18 as well as HT STAs.

The HT portion of the HT-mixed format preamble enables estimation of the MIMO channel to support demodulation of the data portion of the frame by HT STAs. The HT portion of the HT-mixed format preamble also contains the HT-SIG field that supports HT operation.

19.3.9.3 Non-HT portion of the HT-mixed format preamble

19.3.9.3.1 Introduction

The transmission of the L-STF, L-LTF and the L-SIG as part of an HT-mixed format packet is described in 19.3.9.3.2 to 19.3.9.3.5.

19.3.9.3.2 Cyclic shift definition

The cyclic shift values defined in this subclause apply to the non-HT fields in the HT-mixed format preamble and the HT-SIG in the HT-mixed format preamble.

Cyclic shifts are used to prevent unintentional beamforming when the same signal or scalar multiples of one signal are transmitted through different spatial streams or transmit chains. A cyclic shift of duration T_{CS} on a signal $s(t)$ on interval $0 \le t \le T$ is defined as follows, where T is defined as T_{DFT} as referenced in Table 19-6.

With $T_{CS} \le 0$, replace $s(t)$ with $s(t - T_{CS})$ when $0 \le t < T + T_{CS}$ and with $s(t - T_{CS} - T)$ when $T + T_{CS} \le t \le T$. The cyclic-shifted signal is defined as shown in Equation (19-7).

$$s_{CS}(t;T_{CS})\big|_{T_{CS}<0} = \begin{cases} s(t - T_{CS}) & 0 \le t < T + T_{CS} \\ s(t - T_{CS} - T) & T + T_{CS} \le t \le T \end{cases} \quad (19\text{-}7)$$

The cyclic shift is applied to each OFDM symbol in the packet separately. Table 19-9 specifies the values for the cyclic shifts that are applied in the L-STF (in an HT-mixed format packet), the L-LTF, and L-SIG. It also applies to the HT-SIG in an HT-mixed format packet.

With more than four transmit chains, each cyclic shift on the additional transmit chains shall be between –200 ns and 0 ns.

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Table 19-9—Cyclic shift for non-HT portion of PPDU

$T_{CS}^{i_{TX}}$ values for non-HT portion of PPDU				
Number of transmit chains	**Cyclic shift for transmit chain 1 (ns)**	**Cyclic shift for transmit chain 2 (ns)**	**Cyclic shift for transmit chain 3 (ns)**	**Cyclic shift for transmit chain 4 (ns)**
1	0	—	—	—
2	0	–200	—	—
3	0	–100	–200	—
4	0	–50	–100	–150

19.3.9.3.3 L-STF definition

The non-HT short training OFDM symbol in the 20 MHz channel width is shown in Equation (19-8).

$$S_{-26,26} = \sqrt{1/2} \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\} \quad (19\text{-}8)$$

The normalization factor $\sqrt{1/2}$ is the QPSK normalization.

NOTE—Other than the scaling difference, Equation (19-8) represents the same BPSK constellations per subcarrier as those represented in Equation (17-8).

The non-HT short training OFDM symbol in a 40 MHz channel width is given by Equation (19-9), after rotating the tones in the upper subchannel (subcarriers 6–58) by +90° [see Equation (19-10)].

$$S_{-58,58} = \sqrt{1/2} \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\} \quad (19\text{-}9)$$

In HT-mixed format, the L-STF on transmit chain i_{TX} shall be as shown in Equation (19-10).

$$r_{L-STF}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{L-STF}^{Tone}}} w_{T_{L-STF}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \Upsilon_k S_k \exp(j2\pi k \Delta_F (t - T_{CS}^{i_{TX}})) \quad (19\text{-}10)$$

where

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain i_{TX} and takes values from Table 19-9

Υ_k is defined in Equation (19-5) and Equation (19-6)

The L-STF has a period of 0.8 µs. The entire STF includes ten such periods, with a total duration of $T_{L\text{-}STF}$ = 8 µs.

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19.3.9.3.4 L-LTF definition

The non-HT long training OFDM symbol is identical to the Clause 17 long training OFDM symbol. In the 20 MHz channel width, the long training OFDM symbol is given by Equation (19-11).

$$L_{-26,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0,$$
$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (19\text{-}11)$$

The non-HT long training OFDM symbol in a 40 MHz channel width is given by Equation (19-12), after rotating the tones in the upper subchannel (subcarriers 6–58) by +90° [see Equation (19-13)].

$$L_{-58,58} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0,$$
$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 0, 0, 0, 0,$$
$$0, 0, 0, 0, 0, 0, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0,$$
$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (19\text{-}12)$$

The subcarriers at ± 32 in 40 MHz, which are the dc subcarriers for the non-HT 20 MHz transmission, are both nulled in the L-LTF. Such an arrangement allows proper synchronization of a 20 MHz non-HT STA.

The L-LTF waveform shall be as shown in Equation (19-13).

$$r_{L-LTF}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{L-LTF}^{Tone}}} w_{T_{L-LTF}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \Upsilon_k L_k \exp(j2\pi k \Delta_F (t - T_{GI2} - T_{CS}^{i_{TX}})) \quad (19\text{-}13)$$

where

T_{GI2} is 1.6 µs

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain i_{TX} and takes values specified in Table 19-9

Υ_k is defined in Equation (19-5) and Equation (19-6)

The entire LTF includes two 3.2 µs IDFT/DFT periods and an additional 1.6 µs double GI. The entire LTF is modulated with the L-LTF waveform.

19.3.9.3.5 L-SIG definition

The L-SIG is used to communicate rate and length information.The structure of the L-SIG is shown in Figure 19-5.

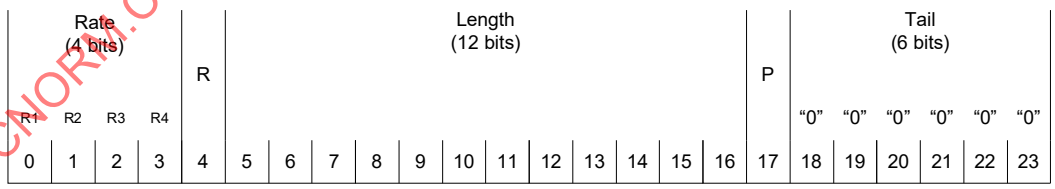

Figure 19-5—L-SIG structure

The value in the Rate field is obtained from the L_DATARATE field of the TXVECTOR. The value in the Length field is obtained from the L_LENGTH field of the TXVECTOR. The Length field is transmitted LSB first.

The reserved bit shall be set to 0.

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The parity field has the even parity of bits 0–16.

The L-SIG shall be encoded, interleaved and mapped, and it shall have pilots inserted following the steps described in 17.3.5.6, 17.3.5.7, and 17.3.5.9. The stream of 48 complex numbers generated by the steps described in 17.3.5.7 is denoted by $d_k, k = 0 \ldots 47$. The time domain waveform of the L-SIG in 20 MHz transmission shall be as given by Equation (19-14).

$$r_{L-SIG}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{L-SIG}^{Tone}}} w_{T_{SYM}}(t) \sum_{k=-26}^{26} (D_k + p_0 P_k) \exp(j2\pi k \Delta_F (t - T_{GI} - T_{CS}^{i_{TX}})) \quad (19\text{-}14)$$

In a 40 MHz transmission the time domain waveform of the L-SIG shall be as given by Equation (19-15).

$$r_{L-SIG}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{L-SIG}^{Tone}}} w_{T_{SYM}}(t) \sum_{k=-26}^{26} (D_k + p_0 P_k) \cdot (\exp(j2\pi(k-32)\Delta_F (t - T_{GI} - T_{CS}^{i_{TX}})) + j \exp(j2\pi(k+32)\Delta_F (t - T_{GI} - T_{CS}^{i_{TX}}))) \quad (19\text{-}15)$$

where

$$D_k = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M^r(k)}, \text{otherwise} \end{cases}$$

$$M^r(k) = \begin{cases} k + 26, -26 \le k \le -22 \\ k + 25, -20 \le k \le -8 \\ k + 24, -6 \le k \le -1 \\ k + 23, 1 \le k \le 6 \\ k + 22, 8 \le k \le 20 \\ k + 21, 22 \le k \le 26 \end{cases}$$

P_k is defined in 17.3.5.10

p_0 is the first pilot value in the sequence defined in 17.3.5.10

N_{L-SIG}^{Tone} has the value given in Table 19-8

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain i_{TX} and is defined by Table 19-9 for HT-mixed format PPDUs

NOTE—D_k exists for $-N_{SR} \le k \le N_{SR}$ and takes the values from d_k that exists for $0 \le k \le N_{SD} - 1$. $M^r(k)$ is a "reverse" function of the function $M(k)$ defined in 17.3.5.10.

19.3.9.4 HT portion of HT-mixed format preamble

19.3.9.4.1 Introduction

When an HT-mixed format preamble is transmitted, the HT preamble consists of the HT-STF, the HT-LTFs, and the HT-SIG.

All numeric fields are transmitted in unsigned format, LSB first.

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19.3.9.4.2 Cyclic shift definition

The cyclic shift values defined in this subclause apply to the HT-STF and HT-LTFs of the HT-mixed format preamble. The cyclic shift values defined in 19.3.9.3.2 apply to the HT-SIG in an HT-mixed format preamble.

Throughout the HT portion of an HT-mixed format preamble, cyclic shift is applied to prevent beamforming when similar signals are transmitted in different space-time streams. The same cyclic shift is applied to these streams during the transmission of the data portion of the frame. The values of the cyclic shifts to be used during the HT portion of the HT-mixed format preamble (with the exception of the HT_SIG) and the data portion of the frame are specified in Table 19-10.

Table 19-10—Cyclic shift values of HT portion of PPDU

$T_{CS}^{i_{STS}}$ values for HT portion of PPDU				
Number of space-time streams	**Cyclic shift for space-time stream 1 (ns)**	**Cyclic shift for space-time stream 2 (ns)**	**Cyclic shift for space-time stream 3 (ns)**	**Cyclic shift for space-time stream 4 (ns)**
1	0	—	—	—
2	0	–400	—	—
3	0	–400	–200	—
4	0	–400	–200	–600

19.3.9.4.3 HT-SIG definition

The HT-SIG is used to carry information required to interpret the HT packet formats. The fields of the HT-SIG are described in Table 19-11.

Table 19-11—HT-SIG fields

Field	Number of bits	Explanation and coding
Modulation and Coding Scheme	7	Index into the MCS table.
CBW 20/40	1	Set to 0 for 20 MHz or 40 MHz upper/lower. Set to 1 for 40 MHz.
HT Length	16	The number of octets of data in the PSDU. See NOTE.
Smoothing	1	Set to 1 indicates that channel estimate smoothing is recommended. Set to 0 indicates that only per-carrier independent (unsmoothed) channel estimate is recommended. See 19.3.11.11.2.
Not Sounding	1	Set to 0 indicates that PPDU is a sounding PPDU. Set to 1 indicates that the PPDU is not a sounding PPDU.
Reserved	1	Set to 1.

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Table 19-11—HT-SIG fields *(continued)*

Field	Number of bits	Explanation and coding
Aggregation	1	Set to 1 to indicate that the PPDU in the data portion of the packet contains an A-MPDU; otherwise, set to 0.
STBC	2	Set to a nonzero number, to indicate the difference between the number of space-time streams (N_{STS}) and the number of spatial streams (N_{SS}) indicated by the MCS. Set to 00 to indicate no STBC ($N_{STS} = N_{SS}$).
FEC Coding	1	Set to 1 for LDPC. Set to 0 for BCC.
Short GI	1	Set to 1 to indicate that the short GI is used after the HT-LTFs. Set to 0 otherwise.
Number of Extension Spatial Streams	2	Indicates the number of extension spatial streams (N_{ESS}). Set to 0 for no extension spatial stream. Set to 1 for 1 extension spatial stream. Set to 2 for 2 extension spatial streams. Set to 3 for 3 extension spatial streams.
CRC	8	CRC of bits 0–23 in HT-SIG$_1$ and bits 0–9 in HT-SIG$_2$. See 19.3.9.4.4. The first bit to be transmitted is bit C7 as explained in 19.3.9.4.4.
Tail Bits	6	Used to terminate the trellis of the convolution coder. Set to 0.
NOTE—A value of 0 in the HT Length field indicates a PPDU that does not include a data field, i.e., NDP. NDP transmissions are used for sounding purposes only (see 10.36.2). The packet ends after the last HT-LTF or the HT-SIG.		

The structure of the HT-SIG$_1$ and HT-SIG$_2$ fields is defined in Figure 19-6.

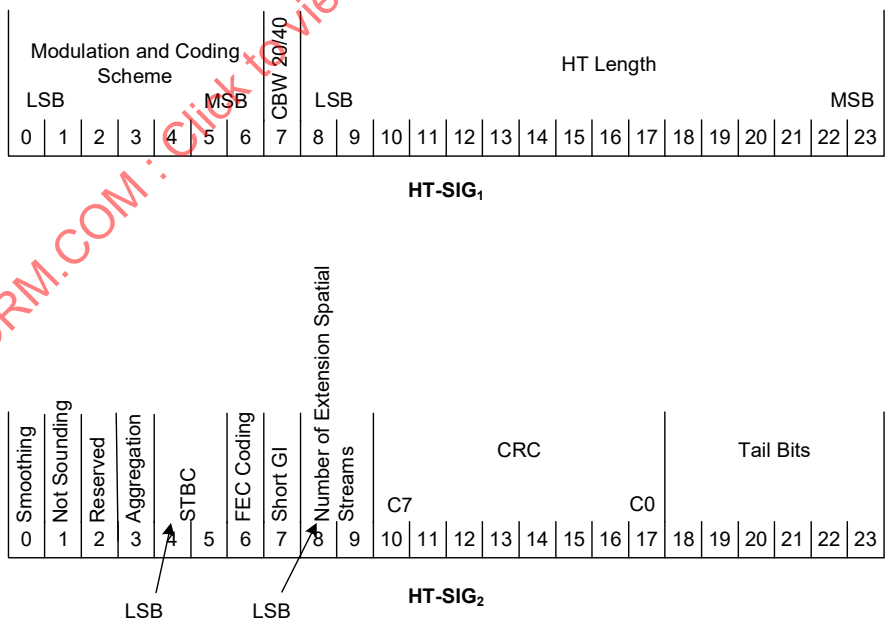

Figure 19-6—Format of HT-SIG$_1$ and HT-SIG$_2$

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The HT-SIG is composed of two parts, HT-SIG$_1$ and HT-SIG$_2$, each containing 24 bits, as shown in Figure 19-6. All of the fields in the HT-SIG are transmitted LSB first, and HT-SIG$_1$ is transmitted before HT-SIG$_2$.

The HT-SIG parts shall be encoded at R = 1/2, interleaved, and mapped to a BPSK constellation, and they have pilots inserted following the steps described in 17.3.5.6, 17.3.5.7, 17.3.5.8, and 17.3.5.9, respectively. The BPSK constellation is rotated by 90° relative to the L-SIG in order to accommodate detection of the start of the HT-SIG. The stream of 96 complex numbers generated by these steps is divided into two groups of 48 complex numbers: $d_{k,n}$, $0 \le k \le 47$, $n = 0, 1$. The time domain waveform for the HT-SIG in an HT-mixed format packet in a 20 MHz transmission shall be as shown in Equation (19-16).

$$r_{HT-SIG}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{HT-SIG}^{Tone}}} \sum_{n=0}^{1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-26}^{26} (jD_{k,n} + p_{n+1}P_k) \exp(j2\pi k\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}})) \quad (19\text{-}16)$$

In a 40 MHz transmission the time domain waveform shall be as shown in Equation (19-17).

$$r_{HT-SIG}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{HT-SIG}^{Tone}}} \sum_{n=0}^{1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-26}^{26} (jD_{k,n} + p_{n+1}P_k)(\exp(j2\pi(k-32)\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}})) + j\exp(j2\pi(k+32)\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}}))) \quad (19\text{-}17)$$

where

$$D_{k,n} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M^r(k),n}, \text{otherwise} \end{cases}$$

$M^r(k)$ is defined in 19.3.9.3

P_k and p_n are defined in 17.3.5.10

N_{HT-SIG}^{Tone} has the value given in Table 19-8

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain i_{TX} and is defined by Table 19-9 for HT-mixed format PPDUs

NOTE—This definition results in a quadrature binary phase shift keying (QBPSK) modulation in which the constellation of the data tones is rotated by 90° relative to the L-SIG in HT-mixed format PPDUs and relative to the first HT-LTF in HT-greenfield format PPDUs (see Figure 19-7). In HT-mixed format PPDUs, the HT-SIG is transmitted with the same number of subcarriers and the same cyclic shifts as the preceding non-HT portion of the preamble. This is done to accommodate the estimation of channel parameters needed to robustly demodulate and decode the information contained in the HT-SIG.

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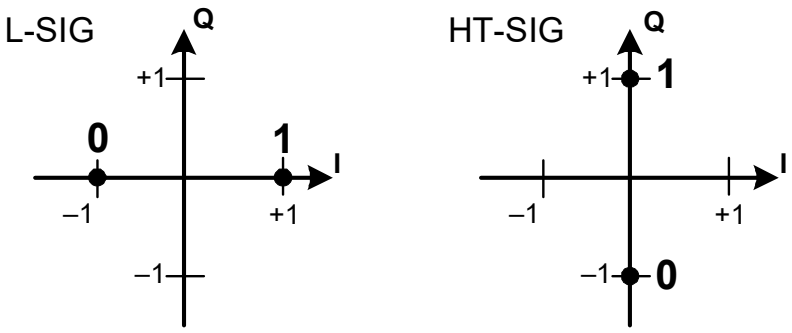

Figure 19-7—Data tone constellations in an HT-mixed format PPDU

19.3.9.4.4 CRC calculation for HT-SIG

The CRC protects bits 0–33 of the HT-SIG (bits 0–23 of HT-SIG$_1$ and bits 0–9 of HT-SIG$_2$). The value of the CRC field shall be the 1s complement of

$$crc(D) = (M(D) \oplus I(D))D^8 \bmod G(D) \tag{19-18}$$

where

$M(D) = m_0 D^{33} + m_1 D^{32} + \ldots + m_{32} D + m_{33}$ is the HT-SIG represented as a polynomial

where

m_0 is bit 0 of HT-SIG$_1$

m_{33} is bit 9 of HT-SIG$_2$

$I(D) = \sum_{i=26}^{33} D^i$ are initialization values that are added modulo 2 to the first 8 bits of HT-SIG$_1$

$G(D) = D^8 + D^2 + D + 1$ is the CRC generating polynomial

$crc(D) = c_0 D^7 + c_1 D^6 + \ldots + c_6 D + c_7$

The CRC field is transmitted with c_7 first.

Figure 19-8 shows the operation of the CRC. First, the shift register is reset to all 1s. The bits are then passed through the XOR operation at the input. When the last bit has entered, the output is generated by shifting the bits out of the shift register, C7 first, through an inverter.

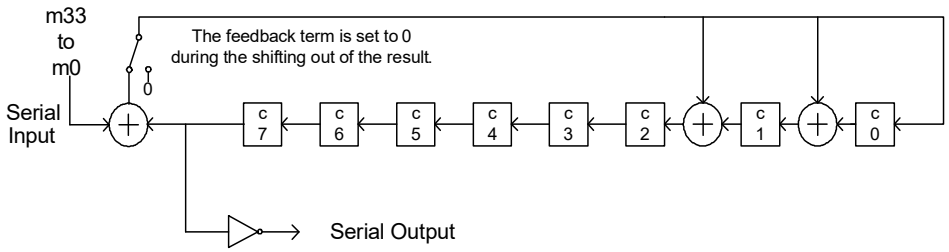

Figure 19-8—HT-SIG CRC calculation

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As an example, if bits $\{m_0 \ldots m_{33}\}$ are given by $\{1\,1\,1\,1\,0\,0\,0\,1\,0\,0\,1\,0\,0\,1\,1\,0\,0\,0\,0\,0\,0\,0\,0\,1\,1\,1\,0\,0\,0\,0\,0\,0\}$, the output bits $\{B_7 \ldots B_0\}$, where B_7 is output first, are $\{1\,0\,1\,0\,1\,0\,0\,0\}$.

19.3.9.4.5 HT-STF definition

The purpose of the HT-STF is to improve automatic gain control estimation in a MIMO system. The duration of the HT-STF is 4 µs. In a 20 MHz transmission, the frequency sequence used to construct the HT-STF is identical to L-STF. In a 40 MHz transmission, the HT-STF is constructed from the 20 MHz version by duplicating and frequency shifting and by rotating the upper subcarriers by 90°. The frequency sequences are shown in Equation (19-19) and Equation (19-20).

For 20 MHz:

$$\begin{aligned} HTS_{-28,28} = \sqrt{1/2} \\ \{&0, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, \\ &0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 0\} \end{aligned} \tag{19-19}$$

For 40 MHz:

$$\begin{aligned} HTS_{-58,58} = \sqrt{1/2} \\ \{&0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, \\ &0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, \\ &0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\} \end{aligned} \tag{19-20}$$

The time domain representation of the transmission in transmit chain i_{TX} shall be as shown in Equation (19-21).

$$\begin{aligned} r_{HT-STF}^{i_{TX}}(t) = &\frac{1}{\sqrt{N_{STS} \cdot N_{HT-STF}^{Tone}}} w_{T_{HT-STF}}(t) \\ &\sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} \Upsilon_k HTS_k \exp(j2\pi k \Delta_F (t - T_{CS}^{i_{STS}})) \end{aligned} \tag{19-21}$$

where

$T_{CS}^{i_{STS}}$ represents the cyclic shift for the space-time stream i_{STS} and takes the values given in Table 19-10

Q_k is defined in 19.3.11.11.2

Υ_k is defined in Equation (19-5) and Equation (19-6)

19.3.9.4.6 HT-LTF definition

The HT-LTF provides a means for the receiver to estimate the MIMO channel between the set of QAM mapper outputs (or, if STBC is applied, the STBC encoder outputs) and the receive chains. If the transmitter is providing training for exactly the space-time streams (spatial mapper inputs) used for the transmission of the PSDU, the number of training symbols, N_{LTF}, is equal to the number of space-time streams, N_{STS}, except that for three space-time streams, four training symbols are required. If the transmitter is providing

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training for more space-time streams (spatial mapper inputs) than the number used for the transmission of the PSDU, the number of training symbols is greater than the number of space-time streams. This latter case happens in a sounding PPDU.

The HT-LTF portion has one or two parts. The first part consists of one, two, or four HT-LTFs that are necessary for demodulation of the HT-Data portion of the PPDU. These HT-LTFs are referred to as *HT-DLTFs*. The optional second part consists of zero, one, two, or four HT-LTFs that may be used to sound extra spatial dimensions of the MIMO channel that are not utilized by the HT-Data portion of the PPDU. These HT-LTFs are referred to as *HT-ELTFs*. If a receiver has not advertised its ability to receive HT-ELTFs, it shall either issue a PHY-RXEND.indication(UnsupportedRate) primitive upon reception of a frame that includes HT-ELTFs or decode that frame. (When an HT packet includes one or more HT-ELTFs, it is optional for a receiver that has not advertised its capability to receive HT-ELTFs to decode the data portion of the PPDU.)

The number of HT-DLTFs is denoted $N_{HT\text{-}DLTF}$. The number of HT-ELTFs is denoted $N_{HT\text{-}ELTF}$. The total number of HT-LTFs is shown in Equation (19-22).

$$N_{HT\text{-}LTF} = N_{HT\text{-}DLTF} + N_{HT\text{-}ELTF} \tag{19-22}$$

$N_{HT\text{-}LTF}$ shall not exceed 5. Table 19-12 shows the determination of the number of space-time streams from the MCS and STBC fields in the HT-SIG. Table 19-13 shows the number of HT-DLTFs as a function of the number of space-time streams (N_{STS}). Table 19-14 shows the number of HT-ELTFs as a function of the number of extension spatial streams (N_{ESS}). N_{STS} plus N_{ESS} is less than or equal to 4. In the case where N_{STS} equals 3, N_{ESS} cannot exceed one; if N_{ESS} equals one in this case then N_{LTF} equals 5.

Table 19-12—Determining the number of space-time streams

Number of spatial streams (from MCS) N_{SS}	STBC field	Number of space-time streams N_{STS}
1	0	1
1	1	2
2	0	2
2	1	3
2	2	4
3	0	3
3	1	4
4	0	4

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Table 19-13—Number of HT-DLTFs required for data space-time streams

N_{STS}	N_{HTDLTF}
1	1
2	2
3	4
4	4

Table 19-14—Number of HT-ELTFs required for extension spatial streams

N_{ESS}	$N_{HT\text{-}ELTF}$
0	0
1	1
2	2
3	4

The HT-LTF sequence shown in Equation (19-23) is transmitted in the case of 20 MHz operation.

$$HT\text{-}LTF_{-28,28} = \{1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0,$$
$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, 1, -1, 1, -1, 1, -1, 1, 1, 1, 1, -1, -1\} \quad (19\text{-}23)$$

NOTE 1—This sequence is an extension of the L-LTF where the four extra subcarriers are filled with +1 for negative frequencies and –1 for positive frequencies.

In 40 MHz transmissions, including MCS 32 format frames, the sequence to be transmitted is shown in Equation (19-24).

$$HT\text{-}LTF_{-58,58} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1,$$
$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, -1, -1, -1, 1, 0,$$
$$0, 0, -1, 1, 1, -1, 1, 1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1,$$
$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, 1\} \quad (19\text{-}24)$$

NOTE 2—This sequence is also constructed by extending the L-LTF in the following way: first, the L-LTF is duplicated and shifted as explained in 19.3.9.3.4 for the non-HT duplicate format; then the missing subcarriers [–32, –5, –4, –3, –2, 2, 3, 4, 5, 32] are filled with the values [1, –1, –1, –1, 1, –1, 1, 1, –1, 1], respectively.

This sequence, occupying 114 tones, is used even if the data portion is transmitted with MCS 32 format, which uses 104 tones.

NOTE 3—This sequence uses 114 tones when MCS 32 format is used to retain consistency with other 40 MHz formats and to facilitate channel estimation for beamforming and link adaptation.

In an HT-mixed format preamble, each HT-LTF consists of a single occurrence of the sequence plus a GI insertion and has a duration of 4 μs. In case of multiple space-time streams, cyclic shift is invoked as specified in Table 19-10.

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The generation of HT-DLTFs is shown in Figure 19-9. The generation of HT-ELTFs is shown in Figure 19-10. In these figures, and in the following text, the following notational conventions are used:

— $[X]_{m,n}$ indicates the element in row m and column n of matrix X

— $[X]_N$ indicates a matrix consisting of the first N columns of matrix X

— $[X]_{M:N}$ indicates a matrix consisting of columns M to N of matrix X

where

$M \leq N$

X is either Q_k or $P_{HT\text{-}LTF}$

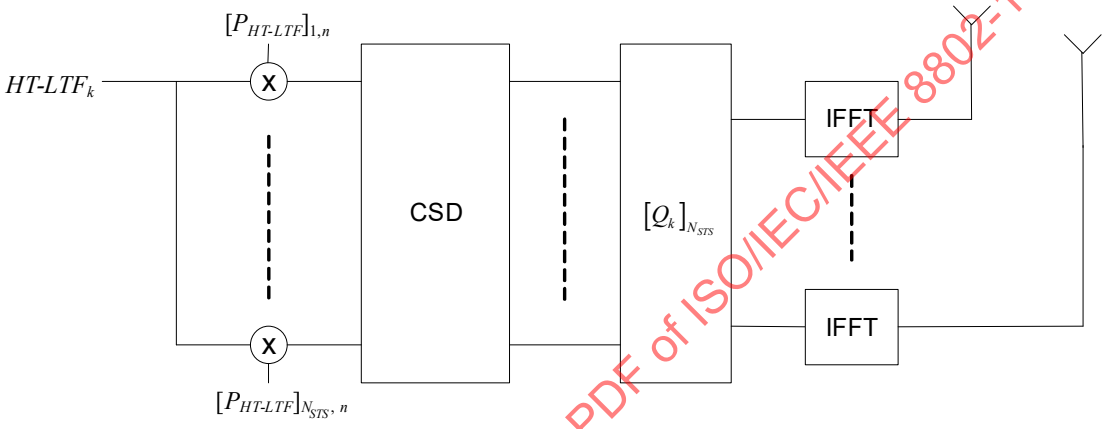

Figure 19-9—Generation of HT-DLTFs

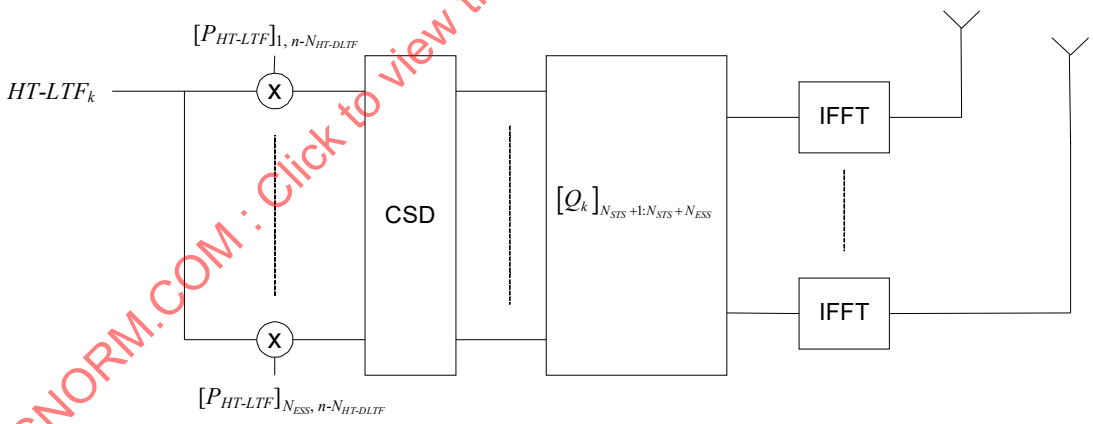

Figure 19-10—Generation of HT-ELTFs

The mapping between space-time streams and transmit chains is defined by the columns of an antenna map matrix Q_k for subcarrier k. The first N_{STS} columns define the space-time streams used for data transmission, and the next N_{ESS} columns (up to $N_{TX} - N_{STS}$ columns) define the extension spatial streams. Thus, for the purpose of defining HT-LTFs, Q_k is an $N_{TX} \times (N_{STS} + N_{ESS})$ dimension matrix. Columns

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$1 \ldots N_{STS}$ of Q_k are excited by the HT-DLTFs, and columns $N_{STS}+1 \ldots N_{STS}+N_{ESS}$ are excited by the HT-ELTFs, where $N_{STS}+N_{ESS} \leq N_{TX}$ is the total number of spatial streams being probed by the HT-LTFs.

Possible forms of Q_k and other limitations on Q_k are specified in 19.3.11.11.2. $P_{HT\text{-}LTF}$ is defined in Equation (19-27).

The time domain representation of the waveform transmitted on transmit chain i_{TX} during HT-DLTF n, where $1 \leq n \leq N_{HT\text{-}DLTF}$, shall be as shown in Equation (19-25).

$$r_{HT-LTF}^{n,i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-LTF}^{Tone}}} w_{T_{HT-LTFs}}(t) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} [P_{HT\text{-}LTF}]_{i_{STS}, n} \Upsilon_k HT\text{-}LTF_k \exp(j2\pi k \Delta_F (t - T_{GI} - T_{CS}^{i_{STS}})) \tag{19-25}$$

For the HT-ELTFs ($N_{HT\text{-}DLTF} < n \leq N_{HT\text{-}LTF}$), it shall be as shown in Equation (19-26).

$$r_{HT-LTF}^{n,i_{TX}}(t) = \frac{1}{\sqrt{N_{HT-LTF}^{Tone} \cdot N_{ESS}}} w_{T_{HT-LTFs}}(t) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{ESS}=1}^{N_{ESS}} \left([Q_k]_{i_{TX}, N_{STS}+i_{ESS}} [P_{HT\text{-}LTF}]_{i_{ESS}, n-N_{HTDLTF}} \Upsilon_k HT\text{-}LTF_k \cdot \exp(j2\pi k \Delta_F (t - T_{GI} - T_{CS}^{i_{ESS}})) \right) \tag{19-26}$$

where

$T_{CS}^{i_{STS}}$ cyclic shift values are given in Table 19-10

$T_{CS}^{i_{ESS}}$ cyclic shift values are given in Table 19-10 with $i_{ESS} = i_{STS}$

Q_k is defined in 19.3.11.11.2

Υ_k is defined in Equation (19-5) and Equation (19-6)

$P_{HT\text{-}LTF}$ the HT-LTF mapping matrix, is given by Equation (19-27)

$$P_{HT\text{-}LTF} = \begin{bmatrix} 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \\ -1 & 1 & 1 & 1 \end{bmatrix} \tag{19-27}$$

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19.3.9.5 HT-greenfield format preamble

19.3.9.5.1 General

For HT-greenfield operation, compatibility with Clause 17 and Clause 18 STAs is not required. Therefore, the portions of the preamble that are compatible with Clause 17 and Clause 18 STAs are not included. The result is a shorter and more efficient PHY frame format that includes a STF, LTF(s), and an HT-SIG.

19.3.9.5.2 Cyclic shift definition for HT-greenfield format preamble

Throughout the HT-greenfield format preamble, cyclic shift is applied to prevent beamforming when similar signals are transmitted on different spatial streams. The same cyclic shift is applied to these streams during the transmission of the data portion of the frame. The values of the cyclic shift to be used during the HT-greenfield format preamble, as well as the data portion of the HT-greenfield format frame, are specified in Table 19-10.

19.3.9.5.3 HT-GF-STF definition

The HT-GF-STF is placed at the beginning of an HT-greenfield format frame. The time domain waveform for the HT-GF-STF on transmit chain i_{TX} shall be as shown in Equation (19-28).

$$r_{HT-GF-STF}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-GF-STF}^{Tone}}} w_{T_{HT-GF-STF}}(t) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} [P_{HT\text{-}LTF}]_{i_{STS}, 1} \Upsilon_k S_k \exp(j2\pi k \Delta_F (t - T_{CS}^{i_{STS}})) \quad (19\text{-}28)$$

where

$T_{CS}^{i_{STS}}$ represents the cyclic shift for the space-time stream i_{STS} and takes values from Table 19-10

Q_k is defined in 19.3.11.11.2

$P_{HT\text{-}LTF}$ is defined in Equation (19-27)

S_k is defined in non-HT-STF (L-STF), Equation (19-8) for 20 MHz operation and Equation (19-9) for 40 MHz operation

Υ_k is defined in Equation (19-5) and Equation (19-6)

The waveform defined by Equation (19-28) has a period of 0.8 µs, and the HT-GF-STF includes ten such periods, with a total duration of $T_{HT-GF-STF} = 8$ µs.

19.3.9.5.4 HT-greenfield format HT-SIG

The content and format of the HT-SIG of an HT-greenfield format frame is identical to the HT-SIG in an HT-mixed format frame, as described in 19.3.9.4.3. The placement of the HT-SIG in an HT-greenfield format frame is shown in Figure 19-1. In HT-greenfield format frames, the HT-SIG is transmitted with the same cyclic shifts and the same spatial mapping as the preceding portions of the preamble. This use of the same cyclic shifts and spatial mapping is done to accommodate the estimation of channel parameters needed to robustly demodulate and decode the information contained in the HT-SIG.

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The time domain waveform for the HT-SIG on transmit chain i_{TX} with 20 MHz operation shall be as shown in Equation (19-29).

$$r_{HT-SIG}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-SIG}^{Tone}}} \sum_{n=0}^{1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-26}^{26} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} [P_{HT\text{-}LTF}]_{i_{STS}, 1} (jD_{k,n} + p_n P_k) \cdot \exp(j2\pi k\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{STS}})) \quad (19\text{-}29)$$

where

P_k and p_n are defined in 17.3.5.10

$D_{k,n}$ is defined in 19.3.9.4.3

$T_{CS}^{i_{STS}}$ represents the cyclic shift for space-time stream i_{STS} and takes values from Table 19-10

Q_k is defined in 19.3.11.11.2

$P_{HT\text{-}LTF}$ is defined in Equation (19-27)

The time domain waveform for the HT-SIG on transmit chain i_{TX} with 40 MHz operation shall be as shown in Equation (19-30).

$$r_{HT-SIG}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-SIG}^{Tone}}} \sum_{n=0}^{1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-26}^{26} \sum_{i_{STS}=1}^{N_{STS}} [P_{HT\text{-}LTF}]_{i_{STS}, 1} (jD_{k,n} + p_n P_k) \cdot ([Q_{k-32}]_{i_{TX}, i_{STS}} \exp(j2\pi(k-32)\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{STS}})) + j[Q_{k+32}]_{i_{TX}, i_{STS}} \exp(j2\pi(k+32)\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{STS}}))) \quad (19\text{-}30)$$

where

p_n and P_k are defined in 17.3.5.10

$D_{k,n}$ is defined in 19.3.9.4.3

$T_{CS}^{i_{STS}}$ represents the cyclic shift for space-time stream i_{STS} and takes values from Table 19-10

Q_k is defined in 19.3.11.11.2

$P_{HT\text{-}LTF}$ is defined in Equation (19-27)

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19.3.9.5.5 HT-greenfield format LTF

The format of the LTF portion of the preamble in an HT-greenfield format frame is similar to that of the HT-LTF in an HT-mixed format frame, as described in 19.3.9.4.6, with the difference that the first HT-LTF (HT-LTF1) is twice as long (8 μs) as the other HT-LTFs. The time domain waveform for the long training symbol on transmit chain i_{TX} for the first HT-LTF in an HT-greenfield format frame shall be as shown in Equation (19-31).

$$r_{HT-LTF}^{1,i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-LTF}^{Tone}}} w_{T_{HT-LTF1}}(t) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} [P_{HT\text{-}LTF}]_{i_{STS},1} \Upsilon_k HT\text{-}LTF(k) \exp(j2\pi k \Delta_F (t - T_{GI2} - T_{CS}^{i_{STS}})) \quad (19\text{-}31)$$

where

$T_{CS}^{i_{STS}}$ represents the cyclic shift for space-time stream i_{STS} and takes values from Table 19-10

Q_k is defined in 19.3.11.11.2

$P_{HT\text{-}LTF}$ is defined in Equation (19-27)

The first HT-LTF (HT-LTF1) consists of two periods of the long training symbol, preceded by a double-length (1.6 μs) cyclic prefix. The placement of the first and subsequent HT-LTFs in an HT-greenfield format frame is shown in Figure 19-1.

19.3.10 Transmission of NON_HT format PPDUs with more than one transmit chain

When an HT device transmits a NON_HT format PPDU with the MODULATION parameter equal to OFDM or ERP-OFDM using more than one transmit chain, it shall apply the cyclic shifts defined in Table 19-9 to the transmission in each chain.

19.3.11 Data field

19.3.11.1 General

When BCC encoding is used, the Data field consists of the 16-bit SERVICE field, the PSDU, either six or twelve tail bits, depending on whether one or two encoding streams are represented, and pad bits. When LDPC encoding is used, the Data field consists of the 16-bit SERVICE field and the PSDU, processed by the procedure in 19.3.11.7.5.

The number of OFDM symbols in the data field when BCC encoding is used is computed as shown in Equation (19-32).

$$N_{SYM} = m_{STBC} \left\lceil \frac{8 \cdot length + 16 + 6 \cdot N_{ES}}{m_{STBC} \cdot N_{DBPS}} \right\rceil \quad (19\text{-}32)$$

where

m_{STBC} is 2 if STBC is used and 1 otherwise (making sure that the number of symbols is even when STBC is used)

length is the value of the HT Length field in the HT-SIG field defined in Table 19-11

N_{DBPS} takes the values defined in Table 19-27 to Table 19-41

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The number of "zero" pad bits is thus $N_{SYM} \times N_{DBPS} - 8 \times length - 16 - 6 \times N_{ES}$. The number of symbols in the data field when LDPC encoding is used is described in 19.3.11.7.

For LDPC encoding, the number of encoded data bits, N_{avbits}, is given by Equation (19-39); the number of OFDM symbols, N_{SYM}, is given by Equation (19-41); and the number of repeated encoded bits for padding, N_{rep}, is given by Equation (19-42), in 19.3.11.7.5.

19.3.11.2 SERVICE field

The SERVICE field is used for scrambler initialization. The SERVICE field is composed of 16 bits, all set to 0 before scrambling. In non-HT PPDUs, the SERVICE field is the same as in 17.3.5.2. In HT PPDUs, the SERVICE field is composed of 16 zero bits, scrambled by the scrambler, as defined in 19.3.11.3.

19.3.11.3 Scrambler

The data field shall be scrambled by the scrambler defined in 17.3.5.5. The Clause 17 TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT shall not be present; therefore, the initial state of the scrambler shall be set to a pseudorandom nonzero seed.

19.3.11.4 Coding

The Data field shall be encoded using either the BCC defined in 17.3.5.6 or the LDPC code defined in 19.3.11.7. The encoder is selected by the FEC coding field in the HT-SIG, as described in 19.3.9.4.3. A single FEC encoder is always used when LDPC coding is used. When the BCC FEC encoder is used, a single encoder is used, except that two encoders are used when the selected MCS has a PHY rate greater than 300 Mb/s (see 19.5). To determine whether to use one or two BCC FEC encoders, the rate is calculated based on the use of an 800 ns GI. The operation of the BCC FEC is described in 19.3.11.6. The operation of the LDPC coder is described in 19.3.11.7.

Support for the reception of BCC-encoded Data field frames is mandatory.

19.3.11.5 Encoder parsing operation for two BCC FEC encoders

If two BCC encoders are used, the scrambled data bits are divided between the encoders by sending alternating bits to different encoders. Bit with index i sent to the encoder j, denoted $x_i^{(j)}$, is shown in Equation (19-33).

$$x_i^{(j)} = b_{N_{ES} \cdot i + j} \quad ; \quad 0 \le j \le N_{ES} - 1 \tag{19-33}$$

Following the parsing operation, 6 scrambled "zero" bits following the end of the message bits in each BCC input sequence are replaced by unscrambled "zero" bits, as described in 17.3.5.3.

The replaced bits are shown in Equation (19-34).

$$x_i^{(j)} \quad : \quad 0 \le j \le N_{ES} - 1 \quad ; \quad \frac{length \cdot 8 + 16}{N_{ES}} \le i \le \frac{length \cdot 8 + 16}{N_{ES}} + 5 \tag{19-34}$$

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19.3.11.6 BCC coding and puncturing

When BCC encoding is used, the encoder parser output sequences $\{x_i^0\}$, and $\{x_i^1\}$ where applicable, are each encoded by the rate 1/2 convolutional encoder defined in 17.3.5.6. After encoding, the encoded data shall be punctured by the method defined in 17.3.5.7 to achieve the rate selected by the MCS.

If rate 5/6 coding is selected, the puncturing scheme is defined in Figure 19-11.

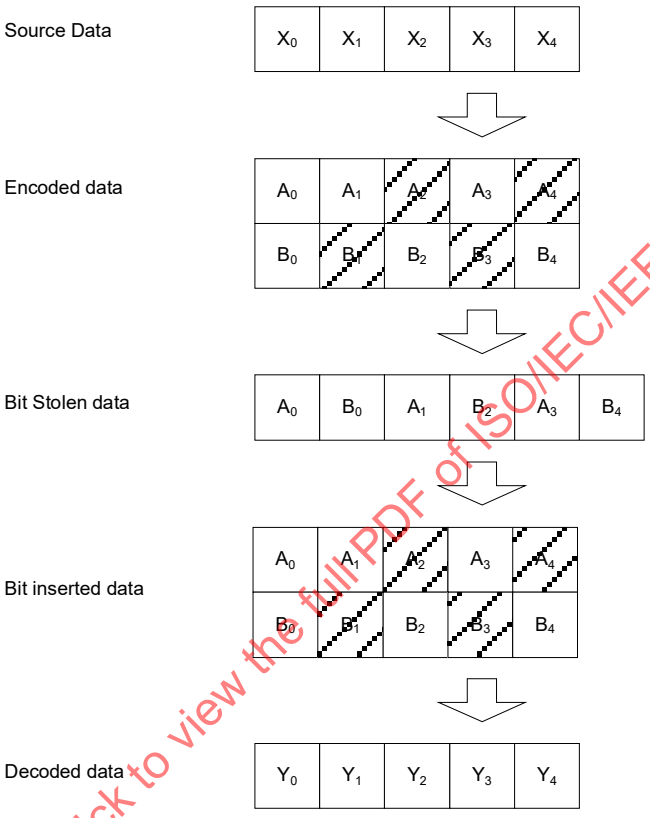

Figure 19-11—Puncturing at rate 5/6

19.3.11.7 LDPC codes

19.3.11.7.1 Introduction

HT LDPC codes are described in 19.3.11.7.2 to 19.3.11.7.6. These codes are optionally used in the HT system as a high-performance error correcting code instead of the convolutional code (19.3.11.6). The LDPC encoder shall use the rate-dependent parameters in Table 19-27 to Table 19-41, with the exception of the N_{ES} parameter.

Support for LDPC codes is optional.

19.3.11.7.2 LDPC coding rates and codeword block lengths

The supported coding rates, information block lengths, and codeword block lengths are described in Table 19-15.

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Table 19-15—LDPC parameters

Coding rate (R)	LDPC information block length (bits)	LDPC codeword block length (bits)
1/2	972	1944
1/2	648	1296
1/2	324	648
2/3	1296	1944
2/3	864	1296
2/3	432	648
3/4	1458	1944
3/4	972	1296
3/4	486	648
5/6	1620	1944
5/6	1080	1296
5/6	540	648

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19.3.11.7.3 LDPC encoder

For each of the three available codeword block lengths, the LDPC encoder supports rate 1/2, rate 2/3, rate 3/4, and rate 5/6 encoding. The LDPC encoder is systematic, i.e., it encodes an information block, $c=(i_0,i_1,\ldots, i_{(k-1)})$, of size k, into a codeword, **c**, of size n, $\mathbf{c}=(i_0,i_1,\ldots i_{(k-1)}, p_0, p_1,\ldots, p_{(n-k-1)})$, by adding $n-k$ parity bits obtained so that $\mathbf{H}\times\mathbf{c}^T = \mathbf{0}$, where **H** is an $(n-k)\times n$ parity-check matrix. The selection of the codeword block length (n) is achieved via the LDPC PPDU encoding process described in 19.3.11.7.5.

19.3.11.7.4 Parity-check matrices

Each of the parity-check matrices is partitioned into square subblocks (submatrices) of size $Z \times Z$. These submatrices are either cyclic-permutations of the identity matrix or null submatrices.

The cyclic-permutation matrix P_i is obtained from the $Z \times Z$ identity matrix by cyclically shifting the columns to the right by i elements. The matrix P_0 is the $Z \times Z$ identity matrix. Figure 19-12 illustrates examples (for a subblock size of 8 × 8) of cyclic-permutation matrices P_i.

Table F-1 displays the "matrix prototypes" of parity-check matrices for all four coding rates at block length n=648 bits. The integer i denotes the cyclic-permutation matrix P_i, as illustrated in Figure 19-12. Vacant entries of the table denote null (zero) submatrices.

Table F-2 displays the matrix prototypes of parity-check matrices for block length n=1296 bits, in the same fashion.

Table F-3 displays the matrix prototypes of parity-check matrices for block length n=1944 bits, in the same fashion.

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$$P_0 = \begin{bmatrix} 1&0&0&0&0&0&0&0\\ 0&1&0&0&0&0&0&0\\ 0&0&1&0&0&0&0&0\\ 0&0&0&1&0&0&0&0\\ 0&0&0&0&1&0&0&0\\ 0&0&0&0&0&1&0&0\\ 0&0&0&0&0&0&1&0\\ 0&0&0&0&0&0&0&1 \end{bmatrix}, P_1 = \begin{bmatrix} 0&1&0&0&0&0&0&0\\ 0&0&1&0&0&0&0&0\\ 0&0&0&1&0&0&0&0\\ 0&0&0&0&1&0&0&0\\ 0&0&0&0&0&1&0&0\\ 0&0&0&0&0&0&1&0\\ 0&0&0&0&0&0&0&1\\ 1&0&0&0&0&0&0&0 \end{bmatrix}, P_5 = \begin{bmatrix} 0&0&0&0&0&1&0&0\\ 0&0&0&0&0&0&1&0\\ 0&0&0&0&0&0&0&1\\ 1&0&0&0&0&0&0&0\\ 0&1&0&0&0&0&0&0\\ 0&0&1&0&0&0&0&0\\ 0&0&0&1&0&0&0&0\\ 0&0&0&0&1&0&0&0 \end{bmatrix}$$

Figure 19-12—Examples of cyclic-permutation matrices with *Z*=8

19.3.11.7.5 LDPC PPDU encoding process

To encode an LDPC PPDU, step a) to step g) shall be performed in sequence:

a) Compute the number of available bits, N_{avbits}, in the minimum number of OFDM symbols in which the Data field of the packet may fit.

$$N_{pld} = length \times 8 + 16 \tag{19-35}$$

$$N_{avbits} = N_{CBPS} \times m_{STBC} \times \left\lceil \frac{N_{pld}}{N_{CBPS} \times R \times m_{STBC}} \right\rceil \tag{19-36}$$

where

m_{STBC} is 2 if STBC is used and 1 otherwise
length is the value of the HT Length field in the HT-SIG field defined in Table 19-11
N_{pld} is the number of bits in the PSDU and SERVICE field

b) Compute the integer number of LDPC codewords to be transmitted, N_{CW}, and the length of the codewords to be used, L_{LDPC} from Table 19-16.

Table 19-16—PPDU encoding parameters

Range of N_{avbits} (bits)	Number of LDPC codewords (N_{CW})	LDPC codeword length L_{LDPC} (bits)
$N_{avbits} \le 648$	1	1296, if $N_{avbits} \ge N_{pld} + 912 \times (1\text{-}R)$ 648, otherwise
$648 < N_{avbits} \le 1296$	1	1944, if $N_{avbits} \ge N_{pld} + 1464 \times (1\text{-}R)$ 1296, otherwise
$1296 < N_{avbits} \le 1944$	1	1944
$1944 < N_{avbits} \le 2592$	2	1944, if $N_{avbits} \ge N_{pld} + 2916 \times (1\text{-}R)$ 1296, otherwise
$2592 < N_{avbits}$	$\left\lceil \frac{N_{pld}}{1944 \cdot R} \right\rceil$	1944

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c) Compute the number of shortening bits, N_{shrt}, to be padded to the N_{pld} data bits before encoding, as shown in Equation (19-37).

$$N_{shrt} = \max(0, (N_{CW} \times L_{LDPC} \times R) - N_{pld}) \quad (19\text{-}37)$$

When $N_{shrt} = 0$, shortening is not performed. (Note that N_{shrt} is inherently restricted to be non-negative due to the codeword length and count selection of Table 19-16). When $N_{shrt} > 0$, shortening bits shall be equally distributed over all N_{CW} codewords with the first N_{shrt} mod N_{CW} codewords shortened 1 bit more than the remaining codewords. Define $N_{spcw} = \lfloor N_{shrt} / N_{CW} \rfloor$. Then, when $N_{shrt} > 0$, the shortening is performed by setting information bits $i_{k-N_{spcw}-1}, \ldots, i_{k-1}$ to 0 in the first N_{shrt} mod N_{CW} codewords and setting information bits $i_{k-N_{spcw}}, \ldots, i_{k-1}$ to 0 in the remaining codewords. For all values of N_{shrt}, encode each of the N_{CW} codewords using the LDPC encoding technique described in 19.3.11.7.2 to 19.3.11.7.4. When $N_{shrt} > 0$, the shortened bits shall be discarded after encoding.

d) Compute the number of bits to be punctured, N_{punc}, from the codewords after encoding, as shown in Equation (19-38).

$$N_{punc} = \max(0, (N_{CW} \times L_{LDPC}) - N_{avbits} - N_{shrt}) \quad (19\text{-}38)$$

If $\left((N_{punc} > 0.1 \times N_{CW} \times L_{LDPC} \times (1-R)) \text{ AND } \left(N_{shrt} < 1.2 \times N_{punc} \times \frac{R}{1-R}\right)\right)$ is true OR if $(N_{punc} > 0.3 \times N_{CW} \times L_{LDPC} \times (1-R))$ is true, increment N_{avbits} and recompute N_{punc} by the following two equations once:

$$N_{avbits} = N_{avbits} + N_{CBPS} \times m_{STBC} \quad (19\text{-}39)$$

$$N_{punc} = \max(0, (N_{CW} \times L_{LDPC}) - N_{avbits} - N_{shrt}) \quad (19\text{-}40)$$

The punctured bits shall be equally distributed over all N_{CW} codewords with the first N_{punc} mod N_{CW} codewords punctured 1 bit more than the remaining codewords. Define $N_{\text{ppcw}} = \lfloor N_{\text{punc}} / N_{\text{CW}} \rfloor$. When $N_{\text{ppcw}} > 0$, the puncturing is performed by discarding parity bits $p_{n-k-N_{ppcw}-1}, \ldots, p_{n-k-1}$ of the first N_{punc} mod N_{CW} codewords and discarding parity bits $(p_{n-k-N_{ppcw}}, \ldots, p_{n-k-1})$ of the remaining codewords after encoding. The number of OFDM symbols to be transmitted in the PPDU is computed as shown in Equation (19-41).

$$N_{SYM} = N_{avbits} / N_{CBPS} \quad (19\text{-}41)$$

e) Compute the number of coded bits to be repeated, N_{rep}, as shown in Equation (19-42).

$$N_{rep} = \max(0, N_{avbits} - N_{CW} \times L_{LDPC} \times (1-R) - N_{pld}) \quad (19\text{-}42)$$

The number of coded bits to be repeated shall be equally distributed over all N_{CW} codewords with one more bit repeated for the first N_{rep} mod N_{CW} codewords than for the remaining codewords.

NOTE—When puncturing occurs, the coded bits are not repeated, and vice versa.

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The coded bits to be repeated for any codeword shall be copied only from that codeword itself, starting from information bit i_0 and continuing sequentially through the information bits and, when necessary, into the parity bits, until the required number of repeated bits is obtained for that codeword. Note that these repeated bits are copied from the codeword after the shortening bits have been removed. If for a codeword the required number of repeated bits are not obtained in this manner (i.e., repeating the codeword once), the procedure is repeated until the required number is achieved. These repeated bits are then concatenated to the codeword after the parity bits in their same order. This process is illustrated in Figure 19-13. In this figure, the outlined arrows indicate the encoding procedure steps, while the solid arrows indicate the direction of puncturing and padding with repeated bits.

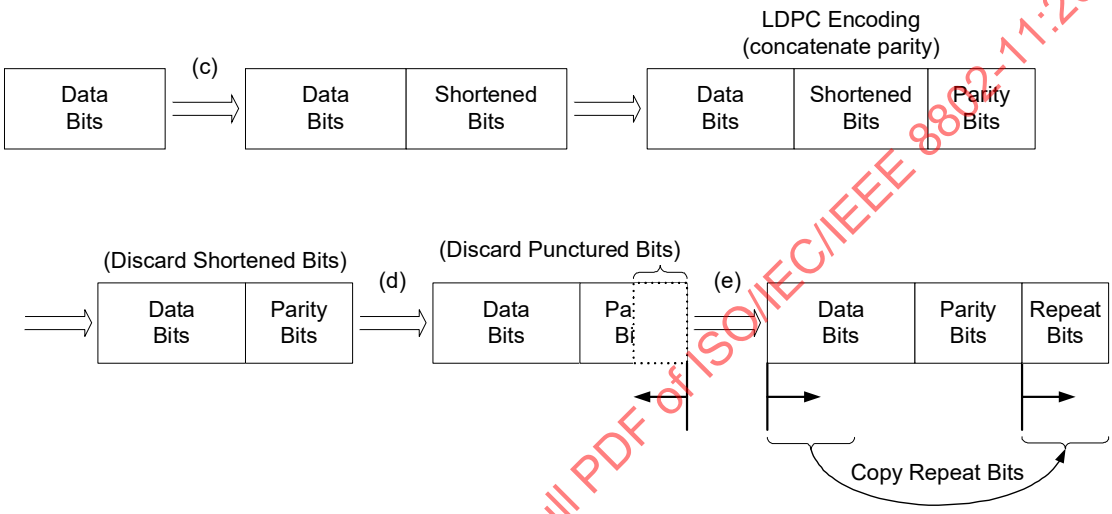

Figure 19-13—LDPC PPDU encoding padding and puncturing of a single codeword

f) For each of the N_{CW} codewords, process the data using the number of shortening bits per codeword as computed in step c) for encoding, and puncture or repeat bits per codeword as computed per step d) and step e), as illustrated in Figure 19-13.

g) Aggregate all codewords and parse as defined in 19.3.11.7.6.

19.3.11.7.6 LDPC parser

The succession of LDPC codewords that result from the encoding process of 19.3.11.7.5 shall be converted into a bitstream in sequential fashion. Within each codeword, bit i_0 is ordered first. The parsing of this encoded data stream into spatial streams shall follow exactly the parsing rules defined for the BCC encoder, as defined in 19.3.11.8.1. However, the frequency interleaver of 19.3.11.8.3 is bypassed.

19.3.11.8 Data interleaver

19.3.11.8.1 Overview

After coding and puncturing, the data bit streams at the output of the FEC encoders are rearranged into blocks of $N_{CBPSS}(i_{SS})$ bits, where $i_{SS} = 1, 2, \ldots N_{SS}$ is the spatial stream index. This operation is referred to as *stream parsing* and is described in 19.3.11.8.2. If BCC encoding was used, each of these blocks is then interleaved by an interleaver that is a modification of the Clause 17 interleaver.

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19.3.11.8.2 Stream parser

The number of bits assigned to a single axis (real or imaginary) in a constellation point in spatial stream i_{SS} is denoted by Equation (19-43).

$$s(i_{SS}) = \max\left\{1, \frac{N_{BPSCS}(i_{SS})}{2}\right\} \tag{19-43}$$

The sum of these over all streams is $S = \sum_{i_{SS}=1}^{N_{SS}} s(i_{SS})$.

NOTE—If equal MCS is used for all spatial streams, this sum becomes $N_{SS} \cdot s$, where s is the number of bits for an axis common to all streams.

Consecutive blocks of $s(i_{SS})$ bits are assigned to different spatial streams in a round robin fashion.

If two encoders are present, the output of each encoder is used alternately for each round robin cycle, i.e., at the beginning S bits from the output of first encoder are fed into all spatial streams, and then S bits from the output of second encoder are used, and so on.

Input k to spatial stream i_{SS} shall be $y_i^{(j)}$, which is output bit i of the encoder j,

where

$$j = \left\lfloor \frac{k}{s(i_{SS})} \right\rfloor \bmod N_{ES} \tag{19-44}$$

$$i = \sum_{i'=1}^{i_{SS}-1} s(i') + S \cdot \left\lfloor \frac{k}{N_{ES} \cdot s(i_{SS})} \right\rfloor + k \bmod s(i_{SS}) \tag{19-45}$$

$1 \le i_{SS} \le N_{SS}$

For $i_{SS} = 1$, the first term in Equation (19-45) has a value of 0.

19.3.11.8.3 Frequency interleaver

MCS 32 interleaving shall be as defined in 17.3.5.7. Interleaving for all other MCSs is defined in this subclause.

The bits at the output of the stream parser are divided into blocks of $N_{CBPSS}(i_{SS})$, $i_{SS} = 1, 2, \ldots N_{SS}$ bits; and if BCC encoding was used, each block shall be interleaved by an interleaver based on the Clause 17 interleaver. This interleaver, which is based on entering the data in rows and reading them out in columns, has a different number of columns and rows depending on whether a 20 MHz channel or a 40 MHz channel is used. Table 19-17 defines the interleaver parameters. If LDPC encoding was used, no frequency interleaving is performed; hence the parsed streams are immediately mapped to symbols as defined in 19.3.11.9.

If more than one spatial stream exists after the operations based on the Clause 17 interleaver have been applied, a third operation called *frequency rotation* shall be applied to the additional spatial streams. The parameter for the frequency rotation is N_{ROT}.

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Table 19-17—Number of rows and columns in the interleaver

Parameter	20 MHz	40 MHz
N_{COL}	13	18
N_{ROW}	$4 \times N_{BPSCS}(i_{SS})$	$6 \times N_{BPSCS}(i_{SS})$
N_{ROT}	11	29

The interleaving is defined using three permutations. The first permutation is defined by the rule shown in Equation (19-46).

$$i = N_{ROW} \times (k \bmod N_{COL}) + \lfloor k/N_{COL} \rfloor, \qquad k = 0, 1, \ldots, N_{CBPSS}(i_{SS}) - 1 \tag{19-46}$$

The second permutation is defined by the rule shown in Equation (19-47).

$$j = s(i_{SS}) \times \lfloor i/s(i_{SS}) \rfloor + (i + N_{CBPSS}(i_{SS}) - \lfloor N_{COL} \times i/N_{CBPSS}(i_{SS}) \rfloor) \bmod s(i_{SS}); \quad i = 0, 1, \ldots, N_{CBPSS}(i_{SS}) - 1 \tag{19-47}$$

The value of $s(i_{SS})$ is determined by the number of coded bits per subcarrier as shown in Equation (19-48).

$$s(i_{SS}) = \max(N_{BPSCS}(i_{SS})/2, 1) \tag{19-48}$$

If more than one spatial stream exists, a frequency rotation is applied to the output of the second permutation as shown in Equation (19-49).

$$r = \left(j - \left(((i_{SS} - 1) \times 2) \bmod 3 + 3 \times \left\lfloor \frac{i_{SS} - 1}{3} \right\rfloor\right) \times N_{ROT} \times N_{BPSCS}(i_{SS})\right) \bmod N_{CBPSS}(i_{SS}); \quad j = 0, 1, \ldots, N_{CBPSS}(i_{SS}) - 1 \tag{19-49}$$

where

$i_{SS} = 1, 2, \ldots, N_{SS}$ is the index of the spatial stream on which this interleaver is operating

The deinterleaver uses the following operations to perform the inverse rotation. The index of the bit in the received block (per spatial stream) is denoted by r. The first permutation reverses the third (frequency rotation) permutation of the interleaver as shown in Equation (19-50).

$$j = \left(r + \left(((i_{SS} - 1) \times 2) \bmod 3 + 3 \times \left\lfloor \frac{i_{SS} - 1}{3} \right\rfloor\right) \times N_{ROT} \times N_{BPSCS}(i_{SS})\right) \bmod N_{CBPSS}(i_{SS}); \quad r = 0, 1, \ldots, N_{CBPSS}(i_{SS}) - 1 \tag{19-50}$$

The second permutation reverses the second permutation in the interleaver as shown in Equation (19-51).

$$i = s(i_{SS}) \times \lfloor j/s(i_{SS}) \rfloor + (j + \lfloor N_{COL} \times j/N_{CBPSS}(i_{SS}) \rfloor) \bmod s(i_{SS}); \quad j = 0, 1, \ldots, N_{CBPSS}(i_{SS}) - 1 \tag{19-51}$$

where $s(i_{SS})$ is defined in Equation (19-48).

The third permutation reverses the first permutation of the interleaver as shown in Equation (19-52).

$$k = N_{COL} \times i - (N_{CBPSS}(i_{SS}) - 1) \times \lfloor i/N_{ROW} \rfloor \qquad i = 0, 1, \ldots, N_{CBPSS}(i_{SS}) - 1 \tag{19-52}$$

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19.3.11.9 Constellation mapping

19.3.11.9.1 General

The mapping between bits at the output of the interleaver and complex constellation points for BPSK, QPSK, 16-QAM, and 64-QAM follows the rules defined in 17.3.5.8.

The streams of complex numbers are denoted as shown in Equation (19-53).

$$d_{k,\,l,\,n},\ 0 \le k \le N_{SD}-1;1 \le l \le N_{SS};0 \le n \le N_{SYM}-1 \tag{19-53}$$

19.3.11.9.2 Space-time block coding (STBC)

This subclause defines a set of optional robust transmission formats that are applicable only when N_{STS} is greater than N_{SS}. In this case, N_{SS} spatial streams are mapped to N_{STS} space-time streams, which are mapped to N_{TX} transmit chains. These formats are based on STBC. When the use of STBC is indicated in the STBC field of the HT-SIG, a symbol operation shall occur between the constellation mapper and the spatial mapper (see Figure 19-3) as defined in this subclause.

If STBC is applied, the stream of complex numbers, $d_{k,\,i,\,n};k = 0\ldots N_{SD}-1;i = 1\ldots N_{SS};n = 0\ldots N_{SYM}-1$, generated by the constellation mapper, is the input of the STBC encoder, which produces as output the stream of complex numbers $\tilde{d}_{k,\,i,\,n};k = 0\ldots N_{SD}-1;i = 1\ldots N_{STS};n = 0\ldots N_{SYM}-1$. For given values of k and i, STBC processing operates on the complex modulation symbols in sequential pairs of OFDM symbols so that the value of $\tilde{d}_{k,\,i,\,2m}$ depends on $d_{k,\,i,\,2m}$ and $d_{k,\,i,\,2m+1}$, and $\tilde{d}_{k,\,i,\,2m+1}$ also depends on $d_{k,\,i,\,2m}$ and $d_{k,\,i,\,2m+1}$, as defined in Table 19-18.

Table 19-18—Constellation mapper output to spatial mapper input for STBC

N_{STS}	HT-SIG MCS field (bits 0–6 in HT-SIG$_1$)	N_{SS}	HT-SIG STBC field (bits 4–5 in HT-SIG$_2$)	i_{STS}	$\tilde{d}_{k,\,i,\,2m}$	$\tilde{d}_{k,\,i,\,2m+1}$
2	0–7	1	1	1	$d_{k,\,1,\,2m}$	$d_{k,\,1,\,2m+1}$
				2	$-d^{*}_{k,\,1,\,2m+1}$	$d^{*}_{k,\,1,\,2m}$
3	8–15, 33–38	2	1	1	$d_{k,\,1,\,2m}$	$d_{k,\,1,\,2m+1}$
				2	$-d^{*}_{k,\,1,\,2m+1}$	$d^{*}_{k,\,1,\,2m}$
				3	$d_{k,\,2,\,2m}$	$d_{k,\,2,\,2m+1}$

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Table 19-18—Constellation mapper output to spatial mapper input for STBC *(continued)*

N_{STS}	HT-SIG MCS field (bits 0–6 in HT-SIG$_1$)	N_{SS}	HT-SIG STBC field (bits 4–5 in HT-SIG$_2$)	i_{STS}	$\tilde{d}_{k,i,2m}$	$\tilde{d}_{k,i,2m+1}$
4	8–15	2	2	1	$d_{k,1,2m}$	$d_{k,1,2m+1}$
				2	$-d^{*}_{k,1,2m+1}$	$d^{*}_{k,1,2m}$
				3	$d_{k,2,2m}$	$d_{k,2,2m+1}$
				4	$-d^{*}_{k,2,2m+1}$	$d^{*}_{k,2,2m}$
4	16–23, 39, 41, 43, 46, 48, 50	3	1	1	$d_{k,1,2m}$	$d_{k,1,2m+1}$
				2	$-d^{*}_{k,1,2m+1}$	$d^{*}_{k,1,2m}$
				3	$d_{k,2,2m}$	$d_{k,2,2m+1}$
				4	$d_{k,3,2m}$	$d_{k,3,2m+1}$
NOTE—The '*' operator represents the complex conjugate.						

If STBC is not applied, $\tilde{d}_{k,i,n} = d_{k,i,n}$ and $N_{SS} = N_{STS}$.

NOTE 1—The specific STBC schemes for single spatial streams ($N_{SS} = 1$) with $N_{TX} \geq 3$ are not detailed in this subclause since they are covered through the use of spatial expansion as detailed in 19.3.11.11.2.

NOTE 2—STBC is applied only for the HT-SIG MCS field values specified in Table 19-18 and is not used with MCS 32.

19.3.11.10 Pilot subcarriers

In a 20 MHz transmission four pilot tones shall be inserted in the same subcarriers used in Clause 17, i.e., in subcarriers –21, –7, 7, and 21. The pilot sequence for the n^{th} symbols and $i_{STS}{}^{th}$ space-time stream shall be as shown in Equation (19-54).

$$P^{-28,28}_{(i_{STS},n)} = \{0,0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},n \bmod 4},0,0,0,0,0,0,0,0,0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},(n+1) \bmod 4},0,0,0,0,0,0,0,$$
$$0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},(n+2) \bmod 4},0,0,0,0,0,0,0,0,0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},(n+3) \bmod 4},0,0,0,0,0,0,0\} \quad (19\text{-}54)$$

In a 40 MHz transmission (excluding MCS 32; see 19.3.11.11.5), pilot signals shall be inserted in subcarriers –53, –25, –11, 11, 25, and 53. The pilot sequence for symbol n and space-time stream i_{STS} shall be as shown in Equation (19-55).

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$$P^{-58,58}_{(i_{STS},\,n)} = \{0, 0, 0, 0, 0, \Psi^{(N_{STS})}_{i_{STS},\,n \bmod 6}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,$$
$$0, 0, \Psi^{(N_{STS})}_{i_{STS},\,(n+1) \bmod 6}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \Psi^{(N_{STS})}_{i_{STS},\,(n+2) \bmod 6}, 0, 0, 0, 0, 0, 0, 0, 0, 0,$$
$$0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \Psi^{(N_{STS})}_{i_{STS},\,(n+3) \bmod 6}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \Psi^{(N_{STS})}_{i_{STS},\,(n+4) \bmod 6},$$
$$0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \Psi^{(N_{STS})}_{i_{STS},\,(n+5) \bmod 6}, 0, 0, 0, 0, 0\} \quad (19\text{-}55)$$

where the patterns $\Psi^{(N_{STS})}_{i_{STS},\,n}$ are defined in Table 19-19 and Table 19-20.

NOTE—For each space-time stream, there is a different pilot pattern, and the pilot patterns are cyclically rotated over symbols.

The basic patterns are also different according to the total number of space-time streams for the packet.

Table 19-19—Pilot values for 20 MHz transmission

N_{STS}	i_{STS}	$\Psi^{(N_{STS})}_{i_{STS},0}$	$\Psi^{(N_{STS})}_{i_{STS},1}$	$\Psi^{(N_{STS})}_{i_{STS},2}$	$\Psi^{(N_{STS})}_{i_{STS},3}$
1	1	1	1	1	–1
2	1	1	1	–1	–1
2	2	1	–1	–1	1
3	1	1	1	–1	–1
3	2	1	–1	1	–1
3	3	–1	1	1	–1
4	1	1	1	1	–1
4	2	1	1	–1	1
4	3	1	–1	1	1
4	4	–1	1	1	1

Table 19-20—Pilots values for 40 MHz transmission (excluding MCS 32)

N_{STS}	i_{STS}	$\Psi^{(N_{STS})}_{i_{STS},0}$	$\Psi^{(N_{STS})}_{i_{STS},1}$	$\Psi^{(N_{STS})}_{i_{STS},2}$	$\Psi^{(N_{STS})}_{i_{STS},3}$	$\Psi^{(N_{STS})}_{i_{STS},4}$	$\Psi^{(N_{STS})}_{i_{STS},5}$
1	1	1	1	1	–1	–1	1
2	1	1	1	–1	–1	–1	–1
2	2	1	1	1	–1	1	1
3	1	1	1	–1	–1	–1	–1
3	2	1	1	1	–1	1	1
3	3	1	–1	1	–1	–1	1

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Table 19-20—Pilots values for 40 MHz transmission (excluding MCS 32) *(continued)*

N_{STS}	i_{STS}	$\Psi^{(N_{STS})}_{i_{STS},0}$	$\Psi^{(N_{STS})}_{i_{STS},1}$	$\Psi^{(N_{STS})}_{i_{STS},2}$	$\Psi^{(N_{STS})}_{i_{STS},3}$	$\Psi^{(N_{STS})}_{i_{STS},4}$	$\Psi^{(N_{STS})}_{i_{STS},5}$
4	1	1	1	–1	–1	–1	–1
4	2	1	1	1	–1	1	1
4	3	1	–1	1	–1	–1	1
4	4	–1	1	1	1	–1	1

19.3.11.11 OFDM modulation

19.3.11.11.1 General

The time domain signal is composed from the stream of complex numbers as shown in Equation (19-56).

$$\tilde{d}_{k,l,n},\ 0 \le k \le N_{SD}-1;1 \le l \le N_{STS};0 \le n \le N_{SYM}-1 \tag{19-56}$$

and from the pilot signals. In a 40 MHz transmission, the upper subcarriers are rotated 90° relative to the lower subcarriers.

19.3.11.11.2 Spatial mapping

The transmitter may choose to rotate and/or scale the constellation mapper output vector (or the space-time block coder output, if applicable). This rotation and/or scaling is useful in the following cases:

— When there are more transmit chains than space-time streams, $N_{STS} < N_{TX}$
— As part of (an optional) sounding PPDU
— As part of (an optional) calibration procedure
— When the packet is transmitted using one of the (optional) beamforming techniques

If the data to be transmitted on subcarrier k on space-time stream i_{STS} are $X_k^{(i_{STS})}$, the transmitted data on the transmit chain i_{TX} shall be as shown in Equation (19-57).

$$r_{Field}^{(i_{TX})} = \frac{1}{\sqrt{N_{STS}\cdot N_{Field}^{Tone}}} w_{T_{Field}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX},i_{STS}} X_k^{(i_{STS})} \exp(j2\pi k\Delta_F(t - T_{CS}^{i_{STS}})) \tag{19-57}$$

where

$[Q_k]_{i_{TX},i_{STS}}$ is the element in row i_{TX} and column i_{STS} in a matrix Q_k with N_{TX} rows and N_{STS} columns; Q_k may be frequency dependent

Field is any field, as defined in 19.3.7, excluding L-STF, L-LTF, L-SIG, and HT-SIG in HT_MF PPDU

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Below are examples of spatial mapping matrices that might be used. There exist many other alternatives; implementation is not restricted to the spatial mapping matrices shown. The examples are as follows:

a) *Direct mapping*: Q_k is a diagonal matrix of unit magnitude complex values that takes one of two forms:

   1) $Q_k = \mathbf{I}$, the identity matrix

   2) A CSD matrix in which the diagonal elements represent cyclic shifts in the time domain: $[Q_k]_{i,i} = \exp(-j2\pi k\Delta_F\tau_{CS}^i)$, where τ_{CS}^i, $i = 1, \ldots, N_{TX}$ represents the CSD applied.

b) *Indirect mapping:* Q_k may be the product of a CSD matrix and a unitary matrix such as the Hadamard matrix or the Fourier matrix.

c) *Spatial expansion:* Q_k is the product of a CSD matrix and a square matrix formed of orthogonal columns. As an illustration:

   1) The spatial expansion may be performed by duplicating some of the N_{STS} streams to form the N_{TX} streams, with each stream being scaled by the normalization factor $\sqrt{N_{STS}/N_{TX}}$. The spatial expansion may be performed by using, for instance, one of the following matrices, denoted D, left-multiplied by a CSD matrix, denoted $M_{CSD}(k)$, and/or possibly multiplied by any unitary matrix. The resulting spatial mapping matrix is then $Q_k = M_{CSD}(k) \cdot D$, where D may take on one of the following values:

      i) N_{TX}=2, N_{STS}=1, $D = \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\end{bmatrix}^T$

      ii) N_{TX}=3, N_{STS}=1, $D = \frac{1}{\sqrt{3}}\begin{bmatrix}1 & 1 & 1\end{bmatrix}^T$

      iii) N_{TX}=4, N_{STS}=1, $D = \frac{1}{2}\begin{bmatrix}1 & 1 & 1 & 1\end{bmatrix}^T$

      iv) N_{TX}=3, N_{STS}=2, $D = \sqrt{\frac{2}{3}}\begin{bmatrix}1 & 0\\ 0 & 1\\ 1 & 0\end{bmatrix}$

      v) N_{TX}=4, N_{STS}=2, $D = \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 0\\ 0 & 1\\ 1 & 0\\ 0 & 1\end{bmatrix}$

      vi) N_{TX}=4, N_{STS}=3, $D = \frac{\sqrt{3}}{2}\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\\ 1 & 0 & 0\end{bmatrix}$

   2) Different spatial expansion over subcarriers should be used in HT-mixed format only and with the Smoothing bit equal to 0:

      i) N_{TX}=2, N_{STS}=1, $[Q_k]_{N_{STS}} = \begin{bmatrix}1 & 0\end{bmatrix}^T$ or $[Q_k]_{N_{STS}} = \begin{bmatrix}0 & 1\end{bmatrix}^T$

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ii) N_{TX}=3, N_{STS}=2, $[Q_k]_{N_{STS}} = \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix}$ or $\begin{bmatrix} 0 & 0 \\ 1 & 0 \\ 0 & 1 \end{bmatrix}$

iii) N_{TX}=4, N_{STS}=2, $[Q_k]_{N_{STS}} = \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix}, \begin{bmatrix} 0 & 0 \\ 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix}$ or $\begin{bmatrix} 0 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix}$

iv) N_{TX}=4, N_{STS}=3, $[Q_k]_{N_{STS}} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$ or $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

d) *Beamforming steering matrix:* Q_k is any matrix that improves the reception in the receiver based on some knowledge of the channel between the transmitter and the receiver. With transmit beamforming with explicit feedback, the steering matrix Q_k is determined using either H_{eff} for CSI feedback or V_k for noncompressed and compressed matrices feedback from the STA to which the beamformed packet is addressed.

When there are fewer space-time streams than transmit chains, the first N_{STS} columns of the matrices above that are square might be used.

The same matrix Q_k shall be applied to subcarrier k during all parts of the packet in HT-greenfield format and all parts of the packet following and including the HT-STF field in an HT-mixed format packet. This operation is transparent to the receiver.

When a beamforming steering matrix is applied, the Smoothing bit should be set to 0.

The CSD of Table 19-10 shall be applied at the input of the spatial mapper.

For the identity matrix direct mapping, the Smoothing bit should be set to 1.

If no spatial mapping is applied, the matrix Q_k is equal to the identity matrix and $N_{STS} = N_{TX}$.

Sounding PPDUs using spatial expansion shall use an orthonormal column matrix Q_k. When the number of rows and columns is equal, the orthonormal column matrix becomes a unitary matrix.

19.3.11.11.3 Transmission in 20 MHz HT format

For 20 MHz HT transmissions, the signal from transmit chain i_{TX}, $1 \le i_{TX} \le N_{TX}$ shall be as shown in Equation (19-58).

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$$r_{HT-DATA}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-DATA}^{Tone}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM})$$

$$\cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} ([Q_k]_{i_{TX}, i_{STS}} (\tilde{D}_{k, i_{STS}, n} + p_{n+z} P^k_{(i_{STS}, n)})$$

$$\cdot \exp(j2\pi k\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{STS}}))) \quad (19\text{-}58)$$

where

z is 3 in an HT-mixed format packet and 2 in an HT-greenfield format packet

p_n is defined in 17.3.5.10

$$\tilde{D}_{k, i_{STS}, n} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ \tilde{d}_{M^r(k), i_{STS}, n}, \text{otherwise} \end{cases}$$

$$M^r(k) = \begin{cases} k + 28, -28 \le k \le -22 \\ k + 27, -20 \le k \le -8 \\ k + 26, -6 \le k \le -1 \\ k + 25, 1 \le k \le 6 \\ k + 24, 8 \le k \le 20 \\ k + 23, 22 \le k \le 28 \end{cases}$$

$P^k_{(i_{STS}, n)}$ is defined in Equation (19-54)

19.3.11.11.4 Transmission in 40 MHz HT format

For 40 MHz HT transmissions, the signal from transmit chain i_{TX} shall be as shown in Equation (19-59).

$$r_{HT-DATA}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-DATA}^{Tone}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM})$$

$$\cdot \sum_{k=-N_{SR} i_{STS}=1}^{N_{SR}} \sum^{N_{STS}} ([Q_k]_{i_{TX}, i_{STS}} (\tilde{D}_{k, i_{STS}, n} + p_{n+z} P^k_{(i_{STS}, n)}) \Upsilon_k \quad (19\text{-}59)$$

$$\cdot \exp(j2\pi k\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{STS}})))$$

where

z is 3 in an HT-mixed format packet and 2 in an HT-greenfield format packet

p_n is defined in 17.3.5.10

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$$\tilde{D}_{k,i_{STS},n} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 25, \pm 53 \\ \tilde{d}_{M^r(k),i_{STS},n}, \text{otherwise} \end{cases}$$

$$M^r(k) = \begin{cases} k+58, -58 \le k \le -54 \\ k+57, -52 \le k \le -26 \\ k+56, -24 \le k \le -12 \\ k+55, -10 \le k \le -2 \\ k+52, 2 \le k \le 10 \\ k+51, 12 \le k \le 24 \\ k+50, 26 \le k \le 52 \\ k+49, 54 \le k \le 58 \end{cases}$$

$P^k_{(i_{STS},n)}$ is defined in Equation (19-55)

NOTE—The 90° rotation that is applied to the upper part of the 40 MHz channel is applied in the same way to the HT-STF, HT-LTF, and HT-SIG. The rotation applies to both pilots and the data in the upper part of the 40 MHz channel.

19.3.11.11.5 Transmission in MCS 32 format

The use of MCS 32 format is deprecated.

MCS 32 format provides the lowest transmission rate in 40 MHz. It is used only for one spatial stream and only with BPSK modulation and rate 1/2 coding.

In the MCS 32 format, the signal shall be as shown in Equation (19-60).

$$r^{i_{TX}}_{HT-DATA}(t) = \frac{1}{\sqrt{N^{Tone}_{HT-Duplicate}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-N_{SR}}^{N_{SR}} (D_{k,n} + p_{n+z}P_k)([Q_{k-32}]_{i_{TX},1} \exp(j2\pi(k-32)\Delta_F(t - nT_{SYM} - T_{GI})) + j[Q_{k+32}]_{i_{TX},1} \exp(j2\pi(k+32)\Delta_F(t - nT_{SYM} - T_{GI}))) \quad (19\text{-}60)$$

where

z is defined in 19.3.11.11.3

P_k and p_n are defined in 17.3.5.10

$D_{k,n}$ is defined in 19.3.9.4.3

N_{SR} has the value defined for non-HT 20 MHz transmission

$[Q_k]_{i_{TX},1}$ is an element from a vector of length N_{TX}, which may be frequency dependent

$N^{Tone}_{HT-Duplicate}$ is defined in Table 19-8

The rules of spatial expansion CSD limitation, as specified in 19.3.11.11.2, shall apply to $[Q_k]_{i_{TX},1}$.

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19.3.11.11.6 Transmission with a short GI

Short GI is used in the data field of the packet when the Short GI field in the HT-SIG is equal to 1. When it is used, the same formula for the formation of the signal shall be used as in 19.3.11.11.3, 19.3.11.11.4, and 19.3.11.11.5, with T_{GI} replaced by T_{GIS} and T_{SYM} replaced by T_{SYMS}.

NOTE—Short GI is not used in HT-greenfield format with one spatial stream, in which case the HT-SIG is immediately followed by data. It is very difficult to parse the HT-SIG in time to demodulate these data with the correct GI length if the GI length is not known in advance.

19.3.11.12 Non-HT duplicate transmission

Non-HT duplicate transmission is used to transmit to Clause 17 STAs, Clause 18 STAs, and Clause 19 STAs that may be present in either the upper or lower halves of the 40 MHz channel. The L-STF, L-LTF, and L-SIG shall be transmitted in the same way as in the HT 40 MHz transmission. The HT-SIG, HT-STF, and HT-LTF are not transmitted. Data transmission shall be as defined in Equation (19-61).

$$r^{i_{TX}}_{LEG-DUP}(t) = \frac{1}{\sqrt{N^{Tone}_{Non\text{-}HT\ Duplicate}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-26}^{26} (D_{k,n} + p_{n+1}P_k)(\exp(j2\pi(k-32)\Delta_F(t - nT_{SYM} - T_{GI} - T^{i_{TX}}_{CS})) + j\exp(j2\pi(k+32)\Delta_F(t - nT_{SYM} - T_{GI} - T^{i_{TX}}_{CS}))) \quad (19\text{-}61)$$

where

P_k and p_n are defined in 17.3.5.10

$D_{k,n}$ is defined in 19.3.9.4.3

$T^{i_{TX}}_{CS}$ represents the cyclic shift of the transmit chain i_{TX} and is defined in Table 19-9

$N^{Tone}_{Non\text{-}HT\ Duplicate}$ is defined in Table 19-8

19.3.12 Beamforming

19.3.12.1 General

Beamforming is a technique in which the beamformer utilizes the knowledge of the MIMO channel to generate a steering matrix Q_k that improves reception in the beamformee.

The equivalent complex baseband MIMO channel model (3×2 example) is one in which, when a vector $\mathbf{x}_k = [x_1, x_2, \ldots x_{N_{TX}}]^T$ is transmitted in subcarrier k, the received vector $\mathbf{y}_k = [y_1, y_2, \ldots y_{N_{RX}}]^T$ is modeled as shown in Equation (19-62).

$$\mathbf{y}_k = H_k\mathbf{x}_k + \mathbf{n} \quad (19\text{-}62)$$

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where

H_k is channel matrix of dimensions $N_{RX} \times N_{TX}$

n is white (spatially and temporally) Gaussian noise as illustrated in Figure 19-14

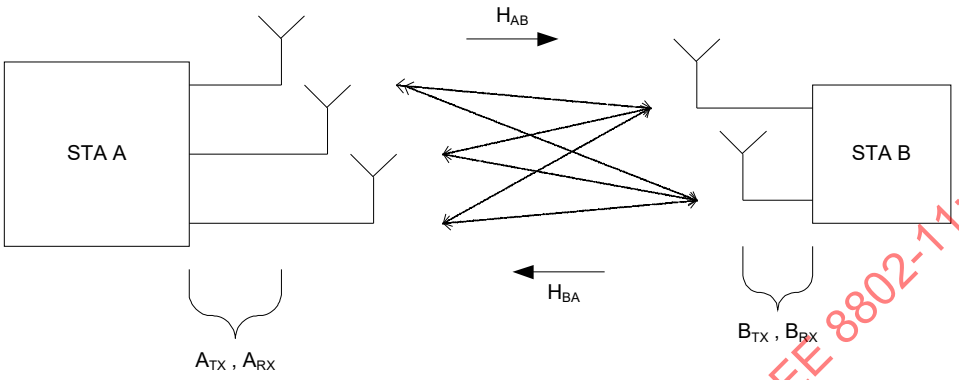

Figure 19-14—Beamforming MIMO channel model (3×2 example)

When beamforming is used, the beamformer replaces $\mathbf{x}_k$, which in this case has $N_{STS} \leq N_{TX}$ elements, with $Q_k\mathbf{x}_k$, where Q_k has N_{TX} rows and N_{STS} columns, so that the received vector is as shown in Equation (19-63).

$$\mathbf{y}_k = H_k Q_k \mathbf{x}_k + \mathbf{n} \tag{19-63}$$

The beamforming steering matrix that is computed (or updated) from a new channel measurement replaces the existing Q_k for the next beamformed data transmission. There are several methods of beamforming, differing in the way the beamformer acquires the knowledge of the channel matrices H_k and on whether the beamformer generates Q_k or the beamformee provides feedback information for the beamformer to generate Q_k.

19.3.12.2 Implicit feedback beamforming

Implicit feedback beamforming is a technique that relies on reciprocity in the time division duplex channel to estimate the channel over which a device is transmitting based on the MIMO reference that is received from the device to which it plans to transmit. This technique allows the transmitting device to calculate a set of transmit steering matrices, Q_k, one for each subcarrier, which are intended to optimize the performance of the link.

Referring to Figure 19-14, beamforming transmissions from STA A to STA B using implicit techniques are enabled when STA B sends STA A a sounding PPDU, the reception of which allows STA A to form an estimate of the MIMO channel from STA B to STA A, for all subcarriers. In a TDD channel in which the forward and reverse channels are reciprocal, the channel from STA A to STA B in subcarrier k is the matrix transpose of the channel from STA B to STA A in subcarrier k to within a complex scaling factor, i.e., $H_{\mathrm{AB},k} = \rho[H_{\mathrm{BA},k}]^T$. Here $H_{\mathrm{AB},k}$ is the MIMO channel matrix from STA A to STA B at subcarrier k, and $H_{\mathrm{BA},k}$ is the channel matrix from STA B to STA A at subcarrier k. STA A uses this relationship to compute transmit steering matrices that are suitable for transmitting to STA B over $H_{\mathrm{AB},k}$.

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NOTE 1—In order for the recipient of the sounding to compute steering matrices when steered or unsteered sounding is used, the steering matrices need to have the property $(H_k Q_k)(H_k Q_k)^H = H_k H_k^H$, where X^H indicates the conjugate transpose of the matrix X.

While the over-the-air channel between the antenna(s) at one STA and the antenna(s) at a second STA is reciprocal, the observed baseband-to-baseband channel used for communication might not be, as it includes the transmit and receive chains of the STAs. Differences in the amplitude and phase characteristics of the transmit and receive chains associated with individual antennas degrade the reciprocity of the over-the-air channel and cause degradation of performance of implicit beamforming techniques. The over-the-air calibration procedure described in 10.34.2.4 may be used to restore reciprocity. The procedure provides the means for calculating a set of correction matrices that can be applied at the transmit side of a STA to correct the amplitude and phase differences between the transmit and receive chains in the STA. If this correction is done at least at the STA that serves as the beamformer, there is sufficient reciprocity for implicit feedback in the baseband-to-baseband response of the forward link and reverse channel.

Figure 19-15 illustrates the observed baseband-to-baseband channel, including reciprocity correction. Spatial mapping matrices $Q_{\mathrm{A},k}$ and $Q_{\mathrm{B},k}$ are assumed to be identity matrices here for simplicity of illustration.

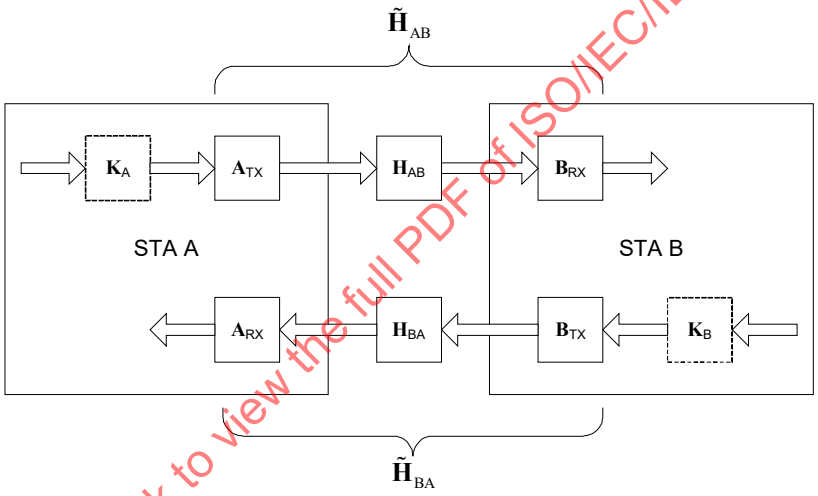

Figure 19-15—Baseband-to-baseband channel

NOTE 2—Spatial mapping matrix for sounding PPDUs are specified in 19.3.13.3.

The amplitude and phase responses of the transmit and receive chains can be expressed as diagonal matrices with complex valued diagonal entries, of the form $A_{TX,k}$ and $A_{RX,k}$ at STA A. The relationship between the baseband-to-baseband channel, $\tilde{H}_{\mathrm{AB},k}$, and the over-the-air channel, $H_{\mathrm{AB},k}$, is shown in Equation (19-64).

$$\tilde{H}_{\mathrm{AB},k} = B_{\mathrm{RX},k} H_{\mathrm{AB},k} A_{\mathrm{TX},k} \tag{19-64}$$

Similarly, the relationship between $\tilde{H}_{\mathrm{BA},k}$ and $H_{\mathrm{BA},k}$ is shown in Equation (19-65).

$$\tilde{H}_{\mathrm{BA},k} = A_{\mathrm{RX},k} H_{\mathrm{BA},k} B_{\mathrm{TX},k} \tag{19-65}$$

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As an example, consider the case where calibration is performed at both STA A and STA B. The objective is to compute correction matrices, $K_{A,k}$ and $K_{B,k}$, that restore reciprocity so that Equation (19-66) is true.

$$\tilde{H}_{AB,k}K_{A,k} = \rho[\tilde{H}_{BA,k}K_{B,k}]^{T} \quad (19\text{-}66)$$

The correction matrices are diagonal matrices with complex valued diagonal entries. The reciprocity condition in Equation (19-66) is enforced when Equation (19-67) and Equation (19-68) are true.

$$K_{A,k} = \alpha_{A,k}[A_{TX,k}]^{-1}A_{RX,k} \quad (19\text{-}67)$$

and

$$K_{B,k} = \alpha_{B,k}[B_{TX,k}]^{-1}B_{RX,k} \quad (19\text{-}68)$$

where $\alpha_{A,k}$ and $\alpha_{B,k}$ are complex valued scaling factors.

Using these expressions for the correction matrices, the calibrated baseband-to-baseband channel between STA A and STA B is expressed as shown in Equation (19-69).

$$\hat{H}_{AB,k} = \tilde{H}_{AB,k}K_{A,k} = \alpha_{A,k}B_{RX,k}H_{AB,k}A_{RX,k} \quad (19\text{-}69)$$

If both sides apply the correction matrices, the calibrated baseband-to-baseband channel between STA A and STA B is expressed as shown in Equation (19-70).

$$\hat{H}_{BA,k} = \alpha_{B,k}A_{RX,k}H_{BA,k}B_{RX,k} = \frac{\alpha_{B,k}}{\alpha_{A,k}}[\hat{H}_{AB,k}]^{T} \quad (19\text{-}70)$$

Focusing on STA A, the procedure for estimating $K_{A,k}$ is as follows:

a) STA A sends STA B a sounding PPDU, the reception of which allows STA B to estimate the channel matrices $\tilde{H}_{AB,k}$.

b) STA B sends STA A a sounding PPDU, the reception of which allows STA A to estimate the channel matrices $\tilde{H}_{BA,k}$.

c) STA B sends the quantized estimates of $\tilde{H}_{AB,k}$ to STA A.

d) STA A uses its local estimates of $\tilde{H}_{BA,k}$ and the quantized estimates of $\tilde{H}_{AB,k}$ received from STA B to compute the correction matrices $K_{A,k}$.

NOTE 3—When a nonidentity matrix is used for $Q_{A,k}$, STA A is responsible for accounting for the spatial mapping in its local channel estimate as well as in the quantized CSI fed back since the channel feedback received in step c) is actually $\tilde{H}_{AB,k}Q_{A,k}$ and not $\tilde{H}_{AB,k}$. Furthermore, since $Q_{B,k}$ is defined in 19.3.13.3, additional steps might be taken in STA A to remove the effect of $Q_{B,k}$ when computing the correction matrix $K_{A,k}$.

Steps a) and b) occur over a short time interval to so the channel changes as little as possible between measurements. A similar procedure is used to estimate $K_{B,k}$ at STA B. The details of the computation of the correction matrices is implementation specific and beyond the scope of this standard.

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19.3.12.3 Explicit feedback beamforming

19.3.12.3.1 General

In explicit beamforming, in order for STA A to transmit a beamformed packet to STA B, STA B measures the channel matrices and sends STA A either the effective channel, $H_{eff,k}$, or the beamforming feedback matrix, V_k, for STA A to determine a steering matrix, $Q_{\text{steer},k} = Q_k V_k$, with V_k found from $H_k Q_k$, where Q_k is the orthonormal spatial mapping matrix that was used to transmit the sounding PPDU that elicited the V_k feedback. The effective channel, $H_{eff,k} = H_k Q_k$, is the product of the spatial mapping matrix used on transmit with the channel matrix. When new steering matrix $Q_{\text{steer},k}$ is found, $Q_{\text{steer},k}$ may replace Q_k for the next beamformed data transmission.

NOTE—$Q_{\text{steer},k}$ is a mathematical term to update a new steering matrix for Q_k in the next beamformed data transmission.

19.3.12.3.2 CSI matrices feedback

In CSI matrices feedback, the beamformer receives the quantized MIMO channel matrix, H_{eff}, from the beamformee. The beamformer then may use this matrix to compute a set of transmit steering matrices, Q_k. The CSI matrix, H_{eff}, shall be determined from the transmitter spatial mapper input to the receiver FFT outputs. The beamformee shall remove the CSD in Table 19-10 from the measured channel matrix.

The matrices $H_{eff}(k)$, where k is the subcarrier index, are encoded so that applying the procedure in 19.3.12.3.3 optimally reconstructs the matrix.

19.3.12.3.3 CSI matrices feedback decoding procedure

The received, quantized matrix $H^q_{eff}(k)$ (of a specific subcarrier, k) shall be decoded as follows:

a) The real and imaginary parts of each element of the matrix, $H^{q(R)}_{eff(m,l)}(k)$ and $H^{q(I)}_{eff(m,l)}(k)$, are decoded as a pair of 2s complement numbers to create the complex element, where $1 \le m \le N_r$ and $1 \le l \le N_c$.

b) Each element in the matrix of subcarrier k is then scaled using the value in the carrier matrix amplitude field (3 bits), $M_H(k)$, interpreted as a positive integer, in decibels, as follows:

   1) Calculate the linear value as defined in Equation (19-71).
   2) Calculate decoded values of the real and imaginary parts of the matrix element as defined in Equation (19-72) and Equation (19-73).

$$r(k) = 10^{M_H(k)/20} \tag{19-71}$$

$$\text{Re}\{\tilde{H}_{eff(m,l)}(k)\} = \frac{H^{q(R)}_{eff(m,l)}(k)}{r(k)} \tag{19-72}$$

$$\text{Im}\{\tilde{H}_{eff(m,l)}(k)\} = \frac{H^{q(I)}_{eff(m,l)}(k)}{r(k)} \tag{19-73}$$

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19.3.12.3.4 Example of CSI matrices feedback encoding

The following is an example of an encoding process:

a) The maximums of the real and imaginary parts of each element of the matrix in each subcarrier are found, as defined by Equation (19-74).

$$m_H(k) = \max\left\{\max\left\{\left|\mathrm{Re}(H_{eff(m,l)}(k))\right|_{m=1,l=1}^{m=N_r,l=N_c}\right\}, \max\left\{\left|\mathrm{Im}(H_{eff(m,l)}(k))\right|_{m=1,l=1}^{m=N_r,l=N_c}\right\}\right\} \quad (19\text{-}74)$$

b) The scaling ratio is calculated and quantized to 3 bits as defined by Equation (19-75). A linear scaler is given by Equation (19-76).

$$M_H(k) = \min\left\{7, \left\lfloor 20\log_{10}\left(\frac{\max\{m_H(z)\}_{z=-N_{SR}}^{z=N_{SR}}}{m_H(k)}\right)\right\rfloor\right\} \quad (19\text{-}75)$$

where

$$M_H^{\mathrm{lin}}(k) = \frac{\max\{m_H(z)\}_{z=-N_{SR}}^{z=N_{SR}}}{10^{M_H(k)/20}} \quad (19\text{-}76)$$

c) The real and imaginary parts of each element in the matrix $H_{eff(m,l)}(k)$ are quantized to N_b bits in 2s complement encoding as defined by Equation (19-77) and Equation (19-78).

$$H_{eff(m,l)}^{q(R)}(k) = \left\lfloor \frac{\mathrm{Re}\{H_{eff(m,l)}(k)\}}{M_H^{\mathrm{lin}}(k)}(2^{N_b-1}-1)+0.5 \right\rfloor \quad (19\text{-}77)$$

$$H_{eff(m,l)}^{q(I)}(k) = \left\lfloor \frac{\mathrm{Im}\{H_{eff(m,l)}(k)\}}{M_H^{\mathrm{lin}}(k)}(2^{N_b-1}-1)+0.5 \right\rfloor \quad (19\text{-}78)$$

Each matrix is encoded using $3+2\times N_b\times N_r\times N_c$ bits, where N_r and N_c are the number of rows and columns, respectively, in the channel matrix estimate computed by the receiving station and where N_b may have the value of 4, 5, 6, or 8 bits.

19.3.12.3.5 Noncompressed beamforming feedback matrix

In noncompressed beamforming feedback matrix, the beamformee shall remove the space-time stream CSD in Table 19-10 from the measured channel before computing a set of matrices for feedback to the beamformer. The beamforming feedback matrices, $V(k)$, found by the beamformee are sent to the beamformer in the order of real and imaginary components per tone as specified in 9.4.1.28. The beamformer might use these matrices to determine the steering matrices, Q_k.

The beamformee shall encode the matrices $V(k)$ so a beamformer applying the procedure below optimally reconstructs the matrix.

The received matrix $V^q(k)$ (of a specific subcarrier k) shall be decoded as follows:

a) The real and imaginary parts of each element of the matrix, $V_{m,l}^{q,R}$ and $V_{m,l}^{q,I}$, shall be decoded as a pair of 2s complement numbers to create the complex element, where $1 \le m \le N_r$ and $1 \le l \le N_c$.

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b) The dimensions of the beamforming feedback matrices are $N_r \times N_c$, where N_r and N_c are the number of rows and columns, respectively, in the beamforming feedback matrix computed by the receiving station. Each matrix is encoded using $2 \times N_b \times N_r \times N_c$ bits. N_b may have the value of 2, 4, 6, or 8 bits.

c) Columns $1 \ldots N_c$ of the beamforming feedback matrix correspond to spatial streams $1 \ldots N_c$, respectively. The mapping of spatial stream to modulation is defined in the MCS tables in 19.5. A transmitter shall not reorder the columns of the beamforming feedback matrices.

19.3.12.3.6 Compressed beamforming feedback matrix

In compressed beamforming feedback matrix, the beamformee shall remove the space-time stream CSD in Table 19-10 from the measured channel before computing a set of matrices for feedback to the beamformer. The beamforming feedback matrices, $V(k)$, found by the beamformee are compressed in the form of angles, which are sent to the beamformer. The beamformer might use these angles to decompress the matrices and determine the steering matrices Q_k.

The matrix V per tone shall be compressed as follows: The $N_r \times N_c$ beamforming feedback orthonormal column matrix V found by the beamformee shall be represented as shown in Equation (19-79). When the number of rows and columns is equal, the orthonormal column matrix becomes a unitary matrix.

$$V = \left[\prod_{i=1}^{\min(N_c, N_r - 1)} \left[D_i \left(1_{i-1} \; e^{j\phi_{i,i}} \; \ldots \; e^{j\phi_{N_r-1,i}} \; 1 \right) \prod_{l=i+1}^{N_r} G_{li}^{T}(\psi_{li}) \right] \right] \tilde{I}_{N_r \times N_c} \tag{19-79}$$

The matrix $D_i\left(1_{i-1} \; e^{j\phi_{i,i}} \; \ldots \; e^{j\phi_{N_r-1,i}} \; 1 \right)$ is an $N_r \times N_r$ diagonal matrix, where 1_{i-1} represents a sequence of 1s with length of *i*–1, as shown in Equation (19-80).

$$D\left(1_{i-1} \; e^{j\phi_{i,i}} \ldots \; e^{j\phi_{N_r-1,i}} \; 1\right) = \begin{bmatrix} I_{i-1} & 0 & \ldots & \ldots & 0 \\ 0 & e^{j\phi_{i,i}} & 0 & \ldots & 0 \\ \ldots & 0 & \ddots & 0 & 0 \\ \ldots & \ldots & 0 & e^{j\phi_{N_r-1,i}} & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \tag{19-80}$$

The matrix $G_{li}(\psi)$ is an $N_r \times N_r$ Givens rotation matrix as shown in Equation (19-81).

$$G_{li}(\psi) = \begin{bmatrix} I_{i-1} & 0 & 0 & 0 & 0 \\ 0 & \cos(\psi) & 0 & \sin(\psi) & 0 \\ 0 & 0 & I_{l-i-1} & 0 & 0 \\ 0 & -\sin(\psi) & 0 & \cos(\psi) & 0 \\ 0 & 0 & 0 & 0 & I_{N_r-l} \end{bmatrix} \tag{19-81}$$

where each I_m is an $m \times m$ identity matrix, and $\cos(\psi)$ and $\sin(\psi)$ are located at row *l* and column *i*. $\tilde{I}_{N_r \times N_c}$ is an identity matrix padded with 0s to fill the additional rows or columns when $N_r \neq N_c$.

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For example, a 4×2 V matrix has the representation shown in Equation (19-82).

$$V = \begin{bmatrix} e^{j\phi_{11}} & 0 & 0 & 0 \\ 0 & e^{j\phi_{21}} & 0 & 0 \\ 0 & 0 & e^{j\phi_{31}} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} \cos\psi_{21} & \sin\psi_{21} & 0 & 0 \\ -\sin\psi_{21} & \cos\psi_{21} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}^T \times \begin{bmatrix} \cos\psi_{31} & 0 & \sin\psi_{31} & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\psi_{31} & 0 & \cos\psi_{31} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}^T \times \begin{bmatrix} \cos\psi_{41} & 0 & 0 & \sin\psi_{41} \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\sin\psi_{41} & 0 & 0 & \cos\psi_{41} \end{bmatrix}^T$$
$$\times \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & e^{j\phi_{22}} & 0 & 0 \\ 0 & 0 & e^{j\phi_{32}} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\psi_{32} & \sin\psi_{32} & 0 \\ 0 & -\sin\psi_{32} & \cos\psi_{32} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}^T \times \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\psi_{42} & 0 & \sin\psi_{42} \\ 0 & 0 & 1 & 0 \\ 0 & -\sin\psi_{42} & 0 & \cos\psi_{42} \end{bmatrix}^T \times \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \\ 0 & 0 \end{bmatrix} \quad (19\text{-}82)$$

The procedure for finding a compressed V matrix is described as follows:

A $N_r \times N_c$ beamforming feedback orthonormal column matrix V is column-wise phase invariant because the steering matrix needs a reference in phase per each column. When the number of rows and columns is equal, the orthonormal column matrix becomes a unitary matrix. In other words, V is equivalent to $\tilde{V}\tilde{D}$, where $\tilde{D}$ is a column-wise phase shift matrix such as $\tilde{D} = \text{diag}\left(e^{j\theta_1}, e^{j\theta_2}, \ldots, e^{j\theta_{N_c}}\right)$. When the beamformee estimates the channel, it may find $\tilde{V}$ for the beamforming feedback matrix for the beamformer, but it should send $\tilde{V}\tilde{D}$ back to the beamformer, where $V = \tilde{V}\tilde{D}$. The angle, θ_i, in $\tilde{D}$ is found to make the last row of $\tilde{V}\tilde{D}$ to be non-negative real numbers.

The angles $\phi_{1,1} \ldots \phi_{N_r-1,1}$ in the diagonal matrix $D_1\left(e^{j\phi_{11}} \ldots e^{j\phi_{N_r-1,1}} \; 1\right)^*$ shall satisfy the constraint that all elements in the first column of $D_1^* V$ are non-negative real numbers. Now, the first column of $(G_{N_r1} \ldots G_{31} G_{21} D_1^*) \times V$ can be $\begin{bmatrix} 1 & 0 & \ldots & 0 \end{bmatrix}^T$ by the Givens rotations G_{l1} such as shown in Equation (19-83).

$$\begin{bmatrix} \cos\psi_{N_r1} & 0 & 0 & \sin\psi_{N_r1} \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\sin\psi_{N_r1} & 0 & 0 & \cos\psi_{N_r1} \end{bmatrix} \ldots \begin{bmatrix} \cos\psi_{31} & 0 & \sin\psi_{31} & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\psi_{31} & 0 & \cos\psi_{31} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\psi_{21} & \sin\psi_{21} & 0 & 0 \\ -\sin\psi_{21} & \cos\psi_{21} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e^{j\phi_{11}} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & e^{j\phi_{N_r-1,1}} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}^* \times V = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & & & \\ 0 & & V_2 & \\ 0 & & & \end{bmatrix} \quad (19\text{-}83)$$

For a new $(N_r - 1) \times (N_c - 1)$ submatrix V_2, this process is applied in the same way. Then, the angles $\phi_{2,2} \ldots \phi_{N_r-1,2}$ in the diagonal matrix $D_2\left(1 \; e^{j\phi_{22}} \ldots e^{j\phi_{N_r-1,2}} \; 1\right)^*$ shall satisfy the constraint that all elements in the second column of $D_2^* \times \text{diag}(1, V_2)$ are non-negative real numbers. Now, the first two columns of $(G_{N_r2} \ldots G_{32} D_2^*)(G_{N_r1} \ldots G_{31} G_{21} D_1^*) \times V$ can be $\tilde{I}_{N_r \times 2}$ by the Givens rotations G_{l2} such as shown in Equation (19-84).

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$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\psi_{N_r,2} & 0 & \sin\psi_{N_r,2} \\ 0 & 0 & 1 & 0 \\ 0 & -\sin\psi_{N_r,2} & 0 & \cos\psi_{N_r,2} \end{bmatrix} \cdots \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\psi_{32} & \sin\psi_{32} & 0 \\ 0 & -\sin\psi_{32} & \cos\psi_{32} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & e^{j\phi_{22}} & 0 & 0 \\ 0 & 0 & e^{j\phi_{N_r-1,2}} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}^* \times G_{N,1} \cdots G_{31} G_{21} D_1^* \times V = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & & \\ 0 & 0 & V_3 & \end{bmatrix} \quad (19\text{-}84)$$

This process continues until the first N_c columns of the right side matrix become $\tilde{I}_{N_r \times N_c}$. When $N_c < N_r$, this process does not need to continue because V_{N_c+1} is nulled out by $\tilde{I}_{N_r \times N_c}$. Then, by multiplying the complex conjugate transpose of the products of the D_i and G_{li} matrices on the left, V can be expressed as shown in Equation (19-85).

$$V = D_1 G_{21}^T G_{31}^T \cdots G_{N_r,1}^T \times D_2 G_{32}^T G_{42}^T \cdots G_{N_r,2}^T \times \ldots \times D_p G_{p+1,p}^T G_{p+2,p}^T \cdots G_{N_r,p}^T \times \tilde{I}_{N_r \times N_C} \quad (19\text{-}85)$$

where $p = \min(N_c, N_r - 1)$, which can be written in short form as in Equation (19-79).

The angles found from the decomposition process above, e.g., the values of $\psi_{i,j}$ and $\phi_{k,l}$, are quantized as described in 9.6.11.7.

Columns $1 \ldots N_c$ of the beamforming feedback matrix correspond to spatial streams $1 \ldots N_c$, respectively. The mapping of spatial stream to modulation is defined in the MCS tables in 19.5. A transmitter shall not reorder the columns of the beamforming feedback matrices in determining steering matrices.

19.3.13 HT Preamble format for sounding PPDUs

19.3.13.1 General

The MIMO channel measurement takes place in every PPDU as a result of transmitting the HT-LTFs as part of the PHY preamble. The number of HT-LTFs transmitted shall be determined by the number of space-time streams transmitted unless additional dimensions are optionally sounded using HT-ELTFs and these are transmitted using the same spatial transformation that is used for the Data field of the HT PPDU. The use of the same spatial transformation enables the computation of the spatial equalization at the receiver.

When the number of space-time streams, N_{STS}, is less than the number of transmit antennas, or less than $\min(N_{TX}, N_{RX})$, sending only N_{STS} HT-LTFs does not allow the receiver to recover a full characterization of the MIMO channel, even though the resulting MIMO channel measurement is sufficient for receiving the Data field of the HT PPDU.

However, it is often desirable to obtain as full a characterization of the channel as possible. This involves the transmission of a sufficient number of HT-LTFs to sound the full dimensionality of the channel, which is in some cases N_{TX} and in other cases $\min(N_{TX}, N_{RX})$. These cases of MIMO channel measurement are referred to as *MIMO channel sounding*. A sounding PPDU may be used to sound available channel dimensions. A sounding PPDU is identified by setting the Not Sounding field in the HT-SIG to 0. A sounding PPDU may have any allowed number of HT-LTFs satisfying $N_{HT\text{-}LTF} \geq N_{STS}$. In general, if the Not Sounding field in the HT-SIG is equal to 0 and $N_{HT\text{-}LTF} > N_{STS}$, HT-ELTFs are used, except where $N_{SS} = 3$ and $N_{HT\text{-}LTF} = 4$ or in an NDP.

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19.3.13.2 Sounding with a NDP

A STA may sound the channel using a NDP (indicated by the HT Length field in the HT-SIG equal to 0) with the Not Sounding field equal to 0. The number of LTFs is the number implied by the MCS, which shall indicate two or more spatial streams. The last HT-LTF of an NDP shall not be followed by a Data field (see Figure 19-16).

It is optional for a STA to process an NDP.

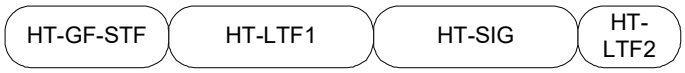

Figure 19-16—Example of an NDP used for sounding

19.3.13.3 Sounding PPDU for calibration

In the case of a bidirectional calibration exchange, two STAs exchange sounding PPDUs, the exchange of which enables the receiving STA to compute an estimate of the MIMO channel matrix H_k for each subcarrier k. In general, in an exchange of calibration messages, the number of spatial streams is less than the number of transmit antennas. In such cases, HT-ELTFs are used. In the case of sounding PPDUs for calibration, the antenna mapping matrix shall be as shown in Equation (19-86).

$$Q_k = C_{CSD}(k)P_{CAL} \tag{19-86}$$

where

$C_{CSD}(k)$ is a diagonal cyclic shift matrix in which the diagonal elements carry frequency domain representation of the cyclic shifts given in Table 19-9

P_{CAL} is one of the following unitary matrices:

For $N_{TX} = 1, P_{CAL} = 1$

For $N_{TX} = 2, P_{CAL} = \frac{\sqrt{2}}{2}\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}$

For $N_{TX} = 3, P_{CAL} = \frac{\sqrt{3}}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & e^{-j2\pi/3} & e^{-j4\pi/3} \\ 1 & e^{-j4\pi/3} & e^{-j2\pi/3} \end{bmatrix}$

For $N_{TX} = 4, P_{CAL} = \frac{1}{2}\begin{bmatrix} 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \\ -1 & 1 & 1 & 1 \end{bmatrix}$

19.3.13.4 Sounding PPDU for channel quality assessment

In response to an MRQ, sent by STA A to STA B, the responding STA B returns to the requesting STA A an MCS selection that STA B determines to be a suitable MCS for STA A to use in subsequent transmissions to STA B. In determining the MCS, STA B performs a channel quality assessment, which entails using whatever information STA B has about the channel, such as an estimate of the MIMO channel derived from

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the sounding PPDU that carries the MRQ. To enable this calculation, the MRQ is sent in conjunction with a sounding PPDU.

The STA sending the MRQ (STA A) determines how many HT-LTFs to send, and whether to use HT-ELTFs or an NDP, based on the Transmit Beamforming Capabilities field, number of space-time streams used in the PPDU carrying the MRQ, the number of transmit chains it is using (N_{TX}), whether the transmit and receive STAs support STBC, and in some cases, the number of receive chains at the responding STA (N_{RX}).

The maximum number of available space-time streams is set by the number of transmit and receive chains and the STBC capabilities of the transmitter and receiver, as is shown in Table 19-21. While the number of receive chains is not communicated in a capabilities indicator, the maximum number of space-time streams supported may be inferred from the MCS capabilities and the STBC capabilities of the receiving STA. When the number of receive chains is known at the transmitter, the number of HT-LTFs sent to obtain a full channel quality assessment is determined according to the maximum number of space-time streams indicated in Table 19-21. The number of HT-LTFs to use in conjunction with the indicated number of space-time streams is determined according to 19.3.9.4.6.

Table 19-21—Maximum available space-time streams

N_{TX}	N_{RX}	$N_{STS,\,max}$ without STBC	$N_{STS,\,max}$ with STBC
1	1	1	N/A
2	1	1	2
3	1	1	2
3	2	2	3
4	1	1	2
4	2	2	4

If the requesting STA A sends an MRQ in a PPDU that uses fewer space-time streams in the data portion than the maximum number of space-time streams possible given the number of antennas at STA A and the responding STA B, the channel quality assessment made by STA B may be based on the HT-DLTFs alone. In this case, the MFB is limited to MCSs using the number of streams used in the Data field of the HT PPDU, or fewer. To determine whether an MCS should be chosen that uses more spatial streams than the PPDU containing the MRQ, it is necessary for the requesting STA A to either use HT-ELTFs (i.e., send the MRQ in a staggered sounding PPDU) or use an NDP (i.e., send the MRQ in conjunction with an NDP).

The sounding PPDU may have nonidentity spatial mapping matrix Q_k. For different receiving STAs, Q_k may vary.

19.3.14 Regulatory requirements

Wireless LANs (WLANs) implemented in accordance with this standard are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The PHY specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regulations are subject to revision or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PHY

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specification. Regulatory requirements that do not affect interoperability are not addressed in this standard. Implementers are referred to the regulatory sources in Annex D for further information. Operation in countries within defined regulatory domains may be subject to additional or alternative national regulations.

19.3.15 Channel numbering and channelization

19.3.15.1 General

The STA may operate in the 5 GHz band and/or 2.4 GHz band. When using 20 MHz channels, it uses channels defined in 17.3.8.4 (5 GHz band) or 16.3.6 (2.4 GHz band). When using 40 MHz channels, it can operate in the channels defined in 19.3.15.2 and 19.3.15.3.

The set of valid operating channel numbers by regulatory domain is defined in Annex E.

19.3.15.2 Channel allocation in the 2.4 GHz band

Channel center frequencies are defined at every integer multiple of 5 MHz in the 2.4 GHz band. The relationship between center frequency and channel number is given by Equation (19-87).

$$\text{Channel center frequency} = 2407 + 5 \times n_{ch}(\text{MHz}) \quad (19\text{-}87)$$

where

n_{ch} = 1, 2, …, 13

19.3.15.3 Channel allocation in the 5 GHz band

Channel center frequencies are defined at every integer multiple of 5 MHz above the channel starting frequency. The relationship between center frequency and channel number is given in Equation (19-88).

$$\text{Channel center frequency} = \text{Channel starting frequency} + 5 \times n_{ch}(\text{MHz}) \quad (19\text{-}88)$$

where

n_{ch} = 1, …, 200

Channel starting frequency is defined as dot11ChannelStartingFactor × 500 kHz or is defined as 5 GHz where dot11OperatingClassesRequired is false or not defined.

A channel center frequency of 5 GHz shall be indicated by dot11ChannelStartingFactor = 8000 and n_{ch} = 200.

19.3.15.4 40 MHz channelization

The set of valid operating channel numbers by regulatory domain is defined in Annex E.

The 40 MHz channels are specified by two fields: (*Nprimary_ch*, *Secondary*). The first field represents the channel number of the primary channel, and the second field indicates whether the secondary channel is above or below the primary channel (1 indicates above, –1 indicates below). The secondary channel number shall be $Nprimary_ch + Secondary \times 4$.

For example, a 40 MHz channel consisting of 40 MHz channel number 36 and Secondary 1 specifies the primary channel is 36 and the secondary channel is 40.

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19.3.16 Slot time

The slot time shall follow 17.3.8.6 for 5 GHz bands and 18.5.4 for 2.4 GHz bands.

The slot time for 40 MHz channel spacing shall be the same as that for 20 MHz channel spacing.

19.3.17 Transmit and receive impedance at the antenna connector

The impedance at the transmit antenna connector and receive antenna connector for each transmit and receive antenna shall follow 17.3.8.7.

19.3.18 PHY transmit specification

19.3.18.1 Transmit spectrum mask

NOTE 1—In the presence of additional regulatory restrictions, the device has to meet both the regulatory requirements and the mask defined in this subclause, i.e., its emissions can be no higher at any frequency offset than the minimum of the values specified in the regulatory and default masks.

NOTE 2—The transmit spectral mask figures in this subclause are not drawn to scale.

For rules regarding TX center frequency leakage levels by VHT STAs, see 21.3.17.4.2.

For the 2.4 GHz band, when transmitting in a 20 MHz channel, the transmitted spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and the maximum of –45 dBr and –53 dBm/MHz at 30 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 19-17. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

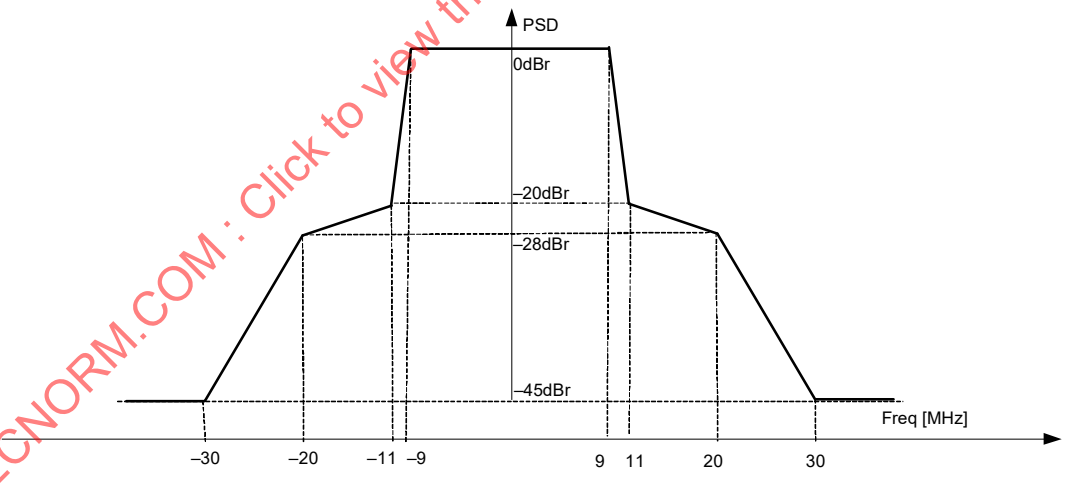

Figure 19-17—Transmit spectral mask for 20 MHz transmission in the 2.4 GHz band

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For the 2.4 GHz band, when transmitting in a 40 MHz channel, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 38 MHz, –20 dBr at 21 MHz frequency offset, –28 dBr at 40 MHz offset, and the maximum of –45 dBr and –56 dBm/MHz at 60 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 19-18.

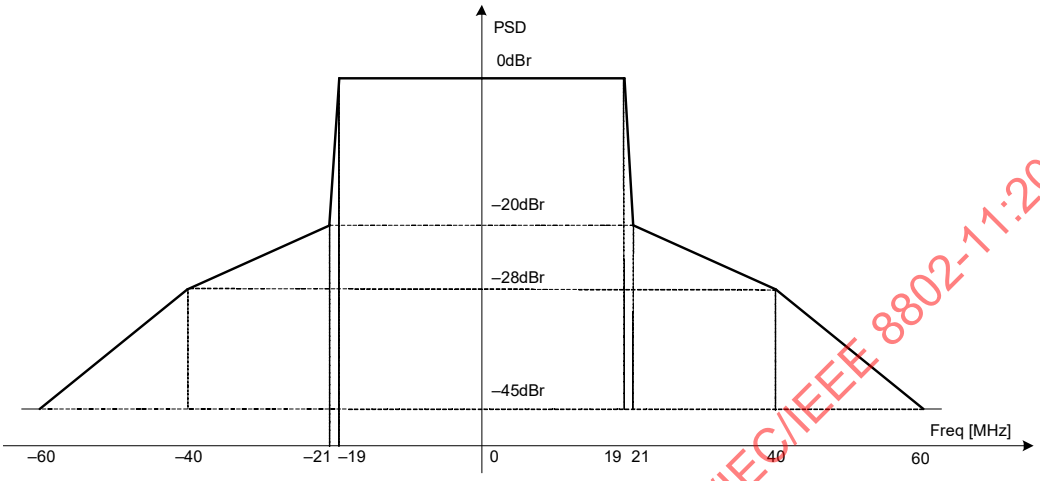

Figure 19-18—Transmit spectral mask for a 40 MHz channel in the 2.4 GHz band

For the 5 GHz band, when transmitting in a 20 MHz channel, the transmitted spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and the maximum of –40 dBr and –53 dBm/MHz at 30 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 19-19. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

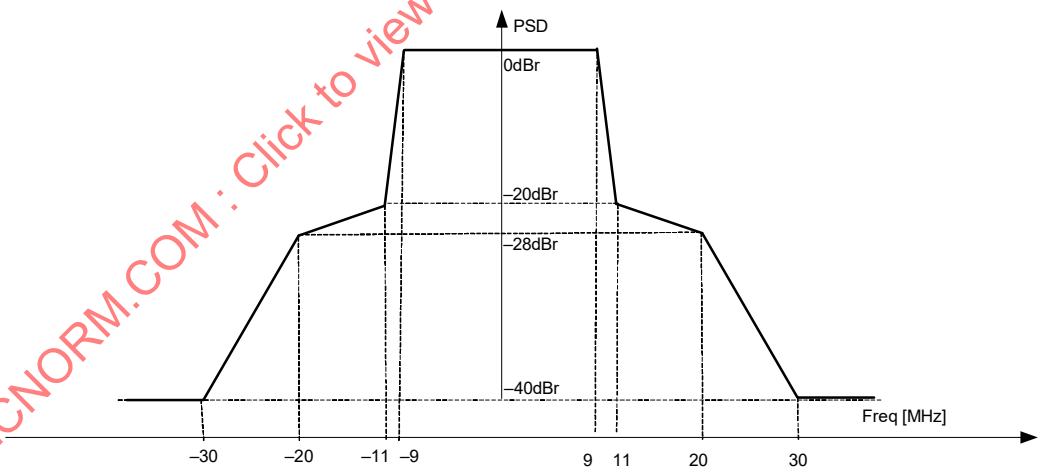

Figure 19-19—Transmit spectral mask for 20 MHz transmission in the 5 GHz band

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For the 5 GHz band, when transmitting in a 40 MHz channel, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 38 MHz, –20 dBr at 21 MHz frequency offset, –28 dBr at 40 MHz offset, and the maximum of –40 dBr and –56 dBm/MHz at 60 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 19-20.

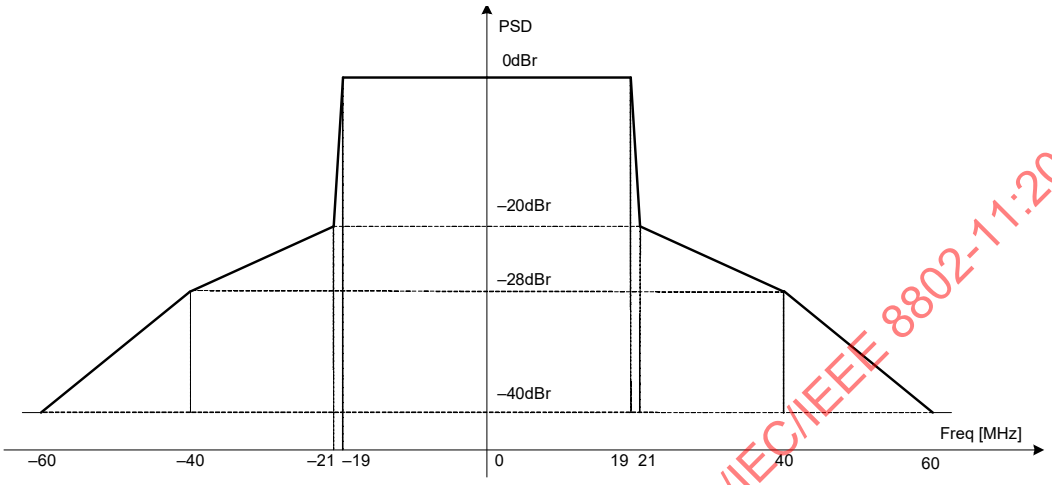

Figure 19-20—Transmit spectral mask for a 40 MHz channel in the 5 GHz band

Transmission with CH_OFF_20U, CH_OFF_20L, or CH_OFF_40 shall comply with the same mask that is used for the 40 MHz channel.

19.3.18.2 Spectral flatness

In a 20 MHz channel and in corresponding 20 MHz transmission in a 40 MHz channel, the average energy of the constellations in each of the subcarriers with indices –16 to –1 and +1 to +16 shall deviate no more than ± 4 dB from their average energy. The average energy of the constellations in each of the subcarriers with indices –28 to –17 and +17 to +28 shall deviate no more than +4/–6 dB from the average energy of subcarriers with indices –16 to –1 and +1 to +16.

In a 40 MHz transmission (excluding PPDUs in MCS 32 format and non-HT duplicate format), the average energy of the constellations in each of the subcarriers with indices –42 to –2 and +2 to +42 shall deviate no more than ± 4 dB from their average energy. The average energy of the constellations in each of the subcarriers with indices –43 to –58 and +43 to +58 shall deviate no more than +4/–6 dB from the average energy of subcarriers with indices –42 to –2 and +2 to +42.

In MCS 32 format and non-HT duplicate format, the average energy of the constellations in each of the subcarriers with indices –42 to –33, –31 to –6, +6 to +31, and +33 to +42 shall deviate no more than ± 4 dB from their average energy. The average energy of the constellations in each of the subcarriers with indices –43 to –58 and +43 to +58 shall deviate no more than +4/–6 dB from the average energy of subcarriers with indices –42 to –33, –31 to –6, +6 to +31, and +33 to +42.

The tests for the spectral flatness requirements may be performed with spatial mapping $Q_k = \mathbf{I}$ (see 19.3.11.11.2).

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19.3.18.3 Transmit power

The maximum allowable output power is measured in accordance with practices specified by the appropriate regulatory bodies.

19.3.18.4 Transmit center frequency tolerance

The transmitter center frequency tolerance shall be ± 20 ppm for the 5 GHz band and ± 25 ppm for the 2.4 GHz band. The different transmit chain center frequencies (LO) and each transmit chain symbol clock frequency shall all be derived from the same reference oscillator.

19.3.18.5 Packet alignment

If no signal extension is required (see 19.3.2), the receiver shall emit a PHY-CCA.indication(IDLE) primitive (see 8.3.5.12) at the 4 µs boundary following the reception of the last symbol of the packet. If a signal extension is required, the receiver shall emit a PHY-CCA.indication(IDLE) primitive a duration of aSignalExtension after the 4 µs boundary following the reception of the last symbol of the packet. This situation is illustrated for an HT-greenfield format packet using short GI in Figure 19-21.

If no signal extension is required, the transmitter shall emit a PHY-TXEND.confirm primitive (see 8.3.5.8) at the 4 µs boundary following the trailing boundary of the last symbol of the PPDU on the WM. If a signal extension is required, the transmitter shall emit a PHY-TXEND.confirm primitive (see 8.3.5.8) a duration of aSignalExtension after the 4 µs boundary following the trailing boundary of the last symbol of the PPDU on the WM. This situation is illustrated in Figure 19-21.

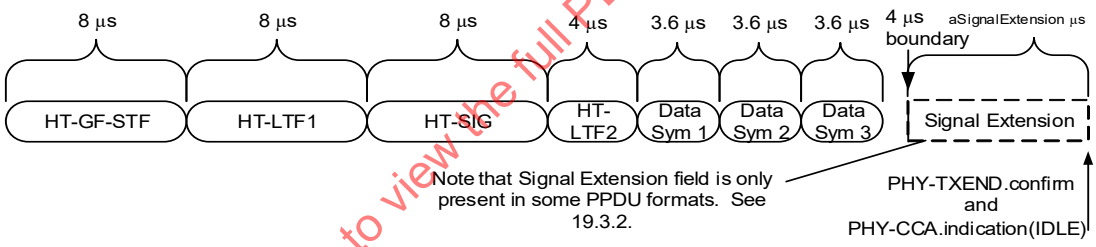

Figure 19-21—PHY-TXEND.confirm alignment (HT-greenfield format with short GI)

19.3.18.6 Symbol clock frequency tolerance

The symbol clock frequency tolerance shall be ± 20 ppm for 5 GHz bands and ± 25 ppm for 2.4 GHz bands. The transmit center frequency and the symbol clock frequency for all transmit antennas shall be derived from the same reference oscillator.

19.3.18.7 Modulation accuracy

19.3.18.7.1 Introduction to modulation accuracy tests

Transmit modulation accuracy specifications are described in 19.3.18.7.2 and 19.3.18.7.3. The test method is described in 19.3.18.7.4.

19.3.18.7.2 Transmit center frequency leakage

For VHT STAs the requirements on transmitter center frequency leakage are defined in 21.3.17.4.2; otherwise, the requirements are defined in this subclause.

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The transmitter center frequency leakage shall follow 17.3.9.7.2 for all transmissions in a 20 MHz channel width. For transmissions in a 40 MHz channel width, the center frequency leakage shall not exceed $max(P-20,-20)$ dBm, or, equivalently, 0 dB relative to the average energy of the rest of the subcarriers. For upper or lower 20 MHz transmissions in a 40 MHz channel, the center frequency leakage (center of a 40 MHz channel) shall not exceed $max(P-17,-20)$ dBm. The transmit center frequency leakage is specified per antenna.

19.3.18.7.3 Transmitter constellation error

The relative constellation frame-averaged RMS error, calculated first by averaging over subcarriers, OFDM frames, and spatial streams, shall not exceed a data-rate-dependent value according to Table 19-22. The number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized testing instrumentation input ports. In the test, $N_{SS} = N_{STS}$ with EQM MCSs shall be used and no beamforming steering matrix shall be used. Each output port of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The same requirement applies both to 20 MHz channels and 40 MHz channels.

Table 19-22—Allowed relative constellation error versus constellation size and coding rate

Modulation	Coding rate	Relative constellation error (dB)
BPSK	1/2	–5
QPSK	1/2	–10
QPSK	3/4	–13
16-QAM	1/2	–16
16-QAM	3/4	–19
64-QAM	2/3	–22
64-QAM	3/4	–25
64-QAM	5/6	–27

19.3.18.7.4 Transmitter modulation accuracy (EVM) test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signals into a streams of complex samples at 40 Msample/s or more, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, and analog-to-digital quantization noise. Each transmit chain is connected directly through a cable to the setup input port. A possible embodiment of such a setup is converting the signals to a low intermediate frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope, and decomposing it digitally into quadrature components. The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or an equivalent procedure:

a) Detect the start of frame.
b) Detect the transition from short sequences to channel estimation sequences, and establish fine timing (with one sample resolution).
c) Estimate the coarse and fine frequency offsets.

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d) Derotate the frame according to estimated frequency offset.

e) Estimate the complex channel response coefficients for each of the subcarriers and each of the transmit chains.

f) For each of the data OFDM symbols, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers in all spatial streams, derotate the subcarrier values according to estimated phase, group the results from all of the receiver chains in each subcarrier to a vector, multiply the vector by a zero-forcing equalization matrix generated from the channel estimated during the channel estimation phase.

g) For each data-carrying subcarrier in each spatial stream, find the closest constellation point and compute the Euclidean distance from it.

h) Compute the average of the RMS of all errors in a frame. It is given by Equation (19-89).

$$Error_{RMS} = \frac{\sum_{i_f=1}^{N_f} \sqrt{\frac{\sum_{i_s=1}^{N_{SYM}} \left[\sum_{i_{ss}=1}^{N_{SS}} \left(\sum_{i_{sc}=1}^{N_{ST}} \left((I(i_f, i_s, i_{ss}, i_{sc}) - I_0(i_f, i_s, i_{ss}, i_{sc}))^2 + (Q(i_f, i_s, i_{ss}, i_{sc}) - Q_0(i_f, i_s, i_{ss}, i_{sc}))^2 \right) \right) \right]}{N_{SYM} \times N_{SS} \times N_{ST} \times P_0}}}{N_f} \quad (19\text{-}89)$$

where

N_f is the number of frames for the measurement

$I_0(i_f, i_s, i_{ss}, i_{sc}), Q_0(i_f, i_s, i_{ss}, i_{sc})$ denotes the ideal symbol point in the complex plane in subcarrier i_{sc}, spatial stream i_{ss}, and OFDM symbol i_s of frame i_f

$I(i_f, i_s, i_{ss}, i_{sc}), Q(i_f, i_s, i_{ss}, i_{sc})$ denotes the observed symbol point in the complex plane in subcarrier i_{sc}, spatial stream i_{ss}, and OFDM symbol i_s of frame i_f

P_0 is the average power of the constellation

The vector error on a phase plane is shown in Figure 17-16.

The test shall be performed over at least 20 frames (N_f), and the average of the RMS shall be taken. The frames under test shall be at least 16 OFDM symbols long. Random data shall be used for the symbols.

19.3.18.8 Time of Departure accuracy

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is

$20 \times 10^6 \left(1 + \left\lceil \frac{f_H - f_L}{20\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to HT_CBW20

$40 \times 10^6 \left(1 + \left\lceil \frac{f_H - f_L}{40\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to HT_CBW40

where

f_H is the nominal center frequency in Hz of the highest channel in the channel set

f_L is the nominal center frequency in Hz of the lowest channel in the channel set, the channel set is the set of channels upon which frames providing measurements are transmitted, the channel set comprises channels uniformly spaced across $f_H - f_L \geq 50$ MHz

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— FIRST_TRANSITION_FIELD is L-STF (for HT-mixed format) or HT-GF-STF (for HT-greenfield format)
— SECOND_TRANSITION_FIELD is L-LTF (for HT-mixed format) or HT-GF-LTF1 (for HT-greenfield format)
— TRAINING_FIELD is L-LTF (for HT-mixed format) or HT-LTF1 (for HT-greenfield format) windowed in a manner which should approximate the windowing described in 17.3.2.5 with T_{TR} = 100 ns.
— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns (for a CH_BANDWIDTH parameter equal to HT_CBW20) or 80 ns (for a CH_BANDWIDTH parameter equal to HT_CBW40).

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

19.3.19 HT PHY receiver specification

19.3.19.1 Receiver minimum input sensitivity

The packet error ratio (PER) shall be less than 10% for a PSDU length of 4096 octets with the rate-dependent input levels listed in Table 19-23 or less. The minimum input levels are measured at the antenna connector and are referenced as the average power per receive antenna. The number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized device under test input ports. Each output port of the transmitting STA shall be connected through a cable to one input port of the device under test. The test in this subclause and the minimum sensitivity levels specified in Table 19-23 apply only to non-STBC modes, MCSs 0–31, 800 ns GI, and BCC.

Table 19-23—Receiver minimum input level sensitivity

Modulation	Rate (R)	Adjacent channel rejection (dB)	Nonadjacent channel rejection (dB)	Minimum sensitivity (20 MHz channel spacing) (dBm)	Minimum sensitivity (40 MHz channel spacing) (dBm)
BPSK	1/2	16	32	–82	–79
QPSK	1/2	13	29	–79	–76
QPSK	3/4	11	27	–77	–74
16-QAM	1/2	8	24	–74	–71
16-QAM	3/4	4	20	–70	–67
64-QAM	2/3	0	16	–66	–63
64-QAM	3/4	–1	15	–65	–62
64-QAM	5/6	–2	14	–64	–61

19.3.19.2 Adjacent channel rejection

For all transmissions in a 20 MHz channel width, the adjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 19-23 and raising the power of an interfering signal of 20 MHz bandwidth until 10% PER is caused for a PSDU length

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of 4096 octets. The difference in power between the signals in the interfering channel and the desired channel is the corresponding adjacent channel rejection. The adjacent channel center frequencies shall be separated by 20 MHz when operating in the 5 GHz band, and the adjacent channel center frequencies shall be separated by 25 MHz when operating in the 2.4 GHz band.

For all transmissions in a 40 MHz channel width, the adjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 19-23 and raising the power of an interfering signal of 40 MHz bandwidth until 10% PER is caused for a PSDU length of 4096 octets. The difference in power between the signals in the interfering channel and the desired channel is the corresponding adjacent channel rejection. The adjacent channel center frequencies shall be separated by 40 MHz.

The interfering signal in the adjacent channel shall be a signal compliant with the HT PHY, unsynchronized with the signal in the channel under test. The corresponding rejection shall be no less than specified in Table 19-23. The interference signal shall have a minimum duty cycle of 50%.

The test in this subclause and the adjacent channel rejection levels specified in Table 19-23 apply only to non-STBC modes, MCSs 0–31, 800 ns GI, and BCC.

19.3.19.3 Nonadjacent channel rejection

For all transmissions in a 20 MHz channel width in the 5 GHz band, the nonadjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 19-23 and raising the power of an interfering signal of 20 MHz bandwidth until a 10% PER occurs for a PSDU length of 4096 octets. The difference in power between the signals in the interfering channel and the desired channel is the corresponding nonadjacent channel rejection. The nonadjacent channel center frequencies shall be separated by 40 MHz or more.

For all transmissions in a 40 MHz channel width in the 5 GHz band, the nonadjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 19-23 and raising the power of an interfering signal of 40 MHz bandwidth until a 10% PER occurs for a PSDU length of 4096 octets. The difference in power between the signals in the interfering channel and the desired channel is the corresponding nonadjacent channel rejection. The nonadjacent channel center frequencies shall be separated by 80 MHz or more.

The interfering signal in the nonadjacent channel shall be a signal compliant with the HT PHY, unsynchronized with the signal in the channel under test. The corresponding rejection shall be no less than specified in Table 19-23. The interference signal shall have a minimum duty cycle of 50%. The nonadjacent channel rejection for transmissions in a 20 MHz or 40 MHz channel width is applicable only to 5 GHz band.

The test in this subclause and the nonadjacent channel rejection level specified in Table 19-23 apply only to non-STBC modes, MCSs 0–31, 800 ns GI, and BCC.

19.3.19.4 Receiver maximum input level

The receiver shall provide a maximum PER of 10% at a PSDU length of 4096 octets, for a maximum input level of –30 dBm in the 5 GHz band and –20 dBm in the 2.4 GHz band, measured at each antenna for any baseband modulation.

19.3.19.5 CCA sensitivity

19.3.19.5.1 General

The thresholds in this subclause are compared with the signal level at each receiving antenna.

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19.3.19.5.2 CCA-Energy Detect (CCA-ED)

For the operating classes requiring CCA-Energy Detect (CCA-ED), the PHY shall also indicate a medium busy condition when CCA-ED detects a channel busy condition.

For improved spectrum sharing, CCA-ED is required in some bands. The behavior class indicating CCA-ED is given in Table D-2. The operating classes requiring the corresponding CCA-ED behavior class are given in E.1. The PHY of a STA that is operating within an operating class that requires CCA-ED shall operate with CCA-ED.

CCA-ED shall detect a channel busy condition when the received signal strength exceeds the CCA-ED threshold as given by dot11OFDMEDThreshold for the primary channel and dot11OFDMEDThreshold for the secondary channel (if present). The CCA-ED thresholds for the operating classes requiring CCA-ED are subject to the criteria in D.2.5.

NOTE—The requirement to detect a channel busy condition as stated in 19.3.19.5.3, 19.3.19.5.4, and 19.3.19.5.5 is a mandatory energy detection requirement on all Clause 19 receivers. Support for CCA-ED is an additional requirement that relates specifically to the sensitivities described in D.2.5.

19.3.19.5.3 CCA sensitivity for non-HT PPDUs

CCA sensitivity requirements for non-HT PPDUs in the primary channel are described in 17.3.10.6 and 18.4.6.

19.3.19.5.4 CCA sensitivity in 20 MHz

For an HT STA with the operating channel width equal to 20 MHz, the start of a 20 MHz HT signal at a receive level greater than or equal to the minimum modulation and coding rate sensitivity of –82 dBm shall cause the PHY to set PHY-CCA.indication(BUSY) with a probability > 90% within 4 μs. The receiver shall indicate a channel busy condition for any signal 20 dB or more above the minimum modulation and coding rate sensitivity (–82 + 20 = –62 dBm) in the 20 MHz channel.

An HT STA that does not support the reception of HT_GF PPDUs shall indicate a channel busy condition [PHY-CCA.indication(BUSY)] for any valid HT_GF signal in the 20 MHz channel at a receive level greater than or equal to –72 dBm.

19.3.19.5.5 CCA sensitivity in 40 MHz

This subclause describes the CCA sensitivity requirements for an HT STA with the operating channel width equal to 40 MHz.

The receiver of a 20/40 MHz STA with the operating channel width equal to 40 MHz shall provide CCA on both the primary and secondary channels.

When the secondary channel is idle, the start of a 20 MHz HT signal in the primary channel at a receive level greater than or equal to the minimum modulation and coding rate sensitivity of –82 dBm shall cause the PHY to generate a PHY-CCA.indication(BUSY, {primary}) primitive with a probability > 90% within 4 μs. The start of a 40 MHz HT signal that occupies both the primary and secondary channels at a receive level greater than or equal to the minimum modulation and coding rate sensitivity of –79 dBm shall cause the PHY to generate a PHY-CCA.indication(BUSY, {primary, secondary}) primitive for both the primary and secondary channels with a probability per channel > 90% within 4 μs.

An HT STA that does not support the reception of HT_GF PPDUs shall indicate a {primary} channel busy condition (PHY-CCA.indication(BUSY, {primary}) primitive) for any valid HT_GF signal in the primary

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channel at a receive level greater than or equal to –72 dBm when the secondary channel is idle. An HT STA that does not support the reception of HT_GF PPDUs shall indicate a {primary, secondary} channel busy condition (PHY-CCA.indication(BUSY, {primary, secondary}) primitive) for any valid 40 MHz HT_GF signal in both the primary and secondary channels at a receive level greater than or equal to –69 dBm.

The receiver shall indicate a {primary} channel busy condition for any signal at or above –62 dBm in the 20 MHz primary channel. This level is 20 dB above the minimum modulation and coding rate sensitivity for a 20 MHz PPDU. When the primary channel is idle, the receiver indicate a {secondary} channel busy condition for any signal at or above –62 dBm in the 20 MHz secondary channel. The receiver shall indicate a {primary, secondary} channel busy condition for any signal present in both the primary and secondary channels that is at or above –62 dBm in the primary channel and at or above –62 dBm in the secondary channel.

19.3.19.6 Received channel power indicator (RCPI) measurement

The RCPI is a measure of the received RF power in the selected channel for a received frame. This parameter shall be a measure by the PHY of the received RF power in the channel measured over the data portion of the received frame. The received power shall be the average of the power in all active receive chains.

The RCPI encoding is defined in 9.4.2.37.

RCPI shall equal the received RF power within an accuracy of ± 5 dB (95% confidence interval) within the specified dynamic range of the receiver. The received RF power shall be determined assuming a receiver noise equivalent bandwidth equal to the channel width multiplied by 1.1.

19.3.19.7 Reduced interframe space (RIFS)

The receiver shall be able to decode a PPDU that was transmitted with a RIFS separation from the previous PPDU.

19.3.20 PHY transmit procedure

There are three options for the transmit PHY procedure. The first two options, for which typical transmit procedures are shown in Figure 19-22 and Figure 19-23, are selected if the FORMAT field of the PHY-TXSTART.request(TXVECTOR) primitive is equal to HT_MF or HT_GF, respectively. These transmit procedures do not describe the operation of optional features, such as LDPC or STBC. The third option is to follow the transmit procedure in Clause 17 or Clause 18 if the FORMAT field is equal to NON_HT. Additionally, if the FORMAT field is equal to NON_HT, CH_BANDWIDTH indicates NON_HT_CBW20, and NON_HT_MODULATION indicates OFDM, follow the transmit procedure in Clause 17. If the FORMAT field is equal to NON_HT, CH_BANDWIDTH indicates NON_HT_CBW20, and NON_HT_MODULATION indicates other than OFDM, follow the transmit procedure in Clause 18. And furthermore, if the FORMAT field is equal to NON_HT and CH_BANDWIDTH indicates NON_HT_CBW40, follow the transmit procedure in Clause 17, except that the signal in Clause 17 is generated simultaneously on each of the upper and lower 20 MHz channels that constitute the 40 MHz channel as defined in 19.3.8 and 19.3.11.12. In all these options, in order to transmit data, the PHY-TXSTART.request primitive shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate frequency through station management via the PLME, as specified in 19.4. Other transmit parameters, such as MCS coding types and transmit power, are set via the PHY SAP with the PHY-TXSTART.request(TXVECTOR) primitive, as described in 19.2.2.

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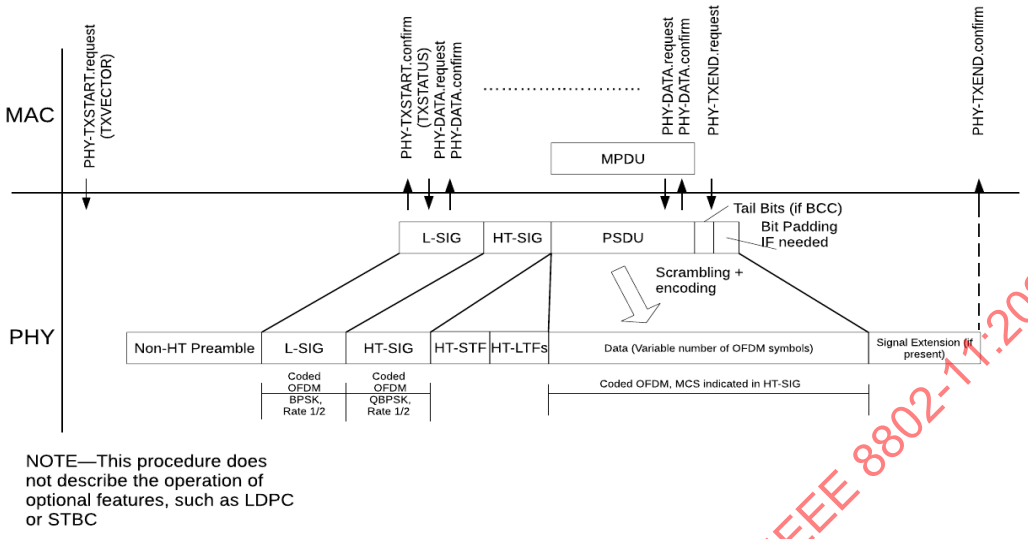
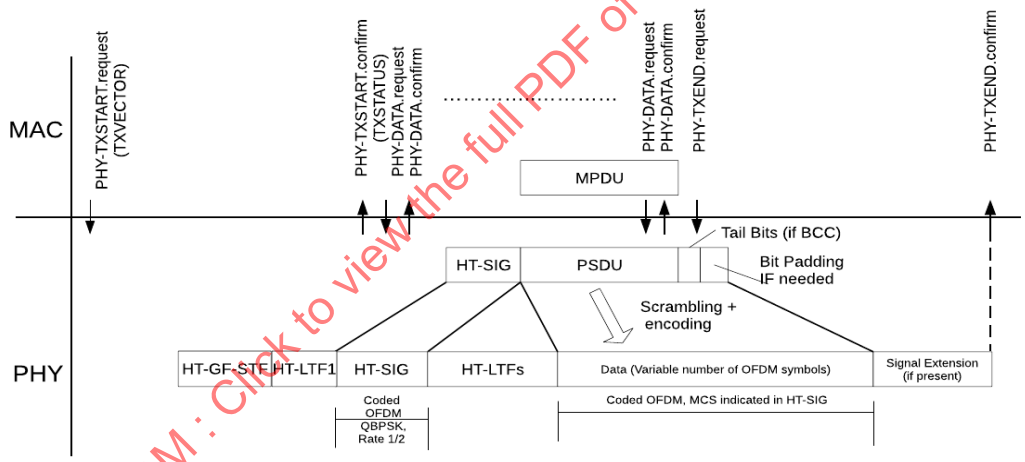


NOTE—This procedure does not describe the operation of optional features, such as LDPC or STBC

Figure 19-22—PHY transmit procedure (HT-mixed format PPDU)



NOTE—This procedure does not describe the operation of optional features, such as LDPC or STBC.

Figure 19-23—PHY transmit procedure (HT-greenfield format PPDU)

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A clear channel shall be indicated by issuing a PHY-CCA.indication(IDLE) primitive. Note that under some circumstances, the MAC uses the latest value of the PHY-CCA.indication primitive before issuing the PHY-TXSTART.request primitive. Transmission of the PPDU shall be initiated after receiving the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request primitive are specified in Table 19-1.

Transmission of the PHY preamble may start if TIME_OF_DEPARTURE_REQUESTED is false, and shall start immediately if TIME_OF_DEPARTURE_REQUESTED is true, based on the parameters passed in the PHY-TXSTART.request primitive.

The data shall then be exchanged between the MAC and the PHY through a series of PHY-DATA.request(DATA) primitives issued by the MAC and PHY-DATA.confirm primitives issued by the PHY. Once PHY preamble transmission is started, the PHY entity shall immediately initiate data scrambling and data encoding. The encoding method shall be based on the FEC_CODING, CH_BANDWIDTH, and MCS parameter of the TXVECTOR. A modulation rate change, if any, shall be initiated starting with the SERVICE field data, as described in 19.3.2.

The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. The SERVICE field and PSDU are encoded by the encoder selected by the FEC_CODING, CH_BANDWIDTH, and MCS parameters of the TXVECTOR as described in 19.3.3. Transmission can be prematurely terminated by the MAC through the primitive PHY-TXEND.request primitive. Normal termination occurs after the transmission of the final bit of the last PSDU octet, according to the number supplied in the LENGTH field.

The packet transmission shall be completed, and the PHY entity shall enter the receive state. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY. If the length of the coded PSDU is not an integer multiple of the OFDM symbol length, bits shall be stuffed to make the coded PSDU length an integer multiple of the OFDM symbol length.

The GI shall be inserted in every OFDM symbol as a countermeasure against delay spread.

In some PPDU formats (as defined in 19.3.2), a signal extension is present. When no signal extension is present, the PHY-TXEND.confirm primitive is generated at the end of last symbol of the PPDU. When a signal extension is present, the PHY-TXEND.confirm primitive is generated at the end of the signal extension.

A typical state machine implementation of the transmit PHY is provided in Figure 19-24. Requests (.request) and confirmations (.confirm) are issued once per state as shown. This state machine does not describe the operation of optional features, such as LDPC or STBC. If the TXVECTOR parameter FORMAT is equal to NON_HT and NON_HT_MODULATION is equal to ERP-OFDM or OFDM, refer to the transmit procedure and state machine in 17.3.11. If the TXVECTOR parameter FORMAT is equal to NON_HT and NON_HT_MODULATION is equal to ERP-DSSS or ERP-CCK, refer to the transmit procedure in 15.3.6 or 16.2.5, respectively.

NOTE—The transmit procedure and state machine for Clause 18 when TXVECTOR parameter NON_HT_MODULATION is ERP-OFDM is described in 17.3.11, except for the signal extension (refer to 18.3.2.4).

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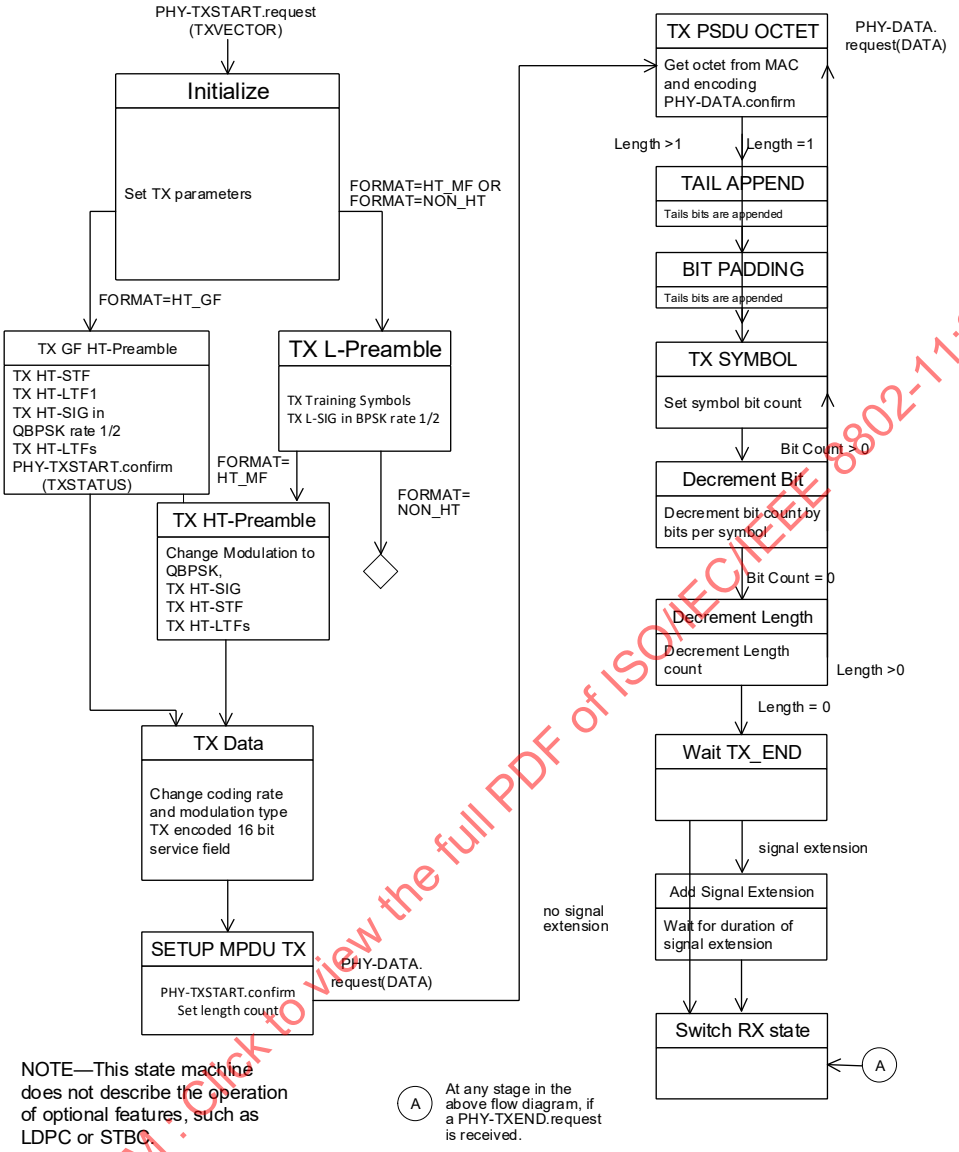

Figure 19-24—PHY transmit state machine

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19.3.21 PHY receive procedure

Typical PHY receive procedures are shown in Figure 19-25 and Figure 19-26. The receive procedures correspond to HT-mixed format and HT-greenfield format, respectively. A typical state machine implementation of the receive PHY is given in Figure 19-27. These receive procedures and state machine do not describe the operation of optional features, such as LDPC or STBC. If the detected format indicates a non-HT PPDU format (denoted “Not HT-SIG” in Figure 19-27), refer to the receive procedure and state machine in 17.3.12 or 18.3.5. Further, through station management (via the PLME), the PHY is set to the appropriate frequency, as specified in 19.4. Other receive parameters, such as RSSI and indicated DATARATE, may be accessed via the PHY SAP.

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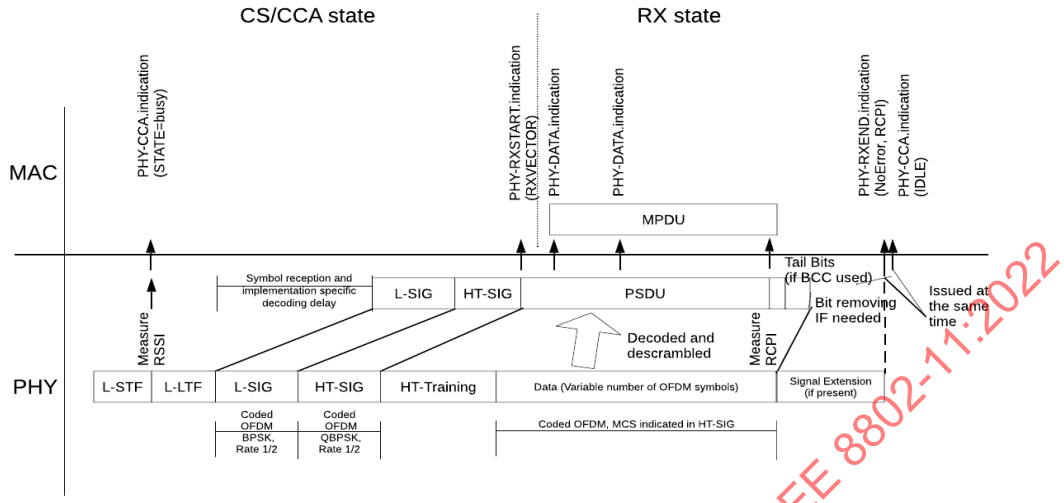
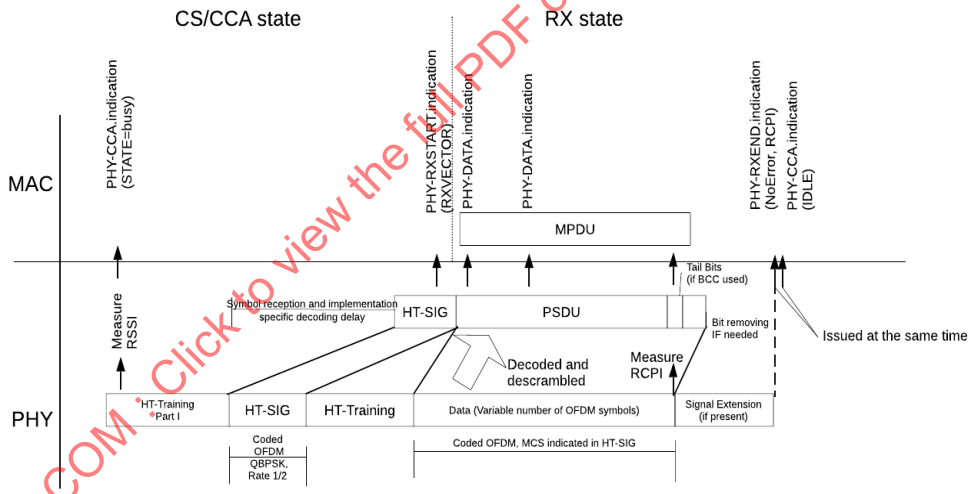


NOTE—This procedure does not describe the operation of optional features, such as LDPC or STBC.

Figure 19-25—PHY receive procedure for HT-mixed format PPDU



NOTE—This procedure does not describe the operation of optional features, such as LDPC or STBC.

Figure 19-26—PHY receive procedure for HT-greenfield format PPDU

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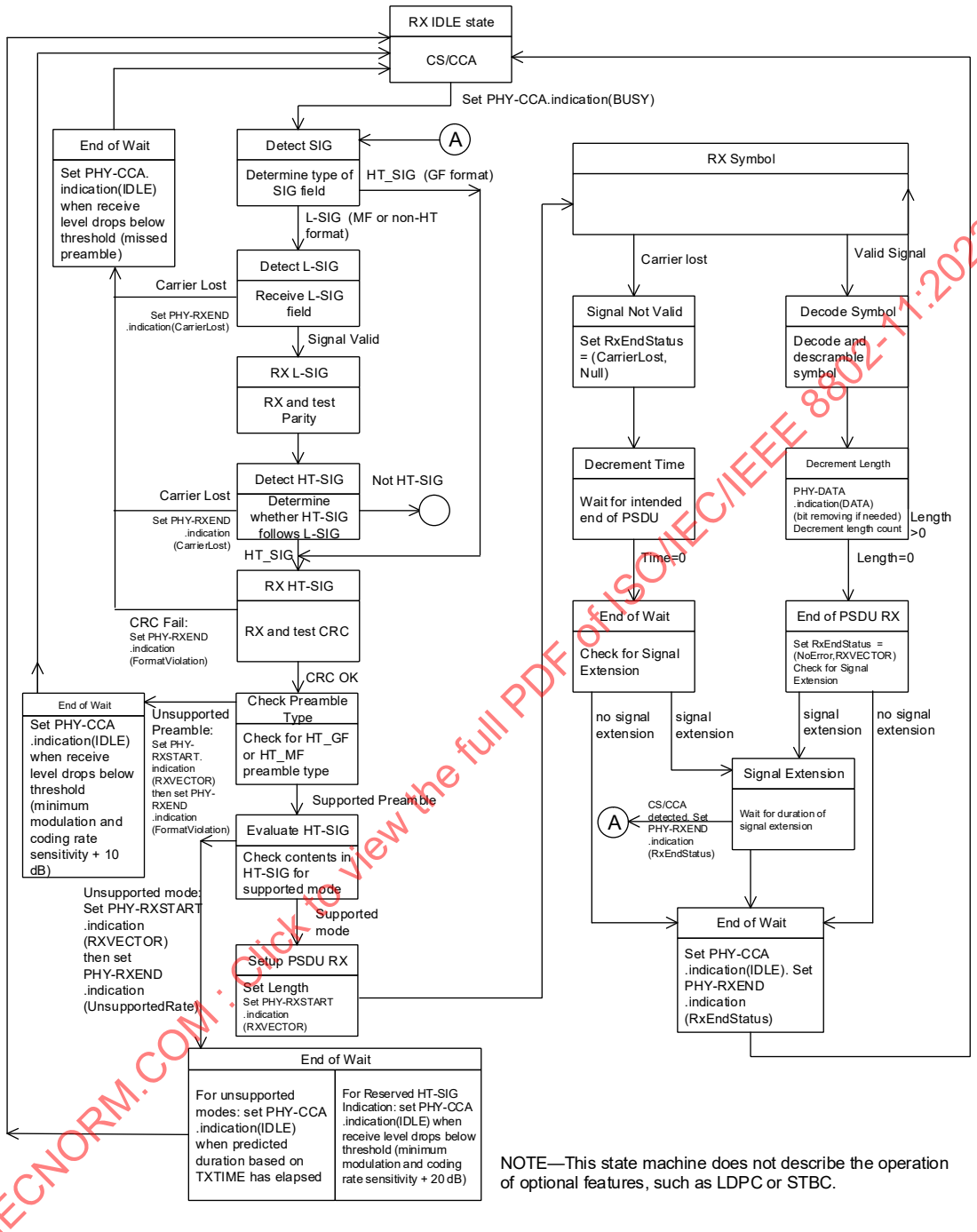

NOTE—This state machine does not describe the operation of optional features, such as LDPC or STBC.

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Figure 19-27—PHY receive state machine

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Upon receiving the transmitted PHY preamble, the PHY measures a receive signal strength. This indicates activity to the MAC via the PHY-CCA.indication primitive. A PHY-CCA.indication(BUSY, channel-list) primitive shall also be issued as an initial indication of reception of a signal. The channel-list parameter of the PHY-CCA.indication primitive is set as follows:

— It is absent when the operating channel width is 20 MHz.
— It is set to {primary} when the operating channel width is 40 MHz and the signal is present only in the primary channel.
— It is set to {secondary} when the operating channel width is 40 MHz and the signal is present only in the secondary channel.
— It is set to {primary, secondary} when the operating channel width is 40 MHz and the signal is present in both the primary and secondary channels.

The RSSI parameter is reported to the MAC in the RXVECTOR.

After the PHY-CCA.indication(BUSY, channel-list) primitive is issued, the PHY entity shall begin receiving the training symbols and searching for SIGNAL and HT-SIG in order to set the length of the data stream, the demodulation type, code type, and the decoding rate. If signal loss occurs before validating L-SIG and/or HT-SIG, the HT PHY shall not generate a PHY-CCA.indication(IDLE) primitive until the received level drops below the CCA sensitivity level (for a missed preamble) specified in 19.3.19.5. If the check of the HT-SIG CRC is not valid, a PHY-RXSTART.indication primitive is not issued. The PHY shall indicate the error condition by issuing a PHY-RXEND.indication(FormatViolation) primitive. The HT PHY shall not generate a PHY-CCA.indication(IDLE) primitive until the received level drops below the CCA sensitivity level (for a missed preamble) specified in 19.3.19.5.

If the PHY preamble reception is successful and a valid HT-SIG CRC is indicated:

— Upon reception of an HT-mixed format preamble, the HT PHY shall not generate a PHY-CCA.indication(IDLE) primitive for the predicted duration of the transmitted frame, as defined by TXTIME in 19.4.3, for all supported and unsupported modes except Reserved HT-SIG Indication. Reserved HT-SIG Indication is defined in the fourth item below.
— Upon reception of a GF preamble by an HT STA that does not support GF, the HT PHY shall not generate a PHY-CCA.indication(IDLE) primitive until either the predicted duration of the packet from the contents of the HT-SIG field, as defined by TXTIME in 19.4.3, except Reserved HT-SIG Indication, elapses or until the received level drops below the receiver minimum sensitivity level of BPSK, R=1/2 in Table 19-23 + 10 dB (–72 dBm for 20 MHz, –69 dBm for 40 MHz). Reserved HT-SIG Indication is defined in the fourth item below.
— Upon reception of a GF preamble by an HT STA that supports GF, the HT PHY shall not generate a PHY-CCA.indication(IDLE) primitive for the predicted duration of the transmitted frame, as defined by TXTIME in 19.4.3, for all supported and unsupported modes except Reserved HT-SIG Indication. Reserved HT-SIG Indication is defined in the fourth item below.
— If the HT-SIG indicates a Reserved HT-SIG Indication, the HT PHY shall not generate a PHY-CCA.indication(IDLE) primitive until the received level drops below the CCA sensitivity level (minimum modulation and coding rate sensitivity + 20 dB) specified in 19.3.19.5. Reserved HT-SIG Indication is defined as an HT-SIG with MCS field in the range 77–127 or Reserved field = 0 or STBC field = 3 and any other HT-SIG field bit combinations that do not correspond to modes of PHY operation defined in Clause 19.

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Subsequent to an indication of a valid HT-SIG CRC, a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. If dot11TimingMsmtActivated is true, the PHY shall do the following:

— Complete receiving the PHY header and verify the validity of the PHY Header.
— If the PHY header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued and RX_START_OF_FRAME_OFFSET parameter within the RXVECTOR shall be forwarded (see 19.2.2).

NOTE—The RX_START_OF_FRAME_OFFSET value is used as described in 6.3.55 in order to estimate when the start of the preamble for the incoming frame was detected on the medium at the receive antenna connector.

The RXVECTOR associated with this primitive includes the parameters specified in Table 19-1. Upon reception of a GF preamble by an HT STA that does not support GF, the FORMAT field of RXVECTOR is equal to HT_GF, the remaining fields may be empty, and the PHY shall indicate the error condition by issuing a PHY-RXEND.indication(FormatViolation) primitive. If the HT-SIG indicates an unsupported mode or Reserved HT-SIG Indication, the PHY shall indicate the error condition by issuing a PHY-RXEND.indication(UnsupportedRate) primitive.

Following training and SIGNAL fields, the coded PSDU (which comprises the coded PHY SERVICE field and scrambled and coded PSDU) shall be received. If signal loss occurs during reception prior to completion of the PSDU reception, the error condition shall be reported to the MAC using a PHY-RXEND.indication(CarrierLost) primitive. After waiting for the intended end of the PSDU, if no signal extension is present (as defined in 19.3.2), the PHY shall generate a PHY-CCA.indication(IDLE) primitive and return to RX IDLE state. Otherwise, the receiver waits for the duration of the signal extension before returning to the RX IDLE state.

The received PSDU bits are assembled into octets, decoded, and presented to the MAC using a series of PHY-DATA.indication(DATA) primitive exchanges. The number of PSDU octets is indicated in the HT Length field of the HT-SIG. The PHY shall proceed with PSDU reception. After the reception of the final bit of the last PSDU octet and possible tail and padding bits, the receiver shall be returned to the RX IDLE state if no signal extension is present (as defined in 19.3.2), as shown in Figure 19-27. Otherwise, the receiver waits for the duration of the signal extension before returning to the RX IDLE state. A PHY-RXEND.indication(NoError) primitive shall be issued on entry to the RX IDLE state.

While in the Signal Extension state, if the receiver detects a CS/CCA event, it issues an RXEND.indication primitive (with the RXERROR parameter set to NoError or CarrierLost, depending on whether a carrier lost event occurred during the reception of the PPDU), leaves the Signal Extension state, and enters the Detect SIG state. This sequence occurs when signal-extended PPDUs are transmitted while separated by a RIFS.

If the BCC is used, any data received after the indicated data length are considered pad bits (to fill out an OFDM symbol) and should be discarded.

19.4 HT PLME

19.4.1 PLME SAP sublayer management primitives

Table 19-24 lists the MIB attributes that may be accessed by the PHY entities and the intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.2 and 6.5.4.

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Table 19-24—HT PHY MIB attributes

Managed object	Default value/range	Operational semantics
dot11PHYOperationTable		
dot11PHYType	HT (X'07')	Static
dot11CurrentRegDomain	Implementation dependent	Dynamic
dot11PHYAntennaTable		
dot11CurrentTxAntenna	Implementation dependent	Dynamic
dot11DiversitySupportImplemented	Implementation dependent	Static
dot11CurrentRxAntenna	Implementation dependent	Dynamic
dot11AntennaSelectionOptionImplemented	false/Boolean	Static
dot11TransmitExplicitCSIFeedbackASOptionImplemented	false/Boolean	Static
dot11TransmitIndicesFeedbackASOptionImplemented	false/Boolean	Static
dot11ExplicitCSIFeedbackASOptionImplemented	false/Boolean	Static
dot11TransmitIndicesComputationASOptionImplemented	false/Boolean	Static
dot11ReceiveAntennaSelectionOptionImplemented	false/Boolean	Static
dot11TransmitSoundingPPDUOptionImplemented	false/Boolean	Static
dot11PHYTxPowerTable		
dot11NumberSupportedPowerLevelsImplemented	Implementation dependent	Static
dot11TxPowerLevel1	Implementation dependent	Static
dot11TxPowerLevel2	Implementation dependent	Static
dot11TxPowerLevel3	Implementation dependent	Static
dot11TxPowerLevel4	Implementation dependent	Static
dot11TxPowerLevel5	Implementation dependent	Static
dot11TxPowerLevel6	Implementation dependent	Static
dot11TxPowerLevel7	Implementation dependent	Static
dot11TxPowerLevel8	Implementation dependent	Static
dot11CurrentTxPowerLevel	Implementation dependent	Dynamic
dot11PhyDSSSTable		
dot11CurrentChannel	Implementation dependent	Dynamic
dot11RegDomainsSupportedTable		
dot11RegDomainsImplementedValue	Implementation dependent	Static
dot11FrequencyBandsSupported	Implementation dependent	Static

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Table 19-24—HT PHY MIB attributes *(continued)*

Managed object	Default value/range	Operational semantics
dot11PHYAntennasListTable		
dot11SupportedTxAntenna	Implementation dependent	Dynamic
dot11SupportedRxAntenna	Implementation dependent	Static
dot11DiversitySelectionRx	Implementation dependent	Dynamic
dot11SupportedDataRatesTxTable		
dot11SupportedDataratesTxValue	X'02' = 1 Mb/s (2.4) X'04' = 2 Mb/s (2.4) X'0B' = 5.5 Mb/s (2.4) X'16' = 11 Mb/s (2.4) X'0C' = 6 Mb/s X'12' = 9 Mb/s X'18' = 12 Mb/s X'24' = 18 Mb/s X'30' = 24 Mb/s X'48' = 36 Mb/s X'60' = 48 Mb/s X'6C' = 54 Mb/s	Static
dot11SupportedDataRatesRxTable		
dot11SupportedDataRatesRxTable	X'02' = 1 Mb/s (2.4) X'04' = 2 Mb/s (2.4) X'0B' = 5.5 Mb/s (2.4) X'16' = 11 Mb/s (2.4) X'0C' = 6 Mb/s X'12' = 9 Mb/s X'18' = 12 Mb/s X'24' = 18 Mb/s X'30' = 24 Mb/s X'48' = 36 Mb/s X'60' = 48 Mb/s X'6C' = 54 Mb/s	Static
dot11HRDSSSPHYTable		
dot11ShortPreambleOptionImplemented	true	Static
dot11PHYOFDMTable		
dot11CurrentFrequency	Implementation dependent	Dynamic
dot11TITThreshold	Implementation dependent	Dynamic
dot11ChannelStartingFactor	Implementation dependent	Dynamic
dot11PHYERPTable		
dot11ShortSlotTimeOptionImplemented	Implementation dependent	Static
dot11ShortSlotTimeOptionActivated	Implementation dependent	Dynamic

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Table 19-24—HT PHY MIB attributes *(continued)*

Managed object	Default value/range	Operational semantics
dot11PHYHTTable		
dot11FortyMHzOperationImplemented	false/Boolean	Static
dot11FortyMHzOperationActivated	false/Boolean	Dynamic
dot11CurrentPrimaryChannel	Implementation dependent	Dynamic
dot11CurrentSecondaryChannel	Implementation dependent	Dynamic
dot11NumberOfSpatialStreamsImplemented	Implementation dependent	Static
dot11NumberOfSpatialStreamsActivated	Implementation dependent	Dynamic
dot11HTGreenfieldOptionImplemented	false/Boolean	Static
dot11HTGreenfieldOptionActivated	false/Boolean	Dynamic
dot11ShortGIOptionInTwentyImplemented	false/Boolean	Static
dot11ShortGIOptionInTwentyActivated	false/Boolean	Dynamic
dot11ShortGIOptionInFortyImplemented	false/Boolean	Static
dot11ShortGIOptionInFortyActivated	false/Boolean	Dynamic
dot11LDPCCodingOptionImplemented	false/Boolean	Static
dot11LDPCCodingOptionActivated	false/Boolean	Dynamic
dot11TxSTBCOptionImplemented	false/Boolean	Static
dot11TxSTBCOptionActivated	false/Boolean	Dynamic
dot11RxSTBCOptionImplemented	false/Boolean	Static
dot11RxSTBCOptionActivated	false/Boolean	Dynamic
dot11BeamFormingOptionImplemented	false/Boolean	Static
dot11BeamFormingOptionActivated	false/Boolean	Dynamic
dot11SupportedHTMCSTxTable		
dot11SupportedHTMCSTxValue	MCS 0–76 for 20 MHz; MCS 0–76 for 40 MHz (MCS 0–7 for 20 MHz mandatory at non-AP STA and at AP that is a VHT AP; MCS 0–15 for 20 MHz mandatory at AP that is not a VHT AP)	Static

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Table 19-24—HT PHY MIB attributes *(continued)*

Managed object	Default value/range	Operational semantics
dot11SupportedHTMCSRxTable		
dot11SupportedHTMCSRxValue	MCS 0–76 for 20 MHz; MCS 0–76 for 40 MHz (MCS 0–7 for 20 MHz mandatory at non-AP STA and at AP that is a VHT AP; MCS 0–15 for 20 MHz mandatory at AP that is not a VHT AP)	Static
dot11TransmitBeamformingConfigTable		
dot11ReceiveStaggerSoundingOptionImplemented	false/Boolean	Static
dot11TransmitStaggerSoundingOptionImplemented	false/Boolean	Static
dot11ReceiveNDPOptionImplemented	false/Boolean	Static
dot11TransmitNDPOptionImplemented	false/Boolean	Static
dot11ImplicitTransmitBeamformingOptionImplemented	false/Boolean	Static
dot11CalibrationOptionImplemented	Implementation dependent	Static
dot11ExplicitCSITransmitBeamformingOptionImplemented	false/Boolean	Static
dot11ExplicitNonCompressedBeamformingMatrixOption-Implemented	false/Boolean	Static
dot11ExplicitTransmitBeamformingCSIFeedbackOption-Implemented	Implementation dependent	Static
dot11ExplicitNoncompressedBeamformingFeedbackOption-Implemented	Implementation dependent	Static
dot11ExplicitCompressedBeamformingFeedbackOption-Implemented	Implementation dependent	Static
dot11NumberBeamFormingCSISupportAntenna	Implementation dependent	Static
dot11NumberNonCompressedBeamformingMatrixSupport-Antenna	Implementation dependent	Static
dot11NumberCompressedBeamformingMatrixSupportAntenna	Implementation dependent	Static
dot11TxMCSSetDefined	false/Boolean	Static
dot11TxRxMCSSetNotEqual	false/Boolean	Static
dot11TxMaximumNumberSpatialStreamsSupported	false/Boolean	Static
dot11TxUnequalModulationSupported	false/Boolean	Static

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19.4.2 PHY MIB

HT PHY MIB attributes are defined in Annex C with specific values defined in Table 19-24. The "Operational semantics" column in Table 19-24 contains two types: static and dynamic.

— Static MIB attributes are fixed and cannot be modified for a given PHY implementation.

— Dynamic MIB attributes are interpreted according to the MAX-ACCESS field of the MIB attribute. When MAX-ACCESS is equal to read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is equal to read-write, the MIB attribute may be read and written by management entities.

19.4.3 TXTIME calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive or calculated for the PHY receive procedure shall be calculated for HT-mixed format according to the Equation (19-90) and Equation (19-91) for short and long GI, respectively, and for HT-greenfield format according to Equation (19-92) and Equation (19-93) for short and long, respectively:

$$\text{TXTIME} = T_{LEG_PREAMBLE} + T_{L_SIG} + T_{HT_TRAINING} + T_{HT_SIG} + T_{SYM} \times \left\lceil \frac{T_{SYMS} \times N_{SYM}}{T_{SYM}} \right\rceil + SignalExtension \quad (19\text{-}90)$$

$$\text{TXTIME} = T_{LEG_PREAMBLE} + T_{L_SIG} + T_{HT_TRAINING} + T_{HT_SIG} + T_{\text{SYM}} \times N_{SYM} + SignalExtension \quad (19\text{-}91)$$

$$\text{TXTIME} = T_{GF_HT_TRAINING} + T_{HT_SIG} + T_{SYMS} \times N_{SYM} + SignalExtension \quad (19\text{-}92)$$

$$\text{TXTIME} = T_{GF_HT_TRAINING} + T_{HT_SIG} + T_{SYM} \times N_{SYM} + SignalExtension \quad (19\text{-}93)$$

where

$T_{LEG_PREAMBLE} = T_{L\text{-}STF} + T_{L\text{-}LTF}$ is the duration of the non-HT preamble

$T_{HT_TRAINING}$ is the duration of the HT-STF and HT-LTFs in HT-mixed format, given by $T_{HT-STF} + T_{HT-LTF1} + (N_{HT\text{-}LTF} - 1)T_{HT-LTFs}$

$T_{GF_HT_TRAINING}$ is the duration of the HT-GF-STF, HT-LTF1 and HT-LTFs in HT-greenfield format, given by $T_{HT-GF-STF} + T_{HT-LTF1} + (N_{HT\text{-}LTF} - 1)T_{HT-LTFs}$

T_{SYM}, T_{SYMS}, $T_{HT\text{-}SIG}$, $T_{L\text{-}STF}$, $T_{HT\text{-}STF}$, $T_{HT\text{-}GF\text{-}STF}$, $T_{L\text{-}LTF}$, $T_{HT\text{-}LTF1}$ and $T_{HT\text{-}LTFs}$ are defined in Table 19-6

SignalExtension is 0 µs when TXVECTOR parameter NO_SIG_EXTN is true and is aSignalExtension as defined in Table 19-25 when TXVECTOR parameter NO_SIG_EXTN is false

$N_{HT\text{-}LTF}$ is defined in Equation (19-22)

N_{SYM} is defined in Equation (19-32) for BCC and Equation (19-41) for LDPC

For non-HT modes of operation, refer to Clause 17 and Clause 18 for TXTIME calculations, except that frames transmitted with a value of NON_HT_DUP_OFDM for the TXVECTOR parameter NON_HT_MODULATION shall use Equation (18-1) for TXTIME calculation.

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19.4.4 HT PHY

The static HT PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, shall be as shown in Table 19-25. The definitions for these characteristics are given in 6.5.4

Table 19-25—HT PHY characteristics

Characteristics	Value
aRIFSTime	2 μs
aSlotTime	When operating in the 2.4 GHz band: If dot11OperatingClassesRequired is false, long slot time = 20 μs If dot11OperatingClassesRequired is true, long slot time = 20 μs plus any coverage-class-dependent aAirPropagationTime (see Table 9-95) If dot11OperatingClassesRequired is false, short slot time = 9 μs If dot11OperatingClassesRequired is true, short slot time= 9 μs plus any coverage-class-dependent aAirPropagationTime (see Table 9-95) When operating in the 5 GHz band: If dot11OperatingClassesRequired is false, 9 μs If dot11OperatingClassesRequired is true, 9 μs plus any coverage-class-dependent aAirPropagationTime (see Table 9-95)
aSIFSTime	10 μs when operating in the 2.4 GHz band 16 μs when operating in the 5 GHz bands
aSignalExtension	0 μs when operating in the 5 GHz band 6 μs when operating in the 2.4 GHz band
aCCATime	Implementation dependent, see 10.3.7.
aRxPHYStartDelay	28 μs for HT-mixed format, 24 μs for HT-greenfield format
aRxTxTurnaroundTime	Implementation dependent, see 10.3.7.
aTxPHYDelay	Implementation dependent, see 10.3.7.
aRxPHYDelay	Implementation dependent, see 10.3.7.
aRxTxSwitchTime	Implementation dependent, see 10.3.7.
aTxRampOnTime	Implementation dependent, see 10.3.7.
aAirPropagationTime	As indicated by the coverage class (see 10.22.5).
aMACProcessingDelay	Implementation dependent, see 10.3.7.
aPSDUMaxLength	65 535 octets
aPPDUMaxTime	10 ms
aIUStime	8 μs
aDTT2UTTTime	32 μs
aCWmin	15
aCWmax	1023
aMaxCSIMatricesReportDelay	250 ms

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For non-HT modes of operation, refer to Clause 17 and Clause 18 for PHY characteristics.

19.5 Parameters for HT-MCSs

Table 19-26 defines the symbols used in the rate-dependent parameter tables.

Table 19-26—Symbols used in MCS parameter tables

Symbol	Explanation
N_{SS}	Number of spatial streams
R	Coding rate
N_{BPSC}	Number of coded bits per single carrier (total across spatial streams)
$N_{BPSCS}(i_{SS})$	Number of coded bits per single carrier for each spatial stream, $i_{SS} = 1,...,N_{SS}$
N_{SD}	Number of complex data numbers per spatial stream per OFDM symbol
N_{SP}	Number of pilot values per OFDM symbol
N_{CBPS}	Number of coded bits per OFDM symbol
N_{DBPS}	Number of data bits per OFDM symbol
N_{ES}	Number of BCC encoders for the DATA field

In the MCS parameter tables that follow, data rates for a 400 ns GI are rounded to 1 decimal place.

The rate-dependent parameters for mandatory 20 MHz, $N_{SS} = 1$ MCSs with $N_{ES} = 1$ shall be as shown in Table 19-27.

Table 19-27—MCS parameters for mandatory 20 MHz, $N_{SS} = 1$, $N_{ES} = 1$

MCS Index	Modulation	R	$N_{BPSCS}(i_{SS})$	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
								800 ns GI	400 ns GI (see NOTE)
0	BPSK	1/2	1	52	4	52	26	6.5	7.2
1	QPSK	1/2	2	52	4	104	52	13.0	14.4
2	QPSK	3/4	2	52	4	104	78	19.5	21.7
3	16-QAM	1/2	4	52	4	208	104	26.0	28.9
4	16-QAM	3/4	4	52	4	208	156	39.0	43.3
5	64-QAM	2/3	6	52	4	312	208	52.0	57.8
6	64-QAM	3/4	6	52	4	312	234	58.5	65.0
7	64-QAM	5/6	6	52	4	312	260	65.0	72.2

NOTE—Support of 400 ns GI is optional on transmit and receive.

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The rate-dependent parameters for optional 20 MHz, N_{SS} = 2 MCSs with N_{ES} = 1 and EQM of the spatial streams shall be as shown in Table 19-28.

Table 19-28—MCS parameters for optional 20 MHz, N_{SS} = 2, N_{ES} = 1, EQM

MCS Index	Modulation	R	$N_{BPSCS}(i_{SS})$	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
								800 ns GI	400 ns GI
8	BPSK	1/2	1	52	4	104	52	13.0	14.4
9	QPSK	1/2	2	52	4	208	104	26.0	28.9
10	QPSK	3/4	2	52	4	208	156	39.0	43.3
11	16-QAM	1/2	4	52	4	416	208	52.0	57.8
12	16-QAM	3/4	4	52	4	416	312	78.0	86.7
13	64-QAM	2/3	6	52	4	624	416	104.0	115.6
14	64-QAM	3/4	6	52	4	624	468	117.0	130.0
15	64-QAM	5/6	6	52	4	624	520	130.0	144.4

The rate-dependent parameters for optional 20 MHz, N_{SS} = 3 MCSs with N_{ES} = 1 and EQM of the spatial streams shall be as shown in Table 19-29.

Table 19-29—MCS parameters for optional 20 MHz, N_{SS} = 3, N_{ES} = 1, EQM

MCS Index	Modulation	R	$N_{BPSCS}(i_{SS})$	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
								800 ns GI	400 ns GI
16	BPSK	1/2	1	52	4	156	78	19.5	21.7
17	QPSK	1/2	2	52	4	312	156	39.0	43.3
18	QPSK	3/4	2	52	4	312	234	58.5	65.0
19	16-QAM	1/2	4	52	4	624	312	78.0	86.7
20	16-QAM	3/4	4	52	4	624	468	117.0	130.0
21	64-QAM	2/3	6	52	4	936	624	156.0	173.3
22	64-QAM	3/4	6	52	4	936	702	175.5	195.0
23	64-QAM	5/6	6	52	4	936	780	195.0	216.7

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The rate-dependent parameters for optional 20 MHz, N_{SS} = 4 MCSs with N_{ES} = 1 and EQM of the spatial streams shall be as shown in Table 19-30.

Table 19-30—MCS parameters for optional 20 MHz, N_{SS} = 4, N_{ES} = 1, EQM

MCS Index	Modulation	*R*	$N_{BPSCS}(i_{SS})$	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
								800 ns GI	400 ns GI
24	BPSK	1/2	1	52	4	208	104	26.0	28.9
25	QPSK	1/2	2	52	4	416	208	52.0	57.8
26	QPSK	3/4	2	52	4	416	312	78.0	86.7
27	16-QAM	1/2	4	52	4	832	416	104.0	115.6
28	16-QAM	3/4	4	52	4	832	624	156.0	173.3
29	64-QAM	2/3	6	52	4	1248	832	208.0	231.1
30	64-QAM	3/4	6	52	4	1248	936	234.0	260.0
31	64-QAM	5/6	6	52	4	1248	1040	260.0	288.9

The rate-dependent parameters for optional 40 MHz, N_{SS} = 1 MCSs with N_{ES} = 1 shall be as shown in Table 19-31.

Table 19-31—MCS parameters for optional 40 MHz, N_{SS} = 1, N_{ES} = 1

MCS Index	Modulation	*R*	$N_{BPSCS}(i_{SS})$	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
								800 ns GI	400 ns GI
0	BPSK	1/2	1	108	6	108	54	13.5	15.0
1	QPSK	1/2	2	108	6	216	108	27.0	30.0
2	QPSK	3/4	2	108	6	216	162	40.5	45.0
3	16-QAM	1/2	4	108	6	432	216	54.0	60.0
4	16-QAM	3/4	4	108	6	432	324	81.0	90.0
5	64-QAM	2/3	6	108	6	648	432	108.0	120.0
6	64-QAM	3/4	6	108	6	648	486	121.5	135.0
7	64-QAM	5/6	6	108	6	648	540	135.0	150.0

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The rate-dependent parameters for optional 40 MHz, N_{SS} = 2 MCSs with N_{ES} = 1 and EQM of the spatial streams shall be as shown in Table 19-32.

Table 19-32—MCS parameters for optional 40 MHz, N_{SS} = 2, N_{ES} = 1, EQM

MCS Index	Modulation	*R*	$N_{BPSCS}(i_{SS})$	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
								800 ns GI	400 ns GI
8	BPSK	1/2	1	108	6	216	108	27.0	30.0
9	QPSK	1/2	2	108	6	432	216	54.0	60.0
10	QPSK	3/4	2	108	6	432	324	81.0	90.0
11	16-QAM	1/2	4	108	6	864	432	108.0	120.0
12	16-QAM	3/4	4	108	6	864	648	162.0	180.0
13	64-QAM	2/3	6	108	6	1296	864	216.0	240.0
14	64-QAM	3/4	6	108	6	1296	972	243.0	270.0
15	64-QAM	5/6	6	108	6	1296	1080	270.0	300.0

The rate-dependent parameters for optional 40 MHz, N_{SS} = 3 MCSs, with EQM of the spatial streams shall be as shown in Table 19-33.

Table 19-33—MCS parameters for optional 40 MHz, N_{SS} = 3, EQM

MCS Index	Modulation	*R*	$N_{BPSCS}(i_{SS})$	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
16	BPSK	1/2	1	108	6	324	162	1	40.5	45.0
17	QPSK	1/2	2	108	6	648	324	1	81.0	90.0
18	QPSK	3/4	2	108	6	648	486	1	121.5	135.0
19	16-QAM	1/2	4	108	6	1296	648	1	162.0	180.0
20	16-QAM	3/4	4	108	6	1296	972	1	243.0	270.0
21	64-QAM	2/3	6	108	6	1944	1296	2	324.0	360.0
22	64-QAM	3/4	6	108	6	1944	1458	2	364.5	405.0
23	64-QAM	5/6	6	108	6	1944	1620	2	405.0	450.0

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The rate-dependent parameters for optional 40 MHz, N_{SS} = 4 MCSs, with EQM of the spatial streams shall be as shown in Table 19-34.

Table 19-34—MCS parameters for optional 40 MHz, N_{SS} = 4, EQM

MCS Index	Modulation	R	$N_{BPSCS}(i_{SS})$	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
24	BPSK	1/2	1	108	6	432	216	1	54.0	60.0
25	QPSK	1/2	2	108	6	864	432	1	108.0	120.0
26	QPSK	3/4	2	108	6	864	648	1	162.0	180.0
27	16-QAM	1/2	4	108	6	1728	864	1	216.0	240.0
28	16-QAM	3/4	4	108	6	1728	1296	2	324.0	360.0
29	64-QAM	2/3	6	108	6	2592	1728	2	432.0	480.0
30	64-QAM	3/4	6	108	6	2592	1944	2	486.0	540.0
31	64-QAM	5/6	6	108	6	2592	2160	2	540.0	600.0

The rate-dependent parameters for optional 40 MHz MCS 32 format with N_{SS} = 1 and N_{ES} = 1 shall be as shown in Table 19-35.

Table 19-35—MCS parameters for optional 40 MHz MCS 32 format, N_{SS} = 1, N_{ES} = 1

MCS Index	Modulation	R	$N_{BPSCS}(i_{SS})$	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
								800 ns GI	400 ns GI
32	BPSK	1/2	1	48	4	48	24	6.0	6.7

The rate-dependent parameters for optional 20 MHz, N_{SS} = 2 MCSs with N_{ES} = 1 and UEQM of the spatial streams shall be as shown in Table 19-36.

Table 19-36—MCS parameters for optional 20 MHz, N_{SS} = 2, N_{ES} = 1, UEQM

MCS Index	Modulation		R	N_{BPSC}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
	Stream 1	Stream 2							800 ns GI	400 ns GI
33	16-QAM	QPSK	1/2	6	52	4	312	156	39	43.3
34	64-QAM	QPSK	1/2	8	52	4	416	208	52	57.8
35	64-QAM	16-QAM	1/2	10	52	4	520	260	65	72.2
36	16-QAM	QPSK	3/4	6	52	4	312	234	58.5	65.0
37	64-QAM	QPSK	3/4	8	52	4	416	312	78	86.7
38	64-QAM	16-QAM	3/4	10	52	4	520	390	97.5	108.3

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The rate-dependent parameters for optional 20 MHz, N_{SS} = 3 MCSs with N_{ES} = 1 and UEQM of the spatial streams shall be as shown in Table 19-37.

Table 19-37—MCS parameters for optional 20 MHz, N_{SS} = 3, N_{ES} = 1, UEQM

MCS Index	Modulation			R	N_{BPSC}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
	Stream 1	Stream 2	Stream 3							800 ns GI	400 ns GI
39	16-QAM	QPSK	QPSK	1/2	8	52	4	416	208	52	57.8
40	16-QAM	16-QAM	QPSK	1/2	10	52	4	520	260	65	72.2
41	64-QAM	QPSK	QPSK	1/2	10	52	4	520	260	65	72.2
42	64-QAM	16-QAM	QPSK	1/2	12	52	4	624	312	78	86.7
43	64-QAM	16-QAM	16-QAM	1/2	14	52	4	728	364	91	101.1
44	64-QAM	64-QAM	QPSK	1/2	14	52	4	728	364	91	101.1
45	64-QAM	64-QAM	16-QAM	1/2	16	52	4	832	416	104	115.6
46	16-QAM	QPSK	QPSK	3/4	8	52	4	416	312	78	86.7
47	16-QAM	16-QAM	QPSK	3/4	10	52	4	520	390	97.5	108.3
48	64-QAM	QPSK	QPSK	3/4	10	52	4	520	390	97.5	108.3
49	64-QAM	16-QAM	QPSK	3/4	12	52	4	624	468	117	130.0
50	64-QAM	16-QAM	16-QAM	3/4	14	52	4	728	546	136.5	151.7
51	64-QAM	64-QAM	QPSK	3/4	14	52	4	728	546	136.5	151.7
52	64-QAM	64-QAM	16-QAM	3/4	16	52	4	832	624	156	173.3

The rate-dependent parameters for optional 20 MHz, N_{SS} = 4 MCSs with N_{ES} = 1 and UEQM in the spatial streams shall be as shown in Table 19-38.

Table 19-38—MCS parameters for optional 20 MHz, N_{SS} = 4, N_{ES} = 1, UEQM

MCS Index	Modulation				R	N_{BPSC}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
	Stream 1	Stream 2	Stream 3	Stream 4							800 ns GI	400 ns GI
53	16-QAM	QPSK	QPSK	QPSK	1/2	10	52	4	520	260	65	72.2
54	16-QAM	16-QAM	QPSK	QPSK	1/2	12	52	4	624	312	78	86.7
55	16-QAM	16-QAM	16-QAM	QPSK	1/2	14	52	4	728	364	91	101.1
56	64-QAM	QPSK	QPSK	QPSK	1/2	12	52	4	624	312	78	86.7
57	64-QAM	16-QAM	QPSK	QPSK	1/2	14	52	4	728	364	91	101.1
58	64-QAM	16-QAM	16-QAM	QPSK	1/2	16	52	4	832	416	104	115.6
59	64-QAM	16-QAM	16-QAM	16-QAM	1/2	18	52	4	936	468	117	130.0

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Table 19-38—MCS parameters for optional 20 MHz, N_{SS} = 4, N_{ES} = 1, UEQM *(continued)*

MCS Index	Modulation				R	N_{BPSC}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
	Stream 1	Stream 2	Stream 3	Stream 4							800 ns GI	400 ns GI
60	64-QAM	64-QAM	QPSK	QPSK	1/2	16	52	4	832	416	104	115.6
61	64-QAM	64-QAM	16-QAM	QPSK	1/2	18	52	4	936	468	117	130.0
62	64-QAM	64-QAM	16-QAM	16-QAM	1/2	20	52	4	1040	520	130	144.4
63	64-QAM	64-QAM	64-QAM	QPSK	1/2	20	52	4	1040	520	130	144.4
64	64-QAM	64-QAM	64-QAM	16-QAM	1/2	22	52	4	1144	572	143	158.9
65	16-QAM	QPSK	QPSK	QPSK	3/4	10	52	4	520	390	97.5	108.3
66	16-QAM	16-QAM	QPSK	QPSK	3/4	12	52	4	624	468	117	130.0
67	16-QAM	16-QAM	16-QAM	QPSK	3/4	14	52	4	728	546	136.5	151.7
68	64-QAM	QPSK	QPSK	QPSK	3/4	12	52	4	624	468	117	130.0
69	64-QAM	16-QAM	QPSK	QPSK	3/4	14	52	4	728	546	136.5	151.7
70	64-QAM	16-QAM	16-QAM	QPSK	3/4	16	52	4	832	624	156	173.3
71	64-QAM	16-QAM	16-QAM	16-QAM	3/4	18	52	4	936	702	175.5	195.0
72	64-QAM	64-QAM	QPSK	QPSK	3/4	16	52	4	832	624	156	173.3
73	64-QAM	64-QAM	16-QAM	QPSK	3/4	18	52	4	936	702	175.5	195.0
74	64-QAM	64-QAM	16-QAM	16-QAM	3/4	20	52	4	1040	780	195	216.7
75	64-QAM	64-QAM	64-QAM	QPSK	3/4	20	52	4	1040	780	195	216.7
76	64-QAM	64-QAM	64-QAM	16-QAM	3/4	22	52	4	1144	858	214.5	238.3

The rate-dependent parameters for optional 40 MHz, N_{SS} = 2 MCSs with N_{ES} = 1 and UEQM of the spatial streams shall be as shown in Table 19-39.

Table 19-39—MCS parameters for optional 40 MHz, N_{SS} = 2, N_{ES} = 1, UEQM

MCS Index	Modulation		R	N_{BPSC}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
	Stream 1	Stream 2							800 ns GI	400 ns GI
33	16-QAM	QPSK	1/2	6	108	6	648	324	81	90
34	64-QAM	QPSK	1/2	8	108	6	864	432	108	120
35	64-QAM	16-QAM	1/2	10	108	6	1080	540	135	150
36	16-QAM	QPSK	3/4	6	108	6	648	486	121.5	135
37	64-QAM	QPSK	3/4	8	108	6	864	648	162	180
38	64-QAM	16-QAM	3/4	10	108	6	1080	810	202.5	225

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The rate-dependent parameters for optional 40 MHz, N_{SS} = 3 MCSs, with UEQM of the spatial streams shall be as shown in Table 19-40.

Table 19-40—MCS parameters for optional 40 MHz, N_{SS} = 3, UEQM

MCS Index	Modulation			R	N_{BPSC}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
	Stream 1	Stream 2	Stream 3								800 ns GI	400 ns GI
39	16-QAM	QPSK	QPSK	1/2	8	108	6	864	432	1	108	120
40	16-QAM	16-QAM	QPSK	1/2	10	108	6	1080	540	1	135	150
41	64-QAM	QPSK	QPSK	1/2	10	108	6	1080	540	1	135	150
42	64-QAM	16-QAM	QPSK	1/2	12	108	6	1296	648	1	162	180
43	64-QAM	16-QAM	16-QAM	1/2	14	108	6	1512	756	1	189	210
44	64-QAM	64-QAM	QPSK	1/2	14	108	6	1512	756	1	189	210
45	64-QAM	64-QAM	16-QAM	1/2	16	108	6	1728	864	1	216	240
46	16-QAM	QPSK	QPSK	3/4	8	108	6	864	648	1	162	180
47	16-QAM	16-QAM	QPSK	3/4	10	108	6	1080	810	1	202.5	225
48	64-QAM	QPSK	QPSK	3/4	10	108	6	1080	810	1	202.5	225
49	64-QAM	16-QAM	QPSK	3/4	12	108	6	1296	972	1	243	270
50	64-QAM	16-QAM	16-QAM	3/4	14	108	6	1512	1134	1	283.5	315
51	64-QAM	64-QAM	QPSK	3/4	14	108	6	1512	1134	1	283.5	315
52	64-QAM	64-QAM	16-QAM	3/4	16	108	6	1728	1296	2	324	360

The rate-dependent parameters for optional 40 MHz, N_{SS} = 4 MCSs, with UEQM of the spatial streams shall be as shown in Table 19-41.

Table 19-41—MCS parameters for optional 40 MHz, N_{SS} = 4, UEQM

MCS Index	Modulation				R	N_{BPSC}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
	Stream 1	Stream 2	Stream 3	Stream 4								800 ns GI	400 ns GI
53	16-QAM	QPSK	QPSK	QPSK	1/2	10	108	6	1080	540	1	135	150
54	16-QAM	16-QAM	QPSK	QPSK	1/2	12	108	6	1296	648	1	162	180
55	16-QAM	16-QAM	16-QAM	QPSK	1/2	14	108	6	1512	756	1	189	210
56	64-QAM	QPSK	QPSK	QPSK	1/2	12	108	6	1296	648	1	162	180
57	64-QAM	16-QAM	QPSK	QPSK	1/2	14	108	6	1512	756	1	189	210

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Table 19-41—MCS parameters for optional 40 MHz, N_{SS} = 4, UEQM *(continued)*

MCS Index	Modulation				R	N_{BPSC}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
	Stream 1	Stream 2	Stream 3	Stream 4								800 ns GI	400 ns GI
58	64-QAM	16-QAM	16-QAM	QPSK	1/2	16	108	6	1728	864	1	216	240
59	64-QAM	16-QAM	16-QAM	16-QAM	1/2	18	108	6	1944	972	1	243	270
60	64-QAM	64-QAM	QPSK	QPSK	1/2	16	108	6	1728	864	1	216	240
61	64-QAM	64-QAM	16-QAM	QPSK	1/2	18	108	6	1944	972	1	243	270
62	64-QAM	64-QAM	16-QAM	16-QAM	1/2	20	108	6	2160	1080	1	270	300
63	64-QAM	64-QAM	64-QAM	QPSK	1/2	20	108	6	2160	1080	1	270	300
64	64-QAM	64-QAM	64-QAM	16-QAM	1/2	22	108	6	2376	1188	1	297	330
65	16-QAM	QPSK	QPSK	QPSK	3/4	10	108	6	1080	810	1	202.5	225
66	16-QAM	16-QAM	QPSK	QPSK	3/4	12	108	6	1296	972	1	243	270
67	16-QAM	16-QAM	16-QAM	QPSK	3/4	14	108	6	1512	1134	1	283.5	315
68	64-QAM	QPSK	QPSK	QPSK	3/4	12	108	6	1296	972	1	243	270
69	64-QAM	16-QAM	QPSK	QPSK	3/4	14	108	6	1512	1134	1	283.5	315
70	64-QAM	16-QAM	16-QAM	QPSK	3/4	16	108	6	1728	1296	2	324	360
71	64-QAM	16-QAM	16-QAM	16-QAM	3/4	18	108	6	1944	1458	2	364.5	405
72	64-QAM	64-QAM	QPSK	QPSK	3/4	16	108	6	1728	1296	2	324	360
73	64-QAM	64-QAM	16-QAM	QPSK	3/4	18	108	6	1944	1458	2	364.5	405
74	64-QAM	64-QAM	16-QAM	16-QAM	3/4	20	108	6	2160	1620	2	405	450
75	64-QAM	64-QAM	64-QAM	QPSK	3/4	20	108	6	2160	1620	2	405	450
76	64-QAM	64-QAM	64-QAM	16-QAM	3/4	22	108	6	2376	1782	2	445.5	495

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20. Directional multi-gigabit (DMG) PHY specification

20.1 DMG PHY introduction

20.1.1 Scope of DMG PHY services

The DMG PHY supports two modulation methods:

— A control modulation using MCS 0 (the DMG control mode; see 20.4)

— A single carrier (SC) modulation using MCS 1 to MCS 12, MCS 9.1, 12.1, 12.2, 12.3, 12.4, 12.5, and 12.6 (the DMG SC mode; see 20.5) and MCS 25 to MCS 31 (the DMG low-power SC mode; see 20.6)

All DMG modulation methods share a similar preamble (see 20.3.6).

The services provided to the MAC by the DMG PHY consist of the following protocol functions:

a) A function that defines a method of mapping the PHY service data units (PSDU) into a framing format (PPDU) suitable for sending and receiving PSDUs between two or more STAs.

b) A function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. Depending on the DMG MCSs, these STAs support a mixture of DMG SC mode, DMG low-power SC mode, and DMG control mode.

20.1.2 DMG PHY functions

The DMG PHY contains two functional entities: the PHY and the layer management function (PLME). Each of these functions is described in detail in 20.3 to 20.11. The DMG PHY service is provided to the MAC through the PHY service primitives defined in Clause 8.

20.1.2.1 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.

20.1.2.2 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, but do not necessarily reflect any particular implementation. The service of a layer or sublayer is the set of capabilities that it offers to a user in the next higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

20.2 DMG PHY service interface

20.2.1 Introduction

The PHY interfaces to the MAC through the TXVECTOR, RXVECTOR, and the PHYCONFIG_VECTOR. Using the TXVECTOR, the MAC supplies the PHY with per-PPDU transmit parameters. Using the RXVECTOR, the PHY informs the MAC of the received packet parameters. Using the PHYCONFIG_VECTOR, the MAC configures the PHY for operation, independent of frame transmission or reception.

This interface is an extension of the generic PHY service interface defined in 8.3.4.

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20.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 20-1 are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive and/or as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive.

Table 20-1—TXVECTOR and RXVECTOR parameters

Parameter	Value	TXVECTOR	RXVECTOR
MCS	The MCS parameter is an enumerated type that indicates the modulation and coding scheme used in the transmission of the packet. Values are integers in the range 0 to 31 and the values 9.1, 12.1, 12.2, 12.3, 12.4, 12.5 and 12.6. — An MCS value of 0 indicates the use of DMG control mode. — MCS values of 1 to 12 and 9.1, 12.1, 12.2, 12.3, 12.4, 12.5, 12.6 indicate use of single carrier modulations. The value is an index to Table 20-15. — MCS values of 25 to 31 indicate use of DMG low-power SC mode. The value is an index to Table 20-21.	Y	Y
LENGTH	Indicates the number of octets in the PSDU in the range 1 to 262 143.	Y	Y
ADD_PPDU	Enumerated Type: — ADD-PPDU indicates that this PPDU is immediately followed by another PPDU with no IFS or preamble on the subsequent PPDU. — NO-ADD-PPDU indicates no additional PPDU follows this PPDU.	Y	Y
PPDU_TYPE	Enumerated Type: — TRN-R indicates either a PPDU whose Data field is followed by one or more TRN subfields, or a PPDU that is requesting TRN subfields to be appended to a future response PPDU. — TRN-T indicates a PPDU whose Data field is followed by one or more TRN subfields. The transmitter may change AWV configuration at the beginning of each TRN subfield. This parameter is reserved if TRN_LEN is 0.	Y	Y
TRN_LEN	TRN_LEN indicates the length of the training field. Values are in the range 0–16 (see 20.9.2.2.3).	Y	Y
AGGREGATION	Indicates whether the PSDU contains an A-MPDU. Enumerated Type: — AGGREGATED indicates this is a PSDU with A-MPDU aggregation. — NOT_AGGREGATED indicates this is a PSDU without A-MPDU aggregation.	Y	Y

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Table 20-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Value	TXVECTOR	RXVECTOR
RSSI	The allowed values for the RSSI parameter are in the range 0 to 255. This parameter is a measure by the PHY of the power observed at the input of the antennas plus the antenna gain, or equivalent antenna gain for a phased-array antenna, used to receive the current PPDU. RSSI shall be measured during the reception of the PHY preamble. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power.	N	Y
SNR	This parameter indicates the SNR measured during the reception of a DMG control mode packet. Values are –13 dB to 50.75 dB in 0.25 dB steps.	N	Y
RCPI	Is a measure of the received RF power measured over the preamble of a received frame. Refer to 20.3.10 for the definition of RCPI.	N	Y
ANT_CONFIG	Indicates which antenna configuration(s) is to be used throughout the transmission of the packet, and when to switch between configurations. Values are implementation dependent.	Y	N
CHAN_MEASUREMENT	Channel as measured during the reception of TRN subfields. Each measurement includes 63 complex numbers.	N	Y
TIME_OF_DEPARTURE_REQUESTED	Enumerated type: — true indicates that the MAC entity requests that the PHY PHY entity measures and reports time of departure parameters corresponding to the time when the first frame energy is sent by the transmitting port. — false indicates that the MAC entity requests that the PHY PHY entity neither measures nor reports time of departure parameters.	O	N
RX_START_OF_FRAME_OFFSET	0 to 2^{32}–1. An estimate of the offset (in 10 nanosecond units) from the point in time at which the start of the preamble corresponding to the incoming frame arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC.	N	See NOTE
BEAM_TRACKING_REQUEST	This parameter indicates whether beam tracking is requested. Enumerated type: BEAM-TRACKING-REQUESTED or BEAM-TRACKING-NOT-REQUESTED	Y	Y
LAST_RSSI	In the TXVECTOR, LAST_RSSI indicates the received power level of the last packet with a valid PHY header that was received a SIFS before transmission of the current packet; otherwise, it is 0 (10.3.2.3.3). In the RXVECTOR, LAST_RSSI indicates the value of the LAST_RSSI field from the PCLP header of the received packet. Valid values are integers in the range 0 to 15: — Values of 2 to 14 represent power levels (–71+value×2) dBm. — A value of 15 represents power greater than or equal to –42 dBm. — A value of 1 represents power less than or equal to –68 dBm. — A value of 0 indicates that the previous packet was not received a SIFS before the current transmission.	Y	Y
TURNAROUND	Set to 1 or 0 as specified in 10.3.2.3.3.	Y	Y

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Table 20-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Value	TXVECTOR	RXVECTOR
PSK_APPLIED	Indicates if π/2-8-PSK is applied for MCS 10 or MCS 11. π/2-8-PSK cannot be applied for MCS other than 10 or 11. Enumerated Type: PSK_APPLIED: indicates that π/2-8-PSK is applied. PSK_NOT_APPLIED: indicates that π/2-8-PSK is not applied.	Y	Y
NOTE— "Y" if dot11TimingMsmtActivated is true, otherwise "N".			

20.2.3 PHYCONFIG_VECTOR parameters

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a DMG PHY contains an OPERATING_CHANNEL parameter, which identifies the operating 2.16 GHz channel. The PHY shall set the channel number to 1, 2, 3, 4, 5, 6, 7, or 8 using the value of OPERATING_CHANNEL parameter, which shall be set to 1, 3, 5, 7, 9, 11, 13, or 15 as defined in 20.3.1.

20.2.4 TXSTATUS parameters

The parameters listed in Table 20-2 are defined as part of the TXSTATUS parameter list in the PHY-TXSTART.confirm primitive.

Table 20-2—TXSTATUS parameters

Parameter	Value
TIME_OF_DEPARTURE	When the first frame energy is sent by the transmitting port, in units equal to 1/TIME_OF_DEPARTURE_ClockRate. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request.
TIME_OF_DEPARTURE_ClockRate	0 to 2^{16}–1. The clock rate, in units of MHz, is used to generate the TIME_OF_DEPARTURE value. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request.
TX_START_OF_FRAME_OFFSET	0 to 2^{32}–1. An estimate of the offset (in 10 nanosecond units) from the point in time at which the start of the preamble corresponding to the frame was transmitted at the transmit antenna connector to the point in time at which this primitive is issued to the MAC.

20.3 Common parameters

20.3.1 Channelization

The DMG PHY operates in the channels defined in Annex E and shall support channel number 2 and may support the other channels.

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The channel center frequency is defined as:

Channel center frequency = Channel starting frequency + Channel spacing × Channel number

where the channel starting frequency is equal to 56.16 GHz, and the channel spacing is defined in Annex E.

The OPERATING_CHANNEL parameter of PHYCONFIG_VECTOR is used to set up the operating channel number. The OPERATING_CHANNEL shall be set to 1, 3, 5, 7, 9, 11, 13, or 15. The relation between the channel number and OPERATING_CHANNEL is defined as follows:

Channel number = ½ × (OPERATING_CHANNEL + 1)

20.3.2 Transmit mask

The transmitted spectrum shall adhere to the transmit spectrum mask shown in the Figure 20-1. The transmit spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 1.88 GHz, –17 dBr at a 1.2 GHz offset, –22 dBr at a 2.7 GHz offset and –30 dBr at a 3.06 GHz offset and above, inside the channels allowed for the regulatory domain in which the device is transmitting. The measurement shall be made using a 1 MHz resolution bandwidth and a 300 kHz video bandwidth.

The transmit mask shall be measured on PPDUs longer than 10 µs without training fields.

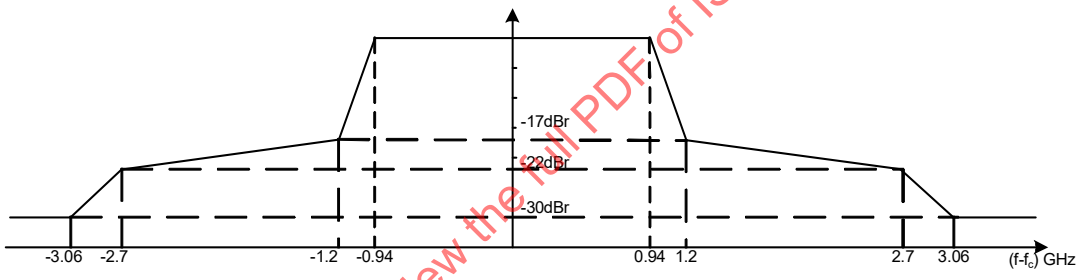

Figure 20-1—Transmit mask

20.3.3 Common requirements

20.3.3.1 Introduction

This subclause describes the common requirement from all three DMG modes: control, SC, and low-power SC.

In all of the modes, all defined fields are transmitted bit 0 first in time.

20.3.3.2 Center frequency tolerance

20.3.3.2.1 General

The transmitter center frequency tolerance shall be ± 20 ppm.

20.3.3.2.2 Center frequency convergence

The transmitter center frequency shall converge to within 1 ppm of its final value within 0.9 µs from the start of the packet.

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20.3.3.3 Symbol clock tolerance

The symbol clock frequency tolerance shall be ± 20 ppm.

The transmit center frequency and the symbol clock frequency shall be derived from the same reference oscillator.

20.3.3.4 Transmit center frequency leakage

The transmitter center frequency leakage shall not exceed –23 dB relative to the overall transmitted power.

20.3.3.5 Transmit rampup and rampdown

The transmit power-on ramp is defined as the time it takes for a transmitter to rise from less than 10% to greater than 90% of the average power to be transmitted in the frame.

The transmit power-on ramp shall be less than 10 ns.

The transmit power-down ramp is defined as the time it takes the transmitter to fall from greater than 90% to less than 10% of the maximum power to be transmitted in the frame.

The transmit power-down ramp shall be less than 10 ns.

20.3.3.6 Antenna setting

Antenna setting shall remain constant for the transmission of the entire packet except for the case of transmission of BRP-TX PPDUs (see 20.9.2.2). During the transmission of BRP-TX PPDUs, it shall remain constant for the transmission of the STF, CE field, and Data field.

20.3.3.7 Maximum input requirement

The receiver maximum input level is the maximum power level at the receive antenna(s) of the incoming signal, in dBm, present at the input of the receiver antenna for which the error rate criterion (defined in 20.3.3.8) is met. A receiver shall have a receiver maximum input level at the receive antenna(s) of at least 10 $\mu W/cm^2$ for each of the modulation formats that the receiver supports.

20.3.3.8 Receive minimum input sensitivity

For MCS 0, the PER shall be less than 5% for a PSDU length of 256 octets with the MCS dependent input levels listed in Table 20-3 defined at the antenna connector. For the other MCSs, the PER shall be less than 1% for a PSDU length of 4096 octets with the MCS dependent input levels listed in Table 20-3 defined at the antenna connector.

NOTE—For RF power measurements performed over the air, the input level shall be corrected to compensate for the antenna gain in the implementation. The gain of the antenna is the maximum estimated gain by the manufacturer. In the case of the phased-array antenna, the gain of the phased-array antenna is the maximum sum of estimated element gain minus 3 dB implementation loss.

Table 20-3 assumes 5 dB implementation loss and 10 dB noise factor (noise figure).

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Table 20-3—Receiver minimum input level sensitivity

MCS	Receive sensitivity (dBm)
0	–78
1	–68
2	–66
3	–65
4	–64
5	–62
6	–63
7	–62
8	–61
9	–59
9.1	–57
10	–55
11	–54
12	–53
12.1	–51
12.2	–50
12.3	–48
12.4	–46
12.5	–44
12.6	–42
25	–64
26	–60
27	–57
28	–57
29	–57
30	–57
31	–57

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20.3.4 Timing-related parameters

Table 20-4 defines timing-related parameters.

Table 20-4—Timing-related parameters

Parameter	Value
N_{GI}	aSCGILength NOTE—aSCGILength is defined in Table 20-30
N_{SPB}	448
F_c: chip rate	1760 MHz
T_c: chip time	$1 / F_c$ (~0.57 ns)
T_{seq}	$128 \times T_c$ (~72.7 ns)
T_{STF}: Detection sequence duration	$17 \times T_{seq}$ (~1236 ns)
T_{CE}: Channel Estimation sequence duration	$9 \times T_{seq}$ (~655 ns)
T_{HEADER}: header duration	2 × aSCBlockSize × T_c (~0.582 μs) NOTE—aSCGIBlockSize is defined in Table 20-30
T_{STF-CM}: control mode short training field duration	$50 \times T_{seq}$ (~3.636 μs)
T_{CE-CM}: control mode channel estimation field duration	T_{CE} (~655 ns)
T_{Data}	(N_{BLKS} × aSCBlockSize + aSCGILength) × T_c NOTE—N_{BLKS} is defined in 20.5.3.2.3.3 and aSCBlockSize and aSCGILength are defined in Table 20-30.

Table 20-5 defines parameters used frequently in Clause 20.

Table 20-5—Frequently used parameters

Symbol	Explanation
N_{CBPS}	Number of coded bits per symbol
N_{DBPS}	Number of data bits per symbol
R	Code rate

20.3.5 Mathematical conventions in the signal description

20.3.5.1 General

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal $r(t)$ by the following relation:

$$r_{RF}(t) = \mathrm{Re}\{r(t)\exp(j2\pi f_c t)\}$$

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where

f_C is the center frequency of the carrier

The transmitted RF signal is generated by modulating the complex baseband signal, which consists of several fields. The fields and the timing boundaries for the various fields are shown in Figure 20-2.

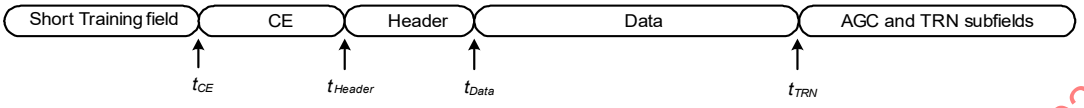

Figure 20-2—PPDU structure

The time offset, t_{Field}, determines the starting time of the corresponding field.

$$r_{PPDU}(t) = r_{STF}(t) + r_{CE}(t - t_{CE}) + r_{Header}(t - t_{Header}) + r_{Data}(t - t_{Data}) + r_{TRN}(t - t_{TRN})$$

where

$$t_{CE} = T_{STF}$$
$$t_{Header} = t_{CE} + T_{CE}$$
$$t_{Data} = t_{Header} + T_{Header}$$
$$t_{TRN} = t_{Data} + T_{Data}$$

The base band waveform for fields defined by time domain sequences or for single carrier transmission is

$$r_{Field}(nT_C) = x(n)$$

where

$x(n)$ is the constellation point n

Conversion from the sampled digital domain to the continuous time domain is beyond the scope of this document. Filtering for pulse shaping such as in GMSK is beyond the scope of this standard.

20.3.6 Common preamble

20.3.6.1 General

The preamble is the part of the PPDU that is used for packet detection, AGC, frequency offset estimation, synchronization, and channel estimation. The format of the preamble consists of a Short Training field followed by a Channel Estimation field. Figure 20-3 illustrates the SC packet preamble.

Figure 20-3—SC preamble

All numeric fields are transmitted in unsigned format, LSB first.

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20.3.6.2 Short Training field

The Short Training field is composed of 16 repetitions of sequences $Ga_{128}(n)$ of length 128 defined in 20.10, followed by a single repetition of $-Ga_{128}(n)$.

The waveform for the Short Training field is

$$r_{STF}(nT_c) = \begin{cases} (Ga_{128}(n \bmod 128))\exp\left(j\pi\frac{n}{2}\right) & n = 0, 1, \ldots, 16 \times 128 - 1 \\ (-Ga_{128}(n \bmod 128))\exp\left(j\pi\frac{n}{2}\right) & n = 16 \times 128, \ldots, 17 \times 128 - 1 \end{cases}$$

where
mod is the modulus operation

20.3.6.3 Channel Estimation field

The Channel Estimation field is used for channel estimation, as well as indication of which modulation is going to be used for the packet. The Channel Estimation field is composed of a concatenation of two sequences $Gu_{512}(n)$ and $Gv_{512}(n)$, where the last 128 samples of $Gu_{512}(n)$ and $Gv_{512}(n)$ are equal to the last 128 samples used in the Short Training field. They are followed by a 128 samples sequence $Gv_{128}(n)$ equal to the first 128 samples of both $Gv_{512}(n)$ and $Gu_{512}(n)$.

The Gu_{512} and Gv_{512} sequences are defined as

$$G_{u_{512}} = \left[-Gb_{128} \quad -Ga_{128} \quad Gb_{128} \quad -Ga_{128}\right]$$

$$G_{v_{512}} = \left[-Gb_{128} \quad Ga_{128} \quad -Gb_{128} \quad -Ga_{128}\right]$$

where
Ga_{128} and Gb_{128} are as defined in 20.10

When the data field of the packet is modulated using single carrier, the Gu_{512} and Gv_{512} fields are concatenated in the order shown in Figure 20-4.

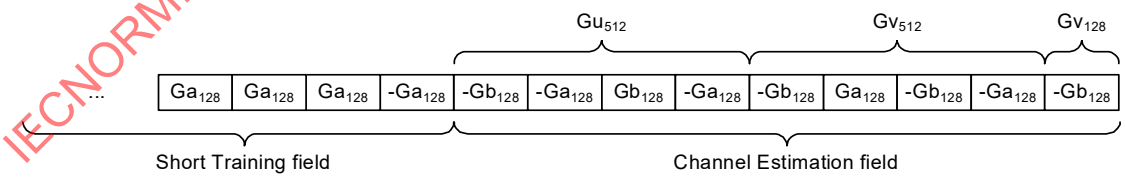

Figure 20-4—Channel Estimation field for SC PPDUs

The waveform for the channel estimation sequence is

$$r_{CE_{SC}}(nT_c) = (Gu_{512}(n) + Gv_{512}(n - 512) + Gv_{128}(n - 1024))\exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots, 1151$$

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Note that sequences $Gu_{512}(n)$ and $Gv_{512}(n)$ are defined for $0 \le n \le 511$. For other values of n, $Gu_{512}(n)$ and $Gv_{512}(n)$ are set to 0.

20.3.7 HCS calculation for headers of DMG control mode and DMG SC mode

The header check sequence (HCS) is a CRC of the header bits. The header is considered to be a stream of bits $B_0,\ldots,B_{M-1}$. The CRC is based on CRC 16-CCITT. The value of the CRC field is the 1s complement of

$$CRC(D) = (M(D) \oplus I(D))D^{16} \bmod G(D)$$

where

$M(D) = B_0D^{M-1} + B_1D^{M-2} + \ldots + B_{M-1}$ is the header bits represented as polynomial (over the binary field) where B_0 is bit 0 of the header and B_{M-1} is bit $M-1$ of the header

$I(D) = \sum_{k=M-16}^{M-1} D^k$ is an initialization polynomial added to the first 16 bits of the header (setting the shift register bits to 1)

$G(D) = D^{16} + D^{12} + D^5 + 1$ is the CRC generating polynomial

$CRC(D) = x_0D^{15} + x_1D^{14} + \ldots x_{14}D + x_{15}$

The CRC field is transmitted with x_{15} first.

For a block diagram and an example of how to calculate the CRC, see 15.3.3.7.

20.3.8 Common LDPC parity matrices

20.3.8.1 General

Four low-density parity check (LDPC) codes are specified, each of a different rate but with a common codeword size of 672 bits.

Each of the parity-check matrices ***H*** is partitioned into square submatrices of size $Z \times Z$. The submatrices are either cyclic-permutations of the identity matrix, or null submatrices with all zero entries.

A location with integer i denotes the cyclic-permutation submatrix P_i obtained from the $Z \times Z$ identity matrix by cyclically shifting the columns to the right by i elements. The matrix P_o is the $Z \times Z$ identity matrix. An empty location denotes a null submatrix of size $Z \times Z$.

Examples with $Z = 4$:

$$P_0 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad P_1 = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \end{bmatrix} \quad P_3 = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

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20.3.8.2 Rate 1/2 LDPC code matrix H = 336 rows x 672 columns, Z = 42

Table 20-6—Rate 1/2 LDPC code matrix
(Each nonblank element i in the table is the cyclic permutation matrix P_i of size $Z \times Z$; blank entries represent the zero matrix of size $Z \times Z$)

40		38		13		5		18							
34		35		27			30	2	1						
	36		31		7		34		10	41					
	27		18		12	20				15	6				
35		41		40		39		28			3	28			
29		0			22		4		28		27		23		
	31		23		21		20			12			0	13	
	22		34	31		14		4				13		22	24

20.3.8.3 Rate 5/8 LDPC code matrix H = 252 rows x 672 columns, Z = 42

Table 20-7—Rate 5/8 LDPC code matrix
(Each nonblank element i in the table is the cyclic permutation matrix P_i of size $Z \times Z$; blank entries represent the zero matrix of size $Z \times Z$)

20	36	34	31	20	7	41	34		10	41					
30	27		18		12	20	14	2	25	15	6				
35		41		40		39		28			3	28			
29		0			22		4		28		27	24	23		
	31		23		21		20		9	12			0	13	
	22		34	31		14		4						22	24

20.3.8.4 Rate 3/4 LDPC code matrix H = 168 rows x 672 columns, Z = 42

Table 20-8—Rate 3/4 LDPC code matrix
(Each nonblank element i in the table is the cyclic permutation matrix P_i of size $Z \times Z$; blank entries represent the zero matrix of size $Z \times Z$)

35	19	41	22	40	41	39	6	28	18	17	3	28			
29	30	0	8	33	22	17	4	27	28	20	27	24	23		
37	31	18	23	11	21	6	20	32	9	12	29		0	13	
25	22	4	34	31	3	14	15	4		14	18	13	13	22	24

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20.3.8.5 Rate 13/16 LDPC code matrix H = 126 rows x 672 columns, Z = 42

Table 20-9—Rate 13/16 LDPC code matrix
(Each nonblank element i in the table is the cyclic permutation matrix P_i of size $Z \times Z$; blank entries represent the zero matrix of size $Z \times Z$)

29	30	0	8	33	22	17	4	27	28	20	27	24	23		
37	31	18	23	11	21	6	20	32	9	12	29	10	0	13	
25	22	4	34	31	3	14	15	4	2	14	18	13	13	22	24

20.3.9 Scrambler

The header and data fields following the scrambler initialization field (including data padding bits) shall be scrambled by XORing each bit in turn with a length 127 periodic sequence generated by the polynomial $S(x) = x^7 + x^4 + 1$. The PHY header bits, with the exception of the first seven bits for SC and the first five bits for control mode, are placed one after the other, bit 7 first (bit 5 first for DMG control mode). The octets of the PSDU and the pad bits shall be placed into a bit stream with bit 0 (LSB) of each octet first and bit 7 of each octet (MSB) last. The generation of the sequence and the XOR operation are defined in Figure 20-5.

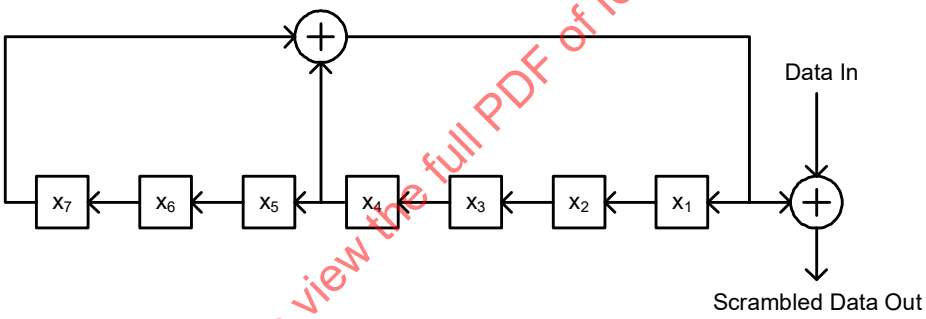

Figure 20-5—Data scrambler

For each PPDU, the transmitter shall select a nonzero seed value for the scrambler (bits x_1 to x_7). The seed value should be selected in a pseudorandom fashion. The seed value is sent in the Scrambler Initialization field of the PHY header. Each data bit in the data field of the PPDU is then XORed with the scrambler output ($x_4 \oplus x_7$) and then the scrambler content is shifted once.

20.3.10 Received channel power indicator (RCPI) measurement

The RCPI is a measure of the received RF power in the selected channel for a received frame. This parameter shall be a measure by the PHY of the received RF power in the channel measured over the preamble of the received frame.

The RCPI encoding is defined in 9.4.2.37.

RCPI shall equal the received RF power with an accuracy of ± 5 dB with 95% confidence interval within the specified dynamic range of the receiver. The received RF power shall be determined assuming a receiver noise equivalent bandwidth equal to the channel width multiplied by 1.1. The relative error between RF power measurements made within a 1 second interval should be less than ± 1 dB.

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20.4 DMG control mode

20.4.1 Introduction

Transmission and reception of control mode PPDUs is mandatory. DMG control mode uses the same chip rate as the DMG SC mode. DMG control mode is transmitted when the TXVECTOR indicates MCS 0.

The modulation and coding scheme for the DMG control mode is shown in Table 20-10.

Table 20-10—DMG control mode modulation and coding scheme

MCS index	Modulation	Code rate	Data rate
0	DBPSK	1/2[a]	27.5 Mb/s[a]

[a] Code rate and data rate might be lower due to codeword shortening.

20.4.2 PPDU format

The DMG control mode PPDU is composed of the Preamble, Header, Data field, and possibly AGC and TRN subfields. This is shown in Figure 20-6.

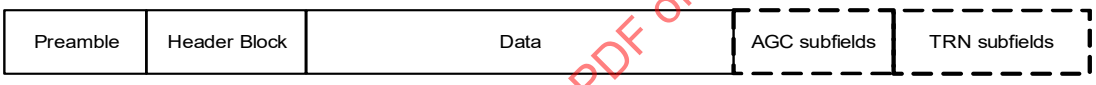

Figure 20-6—DMG control mode PPDU format

20.4.3 Transmission

20.4.3.1 Preamble

20.4.3.1.1 General

The preamble is the part of the DMG control mode PPDU that is used for packet detection, AGC, frequency offset estimation, synchronization, indication of frame type and channel estimation.

The preamble is composed of two parts as shown in Figure 20-7: the Short Training field and the Channel Estimation field.

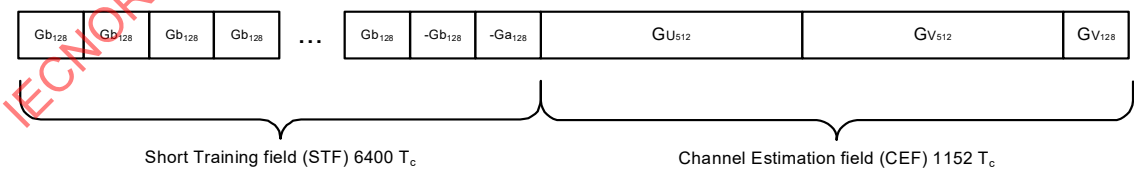

Figure 20-7—DMG control mode preamble

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20.4.3.1.2 Short Training field

The Short Training field is composed of 48 repetitions of the sequence $Gb_{128}(n)$ of length 128, followed by a single –Gb128(n) sequence (for synchronization) and then a single –Ga128(n) sequence. The sequences $Ga_{128}(n)$ and $Gb_{128}(n)$ are defined in 20.10.

The waveform for the Short Training field is

$$r_{STF}(nT_c) = \begin{cases} Gb_{128}(n \bmod 128)\exp\left(j\pi\frac{n}{2}\right) & n = 0, 1, \ldots, 48 \times 128 - 1 \\ -Gb_{128}(n \bmod 128)\exp\left(j\pi\frac{n}{2}\right) & n = 48 \times 128, \ldots, 49 \times 128 - 1 \\ -Ga_{128}(n \bmod 128)\exp\left(j\pi\frac{n}{2}\right) & n = 49 \times 128, \ldots, 50 \times 128 - 1 \end{cases}$$

where mod is the modulus operation. Note that sequences $Ga_{128}(n)$ and $Gb_{128}(n)$ are defined for $0 \le n \le 127$. For other n they are set to 0.

20.4.3.1.3 Channel Estimation field

The Channel Estimation field is the same as the Channel Estimation field of the DMG SC mode, as defined in Figure 20-4 of 20.3.6.3.

20.4.3.2 Header

20.4.3.2.1 General

In the DMG control mode, the preamble is followed by the header block. The header consists of several fields that define the details of the PPDU to be transmitted.

The header fields are described in Table 20-11.

Table 20-11—DMG control mode header fields

Field name	Bit	Description
Differential Encoder Initialization	B0	Used to initialize the differential encoding *c(0)* in 20.4.3.3.4. May be set to any value.
Scrambler Initialization	B1–B4	Bits X1–X4 of the initial scrambler state (see 20.4.3.3.2).
Length	B5–B14	Number of data octets in the PSDU. Range 14–1023.
PPDU Type	B15	As defined in Table 20-13.
Training Length	B16–B20	Length of the training field. The use of this field is defined in 20.9.2.2.3.
Turnaround	B21	Contains a copy of the parameter TURNAROUND from the TXVECTOR.
Reserved bits	B22–B23	
HCS	B24–B39	Header check sequence. Calculation of the header check sequence is defined in 20.3.7.

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Reserved bits are set to 0 by the transmitter and shall be ignored by the receiver.

20.4.3.2.2 Generation of HCS bits

The header check sequence (HCS) is calculated over bits 0-23 and uses CRC 16-CCITT as described in 20.3.7.

20.4.3.2.3 Header encoding and modulation

The header bits followed by the HCS bits are prepended to the data field bits and passed into the data field encoder per 20.4.3.3. The minimal payload length is 14 octets.

20.4.3.3 Data field

20.4.3.3.1 General

The Data field consists of the payload data of the PSDU. The PSDU is scrambled, encoded, modulated and spread as described in the following subclauses.

20.4.3.3.2 Scrambler

The operation of the scrambler is defined in 20.3.9. Bits x1, x2, x3, x4 of the scrambler shift register are initialized using the bits in the scrambler initialization bits from the header, bits x5, x6, x7 are set to 1. The header is scrambled starting from bit 5. The scrambling of the data field continues the scrambling of the header with no reset.

20.4.3.3.3 Encoder

The DMG control mode header and data is encoded using an effective LDPC code rate less than or equal to 1/2, generated from the data PHY rate 3/4 LDPC parity check matrix, with shortening. The following steps are used for the encoding:

1) $L_{CWD} = 168$ is the maximal number of data bits in each LDPC codeword. L_{HDR}=5 is the length of the header (including HCS) in octets. L_{FDCW}=6 is the length of the additional data in the first LDPC codeword in octets.
2) The total (header and additional data) number of bits in the first LDPC codeword is $L_{DPFCW} = (L_{HDR} + L_{FDCW}) \times 8 = 88$.
3) The number of LDPC codewords is $N_{CW} = 1 + \left\lceil \frac{(Length - 6) \times 8}{L_{CWD}} \right\rceil$.
4) The number of bits in the second and any subsequent LDPC codeword (if present), except the last, is $L_{DPCW} = \left\lceil \frac{(Length - 6) \times 8}{N_{CW} - 1} \right\rceil$.
5) The number of bits in the last LDPC codeword is $L_{DPLCW} = (Length - 6) \times 8 - (N_{CW} - 2) \times L_{DPCW}$.

NOTE—For example, if $Length = 128$, then $N_{CW} = 1 + \left\lceil \frac{(128 - 6) \times 8}{L_{CWD}} \right\rceil = 7$, $L_{DPCW} = 163$, and $L_{DPLCW} = 161$. In the first LDPC block, the 88 bits of L_{DPFCW} consist of 40 header+HCS bits along with 48 bits of the data.

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20.4.3.3.4 Modulation

The scrambled and coded bit stream $c(k)$, $k = 0, 1, 2, \ldots$, is converted into a stream of complex constellation points $d(k)$ using differential binary phase shift keying (DBPSK) as follows.

$c(k)$ is converted to the nondifferential stream $s(k) = 2c(k) - 1$. This is converted to the differential stream $d(k) = s(k) \times d(k-1)$, where $d(-1)$ is defined to be 1. $c(0)$ is the Differential Encoder Initialization field of the DMG control mode header.

NOTE—The scrambling process does not affect the Differential Encoder Initialization field of the DMG control mode header.

20.4.3.3.5 Spreading

The constellation points are spread using the sequence $Ga_{32}(n)$, which is defined in 20.10.

The waveform for the modulated and spread data field is

$$r_{DATA}(nT_c) = \left(Ga_{32}(n \bmod 32) \cdot d\left(\left\lfloor \frac{n}{32} \right\rfloor\right)\right) \exp\left(j\pi\frac{n}{2}\right), n = 0, 1, 2, \ldots$$

where $d(k)$ is the modulated constellation point k.

20.4.4 Performance requirements

20.4.4.1 Transmit requirements

20.4.4.1.1 Introduction

Transmitter performance requirements of the DMG control mode are defined in 20.4.4.1.2.

20.4.4.1.2 Transmit EVM

The transmit EVM accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc. The instrumentation shall perform carrier lock, symbol timing recovery, and amplitude adjustment while making the measurements. The instrumentation shall incorporate a rake receiver or equalizer to minimize error resulting from multipath. If used, the equalizer shall be trained using information in the preamble (STF and/or CEF). For the DMG control mode EVM, the signal is first despread using Ga_{32}. The EVM is then calculated on the resulting symbols according to the formula below:

$$EVM = 20\log_{10}\left(\sqrt{\left(\frac{1}{N_s P_{avg}} \sum_{i=1}^{N_s} [(I_i - I_i^* - I_0)^2 + (Q_i - Q_i^* - Q_0)^2]\right)}\right)$$

where

N_S	is the number of symbols to be measured
N_S	should be greater than 511
P_{avg}	is the average power of the constellation
(I_i, Q_i)	is the complex coordinates of the measured symbol i

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(I_i^*,Q_i^*) is the complex coordinates of the ideal constellation point for the measured symbol i

(I_0,Q_0) is the complex DC term chosen to minimize EVM

The test equipment should use a root-raised cosine filter with roll-off factor of 0.25 for the pulse shaping filter when conducting EVM measurement.

The transmit pulse shaping used is left to the implementer.

The EVM shall not exceed a data-rate dependent value according to Table 20-12.

Table 20-12—DMG control mode EVM requirements

MCS index	Description	EVM value [dB]
0	DMG control mode modulation	–6

20.4.4.2 Receive requirements

20.4.4.2.1 Introduction

Subclause 20.4.4.2 describes the performance requirement from the DMG control mode receiver.

20.4.4.2.2 CCA sensitivity

The start of a DMG control mode transmission at a receive level greater than –68 dBm shall cause CCA to indicate busy with a probability > 90% within 3 μs.

20.5 DMG SC mode

20.5.1 Introduction

Transmission and reception of DMG SC mode PPDUs is mandatory for selected MCSs.

20.5.2 PPDU format

A SC frame is composed of the Short Training field (STF), the channel estimation field (CE), the Header, SC blocks and optional training fields, as shown in Figure 20-8.

Figure 20-8—SC frame format

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20.5.3 Transmission

20.5.3.1 Header

20.5.3.1.1 General

In the DMG SC mode, the preamble is followed by the header. The header consists of several fields that define the details of the PPDU to be transmitted. The encoding and modulation of the header is described in 20.5.3.1.4.

The header fields are described in Table 20-13.

Table 20-13—DMG SC mode header fields

Field name	Bit	Description
Scrambler Initialization	B0–B6	Bits X1–X7 of the initial scrambler state (see 20.3.9).
Base MCS	B7–B11	Modulation and Coding Scheme (see Table 20-15)
Length	B12–B29	If the Extended SC MCS Indication field is 0, indicates the number of data octets in the PSDU; range 1–262 143. If the Extended SC MCS Indication field is 1, the Length field value is set to $Base_Length1 - \lfloor (Base_Length2 - N)/4 \rfloor$, where N is the number of data octets in the PSDU in the range 1 to 262 143, and *Base_Length1* and *Base_Length2* are computed according to Table 20-14.
Additional PPDU	B30	Contains a copy of the parameter ADD_PPDU from the TXVECTOR. A value of 1 indicates that this PPDU is immediately followed by another PPDU with no IFS or preamble on the subsequent PPDU. A value of 0 indicates that no additional PPDU follows this PPDU.
PPDU Type	B31	Corresponds to the TXVECTOR parameter PPDU_TYPE. — PPDU Type = 0 (BRP-RX PPDU, see 20.9.2.2.3), indicates either a PPDU whose Data field is followed by one or more TRN subfields (when the Beam Tracking Request field is 0 or in DMG control mode), or a PPDU that contains a request for TRN subfields to be appended to a future response PPDU (when the Beam Tracking Request field is 1). — PPDU Type = 1 (BRP-TX PPDU, see 20.9.2.2.3), indicates a PPDU whose Data field is followed by one or more TRN subfields. The transmitter may change AWV at the beginning of each TRN subfield. The field is reserved when the Training Length field is 0.
Training Length	B32–B36	Corresponds to the TXVECTOR parameter TRN_LEN. If the Beam Tracking Request field is 0, the Training Length field indicates the length of the training field. The use of this field is defined in 20.9.2.2.3. A value of 0 indicates that no training field is present in this PPDU. If the Beam Tracking Request field is 1 and the PPDU Type field is 1, the Training Length field indicates the length of the training field appended to this PPDU. If the PPDU Type field is 0, the Training Length field indicates the length of the training field requested for receive training.
Aggregation	B37	Set to 1 to indicate that the PPDU in the data portion of the packet contains an A-MPDU; otherwise, set to 0.

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Table 20-13—DMG SC mode header fields *(continued)*

Field name	Bit	Description
Beam Tracking Request	B38	Corresponds to the TXVECTOR parameter BEAM_TRACKING_REQUEST. Set to 1 to indicate the need for beam tracking (10.42.7); otherwise, set to 0. The Beam Tracking Request field is reserved when the Training Length field is 0.
Last RSSI	B39–B42	Contains a copy of the parameter LAST_RSSI from the TXVECTOR. The value is an unsigned integer: Values 2 to 14 represent power levels (–71+value×2) dBm. A value of 15 represents a power greater than or equal to –42 dBm. A value of 1 represents a power less than or equal to –68 dBm. A value of 0 indicates that the previous packet was not received a SIFS before the current transmission.
Turnaround	B43	Contains a copy of the parameter TURNAROUND from the TXVECTOR.
Extended SC MCS Indication	B44	The Extended SC MCS Indication field combined with the Base MCS field indicates the MCS. The Extended SC MCS Indication field indicates whether the Length field shall be calculated according to Table 20-14.
π/2-8-PSK Applied	B45	Corresponds to TXVECTOR parameter PSK_APPLIED. If this field is set to 1, π/2-8-PSK with corresponding LDPC shortening code with rates 2/3 or 5/6 is applied at the transmitter for MCS 10 or 11, respectively. If set to 0, π/2-16-QAM with LDPC code with rates 1/2 or 5/8 is applied at the transmitter for MCS 10 or 11, respectively.
Reserved	B46–B47	
HCS	B48–B63	Header check sequence

Reserved bits are set to 0 by the transmitter and shall be ignored by the receiver.

If the Additional PPDU field is equal to 1, the Training Length field shall be set to 0.

When the MCS belongs to the set {9.1, 12.1, 12.2, 12.3, 12.4, 12.5, 12.6}, bits X6, X7 of the initial scrambler state are set so that X6+X7×2 = (*Base_Length2* – *N*) mod 4, where *N* is the number of data octets in the PSDU, and *Base_Length2* is computed according to Table 20-14. Bits X1–X5 are selected in a pseudorandom fashion making sure that at least one bit in X1–X7 is nonzero.

NOTE—The combination of the values of the X6 and X7 in the Scrambler Initialization field and the Length field is unique for different PSDU lengths, i.e., there is a one-to-one mapping between a combination (X6, X7, Length) and a PSDU length, so the receiver can recover the actual PSDU length from the header fields. See 20.5.3.1.5 for an example algorithm for the length recovery.

X1–X7 are sent in the Scrambler Initialization field, as defined in 20.5.3.1.4 and 20.5.3.2.2.

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Table 20-14—Parameters for computing Length field value in SC header when Extended SC MCS Indication field is set to 1

MCS	*Base_Length1* (See NOTEs 1 and 2)	*Base_Length2* (See NOTEs 1 and 3)
9.1	$\left\lfloor \frac{N_{BLKS} \times 4}{3} \right\rfloor \times 42$	$\left\lfloor \left\lfloor \frac{N_{BLKS} \times 56}{39} \right\rfloor \times 68.25 \right\rfloor$
12.1	$\left\lfloor \left\lfloor \frac{N_{BLKS} \times 4}{3} \right\rfloor \times 52.5 \right\rfloor$	$\left\lfloor \left\lfloor \frac{N_{BLKS} \times 8}{3} \right\rfloor \times 68.25 \right\rfloor$
12.2	$\left\lfloor \frac{N_{BLKS} \times 4}{3} \right\rfloor \times 63$	$\left\lfloor \left\lfloor \frac{N_{BLKS} \times 112}{39} \right\rfloor \times 68.25 \right\rfloor$
12.3	$\left\lfloor \left\lfloor \frac{N_{BLKS} \times 4}{3} \right\rfloor \times 68.25 \right\rfloor$	$N_{BLKS} \times 210$
12.4	$\left\lfloor \frac{N_{BLKS} \times 8}{3} \right\rfloor \times 42$	$N_{BLKS} \times 252$
12.5	$\left\lfloor \left\lfloor \frac{N_{BLKS} \times 8}{3} \right\rfloor \times 52.5 \right\rfloor$	$N_{BLKS} \times 273$
12.6	$\left\lfloor \frac{N_{BLKS} \times 8}{3} \right\rfloor \times 63$	$\left\lfloor \left\lfloor \frac{N_{BLKS} \times 56}{13} \right\rfloor \times 68.25 \right\rfloor$

NOTE 1—N_{BLKS} is the number of symbol blocks defined in 20.5.3.2.3.3.

NOTE 2—*Base_Length1* is the maximum Length value such that the packet with the base MCS specified in SC header has the given N_{BLKS}.

NOTE 3—*Base_Length2* is the maximum number of data octets in PSDU such that the packet with the extended MCS has the given N_{BLKS}.

20.5.3.1.2 Modulation and coding scheme

The modulation and coding scheme defines the modulation and code rate that is used in the PPDU. The modulation and coding schemes for SC are defined in Table 20-15 and Table 20-16. PPDUs that have the π/2-8-PSK Applied field set to 0 in Table 20-13 follow Table 20-15. PPDUs that have the π/2-8-PSK Applied field set to 1 in Table 20-13 follow Table 20-15, except that MCS 10 and MCS 11 in this table shall be replaced by those in Table 20-16.

NOTE—The LDPC code with rate 2/3 is generated by employing the LDPC code with rate 3/4 and applying the codeword shortening procedure to achieve the effective code rate. The LDPC code with rate 5/6 is generated by employing the LDPC code with rate 13/16 and applying the codeword shortening and puncturing procedure. See 20.5.3.2.3.3.

Transmit and receive support for MCS 4 and below is mandatory. Other MCSs are optional. For STAs that support MCS 10, the support for π/2-16-QAM for MCS 10 is mandatory and the support for π/2-8-PSK or MCS 10 is optional. For STAs that support MCS 11, the support for π/2-8-16-QAM for MCS 11 is mandatory and the support for π/2-8-PSK for MCS 11 is optional.

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Table 20-15—DMG SC mode modulation and coding schemes

MCS	Base MCS field	Extended SC MCS Indication field	Modulation	N_{CBPS}	Repetition	Code rate	Data rate (Mb/s)
1	1	0	π/2-BPSK	1	2	1/2	385
2	2	0	π/2-BPSK	1	1	1/2	770
3	3	0	π/2-BPSK	1	1	5/8	962.5
4	4	0	π/2-BPSK	1	1	3/4	1155
5	5	0	π/2-BPSK	1	1	13/16	1251.25
6	6	0	π/2-QPSK	2	1	1/2	1540
7	7	0	π/2-QPSK	2	1	5/8	1925
8	8	0	π/2-QPSK	2	1	3/4	2310
9	9	0	π/2-QPSK	2	1	13/16	2502.5
9.1	6	1	π/2-QPSK	2	1	7/8	2695
10	10	0	π/2-16-QAM	4	1	1/2	3080
11	11	0	π/2-16-QAM	4	1	5/8	3850
12	12	0	π/2-16-QAM	4	1	3/4	4620
12.1	7	1	π/2-16-QAM	4	1	13/16	5005
12.2	8	1	π/2-16-QAM	4	1	7/8	5390
12.3	9	1	π/2-64-QAM	6	1	5/8	5775
12.4	10	1	π/2-64-QAM	6	1	3/4	6930
12.5	11	1	π/2-64-QAM	6	1	13/16	7507.5
12.6	12	1	π/2-64-QAM	6	1	7/8	8085

Table 20-16—DMG SC mode modulation and coding schemes when π/2-8-PSK Applied field is 1

MCS	Base MCS field	Extended SC MCS Indication field	Modulation	N_{CBPS}	Repetition	Code rate	Data rate (Mb/s)
10	10	0	π/2-8-PSK	3	1	2/3	3080
11	11	0	π/2-8-PSK	3	1	5/6	3850

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20.5.3.1.3 Generation of the HCS bits

Calculation of the HCS for bits 0–47 of the header is defined in 20.3.7.

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20.5.3.1.4 Header encoding and modulation

The header is encoded using a two SC block of N_{SPB} symbols with N_{GI} guard symbols. The bits are scrambled and encoded as follows:

1) The input header bits (B_1, B_2, …, B_{LH}), where LH = 64, are scrambled as described in 20.3.9, starting from the eighth bit. to create $\mathbf{d_{1s}}=(q_1,q_2,\ldots,q_{LH})$
2) The LDPC codeword $\mathbf{c} = (q_1,q_2,\ldots,q_{LH},0_1,0_2,\ldots,0_{504\text{-}LH},p_1,p_2,\ldots,p_{168})$ is created by concatenating 504-LH zeros to the LH bits of $\mathbf{d_{1s}}$ and then generating the parity bits $p_1,p_2,\ldots,p_{168}$ such that $\mathbf{Hc}^{\mathbf{T}} = \mathbf{0}$, where **H** is the parity check matrix for the rate 3/4 LDPC code specified in 20.5.3.2.3.2.
3) Remove bits LH+1 to 504 and bits 665 to 672 of the codeword **c** to create the sequence $\mathbf{cs1}=(q_1,q_2,\ldots,q_{LH},p_1,p_2,\ldots,p_{160})$.
4) Remove bits LH+1 to 504 and bits 657 to 664 of the codeword **c** to create the sequence $\mathbf{cs2} = (q_1,q_2,\ldots,q_{LH},p_1,p_2,\ldots,p_{152},p_{161},p_{162},\ldots,p_{168})$ and then XOR with a PN sequence that is generated from the LFSR used for data scramblings defined in 20.3.9. The LFSR is initialized to the all 1s vector.
5) **cs1** and **cs2** are concatenated to form the sequence (**cs1**, **cs2**). The resulting 448 bits are then mapped as $\pi/2$-BPSK as described in 20.5.3.2.4.2. The N_{GI} guard symbols are then prepended to the resulting N_{CBPB} symbols as described in 20.5.3.2.5.

The same resulting N_{CBPB} symbols are multiplied by –1 and repeated, and then prepended with N_{GI} guard symbols as described in 20.5.3.2.5. The resulting sequence is then appended after the sequence created in step 5).

20.5.3.1.5 Length recovery for extended SC MCSs at receiver

This subclause describes an example steps to calculate the PSDU length *N* at the receiver when the Extended SC MCS Indication field of the received PPDU is set to 1.

1) Compute N_{BLKS} using the values of the Base MCS and Length fields in the PHY header as if the Extended SC MCS Indication field is set to 0.
2) Compute *Base_Length1* and *Base_Length2* using N_{BLKS} computed in step 1) as defined in Table 20-14
3) Compute the PSDU length *N* using the following equation:

$$N = Base_Length2 - (4 \cdot (Base_Length1 - Length) + (X6 + 2 \cdot X7))$$

where

Length is the value of the Length field in the PHY header

X6 and *X7* are the 6th and 7th bits of the Scrambler Initialization field in the PHY header

NOTE—The equation is derived by the following equations a) to c).

a) The equation that defines the Length field value in the PHY header (see Table 20-13),

$$Length = Base_Length1 - \lfloor (Base_Length2 - N)/4 \rfloor$$

where

N is the PSDU length.

b) The equation that defines the two MSBs of the Scrambler Initialization field, X6 and X7 (see 20.5.3.1.1),

$$X6 + 2 \cdot X7 = (Base_Length2 - N) \bmod 4$$

c) The equations a) and b) mean that (*Base_Length1 – Length*) and ($X6 + 2 \cdot X7$) are respectively the quotient and remainder of dividing (*Base_Length2 – N*) by 4. Thus, the following equation is obtained,

$$Base_Length2 - N = 4 \cdot (Base_Length1 - Length) + (X6 + 2 \cdot X7)$$

and the equation in step 3) of this subclause is obtained after applying simple rearrangement.

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Table 20-17 shows several examples of length recovery.

Table 20-17—Examples of length recovery

PHY header values			Recovered values at receiver				
Base MCS	Length (Octets)	X6, X7 of Scramble Initialization	MCS	N_{BLKS}	Base_Length1 (Octets)	Base_Length2 (Octets)	PSDU Length, *N* (Octets)
6	150	1, 0	9.1	3	168	273	200
7	95	1, 0	12.1	2	105	341	300
8	464	0, 0	12.2	6	504	1160	1000
9	403	0, 1	12.3	5	409	1050	1024
10	838	0, 1	12.4	8	840	2016	2006
11	1323	0, 1	12.5	10	1365	2730	2560
12	1713	1, 1	12.6	11	1764	3207	3000

20.5.3.2 Data field

20.5.3.2.1 General

The data field consists of the payload data of the PSDU and possible padding. The data are padded with zeros, scrambled, encoded and modulated as described in the following subclauses. The amount of padding is defined in 20.5.3.2.3.

20.5.3.2.2 Scrambler

The operation of the scrambler is defined in 20.3.9. The scrambling of the PSDU continues the scrambling of the header with no reset of the scrambler.

20.5.3.2.3 Encoding

20.5.3.2.3.1 General

The data are encoded by a systematic LDPC encoder. The LDPC is a block code. Each block of information bits $(B_1, B_2,...,B_k)$ is concatenated with a block of parity bits $(p_1,p_2,....,p_{n-k})$ to create a codeword $\boldsymbol{c}=(B_1, B_2,...,B_k,p_1,p_2,....,p_{n-k})$ such that $\mathbf{Hc}^T=\mathbf{0}$, where **H** is the $(n-k)\times n$ parity check matrix. The block size n is 672 bits. The code rate, R, is equal to k/n. The set of code rates is defined in Table 20-18. The parity check matrices are defined in 20.5.3.2.3.2. The encoding process is defined in 20.5.3.2.3.3.

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Table 20-18—LDPC code rates

Code rate	Codeword size	Number of data bits
1/2	672	336
5/8	672	420
2/3	504	336
3/4	672	504
13/16	672	546
5/6	468	390
7/8	624	546

20.5.3.2.3.2 Parity check matrices

See 20.3.8.

20.5.3.2.3.3 LDPC encoding process

The LDPC encoding process is composed of several steps that includes deciding the number of shortening/ repetition bits in every codeword, the shortening itself, the coding of each word and then any repetition of bits.

a) First the total number of data pad bits N_{DATA_PAD} is calculated, using the number of LDPC codewords N_{CW}:

$$N_{CW} = \left\lceil \frac{Length \cdot 8}{\frac{L_{CW}}{\rho} \cdot R} \right\rceil$$

if BRP packet and $N_{CW} < N_{CWmin}$; $N_{CW} = N_{CWmin}$

$$N_{DATA_PAD} = N_{CW} \cdot \frac{L_{CW}}{\rho} \cdot R - Length \cdot 8$$

where

L_{CW} is the LDPC codeword length, which is 624 for code rate R=7/8, 504 for code rate R=2/3, 468 for code rate R=5/6, or 672 for all other code rates

$Length$ is the length of the PSDU indicated by the TXVECTOR parameter LENGTH (in octets)

ρ is the repetition factor (1 or 2)

R is the code rate

N_{CWmin} is defined for BRP PPDUs in Table 20-22.

The scrambled PSDU is concatenated with N_{DATA_PAD} zeros. They are scrambled using the continuation of the scrambler sequence that scrambled the PSDU input bits.

b) The procedure for converting the scrambled PSDU data to LDPC codewords depends on the repetition factor.

1) If $\rho = 1$ and the code rate is not one of 2/3, 5/6, 7/8,

i) The output stream of the scrambler is broken into blocks of $L_{CWD} = L_{CW} \times R$ bits such that the m^{th} data word is $(b_1^{(m)}, b_2^{(m)}, \ldots b_{L_{CWD}}^{(m)})$, $m \le N_{CW}$.

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ii) To each data word, $n\text{-}k=L_{CW}-R\times L_{CW}$ parity bits $(p_1^{(m)}, p_2^{(m)}, \ldots, p_{n-k}^{(m)})$ are added to create the codeword $\mathrm{c}^{(m)} = (b_1^{(m)}, b_2^{(m)}, \ldots, b_{L_{CWD}}^{(m)}, p_1^{(m)}, \ldots p_{n-k}^{(m)})$ such that $\mathbf{H}\boldsymbol{c}^{(m)^{\mathrm{T}}} = 0$

2) If ρ = 1 and the code rate is 7/8, 48 bits are punctured from the parity bits of the rate 13/16 parity bits:

i) The output stream of the scrambler is broken into blocks of 546 bits such that the m^{th} data word is $(b_1^{(m)}, b_2^{(m)}, \ldots, b_{546}^{(m)})$, $m \le N_{CW}$.

ii) To each data word, 126 parity bits $(p_1^{(m)}, p_2^{(m)}, \ldots, p_{126}^{(m)})$ are added to create the code word $\tilde{\boldsymbol{c}}^{(m)} = (b_1^{(m)}, b_2^{(m)}, \ldots, b_{546}^{(m)}, p_1^{(m)}, \ldots p_{126}^{(m)})$ such that $\boldsymbol{H}\tilde{\boldsymbol{c}}^{(m)^{\mathrm{T}}} = \mathbf{0}$. The code word $\boldsymbol{c}^{(m)}$ is generated from $\tilde{\boldsymbol{c}}^{(m)}$ by removing the first 48 parity bits so that $\boldsymbol{c}^{(m)} = (b_1^{(m)}, b_2^{(m)}, \ldots, b_{546}^{(m)}, p_{49}^{(m)}, p_{50}^{(m)}, \ldots p_{126}^{(m)})$

3) If ρ = 1 and the code rate is 2/3,

i) The output stream of the scrambler is broken into blocks of L_{CWD} = 336 bits such that he m^{th} data word is $(b_1^{(m)}, b_2^{(m)}, \ldots b_{L_{CWD}}^{(m)})$, $m \le N_{CW}$.

ii) To each data word, 168 zero bits $\mathbf{0}^{(m)} = (0_1, 0_2, \ldots 0_{168})$ and parity bits $\mathbf{p}^{(m)} = (p_1, p_2, \ldots p_{168})$ are added to create the codeword $\mathbf{c}^{(m)} = (\mathbf{b}^{(m)}, \mathbf{0}^{(m)}, \mathbf{p}^{(m)})$ such that $\boldsymbol{H}\boldsymbol{c}^{(m)^{\mathrm{T}}} = \mathbf{0}$, applying the rate 3/4 LDPC code matrix.

iii) Finally, the zero bits are discarded to create the output codeword $\boldsymbol{c}^{(m)} = (b_1^{(m)}, b_2^{(m)}, \ldots, b_{LWD}^{(m)}, p_1^{(m)}, \ldots p_{n-k}^{(m)})$.

4) If ρ = 1 and the code rate is 5/6,

i) The output stream of the scrambler is broken into blocks of L_{CWD} = 390 bits such that he m^{th} data word is $(b_1^{(m)}, b_2^{(m)}, \ldots b_{L_{CWD}}^{(m)})$, $m \le N_{CW}$.

ii) To each data word, 156 zero bits $\mathbf{0}^{(m)} = (0_1, 0_2, \ldots 0_{156})$ and parity bits parity bits $\mathbf{p}^{(m)} = (p_1, p_2, \ldots p_{126})$ are added to create the codeword $\tilde{\boldsymbol{c}}^{(m)} = (\mathbf{b}^{(m)}, \mathbf{0}^{(m)}, \mathbf{p}^{(m)})$ such that $\boldsymbol{H}\tilde{\boldsymbol{c}}^{(m)^{\mathrm{T}}} = \mathbf{0}$, applying the rate 13/16 LDPC code matrix.

iii) Finally, the zero bits are discarded to create the output codeword $\boldsymbol{c}^{(m)} = (b_1^{(m)}, b_2^{(m)}, \ldots, b_{390}^{(m)}, p_{49}^{(m)}, \ldots p_{126}^{(m)})$.

5) If ρ = 2,

i) The data bits in each codeword $(b_1, b_2, \ldots, b_{L_Z})$ where $L_Z = L_{CW}/2\rho$ are concatenated with $L_{CW}/2\rho$ zeros to produce a sequence of length of $2L_Z$ $(b_1, b_2, \ldots, b_{L_Z}, 0_1, 0_2, \ldots, 0_{L_Z})$.

ii) The LDPC codeword $\mathbf{c} = (b_1, b_2, \ldots, b_{L_Z}, 0_1, 0_2, \ldots, 0_{L_Z}, p_1, p_2, \ldots, p_{336})$ is created by generating the parity bits $p_1, p_2, \ldots, p_{336}$ such that $\mathbf{H}\mathbf{c}^{\boldsymbol{T}} = \mathbf{0}$, where $\mathbf{H}$ is the parity matrix for rate 1/2 LDPC coding specified in 20.3.8.

iii) Replace bits $L_Z + 1$ to 336 of the codeword $\mathbf{c}$ with bits from the sequence $b_1, b_2, \ldots, b_{L_Z}$ XORed by a PN sequence that is generated from the LFSR used for data scrambling as defined in 20.3.9. The LFSR is initialized to the all 1s vector and reinitialized to the same vector after every codeword.

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c) The codewords are then concatenated one after the other to create the coded bits stream $(c_1, c_2, \ldots, c_{L_{CW} \cdot N_{CW}})$.

d) The number of symbol blocks, N_{BLKS}, and the number of symbol block padding bits, N_{BLK_PAD}, are calculated:

$$N_{BLKS} = \left\lceil \frac{N_{CW} \cdot L_{CW}}{N_{CBPB}} \right\rceil$$

$$N_{BLK_PAD} = N_{BLKS} \cdot N_{CBPB} - N_{CW} \cdot L_{CW}$$

where N_{CBPB} is the number of coded bits per symbol block, per Table 20-19 in 20.5.3.2.5.

e) The coded bit stream is concatenated with N_{BLK_PAD} zeros. They are scrambled using the continuation of the scrambler sequence that scrambled the PSDU input bits.

20.5.3.2.4 Modulation mapping

20.5.3.2.4.1 General

The coded and padded bit stream is converted into a stream of complex constellation points according to the modulation specified in the MCS table.

20.5.3.2.4.2 π/2-BPSK modulation

In π/2-BPSK modulation, the input bit stream is mapped according to the following equation: $\tilde{s}_k = 2 \cdot c_k - 1$, where c_k is the k^{th} input coded (or scrambled pad) bit. Each output symbol is then rotated according to the following equation: $s_k = \tilde{s}_k \cdot e^{j\pi k/2}$. The constellation bit encoding for BPSK is shown in Figure 20-9.

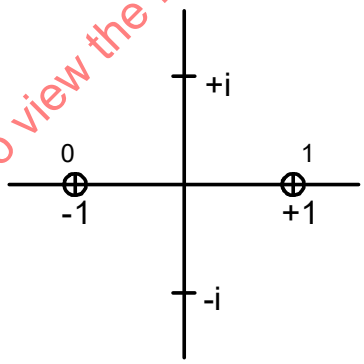

Figure 20-9—BPSK constellation bit encoding

NOTE—With appropriate choice of transmit filtering, π/2-BPSK is equivalent to a precoded pulse-shaped MSK (e.g., GMSK). The precoder is simply $b_{out,k} = b_{in,k} \oplus b_{in,k-1}$, $k = 0, 1, \ldots$, where $b_{in,k}$ is the scrambled input stream, $b_{in,-1}$ is 0, $b_{out,k}$ is the input to the (G)MSK modulator.

20.5.3.2.4.3 π/2-QPSK modulation

In π/2-QPSK modulation, the input bit stream is grouped into sets of 2 bits and mapped according to the following equation: $\tilde{s}_k = \frac{1}{\sqrt{2}}((2c_{2k} - 1) + j(2c_{2k+1} - 1)) \exp\left(-j\frac{\pi}{4}\right)$, where k is the output symbol index,

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k = 0, 1, …. Each output symbol is then rotated according to the following equation: $s_k = \tilde{s}_k \cdot e^{j\pi k/2}$. The constellation bit encoding for QPSK is shown in Figure 20-10.

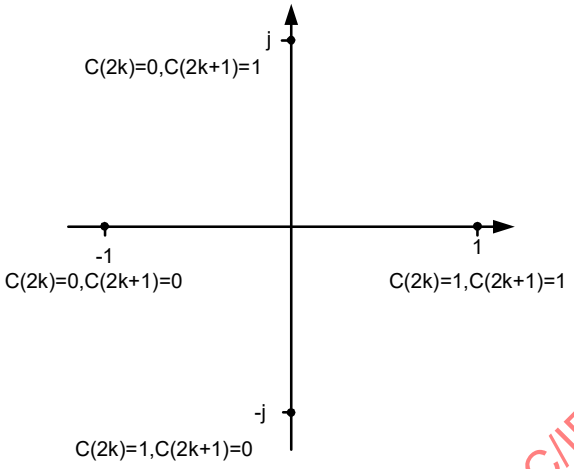

Figure 20-10—QPSK constellation bit encoding

20.5.3.2.4.4 π/2-8-PSK modulation

A DMG STA shall only apply π/2-8-PSK modulation to a PPDU transmitted to a peer STA if the π/2-8-PSK Supported field in the peer STA's DMG Capabilities element is equal to 1.

In π/2-8-PSK modulation, the input stream is grouped into sets of 3 bits and mapped according to the following equation:

$$\tilde{s}_k = \exp\left(j\frac{\pi}{4}(c_{3k} - 3c_{3k+1} - c_{3k+2} - 2c_{3k}c_{3k+1} + 2c_{3k+1}c_{3k+2} + 2c_{3k}c_{3k+2} + 4c_{3k}c_{3k+1}c_{3k+2} + 4)\right)$$

where k is the symbol output index, k = 0, 1, …. Each output symbol is then rotated according to the following equation: $s_k = \tilde{s}_k \cdot e^{j\pi k/2}$. The constellation bit encoding for 8-PSK before π/2 rotation is in Figure 20-11.

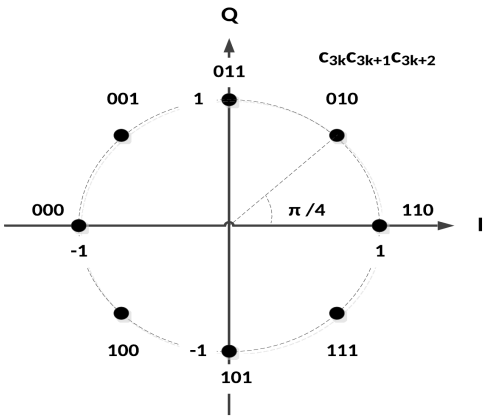

Figure 20-11—8-PSK constellation bit encoding (before π/2 rotation)

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20.5.3.2.4.5 π/2-16-QAM modulation

In π/2-16-QAM modulation, the input bit stream is grouped into sets of 4 bits and mapped according to the following equation:

$$\tilde{s}_k = \frac{1}{\sqrt{10}}\{(4c_{4k}-2)-(2c_{4k}-1)(2c_{4k+1}-1)+j(4c_{4k+2}-2)-j(2c_{4k+2}-1)(2c_{4k+3}-1)\}$$

where k is the output symbol index, k =0, 1, …. Each output symbol is then rotated according to the following equation: $s_k = \tilde{s}_k \cdot e^{j\cdot\pi\cdot k/2}$. The constellation bit encoding for 16-QAM is shown in Figure 20-12.

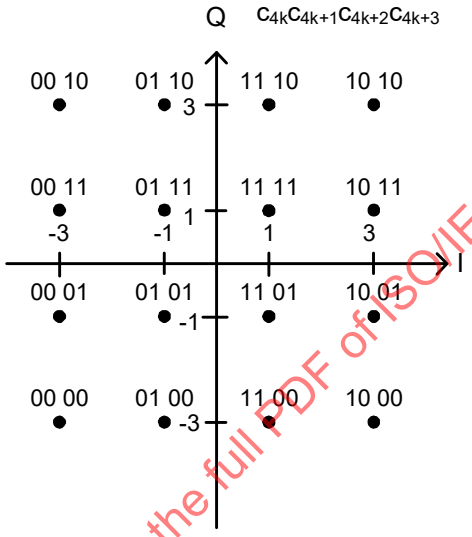

Figure 20-12—16-QAM constellation bit encoding

20.5.3.2.4.6 π/2-64-QAM modulation

In π/2-64-QAM modulation, the input bit stream is grouped in sets of 6 bits and mapped according to the following equation:

$$\tilde{s}_k =$$

$$\frac{1}{\sqrt{42}}((8c_{6k}-4)-(2c_{6k}-1)(4c_{6k+1}-2)+(2c_{6k}-1)(2c_{6k+1}-1)(2c_{6k+2}-1))+$$

$$\frac{j}{\sqrt{42}}((8c_{6k+3}-4)-(2c_{6k+3}-1)(4c_{6k+4}-2)+(2c_{6k+3}-1)(2c_{6k+4}-1)(2c_{6k+5}-1))$$

where k is the output symbol index, k=0,1, …. Each output symbol is then rotated according to the following equation $s_k = \tilde{s}_k \cdot e^{\frac{j\pi k}{2}}$. The constellation bit encoding for 64-QAM is shown in Figure 20-13.

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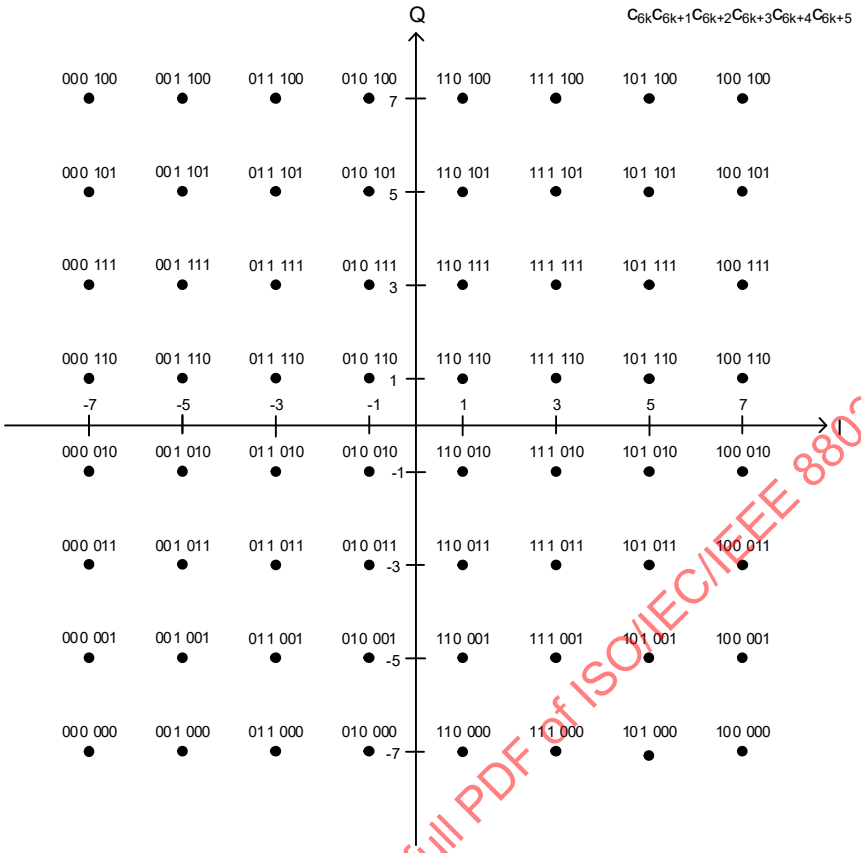

Figure 20-13—64-QAM constellation bit encoding

20.5.3.2.5 Symbol blocking and guard insertion

Each group of N_{CBPB} bits is prepended by π/2-BPSK symbols generated by the 64 point Golay sequence Ga_{64} defined in 20.10. N_{CBPB} values are shown in Table 20-19. The starting index for the first symbol for π/2 rotation is 0.

Table 20-19—Values of N_{CBPB}

Symbol mapping	N_{CBPB}
π/2-BPSK	448
π/2-QPSK	896
π/2-16-QAM	1792
π/2-64-QAM	2688

If the Additional PPDU field within the PHY header is equal to 0, the final block transmitted is followed by the same Golay sequence guard interval. See Figure 20-14. If the Additional PPDU field within the PHY header is equal to 1, the final block transmitted of the last PPDU in an A-PPDU is followed by the same Golay sequence guard interval.

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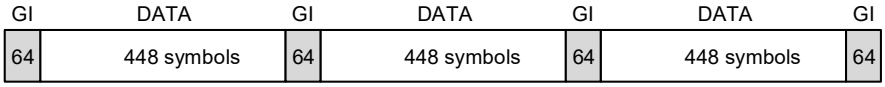

Figure 20-14—Block transmission

20.5.4 Performance requirements

20.5.4.1 Transmit requirements

20.5.4.1.1 Transmit EVM

The transmit EVM accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc.

The instrumentation shall perform carrier lock, symbol timing recovery and amplitude adjustment and equalization while making the measurements. The equalizer shall be trained using information in the SC preamble (STF and/or CEF). For the DMG SC mode EVM, measuring Ns samples at the sample rate, the measured symbols should not contain the first and the last hundred symbols of a given packet (ramp up/down). The EVM is calculated according to the formula below:

$$EVM = 20\log_{10}\left(\sqrt{\left(\frac{1}{N_s P_{avg}}\sum_{i=1}^{N_s}\left[(I_i - I_i^* - I_0)^2 + (Q_i - Q_i^* - Q_0)^2\right]\right)}\right)$$

where N_s is the number of samples to be measured and N_s shall be 1000, P_{avg} is the average power of the constellation, (I_i, Q_i) is the complex coordinates of the measured symbol i, (I_i^*, Q_i^*) is the complex coordinates of the ideal constellation point for the measured symbol i, and (I_o, Q_o) is the complex DC term chosen to minimize EVM.

The test equipment should use a root-raised cosine filter with roll-off factor of 0.25 for the pulse shaping filter when conducting EVM measurement.

The transmit pulse shaping used is left to the implementer.

The relative constellation error (EVM) shall not exceed an MCS dependent value according to Table 20-20.

Table 20-20—DMG SC mode EVM requirements

MCS	Modulation	Coding rate	EVM value [dB]
1	π/2-BPSK	1/2 with repetition	–6
2	π/2-BPSK	1/2	–7
3	π/2-BPSK	5/8	–9
4	π/2-BPSK	3/4	–10
5	π/2-BPSK	13/16	–12
6	π/2-QPSK	1/2	–11

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Table 20-20—DMG SC mode EVM requirements *(continued)*

MCS	Modulation	Coding rate	EVM value [dB]
7	π/2-QPSK	5/8	–12
8	π/2-QPSK	3/4	–13
9	π/2-QPSK	13/16	–15
9.1	π/2-QPSK	7/8	–16
10	π/2-16-QAM	1/2	–19
11	π/2-16-QAM	5/8	–20
12	π/2-16-QAM	3/4	–21
12.1	π/2-16-QAM	13/16	–22
12.2	π/2-16-QAM	7/8	–23
12.3	π/2-64-QAM	5/8	–26
12.4	π/2-64-QAM	3/4	–27
12.5	π/2-64-QAM	13/16	–29
12.6	π/2-64-QAM	7/8	–31

20.5.4.1.2 Time of Departure accuracy

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is 1760×10^6 sample/s
— FIRST_TRANSITION_FIELD is Short Training field
— SECOND_TRANSITION_FIELD is Channel Estimation field
— TRAINING_FIELD is Channel Estimation field
— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

20.5.4.2 Receive requirements

20.5.4.2.1 Introduction

This subclause describes the receiver requirements of the DMG SC mode.

20.5.4.2.2 CCA sensitivity

The start of a DMG SC mode transmission at a receive level greater than the minimum sensitivity for MCS 1 (–68 dBm) shall cause CCA to indicate busy with a probability > 90% within 1 μs. The receiver shall hold the carrier sense signal busy for any signal 20 dB above the minimum sensitivity for MCS 1.

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20.6 DMG low-power SC mode

20.6.1 Introduction

The DMG low-power SC mode is obsolete, and support for this mode might be subject to removal in a future revision of the standard.

The DMG low-power SC mode is an optional SC mode that can provide lower processing power requirements for DMG transceivers.

20.6.2 Transmission

20.6.2.1 Preamble

The DMG low-power SC mode uses the same preamble as the DMG SC mode.

20.6.2.2 Header

20.6.2.2.1 General

The DMG low-power SC mode header fields are the same fields as in the DMG SC mode (see Table 20-13 in 20.5.3.1).

The DMG low-power SC mode modulation and coding schemes are listed in Table 20-21.

Table 20-21—DMG low-power SC mode modulation and coding schemes

MCS	Modulation	Effective code rate	Coding scheme	N_{CPB}	Rate (Mb/s)
25	π/2-BPSK	13/28	RS(224,208)+Block-Code(16,8)	392	626
26	π/2-BPSK	13/21	RS(224,208)+Block-Code(12,8)	392	834
27	π/2-BPSK	52/63	RS(224,208)+SPC(9,8)	392	1112
28	π/2-QPSK	13/28	RS(224,208)+Block-Code(16,8)	392	1251
29	π/2-QPSK	13/21	RS(224,208)+Block-Code(12,8)	392	1668
30	π/2-QPSK	52/63	RS(224,208)+SPC(9,8)	392	2224
31	π/2-QPSK	13/14	RS(224,208)+Block-Code(8,8)	392	2503

20.6.2.2.2 Header encoding and modulation

The DMG low-power SC mode header is encoded and modulated as defined in 20.5.3.1.4.

20.6.2.3 Data field

20.6.2.3.1 General

The data field consists of the payload data of the PSDU and possible padding. The data are padded with zeros, scrambled, encoded and modulated as described in the following subclauses.

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20.6.2.3.2 Scrambler

The operation of the scrambler is defined in 20.3.9. The scrambling of the PSDU continues the scrambling of the header with no reset of the scrambler. The padding bits are also scrambled.

20.6.2.3.3 Encoding

20.6.2.3.3.1 General

Data is encoded using an outer RS(224,208) block code and a short inner code. The inner code is a (16,8) block code for MCSs 25 and 28, a (12,8) block code for MCSs 26 and 29, and a (9,8) single parity check (SPC) block code for MCSs 27 and 30 and the identity block-code for MCS 31. The encoding is further detailed in the following steps:

1) First, the number of block padding bits is calculated:
   a) The total number of Reed Solomon codewords is $N_{RS} = \lceil (Length)/208 \rceil$ and the total number of RS encoded symbols is given by $Length + N_{RS} \times 16$;
   b) After Reed Solomon encoding, the data is encoded with a short block code (N,8) where N can take one of the following values 8, 9, 12, or 16 depending on the MCS as shown in Table 20-21. Therefore:
      i) The total number of encoded bits is $N_{EB} = N \times (Length + N_{RS} \times 16)$;
      ii) The total number of 512 (in length) blocks (each containing 392 data symbols) is $N_{BLKS} = \lceil N_{EB}/(N_{CBPS} \times 392) \rceil$. If BRP PPDU and $N_{BLKS} < N_{BLKS_MIN}$; $N_{BLKS} = N_{BLKS_MIN}$, where $N_{BLKS_MIN} = 18$. The total number of zero block padding bits is $N_{BLK_PAD} = N_{BLKS} \times N_{CBPS} \times 392 - N_{EB}$.
2) The data is broken into blocks of length 208×8 bits (except for possibly the last block).
3) Each block is encoded using the RS(224,208) block code as described in 20.6.2.3.3.2, except perhaps the last block, which is encoded by a shortened version of the code (i.e., if the last block length is K, the shortened block code is RS(16+K,K).
4) The Reed Solomon encoded data stream is further encoded using the block code(N,8) as described in 20.6.2.3.3.3.
5) The coded bit stream is concatenated with N_{BLK_PAD} zeros. They are scrambled with the continuation of the scrambler sequence that scrambled the PSDU input bits.
6) Each set of 7 octets is interleaved using a uniform interleaver of 7 rows and 8 columns. The 7 octets are written row wise and read column wise, i.e., the index i of a bit after interleaving is related to the index k of a bit before interleaving by the following rule:

   $i = 8 \times (k \bmod 7) + \lfloor k/7 \rfloor$, $k = 0, 1, \ldots, 55$

7) The resulting bit stream is modulated and then blocked as described in 20.6.2.3.4 and 20.6.2.3.5.

20.6.2.3.3.2 RS encoding

The RS block code is based on the polynomial

$$g(x) = \prod_{k=1}^{16} (x + a^k)$$

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where $a = 0x02$ is a root of the primitive polynomial $p(x) = 1 + x^2 + x^3 + x^4 + x^8$. Assume that an octet $b_0 b_1 b_2 b_3 b_4 b_5 b_6 b_7$ (b_0 is the LSB) represented by the polynomial

$$M = b_7 x^7 + b_6 x^6 + b_5 x^5 + b_4 x^4 + b_3 x^3 + b_2 x^2 + b_1 x + b_0 .$$

The RS is a systematic block code. Given a block of octets $\mathbf{m} = (m_{M-1}, m_{M-2}, \ldots m_0)$, the additional parity octets $\mathbf{r} = (r_{15}, r_{14}, \ldots r_0)$ are calculated by setting $r = x^{16}\mathbf{m}(x) \bmod \mathrm{g}(x)$, where $\mathbf{r}(x) = \sum_{k=0}^{15} r_k x^k$ and $\mathbf{m}(x) = \sum_{k=0}^{M-1} m_k x^k$ and where the calculation is performed over $GF(2^8)$. The parity octets $\mathbf{r}$ are appended to the uncoded block $\mathbf{m}$ to generate the encoded RS block $m_{M-1}, m_{M-2}, \ldots m_0, r_{15}, r_{14}, \ldots, r_0$.

20.6.2.3.3.3 (N,8) Block-coding

Every octet $\mathbf{b}_{1\times 8} = [b_0 b_1 b_2 b_3 b_4 b_5 b_6 b_7]$ is encoded into an N-bit codeword $\mathbf{c}_{1\times N} = \left[\, \mathbf{b}_{1\times 8} \;\; \mathbf{p}_{1\times(N-8)} \,\right]$ such that $\mathbf{c}_{1\times N} = \mathbf{b}_{1\times 8}\mathbf{G}_{8\times N}$, where the generator matrix $\mathbf{G}_{8\times N}$ is given by the following expressions for $N = 8$, 9, 12, *and* 16, respectively: G_{8x8} is the identity matrix.

$$\mathbf{G}_{8\times 9} = \begin{bmatrix} 1&0&0&0&0&0&0&0&1 \\ 0&1&0&0&0&0&0&0&1 \\ 0&0&1&0&0&0&0&0&1 \\ 0&0&0&1&0&0&0&0&1 \\ 0&0&0&0&1&0&0&0&1 \\ 0&0&0&0&0&1&0&0&1 \\ 0&0&0&0&0&0&1&0&1 \\ 0&0&0&0&0&0&0&1&1 \end{bmatrix}$$

$$\mathbf{G}_{8\times 12} = \begin{bmatrix} 1&0&0&0&0&0&0&0&1&1&0&0 \\ 0&1&0&0&0&0&0&0&1&0&1&0 \\ 0&0&1&0&0&0&0&0&1&0&0&1 \\ 0&0&0&1&0&0&0&0&0&0&1&1 \\ 0&0&0&0&1&0&0&0&1&0&1&1 \\ 0&0&0&0&0&1&0&0&1&1&0&1 \\ 0&0&0&0&0&0&1&0&1&1&1&0 \\ 0&0&0&0&0&0&0&1&0&1&1&1 \end{bmatrix}$$

$$\mathbf{G}_{8\times 16} = \begin{bmatrix} 1&0&0&0&0&0&0&0&0&1&1&0&1&0&1&0 \\ 0&1&0&0&0&0&0&0&0&0&1&1&0&1&0&1 \\ 0&0&1&0&0&0&0&0&1&0&0&1&1&0&1&0 \\ 0&0&0&1&0&0&0&0&0&1&0&0&1&1&0&1 \\ 0&0&0&0&1&0&0&0&1&0&1&0&0&1&1&0 \\ 0&0&0&0&0&1&0&0&0&1&0&1&0&0&1&1 \\ 0&0&0&0&0&0&1&0&1&0&1&0&1&0&0&1 \\ 0&0&0&0&0&0&0&1&1&1&0&1&0&1&0&0 \end{bmatrix}$$

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20.6.2.3.4 Modulation

The same π/2-BPSK described in 20.5.3.2.4.2 and π/2-QPSK described in 20.5.3.2.4.2 are used in the DMG low-power SC mode.

20.6.2.3.5 Blocking

The blocking for the low-power SC is illustrated in Figure 20-15. The data is partitioned into blocks of length 512 wherein each 512-block is constructed from 8 subblocks. Each subblock is of length 64. The first subblock is a G_{64}, which is the π/2-BPSK symbols sequence generated by the 64 point Golay sequence Ga_{64} defined in 20.10. The starting index for the first symbol π/2 rotation is 0, and subblocks 2 to 8 are constructed in the same way, i.e., a data portion of 56 symbols followed by a guard interval of 8 symbols. Note that each 512-block carries 392 symbols of data and 120 symbols of guard.

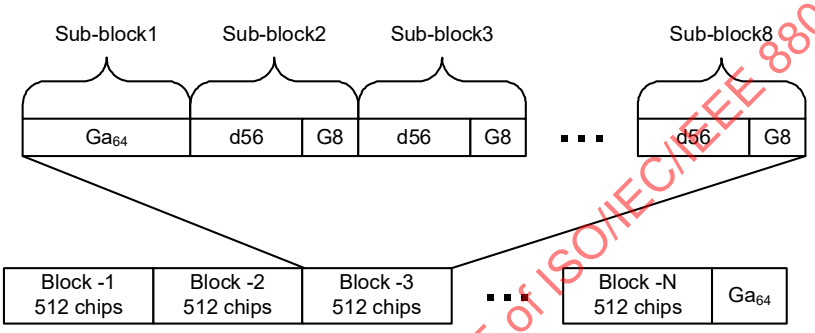

Figure 20-15—Blocking for DMG low-power SC mode

If the Additional PPDU field within the PHY header is equal to 0, the final block transmitted is followed by Ga_{64}. If the Additional PPDU field within the PHY header is equal to 1, the final block transmitted of the last PPDU in an A-PPDU is followed by Ga_{64}.

The G_8 guard interval is a copy of the last 8 samples of Ga_{64}.

NOTE—A STA might estimate the channel impulse response from the CEF, and decides whether to equalize using the 512-block or the short 64-subblock. For example, if the channel impulse response energy is almost concentrated in 8 taps, a 64-equalizer can be used; otherwise, a 512-equalizer is used.

20.7 PHY transmit procedure

The PHY transmit procedure is shown in Figure 20-16. In order to transmit data, a PHY-TXSTART.request primitive shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate frequency through station management via the PLME, as specified in 20.11. Other transmit parameters, such as MCS and transmit power, are set via the PHY SAP with the PHY-TXSTART.request(TXVECTOR) primitive, as described in 20.2.2.

Transmission of the PHY preamble may start if TIME_OF_DEPARTURE_REQUESTED is false, and shall start immediately if TIME_OF_DEPARTURE_REQUESTED is true, based on the parameters passed in the PHY-TXSTART.request primitive.

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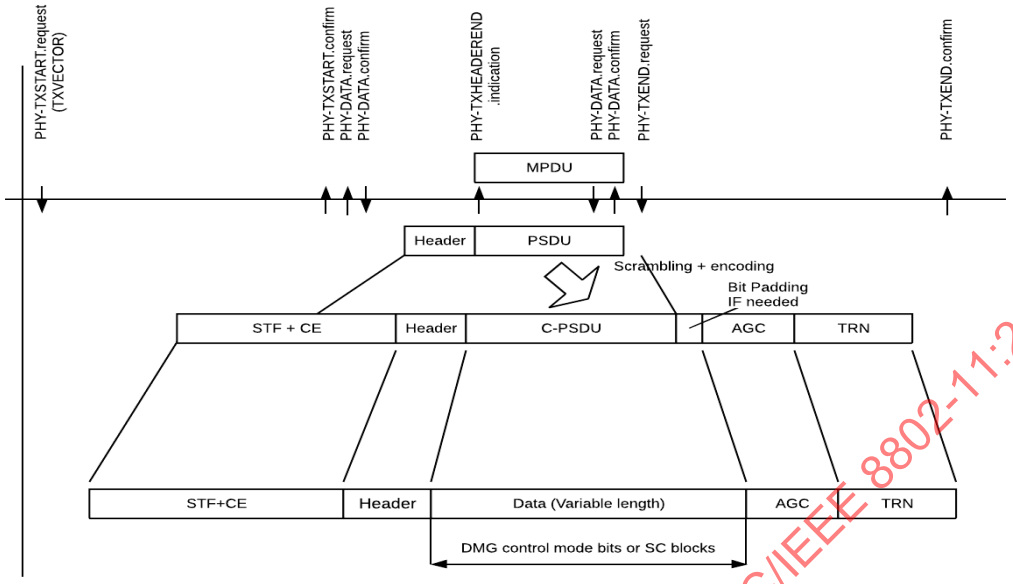

Figure 20-16—PHY transmit procedure

The preamble format (control or SC mode) depend on the MCS in the PHY-TXSTART.request primitive. The PHY shall calculate the length of the packet according the MCS and the length specified in the PHY-TXSTART.request primitive, adding padding bits if necessary.

The PHY continues with the encoding and transmission of the header according to the parameters of the PHY-TXSTART.request(TXVECTOR) primitive. The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. The data are encoded as described in 20.4.3.2.3 and 20.5.3.2.3. The encoded data are then modulated as described in 20.4, 20.5, and 20.6, depending on the MCS requested in the PHY-TXSTART.request primitive. Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive.

Transmission of the PSDU is completed with the transmission of the last bits of the (encoded) PSDU. If no TRN-T/R fields are specified in the PHY-TXSTART.request primitive, the PHY shall issue a PHY-TXEND.confirm primitive after the transmission of the last bits. If TRN units are requested in the PHY-TXSTART.request primitive, the transmission continues with the transmission of AGC subfields and TRN units. The PHY issues the PHY-TXEND.confirm primitive to the MAC after the transmission of the last TRN unit. The packet transmission shall be completed, and the PHY entity shall enter the receive state. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

A typical transmit state machine is shown in Figure 20-17.

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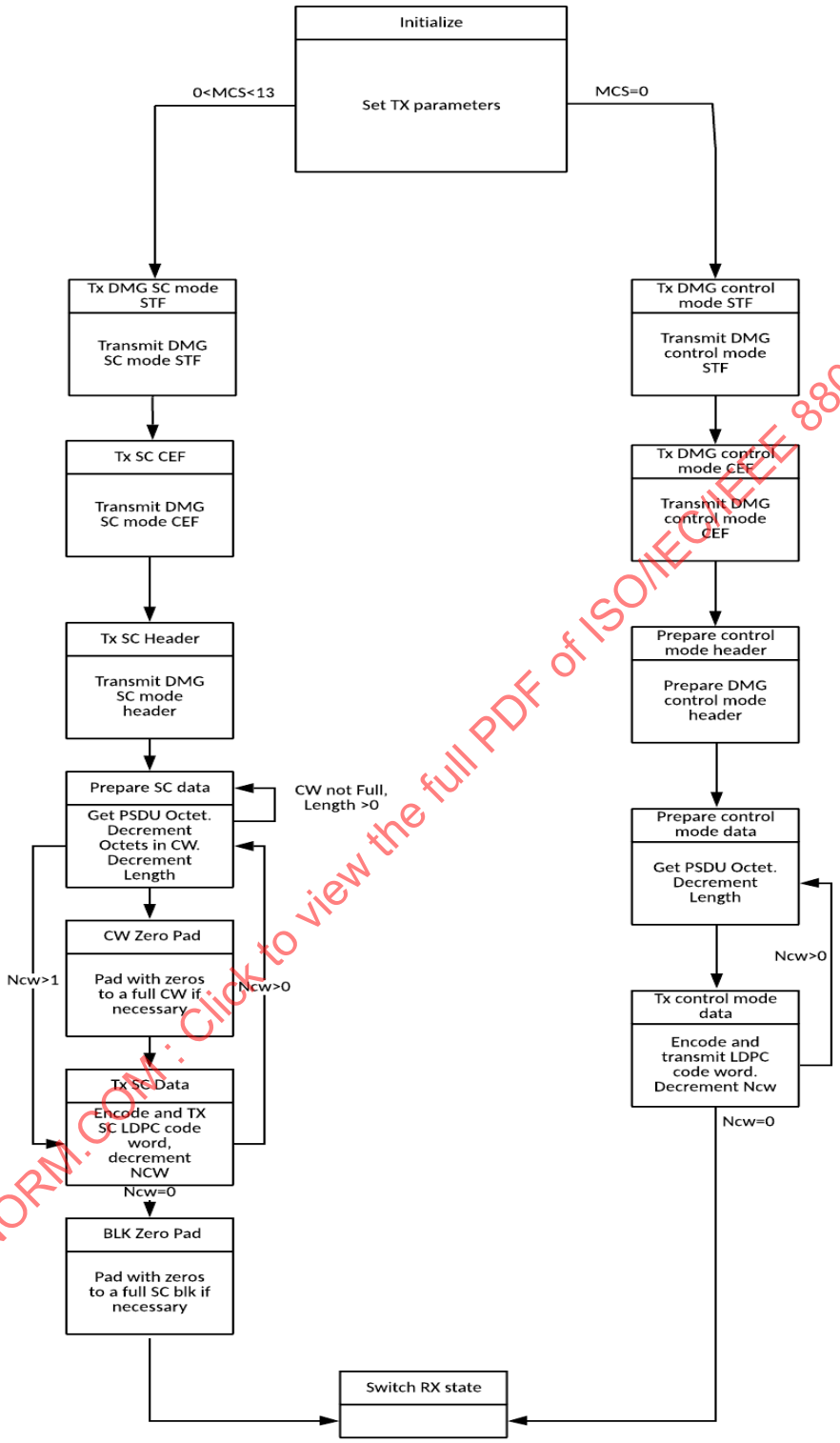

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Figure 20-17—Typical Tx state machine
(Training Length = 0 is assumed; some optional features such as DMG SC low-power mode are not shown)

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20.8 PHY receive procedure

A typical PHY receive procedure is shown in Figure 20-18.

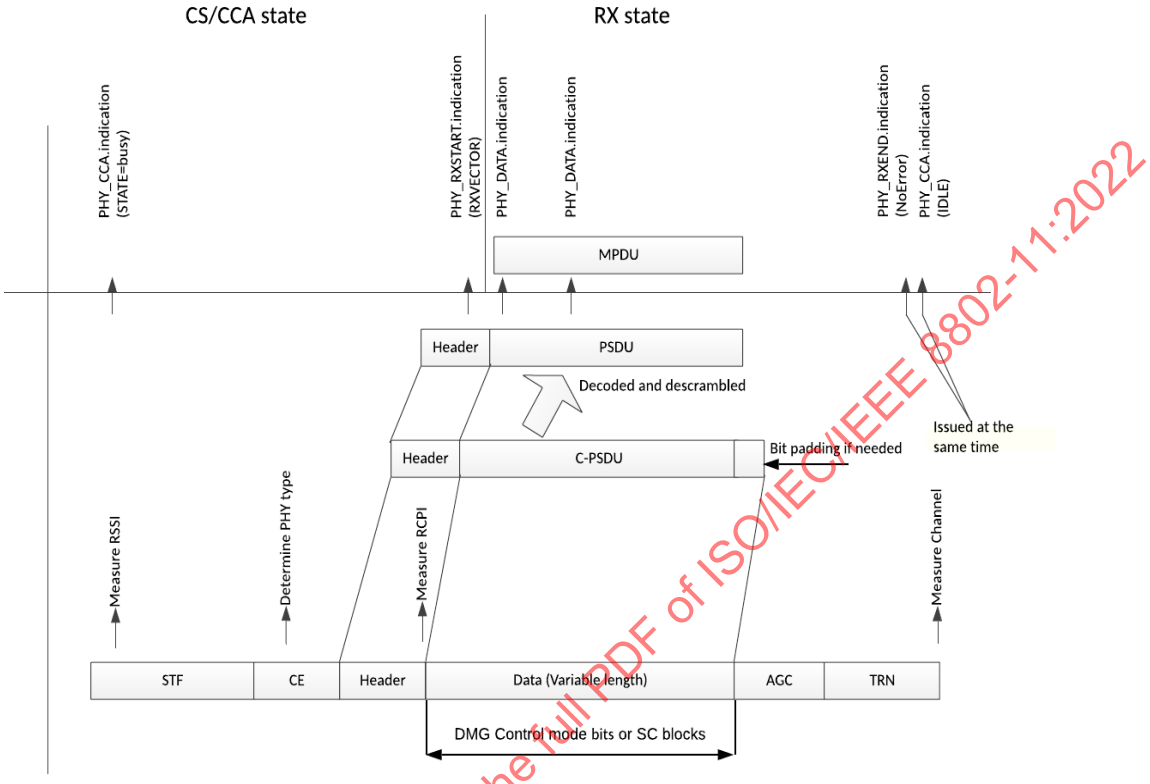

Figure 20-18—PHY receive procedure

Upon receiving the STF, the PHY measures signal strength. This activity is indicated by the PHY to the MAC by issuing a PHY-CCA.indication(BUSY) primitive.

After the PHY-CCA.indication(BUSY) primitive is issued, the PHY entity shall search for the CE field and begin receiving the CE field. The PHY demodulates the header following the reception of the CE field. If the receiver is capable of receiving low-power SC mode, and dot11LowPowerSCPHYActivated is true, then the PHY shall attempt to demodulate both a SC header and an SC low-power header. The PHY shall decode the header and determine the MCS, length and other parameters needed for the demodulation of the packet.

Subsequently, if dot11TimingMsmtActivated is true, a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued and RX_START_OF_FRAME_OFFSET parameter within the RXVECTOR shall be forwarded (see 20.2.2).

NOTE—The RX_START_OF_FRAME_OFFSET value is used as described in 6.3.55 in order to estimate when the start of the preamble for the incoming frame was detected on the medium at the receive antenna connector.

At the end of the data portion of a packet that has the Training Length field in the PHY header equal to 0, the PHY shall issue a PHY-RXEND.indication(No_Error) primitive to the MAC. If the Training Length field in the PHY header is greater than 0, the PHY shall continue to receive these training fields after the data portion of the packet and measure the channel. After the end of the training fields, the PHY shall generate a PHY-CCA.indication(IDLE) primitive and the PHY-RXEND.indication(NoError) primitive.

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In the case of signal loss before the decoding of the header or in the case of an invalid header, the PHY shall not generate a PHY-CCA.indication(IDLE) primitive until the received level drops below a value that is 20 dB higher than the receive sensitivity of MCS 1. In the case of signal loss after decoding of a valid header, the PHY shall not generate a PHY-CCA.indication(IDLE) primitive until the expected end of the packet, including AGC and TRN fields.

A typical receive state machine is shown in Figure 20-19.

20.9 Beamforming

20.9.1 Beamforming concept

Beamforming enables a pair of STAs to train their transmit and receive antennas for subsequent communication. A beamformed link is established following the successful completion of BF training, which is described in 10.42.

DMG STAs use a quasi-omni antenna pattern. The antenna gain of the main beam of a quasi-omni antenna pattern shall be at most 15 dB lower than the antenna gain in the main beam for a directional pattern.

20.9.2 Beamforming frame format

20.9.2.1 Sector-level sweep

PPDUs transmitted during transmit sector sweep are DMG control mode PPDUs. PPDUs transmitted during receive sector sweep are DMG control mode or DMG SC mode PPDUs.

20.9.2.2 Beam refinement

20.9.2.2.1 General

Beam refinement is a process where a STA can improve its antenna configuration (or antenna weight vectors) both for transmission and reception. If the SLS beamforming training did not include an RSS, as in the case where both devices have more than one transmit sector per antenna, beam refinement can serve as the first receive antenna configuration training. The procedure of beam refinement is described in 10.42.6.4.

In the beam refinement procedure, BRP PPDUs are used to train the receiver and transmitter antenna. There are two types of BRP PPDUs: BRP-RX PPDUs and BRP-TX PPDUs:

— BRP-RX PPDUs are PPDUs that have an AGC field and a TRN field following the Data field. These PPDUs enable receiver antenna weight vector training. A BRP-RX PPDU has the header field Training Length greater than zero, PPDU Type equal to zero and Beam Tracking Request (if present) equal to 0.

— BRP-TX PPDUs are PPDUs that have an AGC field and a TRN field following the Data field. The transmitting STA may change antenna configuration at the beginning of each subfield. The receiving STA performs measurements on these subfields and sends feedback to the STA that transmits the BRP-TX PPDU. A BRP-RX PPDU has the header field Training Length greater than zero and PPDU Type equal to 1.

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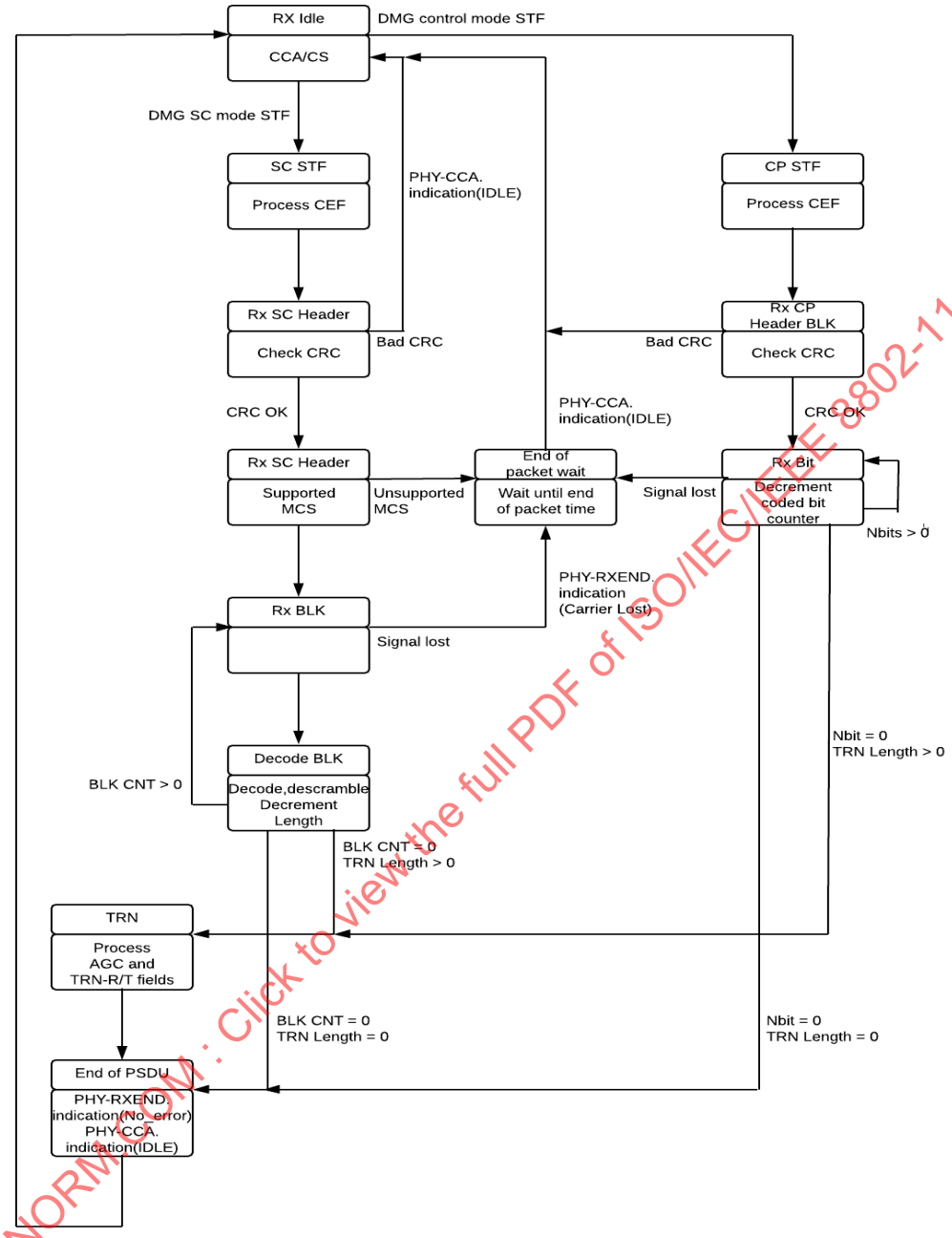

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Figure 20-19—Typical Rx state machine
(some optional features such as DMG low-power SC mode are not shown)

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20.9.2.2.2 BRP PPDU structure

Each BRP PPDU is composed of an STF, a CE field, and a data field followed by an AGC field and a TRN field. This is shown in Figure 20-20.

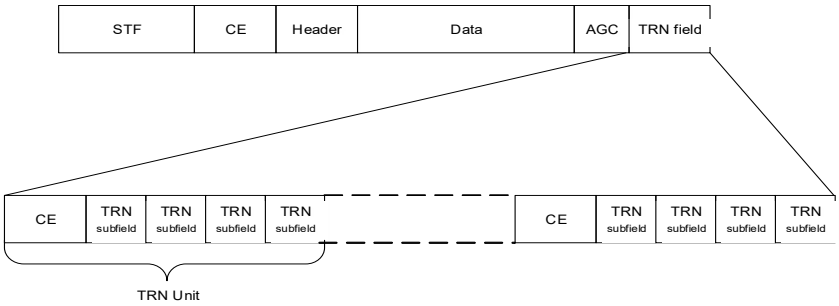

Figure 20-20—BRP PPDU structure

20.9.2.2.3 BRP PPDU header fields

The PPDU Type and Training Length fields present within the SC mode header, control mode header and LP SC mode header are used to indicate that a packet is BRP PPDU and the length of the training fields, respectively.

A value of 0 in both the PPDU Type field and the Beam Tracking Request field indicates a BRP-RX PPDU.

A value of 1 in the PPDU Type field indicates a BRP-TX PPDU.

A value of N in the Training Length field indicates $4\times N$ AGC subfields and that the TRN-R/T field has N TRN Units.

The value N in the Training Length field of a BRP-RX PPDU is equal to the value of the L-RX field requested by the intended receiver of the BRP-RX PPDU at a previously received BRP Request field (see 9.5.4).

20.9.2.2.4 BRP PPDU duration

The minimum duration of the data field of a BRP PPDU when sent in an SC mode is aBRPminSCblocks SC blocks (see 20.5.3.2.5) and, if needed, the data field of the packet shall be extended by extra zero padding to generate the required number of SC blocks. Table 20-22 contains the values of N_{CWmin} for each MCS necessary to compute the padding described in 20.5.3.2.3.3.

The minimum duration of the data field of a BRP PPDU when sent with the low-power SC mode is N_{BLKS_MIN} low-power SC blocks (see 20.6.2.3.3).

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Table 20-22—Zero filling for DMG SC mode BRP PPDUs

MCS index	Modulation	N_{CBPS}	Repetition	Code rate	Data rate (Mb/s)	N_{CWmin}
1	π/2-BPSK	1	2	1/2	385	12
2	π/2-BPSK	1	1	1/2	770	12
3	π/2-BPSK	1	1	5/8	962.5	12
4	π/2-BPSK	1	1	3/4	1155	12
5	π/2-BPSK	1	1	13/16	1251.25	12
6	π/2-QPSK	2	1	1/2	1540	23
7	π/2-QPSK	2	1	5/8	1925	23
8	π/2-QPSK	2	1	3/4	2310	23
9	π/2-QPSK	2	1	13/16	2502.5	23
9.1	π/2-QPSK	2	1	7/8	2695	25
10	π/2-16-QAM	4	1	1/2	3080	46
11	π/2-16-QAM	4	1	5/8	3850	46
12	π/2-16-QAM	4	1	3/4	4620	46
12.1	π/2-16-QAM	4	1	13/16	5005	46
12.2	π/2-16-QAM	4	1	7/8	5390	49
12.3	π/2-64-QAM	6	1	5/8	5775	69
12.4	π/2-64-QAM	6	1	3/4	6930	69
12.5	π/2-64-QAM	6	1	13/16	7507.5	69
12.6	π/2-64-QAM	6	1	7/8	8085	74

20.9.2.2.5 AGC field

The beam refinement AGC field is composed of 4*N* AGC subfields. Each AGC subfield consists of the sequence [Ga_{64} Ga_{64} Ga_{64} Ga_{64} Ga_{64}] when the packet is transmitted using the SC mode and [Gb_{64} Gb_{64} Gb_{64} Gb_{64} Gb_{64}] when the PPDU is transmitted using the control mode. The sequences Ga_{64} and Gb_{64} are defined in 20.10. The sequences are transmitted using rotated π/2-BPSK modulation.

In a BRP-TX PPDU, the transmitter may change the TX AWV configuration at the beginning of each AGC subfield. Any transmit signal transients that occur due to this TX AWV configuration change shall completely settle by the end of the first Ga64 or Gb64 subsequence. The set of AWVs used for the AGC subfields should be the same as that used for the TRN-T subfields. In a BRP-RX PPDU, the transmitter shall use the same TX AWV as in the preamble and data fields of the packet.

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20.9.2.2.6 TRN field

The TRN field enables transmitter and receiver AWV training. The TRN field has the form shown in Figure 20-21.

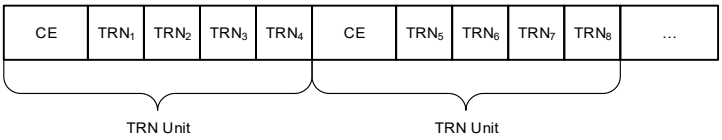

Figure 20-21—TRN field definition

The TRN field is composed of *N* TRN Units. Each TRN Unit is composed of a CE subfield and 4 TRN subfields. Each subfield CE matches the Channel Estimation field defined in 20.3.6.3. The 4N subfields TRN_1 to TRN_{4N} each consist of the sequence [Ga_{128} –Gb_{128} Ga_{128} Gb_{128} Ga_{128}]. The sequences Ga_{128} and Gb_{128} are defined in Table 20-23 and Table 20-24, respectively, in 20.10. The sequences are transmitted using rotated π/2-BPSK modulation.

In a BRP-RX PPDU, all of the TRN and CE subfields are transmitted using the same AWV as the preamble and data field of the packet. In a BRP-TX PPDU, the CE subfield shall be transmitted using the same AWV as the preamble and data field of the packet. In a BRP-TX PPDU, the transmitter may change AWV at the beginning of each TRN subfield. Any transmit signal transients that occur due to TX AWV configuration changes at the beginning of TRN subfields shall settle by the end of the first 64 samples of the subfield.

20.9.2.2.7 Channel measurement

The good autocorrelation properties of the Golay sequence enable reconstructing part of the impulse response of the channel between the transmitter and the receiver. The receiver should find the tap with largest amplitude in the channel during the CE field of the BRP-RX. It selects thereafter the set of taps that is measured around the tap with the largest amplitude, according to dot11ChanMeasFBCKNtaps. It can select a contiguous set of taps or select a noncontiguous set of taps, and include the tap delays subfield as part of the subfield measurement. It then measures the phase and amplitude of the corresponding channel taps in each of the TRN-T subfields (except for those using the CE AWV configuration). The beam refinement feedback subfield k-1 is the relative amplitude and phase of this tap in the k'th repetition compared to this tap in the first TRN-T subfield.

20.10 Golay sequences

The following Golay sequences are used in the preamble, in the single carrier guard interval and in beam refinement TRN-R/T and AGC fields: $Ga_{128}(n)$, $Gb_{128}(n)$, $Ga_{64}(n)$, $Gb_{64}(n)$, $Ga_{32}(n)$, $Gb_{32}(n)$. These are 3 pairs of complementary sequences. The subscript denotes the length of the sequences. These sequences are generated using the following recursive procedure:

$$A_0(n) = \delta(n)$$
$$B_0(n) = \delta(n)$$
$$A_k(n) = W_k A_{k-1}(n) + B_{k-1}(n - D_k)$$
$$B_k(n) = W_k A_{k-1}(n) - B_{k-1}(n - D_k)$$

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where

$$\delta(n) = \begin{cases} 1 & n=0 \\ 0 & \text{otherwise} \end{cases}$$

Note that $A_k(n), B_k(n)$ are zero for n < 0 and for $n \geq 2^k$.

$Ga_{128}(n)=A_7(127-n)$, $Gb_{128}(n)=B_7(127-n)$ when the procedure uses D_k = [1 8 2 4 16 32 64] (k=1,2,…,7) and W_k = [–1 –1 –1 –1 +1 –1 –1].

$Ga_{64}(n)=A_6(63-n)$, $Gb_{64}(n)=B_6(63-n)$ when the procedure uses D_k= [2 1 4 8 16 32] and W_k =[1 1 -1 -1 1 -1].

$Ga_{32}(n)=A_5(31-n)$, $Gb_{32}(n)=B_5(31-n)$ when the procedure uses D_k=[1 4 8 2 16] and W_k =[-1 1 -1 1 -1].

The sequences are defined in Table 20-23 through Table 20-28.

Table 20-23—The sequence $Ga_{128}(n)$

The Sequence $Ga_{128}(n)$, to be transmitted from left to right, up to down
+1 +1 −1 −1 −1 −1 −1 −1 −1 +1 −1 +1 +1 −1 −1 +1 +1 +1 −1 −1 +1 +1 +1 −1 +1 −1 +1 −1 +1 +1 −1 −1 −1 +1 +1 +1 +1 +1 +1 +1 −1 +1 −1 −1 +1 +1 −1 +1 +1 −1 −1 +1 +1 +1 −1 +1 −1 +1 −1 +1 +1 −1 +1 +1 −1 −1 −1 −1 −1 −1 −1 +1 −1 +1 +1 −1 −1 +1 +1 +1 −1 −1 +1 +1 +1 −1 +1 −1 +1 −1 +1 +1 −1 +1 +1 −1 −1 −1 −1 −1 −1 −1 +1 −1 +1 +1 −1 −1 +1 −1 −1 +1 +1 −1 −1 −1 −1 +1 −1 +1 −1 +1 −1 −1 +1

Table 20-24—The sequence $Gb_{128}(n)$

The Sequence $Gb_{128}(n)$, to be transmitted from left to right, up to down
−1 −1 +1 +1 +1 +1 +1 +1 +1 −1 +1 −1 −1 +1 +1 −1 −1 −1 +1 +1 −1 −1 −1 −1 +1 −1 +1 −1 +1 −1 −1 +1 +1 +1 −1 −1 −1 −1 −1 −1 −1 +1 −1 +1 +1 −1 −1 +1 −1 +1 −1 −1 +1 +1 −1 −1 +1 −1 +1 −1 +1 +1 −1 +1 +1 −1 −1 −1 −1 −1 −1 −1 +1 −1 +1 +1 −1 −1 +1 +1 +1 −1 −1 +1 +1 +1 −1 +1 −1 +1 −1 +1 +1 −1 +1 +1 −1 −1 −1 −1 −1 −1 −1 +1 −1 +1 +1 −1 −1 +1 −1 −1 +1 +1 −1 −1 −1 −1 +1 −1 +1 −1 +1 −1 −1 +1

Table 20-25—The sequence $Ga_{64}(n)$

The Sequence $Ga_{64}(n)$, to be transmitted from left to right, up to down
−1 −1 +1 −1 +1 −1 −1 −1 +1 +1 −1 +1 +1 −1 −1 −1 −1 −1 +1 −1 +1 −1 −1 −1 −1 −1 +1 −1 −1 +1 +1 +1 −1 −1 +1 −1 +1 −1 −1 −1 +1 +1 −1 +1 +1 −1 −1 −1 +1 +1 −1 +1 −1 +1 +1 +1 +1 +1 −1 +1 +1 −1 −1 −1

Table 20-26—The sequence $Gb_{64}(n)$

The sequence $Gb_{64}(n)$, to be transmitted from left to right, up to down
+1 +1 −1 +1 −1 +1 +1 +1 −1 −1 +1 −1 −1 +1 +1 +1 +1 +1 −1 +1 −1 +1 +1 +1 +1 +1 −1 +1 +1 −1 −1 −1 −1 −1 +1 −1 +1 −1 −1 −1 +1 +1 −1 +1 +1 −1 −1 −1 +1 +1 −1 +1 −1 +1 +1 +1 +1 +1 −1 +1 +1 −1 −1 −1

Table 20-27—The sequence $Ga_{32}(n)$

The Sequence $Ga_{32}(n)$, to be transmitted from left to right
+1 +1 +1 +1 +1 −1 +1 −1 −1 −1 +1 +1 +1 −1 −1 +1 +1 +1 −1 −1 +1 −1 −1 +1 −1 −1 −1 −1 +1 −1 +1 −1

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Table 20-28—The sequence $Gb_{32}(n)$

The Sequence $Gb_{32}(n)$, to be transmitted from left to right
−1 −1 −1 −1 −1 +1 −1 +1 +1 +1 −1 −1 −1 +1 +1 −1 +1 +1 −1 −1 +1 −1 −1 +1 −1 −1 −1 −1 +1 −1 +1 −1

20.11 DMG PLME

20.11.1 PLME SAP sublayer management primitives

Table 20-29 lists the MIB attributes that may be accessed by the PHY entities and the intra-layer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.5.

20.11.2 DMG PHY MIB

All DMG PHY MIB attributes are defined in Annex C, with specific values defined in Table 20-29. The column titled “Operational semantics” in Table 20-29 contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. Dynamic MIB attributes can be modified by some management entity.

Table 20-29—DMG PHY MIB attribute default values

Managed object	Default value/range	Operational semantics
dot11PHYOperationTable		
dot11PHYType	DMG	Static
dot11PHYDMGTable		
dot11LowPowerSCPHYImplemented	Boolean	Static
dot11LowPowerSCPHYActivated	Boolean	Dynamic

When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.

20.11.3 TXTIME calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated according to the following equations.

For the DMG SC mode (N_{TRN} is Training Length field defined in the header):

$$TXTIME = \begin{cases} T_{STF} + T_{CE} + T_{header} + T_{Data} & N_{TRN} = 0 \\ T_{STF} + T_{CE} + T_{header} + \max\{T_{Data}, (\alpha \times \beta + \gamma) \times T_C\} + N_{TRN} \times T_{TRN-Unit} & N_{TRN} > 0 \text{ and SC} \end{cases}$$

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where

α = aBRPminSCblocks
β = aSCBlockSize
γ = aSCGILength
$T_{TRN-Unit}$ = aBRPTRNBlock × T_C

For the DMG control mode:

$$TXTIME = T_{STF-CM} + T_{CE-CM} + (11 \times 8 + (Length - 6) \times 8 + N_{CW} \times 168) \times T_C \times 32 + N_{TRN} \times T_{TRN-Unit}$$

where N_{CW} calculation is defined in 20.4.3.3.3.

20.11.4 DMG PHY

The static DMG PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, shall be as shown in Table 20-30. The definitions for these characteristics are given in 6.5.4.

Table 20-30—DMG PHY characteristics

PHY parameter	Value
aRIFSTime	1 μs
aSIFSTime	3 μs
aRxPHYDelay	Implementation dependent, see 10.3.7.
aRxTxTurnaroundTime	Implementation dependent, see 10.3.7.
aCCATime	Implementation dependent, see 10.3.7.
aRxTxSwitchTime	Implementation dependent, see 10.3.7.
aRxPHYStartDelay	DMG control mode: 10 μs; DMG SC and SC low-power modes: 3.6 μs
aMACProcessingDelay	Implementation dependent, see 10.3.7.
aTxPHYDelay	Implementation dependent, see 10.3.7.
aTxRampOnTime	Implementation dependent, see 10.3.7.
aSBIFSTime	1 μs
aSBIFSAccuracy	0.03 μs
aAirPropagationTime	100 ns
aDMGDetectionThres	–48 dBm
aBRPIFS	40 μs
aSlotTime	5 μs
aCWmin	15
aCWmax	1023
aBRPminSCblocks	18
aBRPTRNBlock	4992

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Table 20-30—DMG PHY characteristics *(continued)*

PHY parameter	Value
aSCGILength	64
aSCBlockSize	512
aPPDUMaxTime	2 ms
aPSDUMaxLength	262 143 octets

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21. Very high throughput (VHT) PHY specification

21.1 Introduction

21.1.1 Introduction to the VHT PHY

Clause 21 specifies the PHY entity for a very high throughput (VHT) orthogonal frequency division multiplexing (OFDM) system operating in the 5 GHz band.

In addition to the requirements in Clause 21, a VHT STA shall be capable of transmitting and receiving PPDUs that are compliant with the mandatory PHY specifications defined in Clause 19 in the 5 GHz band.

The VHT PHY is based on the HT PHY defined in Clause 19, which in turn is based on the OFDM PHY defined in Clause 17. The VHT PHY extends the maximum number of space-time streams supported to eight and provides support for downlink multi-user (MU) transmissions. A downlink MU transmission supports up to four users with up to four space-time streams per user with the total number of space-time streams not exceeding eight.

NOTE—MU transmission is different from VHT SU group addressed transmission.

The VHT PHY provides support for 20 MHz, 40 MHz, 80 MHz, and 160 MHz contiguous channel widths and support for 80+80 MHz noncontiguous channel width.

The VHT PHY data subcarriers are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), 64-QAM, and 256-QAM. Forward error correction (FEC) coding (convolutional or LDPC coding) is used with coding rates of 1/2, 2/3, 3/4, and 5/6.

A VHT STA shall support the following features:

- Non-HT and non-HT duplicate formats (transmit and receive) for all channel widths supported by the VHT STA
- HT-mixed format (transmit and receive)
- VHT format (transmit and receive)
- 20 MHz, 40 MHz, and 80 MHz channel widths
- Single spatial stream VHT-MCSs 0 to 7 (transmit and receive) in all supported channel widths
- BCC coding

A VHT STA may support the following features:

- HT-greenfield format (transmit and receive)
- 2 or more spatial streams (transmit and receive)
- 400 ns short guard interval (transmit and receive)
- Beamforming sounding (by sending a VHT NDP)
- Responding to transmit beamforming sounding (by providing compressed beamforming feedback)
- STBC (transmit and receive)
- LDPC (transmit and receive)
- VHT MU PPDUs (transmit and receive)
- Support for 160 MHz channel width
- Support for 80+80 MHz channel width
- VHT-MCSs 8 and 9 (transmit and receive)

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21.1.2 Scope of VHT PHY services

The services provided to the MAC by the VHT PHY consist of the following protocol functions:

a) A function that defines a method of mapping the PSDUs into a framing format (PPDU) suitable for sending and receiving PSDUs between two or more STAs.

b) A function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. Depending on the PPDU format, these STAs support a mixture of VHT, Clause 19 and Clause 17 PHYs.

21.1.3 VHT PHY functions

21.1.3.1 General

The VHT PHY contains two functional entities: the PHY function and the physical layer management function (i.e., the PLME). Both of these functions are described in detail in 21.3 and 21.4.

The VHT PHY service is provided to the MAC through the PHY service primitives defined in Clause 8. The VHT PHY service interface is described in 21.2.

21.1.3.2 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.

21.1.3.3 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, but do not necessarily reflect any particular implementation.

The service of a layer is the set of capabilities that it offers to a user in the next higher layer. Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

21.1.4 PPDU formats

The structure of the PPDU transmitted by a VHT STA is determined by the TXVECTOR parameters as defined in Table 21-1.

In a VHT STA the FORMAT parameter determines the overall structure of the PPDU and can take one of the following values:

— Non-HT format (NON_HT), based on Clause 17 and including non-HT duplicate format.
— HT-mixed format (HT_MF) as specified in Clause 19.
— HT-greenfield format (HT_GF) as specified in Clause 19.
— VHT format (VHT). PPDUs of this format contain a preamble compatible with Clause 17 and Clause 19 STAs. The non-VHT portion of the VHT format preamble (the parts of VHT preamble preceding the VHT-SIG-A field) is defined so that it can be decoded by these STAs.

NOTE—Required support for these formats is defined in 11.38, 19.1.1, and 21.1.1.

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A VHT PPDU can be further categorized as a VHT SU PPDU or a VHT MU PPDU. A VHT PPDU using a group ID value of 0 or 63 is a VHT SU PPDU and either carries only one PSDU or no PSDU. A VHT PPDU using a group ID value in the range 1 to 62 is a VHT MU PPDU and carries one or more PSDUs to one or more users.

21.2 VHT PHY service interface

21.2.1 Introduction

The PHY provides an interface to the MAC through an extension of the generic PHY service interface defined in 8.3.4. The interface includes TXVECTOR, RXVECTOR, and PHYCONFIG_VECTOR.

Using the TXVECTOR, the MAC supplies the PHY with per-PPDU transmit parameters. Using the RXVECTOR, the PHY informs the MAC of the received PPDU parameters. Using the PHYCONFIG_VECTOR, the MAC configures the PHY for operation, independent of frame transmission or reception.

21.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 21-1 are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive and/or as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive.

Table 21-1—TXVECTOR and RXVECTOR parameters

Parameter	Condition	Value	TXVECTOR	RXVECTOR
FORMAT		Determines the format of the PPDU. Enumerated type: NON_HT indicates OFDM or non-HT duplicate PPDU format. In this case, the modulation is determined by the NON_HT_MODULATION parameter. HT_MF indicates HT-mixed format. HT_GF indicates HT-greenfield format. VHT indicates VHT format.	Y	Y
NON_HT_MODULATION	FORMAT is NON_HT	In TXVECTOR, indicates the format type of the transmitted non-HT PPDU. In RXVECTOR, indicates the estimated format type of the received non-HT PPDU. Enumerated type: OFDM indicates OFDM format. NON_HT_DUP_OFDM indicates non-HT duplicate format	Y	Y
	Otherwise	Not present	N	N

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Table 21-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
L_LENGTH	FORMAT is VHT	Not present NOTE—The Length field of the L-SIG in VHT PPDUs is defined in Equation (21-24) using the TXTIME value defined by Equation (21-109) and Equation (21-110), which in turn depend on other parameters including the TXVECTOR parameter APEP_LENGTH.	N	N
	Otherwise	See corresponding entry in Table 19-1		
L_DATARATE	FORMAT is VHT	Not present NOTE—The RATE field in the L-SIG field in a VHT PPDU is set to the value representing 6 Mb/s in the 20 MHz channel spacing column of Table 17-6.	N	N
	Otherwise	See corresponding entry in Table 19-1		
LSIGVALID	FORMAT is VHT	Not present	N	N
	Otherwise	See corresponding entry in Table 19-1		
SERVICE	FORMAT is VHT	Not present	N	N
	Otherwise	See corresponding entry in Table 19-1		
SMOOTHING	FORMAT is VHT	Not present	N	N
	Otherwise	See corresponding entry in Table 19-1		
AGGREGATION	FORMAT is VHT	Not present	N	N
	Otherwise	See corresponding entry in Table 19-1		

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Table 21-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
NUM_EXTEN_SS	FORMAT is VHT	Not present	N	N
	Otherwise	See corresponding entry in Table 19-1		
ANTENNA_SET	FORMAT is VHT	Not present	N	N
	Otherwise	See corresponding entry in Table 19-1		
N_TX	FORMAT is VHT	Indicates the number of transmit chains.	Y	N
	Otherwise	See corresponding entry in Table 19-1		
EXPANSION_MAT_TYPE	FORMAT is VHT and EXPANSION_MAT is present.	Set to COMPRESSED_SV	Y	N
	Otherwise	See corresponding entry in Table 19-1		
EXPANSION_MAT	FORMAT is VHT	Contains a vector in the number of selected subcarriers containing feedback matrices as defined in 21.3.11.2 based on the channel measured during the training symbols of a previous VHT NDP.	M U	N
	Otherwise	See corresponding entry in Table 19-1		

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Table 21-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
CHAN_MAT_TYPE	FORMAT is VHT and PSDU_LENGTH equals 0	Set to COMPRESSED_SV	N	Y
	FORMAT is VHT and PSDU_LENGTH is greater than 0	Not present	N	N
	Otherwise	See corresponding entry in Table 19-1		
CHAN_MAT	FORMAT is VHT and PSDU_LENGTH equals 0	Contains a set of compressed beamforming feedback matrices as defined in 21.3.11.2 based on the channel measured during the training symbols of the received VHT NDP.	N	Y
	FORMAT is VHT and PSDU_LENGTH is greater than 0	Not present	N	N
	Otherwise	See corresponding entry in Table 19-1		
DELTA_SNR	FORMAT is VHT	Contains an array of delta SNR values as defined in 9.4.1.51 based on the channel measured during the training symbols of the received VHT NDP. NOTE—In the RXVECTOR this parameter is present only for VHT NDPs for MU sounding.	M U	Y
	Otherwise	Not present	N	N
SNR	FORMAT is VHT	Contains an array of received SNR measurements for each spatial stream. SNR indications of 8 bits are supported. SNR shall be the sum of the decibel values of SNR per tone divided by the number of tones represented in each stream as described in 9.4.1.49	N	Y
	Otherwise	See corresponding entry in Table 19-1		
NO_SIG_EXTN	FORMAT is VHT	Not present	N	N
	Otherwise	See corresponding entry in Table 19-1		
FEC_CODING	FORMAT is VHT	Indicates which FEC encoding is used. Enumerated type: BCC_CODING indicates binary convolutional code. LDPC_CODING indicates low-density parity check code.	M U	Y
	Otherwise	See corresponding entry in Table 19-1		

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Table 21-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
STBC	FORMAT is VHT	Indicates whether STBC is used. 0 indicates no STBC ($N_{STS}=N_{SS}$ in the Data field). 1 indicates STBC is used ($N_{STS}=2N_{SS}$ in the Data field). This parameter is 0 for a VHT MU PPDU.	Y	Y
	Otherwise	See corresponding entry in Table 19-1		
GI_TYPE	FORMAT is VHT	Indicates whether a short guard interval is used in the transmission of the Data field of the PPDU. Enumerated type: LONG_GI indicates short GI is not used in the Data field of the PPDU. SHORT_GI indicates short GI is used in the Data field of the PPDU.	Y	Y
	Otherwise	See corresponding entry in Table 19-1		
TXPWR_LEVEL_INDEX	FORMAT is VHT	The allowed values for the TXPWR_LEVEL_INDEX parameter are in the range 1 to $N/2$, where N is the number of octets in dot11TxPowerLevelExtended. This parameter is used to indicate which of the available transmit output power levels defined in dot11TxPowerLevelExtended shall be used for the current transmission.	Y	N
	Otherwise	See corresponding entry in Table 19-1		
RSSI	FORMAT is VHT	The allowed values for the RSSI parameter are in the range 0 to 255. This parameter is a measure by the PHY of the power observed at the antenna connector used to receive the current PPDU measured during the reception of the VHT-LTF field. RSSI is intended to be used in a relative manner, and it is a monotonically increasing function of the received power.	N	Y
	Otherwise	See corresponding entry in Table 19-1		
MCS	FORMAT is VHT	Indicates the modulation and coding scheme used in the transmission of the PPDU. Integer: range 0 to 9	M U	Y
	Otherwise	See corresponding entry in Table 19-1		
REC_MCS	FORMAT is HT_MF, HT_GF or VHT	Indicates the MCS that the STA's receiver recommends.	N	O
	Otherwise	Not present	N	N

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Table 21-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
CH_BANDWIDTH	FORMAT is HT_MF or HT_GF	See corresponding entry in Table 19-1		
	FORMAT is VHT	Indicates the channel width of the transmitted PPDU: Enumerated type: CBW20 for 20 MHz CBW40 for 40 MHz CBW80 for 80 MHz CBW160 for 160 MHz CBW80+80 for 80+80 MHz	Y	Y
	FORMAT is NON_HT	In TXVECTOR, indicates the channel width of the transmitted PPDU. In RXVECTOR, indicates the estimated channel width of the received PPDU. Enumerated type: CBW40, CBW80, CBW160, or CBW80+80 if NON_HT_MODULATION equals NON_HT_DUP_OFDM CBW20 if NON_HT_MODULATION equals OFDM NOTE—On reception, where valid, the CH_BANDWIDTH_IN_NON_HT parameter is likely to be a more reliable indication of subformat and channel width than the NON_HT_MODULATION and CH_BANDWIDTH parameters, since for non-HT or non-HT duplicate frames, CH_BANDWIDTH is a receiver estimate of the bandwidth, whereas CH_BANDWIDTH_IN_NON_HT is the signaled bandwidth.	Y	Y
DYN_BANDWIDTH_IN_NON_HT	FORMAT is NON_HT	In TXVECTOR, if present, indicates whether the transmitter is capable of Static or Dynamic bandwidth operation. In RXVECTOR, if valid, indicates whether the transmitter is capable of Static or Dynamic bandwidth operation. Enumerated type: Static if the transmitter is capable of Static bandwidth operation Dynamic if the transmitter is capable of Dynamic bandwidth operation NOTE—In the RXVECTOR, the validity of this parameter is determined by the MAC based on the contents of the received MPDU.	O	Y
	Otherwise	Not present	N	N

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Table 21-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
CH_BANDWIDTH_IN_NON_HT	FORMAT is NON_HT	In TXVECTOR, if present, indicates the channel width of the transmitted PPDU, which is signaled via the scrambling sequence. In RXVECTOR, if valid, indicates the channel width of the received PPDU, which is signaled via the scrambling sequence. Enumerated type: CBW20, CBW40, CBW80, CBW160, CBW80+80 NOTE—In the RXVECTOR, the validity of this parameter is determined by the MAC based on the contents of the currently received MPDU (e.g., RTS) or the previous MPDU in an exchange (e.g., the RTS preceding a CTS).	O	Y
	Otherwise	Not present	N	N
LENGTH	FORMAT is VHT	Not present	N	N
	Otherwise	See corresponding entry in Table 19-1		
APEP_LENGTH	FORMAT is VHT	If equal to 0, indicates a VHT NDP for both RXVECTOR and TXVECTOR. If greater than 0 in the TXVECTOR, indicates the number of octets in the range 1 to 1 048 575 in the A-MPDU pre-EOF padding (see 10.12.2) carried in the PSDU. If greater than 0 in the RXVECTOR, this parameter is the value obtained from the VHT-SIG-B Length field multiplied by 4.	M U	O
	Otherwise	Not present	N	N
PSDU_LENGTH	FORMAT is VHT	Indicates the number of octets in the VHT PSDU in the range 0 to aPSDUMaxLength octets (see Table 21-28). A value of 0 indicates a VHT NDP.	N	Y
	Otherwise	Not present	N	N
USER_POSITION	FORMAT is VHT and 1 ≤ GROUP_ID ≤ 62	User position in MU transmission using the group ID GROUP_ID. Integer range: 0-3. NOTE—The entries in the USER_POSITION array are in ascending order.	M U	O
	Otherwise	Not present	N	N

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Table 21-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
NUM_STS	FORMAT is VHT	Indicates the number of space-time streams. Integer: range 1-8 for SU, 1-4 per user in the TXVECTOR and 0-4 in the RXVECTOR for MU. NUM_STS summed over all users is in the range 1 to 8.	M U	Y
	Otherwise	Not present	N	N
GROUP_ID	FORMAT is VHT	Indicates the group ID. Integer: range 0-63 (see Table 21-12) A value of 0 or 63 indicates a VHT SU PPDU. A value in the range 1 to 62 indicates a VHT MU PPDU.	Y	Y
	Otherwise	Not present	N	N
PARTIAL_AID	FORMAT is VHT and GROUP_ID is 0 or 63	Provides an abbreviated indication of the intended recipient(s) of the PSDU (see 10.19). Integer: range 0-511.	Y	Y
	Otherwise	Not present	N	N
NUM_USERS	FORMAT is VHT	Indicates the number of users with nonzero space-time streams. Integer: range 1 to 4.	Y	N
	Otherwise	Not present	N	N
BEAMFORMED	FORMAT is VHT and GROUP_ID is 0 or 63	Set to 1 if a beamforming steering matrix is applied to the waveform in an SU transmission. Set to 0 otherwise. NOTE—When BEAMFORMED is set to 1, frequency domain smoothing as part of channel estimation is not recommended.	Y	O
	Otherwise	Not present	N	N
TXOP_PS_NOT_ALLOWED	FORMAT is VHT	Indicates whether a VHT AP allows non-AP VHT STAs in TXOP power save mode to enter doze state during the TXOP. 0 indicates that the VHT AP allows non-AP VHT STAs to enter doze state during a TXOP. 1 indicates that the VHT AP does not allow non-AP VHT STAs to enter doze state during a TXOP.	Y	Y
	Otherwise	Not present	N	N

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Table 21-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
TIME_OF_DEPARTURE_REQUESTED		See corresponding entry in Table 19-1		
RX_START_OF_FRAME_OFFSET	dot11TimingMsmtActivated is true	0 to 2^{32}– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble corresponding to the incoming frame arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC.	N	Y
	Otherwise	Not present	N	N

NOTE—In the TXVECTOR and RXVECTOR columns, the following apply:
Y indicates that the parameter is always present in that vector;
N indicates that the parameter is never present in that vector;
O indicates that the parameter's presence is an implementation option;
MU indicates that the parameter is present once for a VHT SU PPDU and present per user for a VHT MU PPDU. Parameters specified to be present per user are conceptually supplied as an array of values indexed by *u*, where *u* takes values 0 to NUM_USERS-1.

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21.2.3 PHYCONFIG_VECTOR parameters

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a VHT PHY contains an OPERATING_CHANNEL parameter, which identifies the operating or primary channel. The PHY shall set dot11CurrentPrimaryChannel to the value of this parameter.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a VHT PHY contains a CHANNEL_WIDTH parameter, which identifies the operating channel width and takes one of the values 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz. The PHY shall set dot11CurrentChannelWidth to the value of this parameter.

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The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a VHT PHY contains a CENTER_FREQUENCY_SEGMENT_0 parameter, which identifies the center frequency of the channel (or of segment 0 if the CHANNEL_WIDTH parameter indicates 80+80 MHz) and takes a value between 1 and 200. The PHY shall set dot11CurrentChannelCenterFrequencyIndex0 to the value of this parameter.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a VHT PHY contains a CENTER_FREQUENCY_SEGMENT_1 parameter, which takes the value 0 if the CHANNEL_WIDTH parameter does not indicate 80+80 MHz, and otherwise identifies the center frequency of segment 1 and takes a value between 1 and 200. The PHY shall set dot11CurrentChannelCenterFrequencyIndex1 to the value of this parameter.

21.2.4 Effects of CH_BANDWIDTH parameter on PPDU format

Table 21-2 shows the valid combinations of the FORMAT, NON_HT_MODULATION, and CH_BANDWIDTH parameters and the corresponding PPDU format and value of CH_OFFSET (if applicable). Other combinations are reserved.

Table 21-2—Interpretation of FORMAT, NON_HT_MODULATION, CH_BANDWIDTH, and CH_OFFSET parameters

FORMAT	NON_HT_ MODULATION	CH_BANDWIDTH	CH_OFFSET	PPDU format
VHT	N/A	CBW20	N/A	The STA transmits a VHT PPDU (when FORMAT is VHT) of 20 MHz bandwidth. If the BSS bandwidth is wider than 20 MHz, then the transmission shall use the primary 20 MHz channel.
VHT	N/A	CBW40	N/A	The STA transmits a VHT PPDU (when FORMAT is VHT) of 40 MHz bandwidth. If the BSS bandwidth is wider than 40 MHz, then the transmission shall use the primary 40 MHz channel.
HT_MF or HT_GF	N/A	HT_CBW20 and CHANNEL_WIDTH in PHYCONFIG_VECTOR > 20 MHz and $f_{S20, idx} < f_{P20, idx}$	CH_OFF_20U	The STA transmits an HT-mixed PPDU (when FORMAT is HT_MF) or HT-greenfield PPDU (when FORMAT is HT_GF) of 20 MHz bandwidth. The transmission shall use the primary 20 MHz channel.
HT_MF or HT_GF	N/A	HT_CBW20 and CHANNEL_WIDTH in PHYCONFIG_VECTOR > 20 MHz and $f_{S20, idx} > f_{P20, idx}$	CH_OFF_20L	The STA transmits an HT-mixed PPDU (when FORMAT is HT_MF) or HT-greenfield PPDU (when FORMAT is HT_GF) of 20 MHz bandwidth. The transmission shall use the primary 20 MHz channel.

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Table 21-2—Interpretation of FORMAT, NON_HT_MODULATION, CH_BANDWIDTH, and CH_OFFSET parameters *(continued)*

FORMAT	NON_HT_ MODULATION	CH_BANDWIDTH	CH_OFFSET	PPDU format
HT_MF or HT_GF	N/A	HT_CBW20 and CHANNEL_WIDTH in PHYCONFIG_VECTOR = 20 MHz	CH_OFF_20	The STA transmits an HT-mixed PPDU (when FORMAT is HT_MF) or HT-greenfield PPDU (when FORMAT is HT_GF) of 20 MHz bandwidth.
HT_MF or HT_GF	N/A	HT_CBW40	CH_OFF_40	The STA transmits an HT-mixed PPDU (when FORMAT is HT_MF) or HT-greenfield PPDU (when FORMAT is HT_GF) of 40 MHz bandwidth. If the BSS bandwidth is wider than 40 MHz, then the transmission shall use the primary 40 MHz channel.
VHT	N/A	CBW80		The STA transmits a VHT PPDU of 80 MHz bandwidth. If the BSS bandwidth is 160 MHz or 80+80 MHz, then the transmission shall use the primary 80 MHz channel.
VHT	N/A	CBW160		The STA transmits a VHT PPDU of 160 MHz bandwidth.
VHT	N/A	CBW80+80		The STA transmits a VHT PPDU of 80+80 MHz bandwidth.
NON_HT	OFDM	CBW20		The STA transmits a NON_HT PPDU with NON_HT_MODULATION set to OFDM using the primary 20 MHz channel as defined in Clause 17.
NON_HT	NON_HT_DUP_ OFDM	CBW40		The STA transmits a NON_HT PPDU with NON_HT_MODULATION set to NON_HT_DUP_OFDM using two adjacent 20 MHz channels as defined in 21.3.10.12. If the BSS bandwidth is wider than 40 MHz, then the transmission shall use the primary 40 MHz channel. The one 20 MHz channel higher in frequency is rotated +90º relative to the 20 MHz channel lowest in frequency as defined in Equation (21-15).

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Table 21-2—Interpretation of FORMAT, NON_HT_MODULATION, CH_BANDWIDTH, and CH_OFFSET parameters *(continued)*

FORMAT	NON_HT_ MODULATION	CH_BANDWIDTH	CH_OFFSET	PPDU format
NON_HT	NON_HT_DUP_ OFDM	CBW80		The STA transmits a NON_HT PPDU with NON_HT_MODULATION set to NON_HT_DUP_OFDM using four adjacent 20 MHz channels as defined in 21.3.10.12. If the BSS bandwidth is 160 MHz or 80+80 MHz, then the transmission shall use the primary 80 MHz channel. The three 20 MHz channels higher in frequency are rotated +180º relative to the 20 MHz channel lowest in frequency as defined in Equation (21-16).
NON_HT	NON_HT_DUP_ OFDM	CBW160		The STA transmits a NON_HT PPDU with NON_HT_MODULATION set to NON_HT_DUP_OFDM using eight adjacent 20 MHz channels as defined in 21.3.10.12. The second, third, fourth, sixth, seventh, and eighth 20 MHz channels in the order of increasing frequency are rotated +180º relative to the 20 MHz channel lowest in frequency as defined in Equation (21-17).
NON_HT	NON_HT_DUP_ OFDM	CBW80+80		The STA transmits a NON_HT PPDU with NON_HT_MODULATION set to NON_HT_DUP_OFDM using two nonadjacent frequency segments, with each frequency segment consisting of four adjacent 20 MHz channels as defined in 21.3.10.12. In each frequency segment, the three 20 MHz channels higher in frequency are rotated +180º relative to the 20 MHz channel lowest in frequency as defined in Equation (21-16).

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21.2.5 Support for NON_HT and HT formats

21.2.5.1 General

A VHT STA logically contains Clause 17, Clause 19, and Clause 21 PHYs. The MAC interfaces to the PHYs via the Clause 21 PHY service interface, which in turn interacts with the Clause 17 and Clause 19 PHY service interfaces as shown in Figure 21-1, Figure 21-2, and Figure 21-3.

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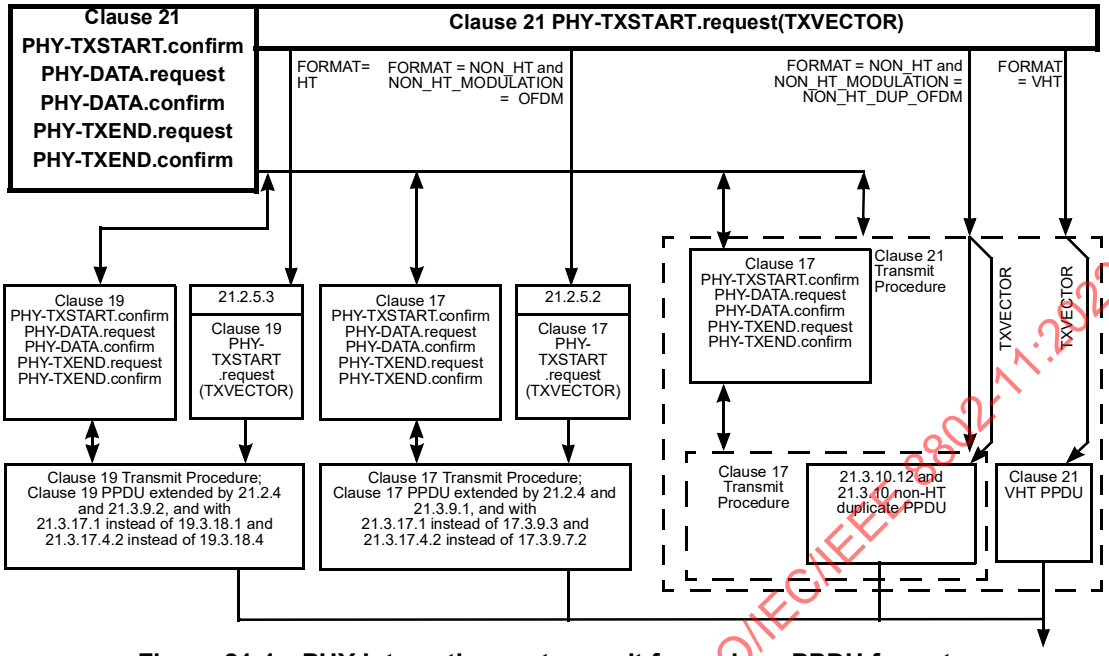

Figure 21-1—PHY interaction on transmit for various PPDU formats

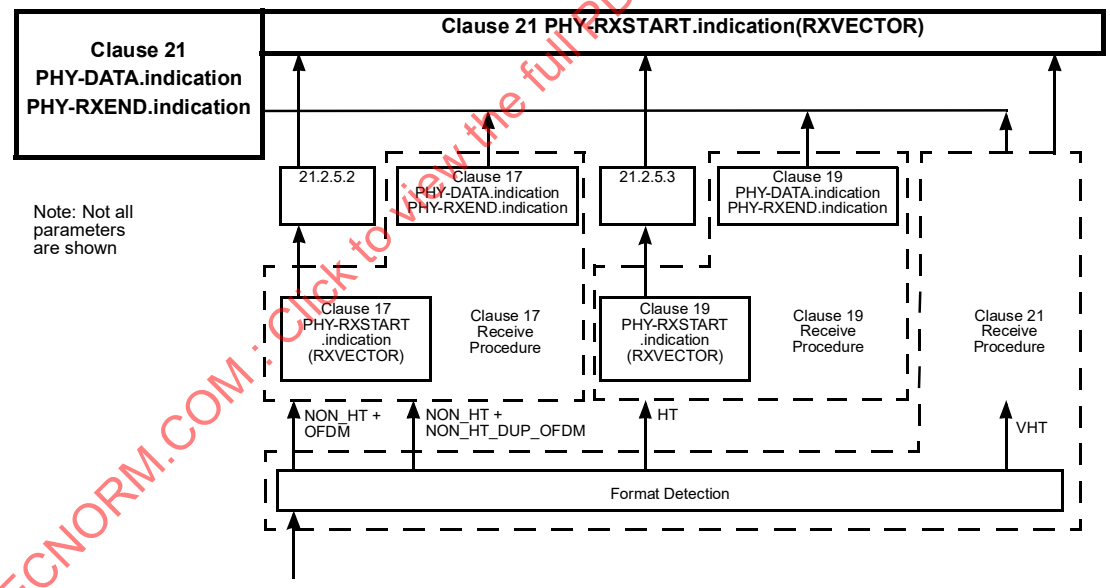

Figure 21-2—PHY interaction on receive for various PPDU formats

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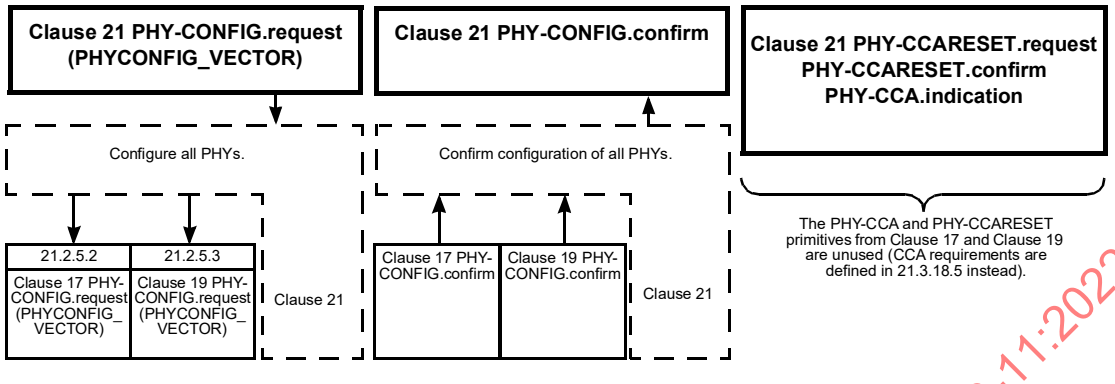

Figure 21-3—PHY-CONFIG and CCA interaction with Clause 17, Clause 19, and Clause 21 PHYs

21.2.5.2 Support for NON_HT format when NON_HT_MODULATION is OFDM

When a PHY-TXSTART.request(TXVECTOR) primitive with the FORMAT parameter equal to NON_HT and the NON_HT_MODULATION parameter equal to OFDM is issued, the behavior of the VHT PHY is defined in Clause 17 with additional requirements described in the following subclauses:

— 21.3.9.1
— 21.3.17.1 instead of 17.3.9.3
— 21.3.17.4.2 instead of 17.3.9.7.2

where the Clause 21 TXVECTOR parameters in Table 21-1 are mapped to Clause 17 TXVECTOR parameters in Table 17-1 according to Table 21-3.

NOTE—When the FORMAT parameter is set to NON_HT and the NON_HT_MODULATION parameter is set to NON_HT_DUP_OFDM in a PHY-TXSTART.request(TXVECTOR) primitive, the behavior of the VHT PHY is defined in Clause 21.

When the VHT PHY receives a Clause 21 PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive, the VHT PHY shall, for the purposes of OFDM PPDU transmission and reception, behave as if it were a Clause 17 PHY that had received a PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive but with the CHANNEL_WIDTH, CENTER_FREQUENCY_SEGMENT_0, and CENTER_FREQUENCY_SEGMENT_1 parameters discarded from PHYCONFIG_VECTOR.

As defined in 21.3.20, once a PPDU is received and detected as a NON_HT PPDU, the behavior of the VHT PHY is defined in Clause 17. The RXVECTOR parameters from the Clause 17 PHY-RXSTART.indication primitive are mapped to the Clause 21 RXVECTOR parameters as defined in Table 21-3. VHT PHY parameters not listed in the table are not present.

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Table 21-3—Mapping of VHT PHY parameters for NON_HT operation

VHT PHY Parameter	5 GHz operation defined by Clause 17	Parameter List
L_LENGTH	LENGTH	TXVECTOR/RXVECTOR
L_DATARATE	DATARATE	TXVECTOR/RXVECTOR
TXPWR_LEVEL_INDEX	TXPWR_LEVEL_INDEX	TXVECTOR
RSSI	RSSI	RXVECTOR
SERVICE	SERVICE	TXVECTOR/RXVECTOR
CH_BANDWIDTH_IN_NON_HT	CH_BANDWIDTH_IN_NON_HT	TXVECTOR/RXVECTOR
DYN_BANDWIDTH_IN_NON_HT	DYN_BANDWIDTH_IN_NON_HT	TXVECTOR/RXVECTOR
OPERATING_CHANNEL	OPERATING_CHANNEL	PHYCONFIG_VECTOR
CHANNEL_WIDTH	discarded	PHYCONFIG_VECTOR
CENTER_FREQUENCY_SEGMENT_0	discarded	PHYCONFIG_VECTOR
CENTER_FREQUENCY_SEGMENT_1	discarded	PHYCONFIG_VECTOR

21.2.5.3 Support for HT formats

When a PHY-TXSTART.request(TXVECTOR) primitive is received with the TXVECTOR parameter FORMAT equal to HT_MF or HT_GF, the behavior of the PHY is defined by Clause 19 with additional requirements defined in the following subclauses:

— 21.3.9.2
— 21.3.17.1 instead of 19.3.18.1
— 21.3.17.4.2 instead of 19.3.18.4

The Clause 21 TXVECTOR parameters in Table 21-1 are mapped directly to Clause 19 TXVECTOR parameters in Table 19-1 and the Clause 19 PHY-TXSTART.request(TXVECTOR) primitive is issued. The PHY shall use a value of CH_OFFSET in the Clause 19 TXVECTOR that is consistent with Table 21-2.

When the VHT PHY receives a Clause 21 PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive, the VHT PHY shall, for the purposes of HT PPDU transmission and reception, behave as if it were a Clause 19 PHY that had received PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive but with the CHANNEL_WIDTH, CENTER_FREQUENCY_SEGMENT_0, and CENTER_FREQUENCY_SEGMENT_1 parameters discarded from the PHYCONFIG_VECTOR and the SECONDARY_CHANNEL_OFFSET parameter set to SECONDARY_CHANNEL_NONE if dot11CurrentChannelWidth indicates 20 MHz, to SECONDARY_CHANNEL_ABOVE if $f_{P20,\,idx} < f_{S20,\,idx}$, or to SECONDARY_CHANNEL_BELOW otherwise.

As defined in 21.3.20, once a PPDU is received and detected as an HT PPDU, the behavior of the VHT PHY is defined in Clause 19. The RXVECTOR parameters in Table 19-1 from the Clause 19 PHY-RXSTART.indication primitive are mapped directly to the RXVECTOR parameters in Table 21-1 and a Clause 21 PHY-RXSTART.indication primitive is issued.

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21.2.6 TXSTATUS parameters

The parameters listed in Table 19-4 are defined as part of the TXSTATUS parameter list in the PHY-TXSTART.confirm primitive.

21.3 VHT PHY

21.3.1 Introduction

This subclause provides the procedure by which PSDUs are converted to and from transmissions on the wireless medium.

During transmission, a PSDU (in the SU case) or one or more PSDUs (in the MU case) are processed (i.e., scrambled and coded) and appended to the PHY preamble to create the PPDU. At the receiver, the PHY preamble is processed to aid in the detection, demodulation, and delivery of the PSDU.

Pre-VHT modulated fields refer to the L-STF, L-LTF, L-SIG, and VHT-SIG-A fields, while VHT modulated fields refer to the VHT-STF, VHT-LTF, VHT-SIG-B, and Data fields (see Figure 21-17).

21.3.2 VHT PPDU format

A single PPDU format is defined for this PHY: the VHT PPDU format. Figure 21-4 shows the VHT PPDU format.

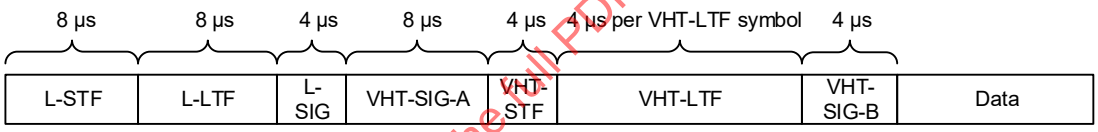

Figure 21-4—VHT PPDU format

The fields of the VHT PPDU format are summarized in Table 21-4.

Table 21-4—Fields of the VHT PPDU

Field	Description
L-STF	Non-HT Short Training field
L-LTF	Non-HT Long Training field
L-SIG	Non-HT SIGNAL field
VHT-SIG-A	VHT Signal A field
VHT-STF	VHT Short Training field
VHT-LTF	VHT Long Training field
VHT-SIG-B	VHT Signal B field
Data	The Data field carrying the PSDU(s)

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The VHT-SIG-A, VHT-STF, VHT-LTF, and VHT-SIG-B fields exist only in VHT PPDUs. In a VHT NDP the Data field is not present. The number of symbols in the VHT-LTF field, $N_{VHT\text{-}LTF}$, can be either 1, 2, 4, 6, or 8 and is determined by the total number of space-time streams across all users being transmitted in the VHT PPDU (see Table 21-13).

21.3.3 Transmitter block diagram

The generation of each field in a VHT PPDU uses many of the following blocks:

a) PHY padding
b) Scrambler
c) BCC encoder parser
d) FEC (BCC or LDPC) encoders
e) Stream parser
f) Segment parser (for 160 MHz and 80+80 MHz transmissions)
g) BCC interleaver
h) Constellation mapper
i) Pilot insertion
j) Replicate over multiple 20 MHz (if BW > 20 MHz)
k) Multiply by first column of $P_{VHT\text{-}LTF}$
l) LDPC tone mapper
m) Segment deparser
n) Space time block code (STBC) encoder
o) Cyclic shift diversity (CSD) per STS insertion
p) Spatial mapper
q) Inverse discrete Fourier transform (IDFT)
r) Cyclic shift diversity (CSD) per chain insertion
s) Guard interval (GI) insertion
t) Windowing

Figure 21-5 to Figure 21-16 show example transmitter block diagrams. The actual structure of the transmitter is implementation dependent. In particular, Figure 21-5 shows the transmit process for the L-SIG and VHT-SIG-A fields of a VHT PPDU using one frequency segment. These transmit blocks are also used to generate L-STF and L-LTF fields, except that the BCC encoder and interleaver are not used for these fields.

Figure 21-6 and Figure 21-7 show the transmit process for generating the VHT-SIG-B field of a VHT SU PPDU and VHT MU PPDU, respectively, in 20 MHz, 40 MHz, and 80 MHz channel widths. Figure 21-8 and Figure 21-9 show the transmit process for generating the VHT_SIG-B field of a 160 MHz and 80+80 MHz VHT SU PPDU, respectively.

Figure 21-10 shows the transmitter blocks used to generate the Data field of a 20 MHz, 40 MHz, and 80 MHz VHT SU PPDU with BCC encoding. A subset of these transmitter blocks consisting of the constellation mapper and CSD blocks, as well as the blocks to the right of, and including, the spatial mapping block, are also used to generate the VHT-LTF fields. This is illustrated in Figure 21-21. A subset of these transmitter blocks consisting of the constellation mapper and CSD blocks, as well as the blocks to the right of, and including, the spatial mapping block, are also used to generate the VHT-STF field but without the multiplication by $A^k_{VHT\text{-}LTF}$ [defined in Equation (21-40)].

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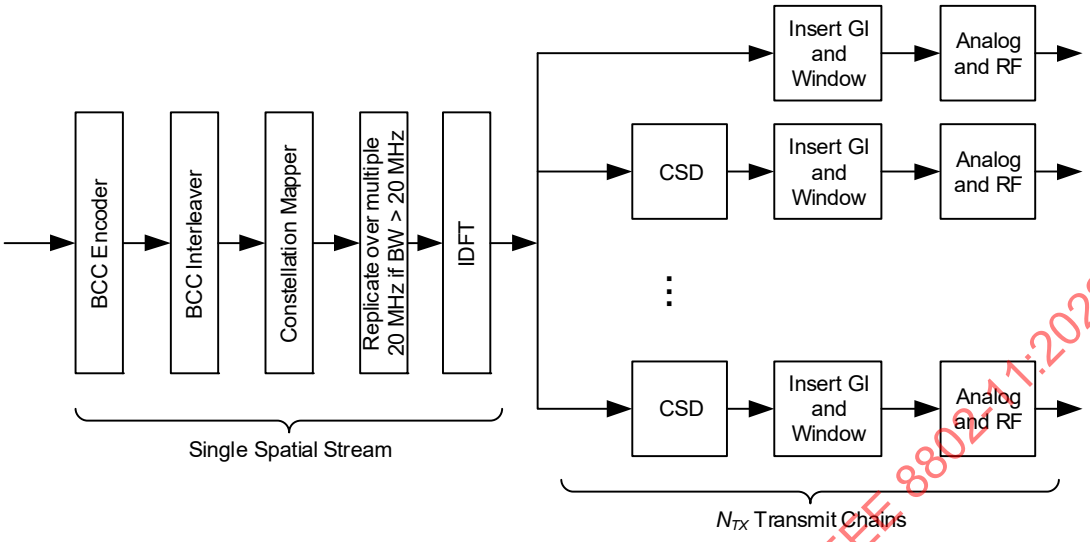

Figure 21-5—Transmitter block diagram for the L-SIG and VHT-SIG-A fields

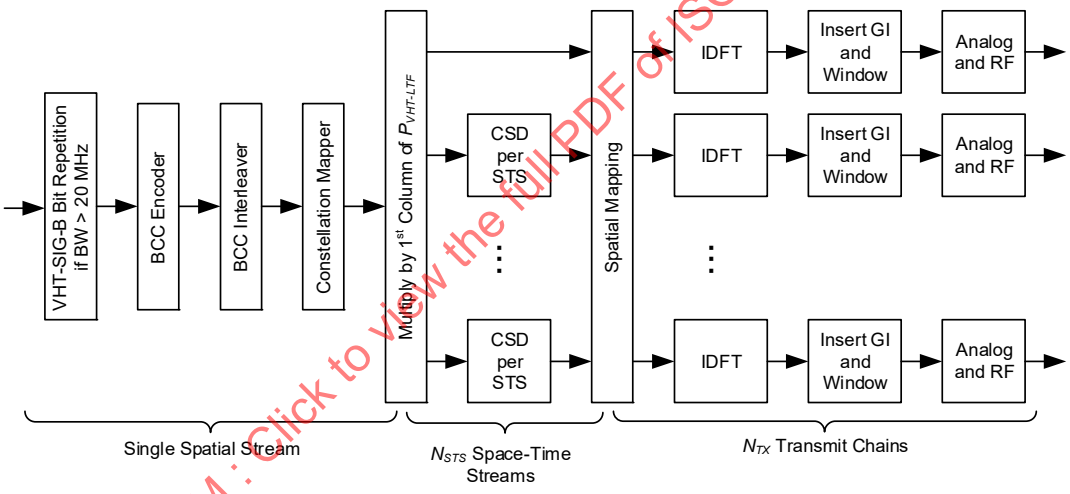

Figure 21-6—Transmitter block diagram for the VHT-SIG-B field of a 20 MHz, 40 MHz, and 80 MHz VHT SU PPDU

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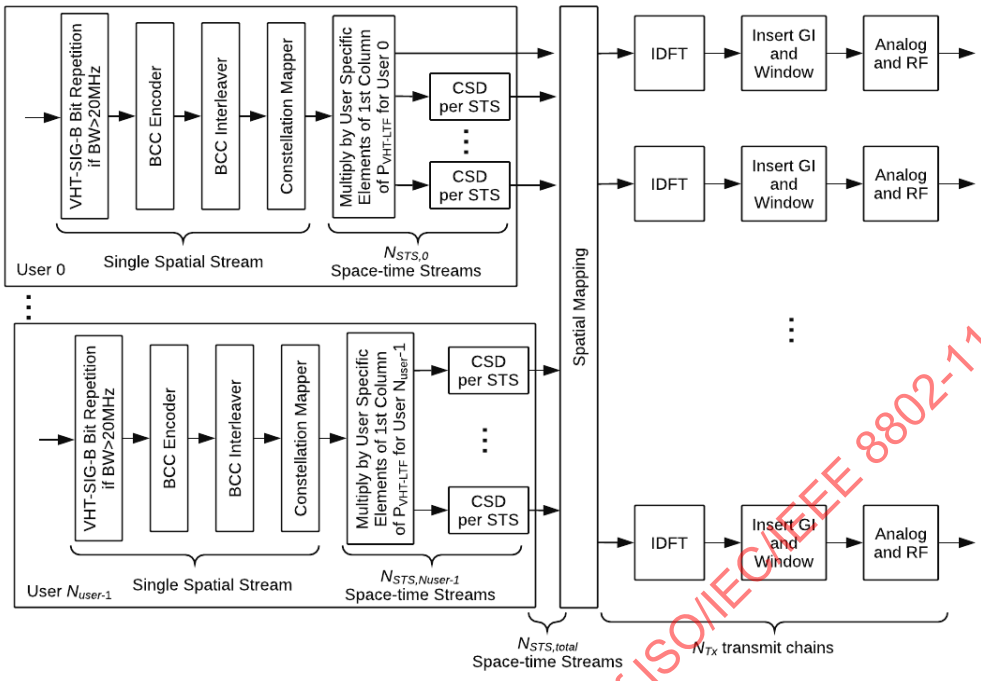

Figure 21-7—Transmitter block diagram for the VHT-SIG-B field of a 20 MHz, 40 MHz, and 80 MHz VHT MU PPDU

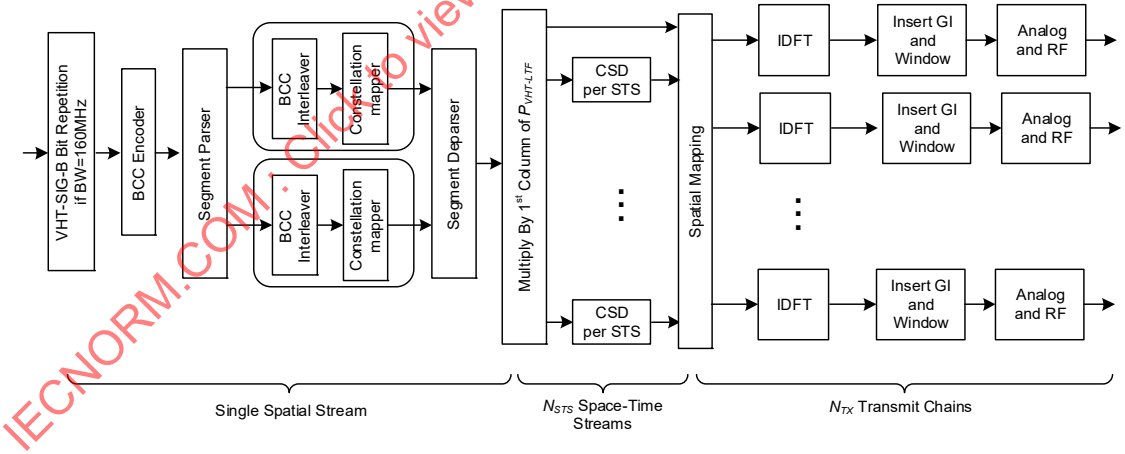

Figure 21-8—Transmitter block diagram for the VHT-SIG-B field of a 160 MHz VHT SU PPDU

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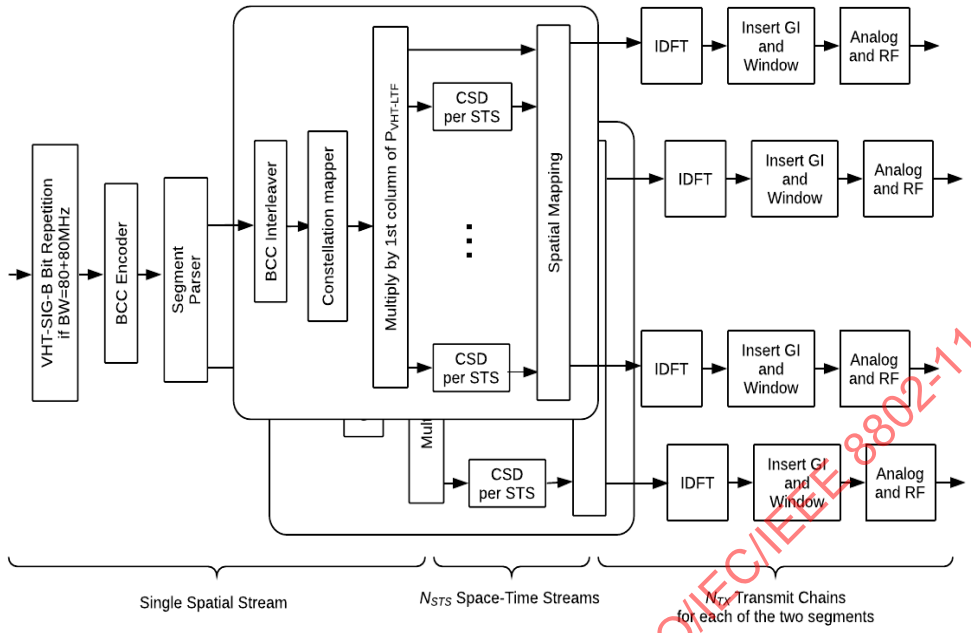

Figure 21-9—Transmitter block diagram for the VHT-SIG-B field of an 80+80 MHz VHT SU PPDU

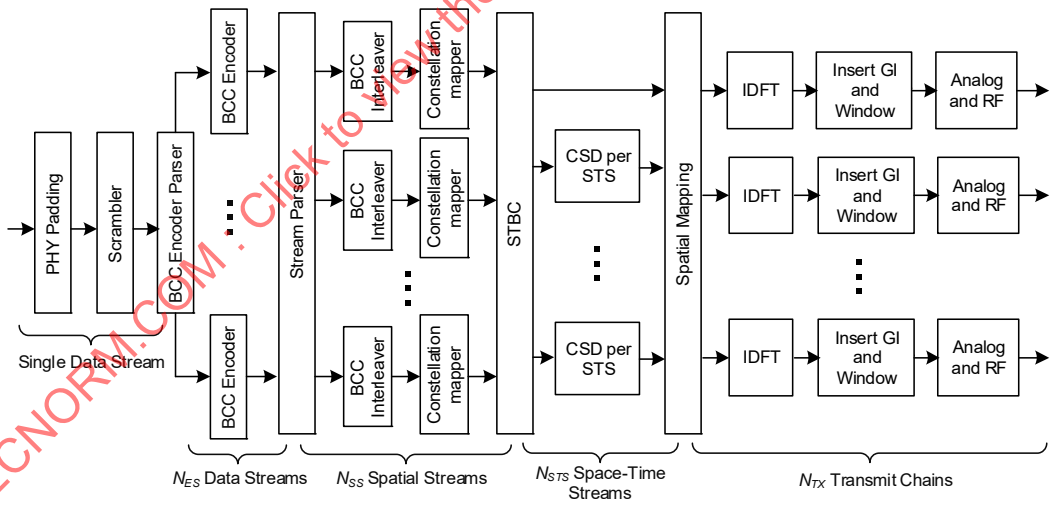

Figure 21-10—Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT SU PPDU with BCC encoding

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Figure 21-11 shows the transmitter blocks used to generate the Data field of a 20 MHz, 40 MHz, and 80 MHz VHT SU PPDU with LDPC encoding for a single frequency segment.

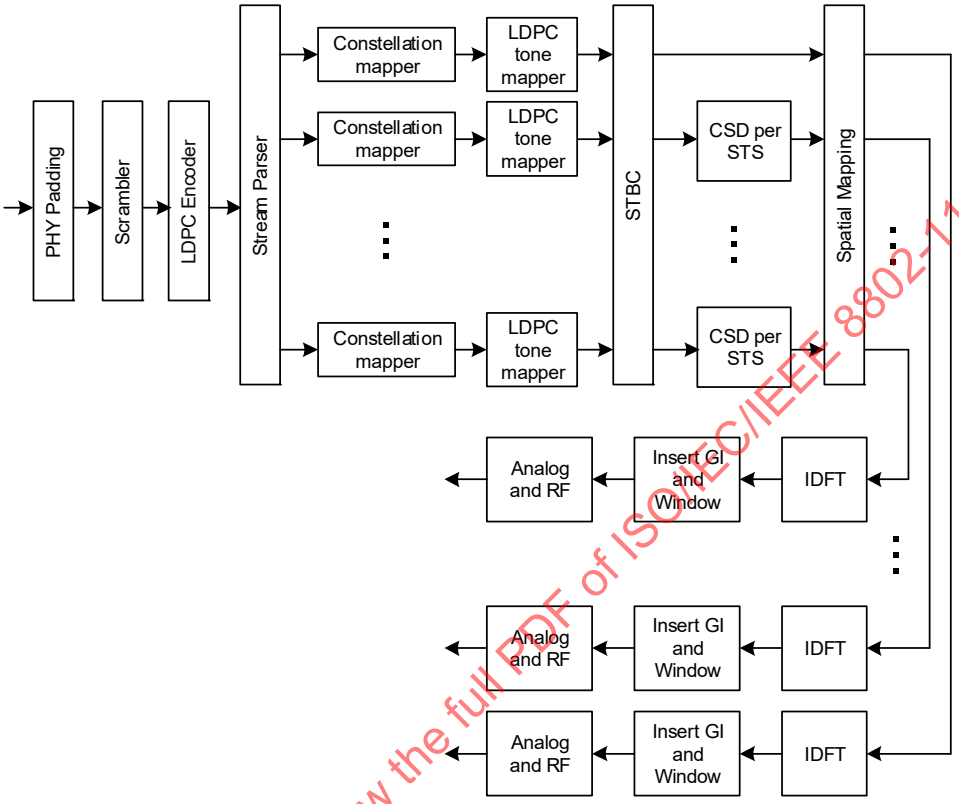

Figure 21-11—Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT SU PPDU with LDPC encoding

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Figure 21-12 shows the transmit process for generating the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT MU PPDU with BCC and LDPC encoding.

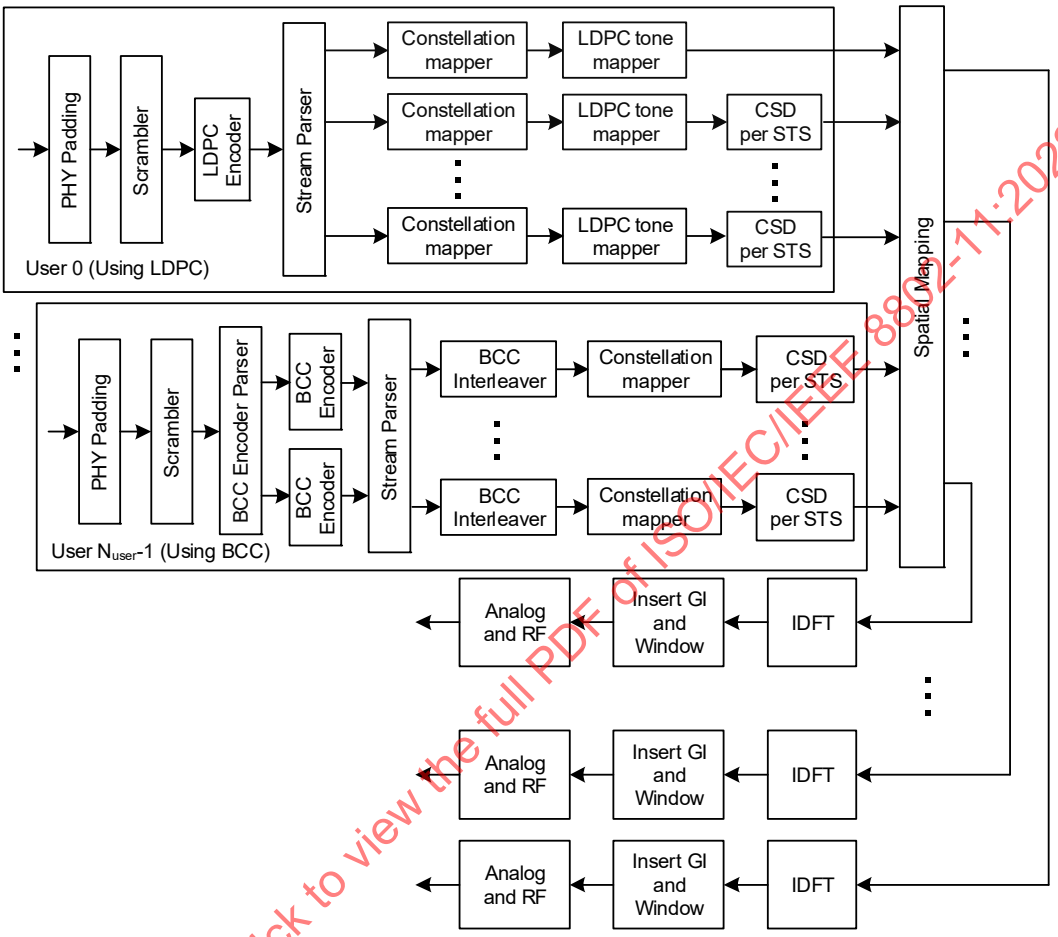

Figure 21-12—Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT MU PPDU

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Figure 21-13 and Figure 21-14 show the transmit process for generating the Data field of a 160 MHz VHT SU PPDU with BCC and LDPC encoding, respectively.

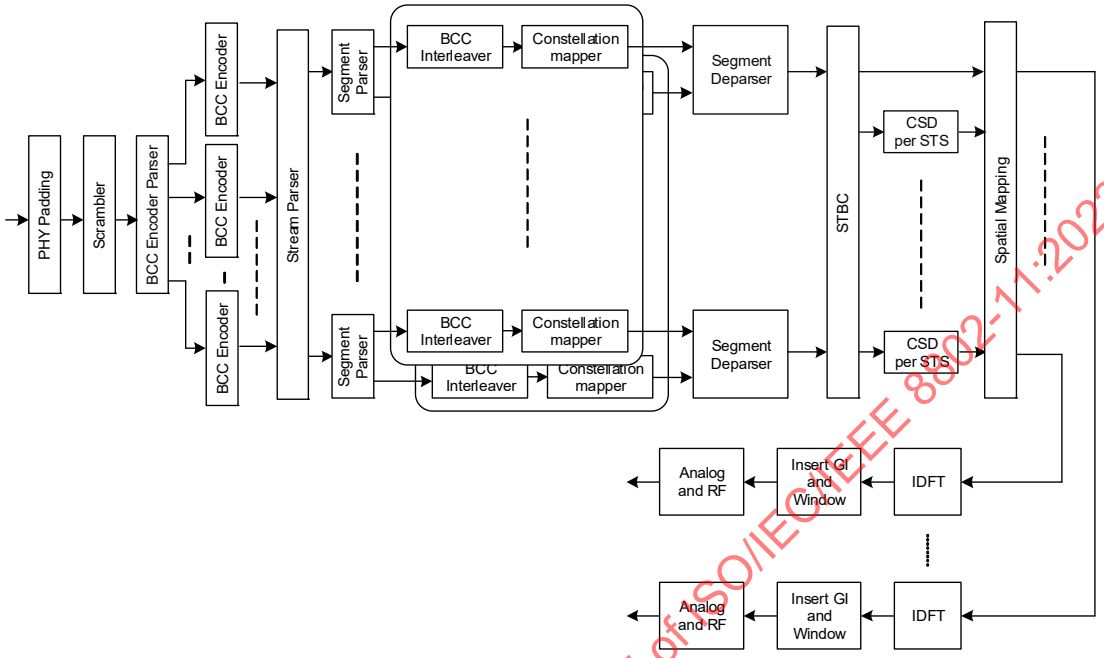

Figure 21-13—Transmitter block diagram for the Data field of a 160 MHz VHT SU PPDU with BCC encoding

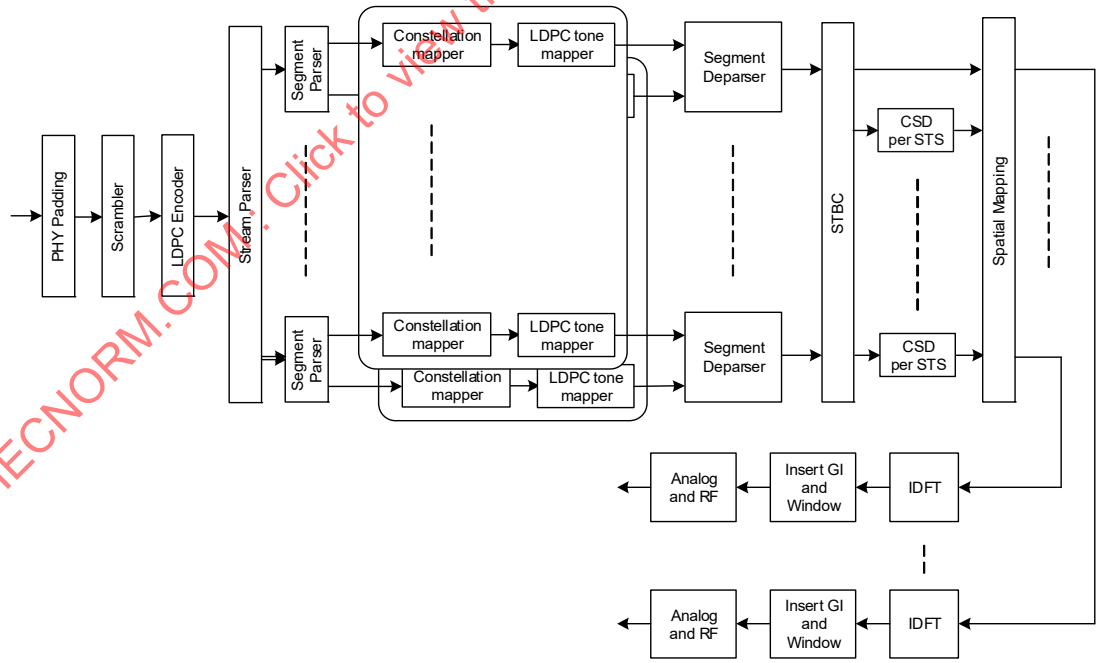

Figure 21-14—Transmitter block diagram for the Data field of a 160 MHz VHT SU PPDU with LDPC encoding

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Figure 21-15 and Figure 21-16 show the transmit process for generating the Data field of an 80+80 MHz VHT SU PPDU with BCC and LDPC encoding, respectively.

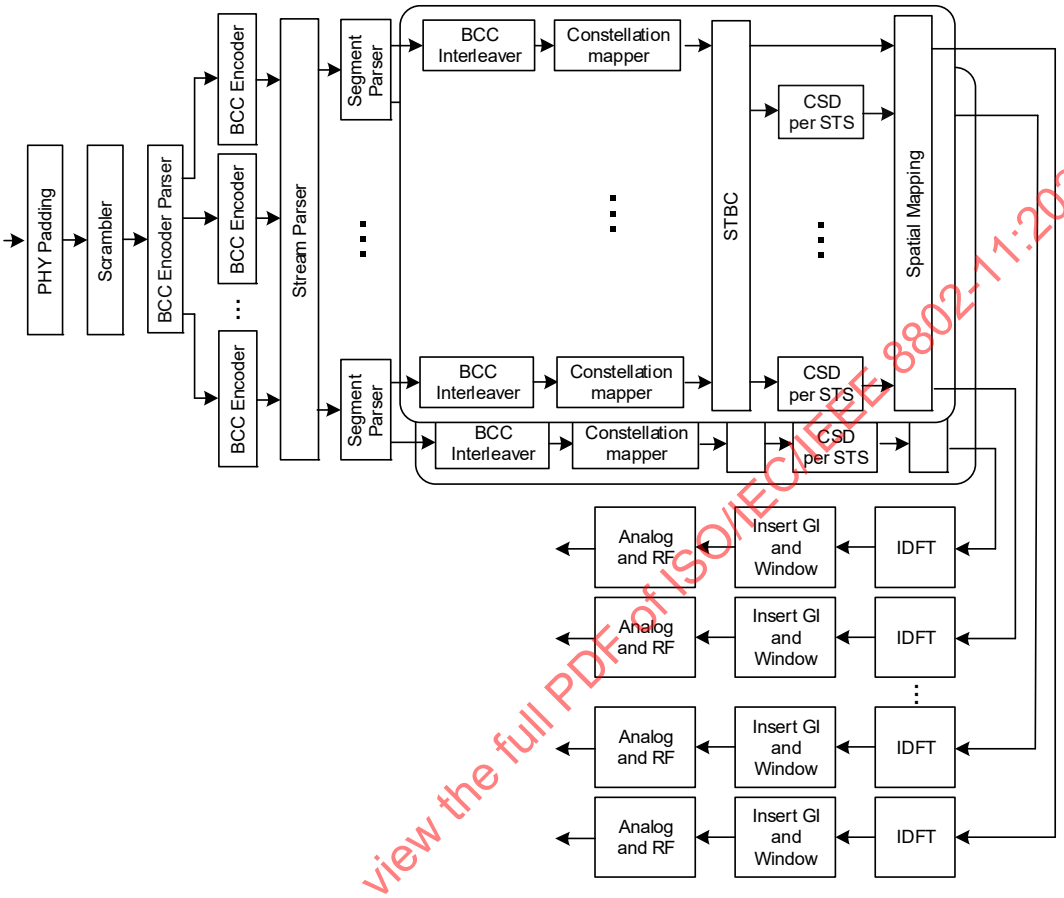

Figure 21-15—Transmitter block diagram for the Data field of an 80+80 MHz VHT SU PPDU with BCC encoding

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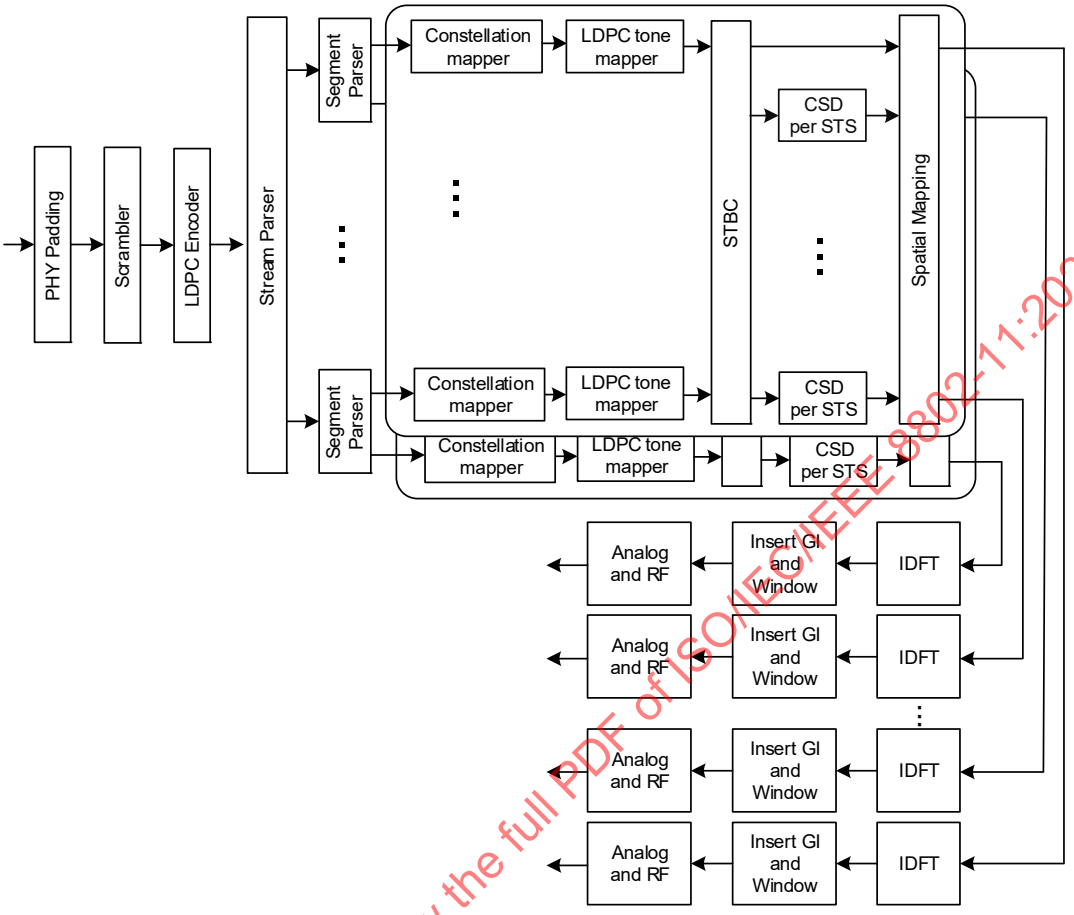

Figure 21-16—Transmitter block diagram for the Data field of an 80+80 MHz VHT SU PPDU with LDPC encoding

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21.3.4 Overview of the PPDU encoding process

21.3.4.1 General

This subclause provides an overview of the VHT PPDU encoding process.

21.3.4.2 Construction of L-STF

Construct the L-STF field as defined in 21.3.8.2.2 with the following highlights:

a) Determine the CH_BANDWIDTH from the TXVECTOR.
b) Sequence generation: Generate the L-STF sequence over the CH_BANDWIDTH as described in 21.3.8.2.2.
c) Phase rotation: Apply appropriate phase rotation for each 20 MHz subchannel as described in 21.3.7.4 and 21.3.7.5.
d) IDFT: Compute the inverse discrete Fourier transform.
e) CSD: Apply CSD for each transmit chain and frequency segment as described in 21.3.8.2.1.

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f) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 21.3.7.4.

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 and 21.3.8 for details.

21.3.4.3 Construction of the L-LTF

Construct the L-LTF field as defined in 21.3.8.2.3 with the following highlights:

a) Determine the CH_BANDWIDTH from the TXVECTOR.

b) Sequence generation: Generate the L-LTF sequence over the CH_BANDWIDTH as described in 21.3.8.2.3.

c) Phase rotation: Apply appropriate phase rotation for each 20 MHz subchannel as described in 21.3.7.4 and 21.3.7.5.

d) IDFT: Compute the inverse discrete Fourier transform.

e) CSD: Apply CSD for each transmit chain and frequency segment as described in 21.3.8.2.1.

f) Insert GI and apply windowing: Prepend a GI ($2 \times$ LONG_GI) and apply windowing as described in 21.3.7.4.

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 and 21.3.8 for details.

21.3.4.4 Construction of L-SIG

Construct the L-SIG field as the SIGNAL field defined by 21.3.8.2.4 with the following highlights:

a) In a VHT PPDU set the RATE subfield in the SIGNAL field to 6 Mb/s. Set the Length, Parity, and Tail bits in the SIGNAL field as described in 21.3.8.2.4.

b) BCC encoder: Encode the SIGNAL field by a convolutional encoder at the rate of R=1/2 as described in 21.3.10.5.3.

c) BCC interleaver: Interleave as described in 21.3.10.8.

d) Constellation Mapper: BPSK modulate as described in 21.3.10.9.

e) Pilot insertion: Insert pilots as described in 21.3.10.11.

f) Duplication and phase rotation: Duplicate the L-SIG field over each 20 MHz of the CH_BANDWIDTH. Apply appropriate phase rotation for each 20 MHz subchannel as described in 21.3.7.4 and 21.3.7.5.

g) IDFT: Compute the inverse discrete Fourier transform.

h) CSD: Apply CSD for each transmit chain and frequency segment as described in 21.3.8.2.1.

i) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 21.3.7.4.

j) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 and 21.3.8 for details.

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21.3.4.5 Construction of VHT-SIG-A

The VHT-SIG-A field consists of two symbols, VHT-SIG-A1 and VHT-SIG-A2, as defined in 21.3.8.3.3 and is constructed as follows:

a) Obtain the CH_BANDWIDTH, STBC, GROUP_ID, PARTIAL_AID (SU only), NUM_STS, GI_TYPE, FEC_CODING, MCS (SU only), BEAMFORMED (SU only), NUM_USERS, and TXOP_PS_NOT_ALLOWED from the TXVECTOR. Add the reserved bits, append the calculated CRC, then append the N_{tail} tail bits as shown in 21.3.8.3.3. This results in 48 uncoded bits.

b) BCC encoder: Encode the data by a convolutional encoder at the rate of R=1/2 as described in 17.3.5.6

c) BCC interleaver: Interleave as described in 17.3.5.7.

d) Constellation mapper: BPSK modulate the first 48 interleaved bits as described in 17.3.5.8 to form the first symbol of VHT-SIG-A. BPSK modulate the second 48 interleaved bits and rotate by 90° counter-clockwise relative to the first symbol to form the second symbol of VHT-SIG-A.

e) Pilot insertion: Insert pilots as described in 17.3.5.9.

f) Duplication and phase rotation: Duplicate VHT-SIG-A1 and VHT-SIG-A2 over each 20 MHz of the CH_BANDWIDTH. Apply the appropriate phase rotation for each 20 MHz subchannel as described in 21.3.7.4 and 21.3.7.5.

g) IDFT: Compute the inverse discrete Fourier transform.

h) CSD: Apply CSD for each transmit chain and frequency segment as described in 21.3.8.2.1.

i) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 21.3.7.4.

j) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 and 21.3.8 for details.

21.3.4.6 Construction of VHT-STF

The VHT-STF field is defined in 21.3.8.3.4 and is constructed as follows:

a) Sequence generation: Generate the VHT-STF in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 21.3.8.3.4.

b) Phase rotation: Apply appropriate phase rotation for each 20 MHz subchannel as described in 21.3.7.4 and 21.3.7.5.

c) CSD: Apply CSD for each space-time stream and frequency segment as described in 21.3.8.3.2.

d) Spatial mapping: Apply the Q matrix as described in 21.3.10.11.1.

e) IDFT: Compute the inverse discrete Fourier transform.

f) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 21.3.7.4.

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 and 21.3.8 for details.

21.3.4.7 Construction of VHT-LTF

The VHT-LTF field is defined in 21.3.8.3.5 and constructed as follows:

a) Sequence generation: Generate the VHT-LTF sequence in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 21.3.8.3.5.

b) Phase rotation: Apply appropriate phase rotation for each 20 MHz subchannel as described in 21.3.7.4 and 21.3.7.5.

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c) $A_{VHT\text{-}LTF}$ matrix mapping: Apply the $P_{VHT\text{-}LTF}$ matrix to the data tones of the VHT-LTF sequence and apply the $R_{VHT\text{-}LTF}$ matrix to the pilot tones as described in 21.3.8.3.5.

d) CSD: Apply CSD for each space-time stream and frequency segment as described in 21.3.8.3.2.

e) Spatial mapping: Apply the Q matrix as described in 21.3.10.11.1.

f) IDFT: Compute the inverse discrete Fourier transform.

g) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 21.3.7.4.

h) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 and 21.3.8 for details.

21.3.4.8 Construction of VHT-SIG-B

The VHT-SIG-B field is constructed per-user as follows:

a) Obtain the VHT-MCS (for MU only) and APEP_LENGTH from the TXVECTOR.

b) VHT-SIG-B bits: Set the VHT-MCS (for MU only) and VHT-SIG-B Length field as described in 21.3.8.3.6. Add the reserved bits (for SU only) and N_{tail} bits of tail. In an NDP set VHT-SIG-B to the fixed bit pattern for the bandwidth used as described in 21.3.8.3.6.

c) VHT-SIG-B Bit Repetition: Repeat the VHT-SIG-B bits as a function of CH_BANDWIDTH as defined in 21.3.8.3.6.

d) BCC encoder: Encode the VHT-SIG-B field using BCC at rate R=1/2 as described in 17.3.5.6.

e) Segment parser (if needed): In a 160 MHz or 80+80 MHz transmission, divide the output bits of the BCC encoder into two frequency subblocks as described in 21.3.10.7. This block is bypassed for 20 MHz, 40 MHz, and 80 MHz VHT PPDU transmissions.

f) BCC interleaver: Interleave as described in 21.3.10.8.

g) Constellation mapper: Map to a BPSK constellation as defined in 17.3.5.8.

h) Segment deparser (if needed): In a 160 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 21.3.10.9.3. This block is bypassed for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz VHT PPDU transmissions.

i) Pilot insertion: Insert pilots following the steps described in 21.3.10.10.

j) $P_{VHT\text{-}LTF}$ matrix mapping: Apply the mapping of the first column of the $P_{VHT\text{-}LTF}$ matrix to the data subcarriers as described in 21.3.8.3.6. The total number of data and pilot subcarriers is the same as in the Data field.

k) CSD: Apply CSD for each space-time stream and frequency segment as described in 21.3.8.3.2.

l) Spatial mapping: Apply the Q matrix as described in 21.3.10.11.1.

m) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 21.3.7.4 and 21.3.7.5.

n) IDFT: Compute the inverse discrete Fourier transform.

o) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 21.3.7.4.

p) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 and 21.3.8 for details.

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21.3.4.9 Construction of the Data field in a VHT SU PPDU

21.3.4.9.1 Using BCC

The construction of the Data field in a VHT SU PPDU with BCC encoding proceeds as follows:

a) Insert the CRC calculated for VHT-SIG-B in the SERVICE field as described in 21.3.10.2 and append the PSDU to the SERVICE field.

b) PHY padding: Append the PHY pad bits and tail bits to the PSDU.

c) Scrambler: Scramble the PHY padded data.

d) BCC encoder: Divide the scrambled bits between the encoders by sending bits to different encoders in a round robin manner. The number of encoders is determined by rate-dependent parameters described in 21.5. BCC encode as described in 21.3.10.5.2 and 21.3.10.5.3.

e) Stream parser: Rearrange the output of the BCC encoders into blocks as described in 21.3.10.6.

f) Segment parser (if needed): In a 160 MHz or 80+80 MHz transmission, divide the output bits of each stream parser into two frequency subblocks as described in 21.3.10.7. This block is bypassed for 20 MHz, 40 MHz, and 80 MHz VHT PPDU transmissions.

g) BCC interleaver: Interleave as described in 21.3.10.8.

h) Constellation mapper: Map to BPSK, QPSK, 16-QAM, 64-QAM, or 256-QAM constellation points as described in 21.3.10.9.

i) Segment deparser (if needed): In a 160 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 21.3.10.9.3. This block is bypassed for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz VHT PPDU transmissions.

j) STBC: Apply STBC as described in 21.3.10.9.4.

k) Pilot insertion: Insert pilots following the steps described in 21.3.10.10.

l) CSD: Apply CSD for each space-time stream and frequency segment as described in 21.3.8.3.2.

m) Spatial mapping: Apply the Q matrix as described in 21.3.10.11.1.

n) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 21.3.7.4 and 21.3.7.5.

o) IDFT: In an 80+80 MHz transmission, map each frequency subblock to a separate IDFT. Compute the inverse discrete Fourier transform.

p) Insert GI and apply windowing: Prepend a GI (SHORT_GI or LONG_GI) and apply windowing as described in 21.3.7.4.

q) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 and 21.3.8 for details.

21.3.4.9.2 Using LDPC

The construction of the Data field in a VHT SU PPDU with LDPC encoding proceeds as follows:

a) Insert the CRC calculated for VHT-SIG-B in the SERVICE field as described in 21.3.10.2 and append the PSDU to the SERVICE field.

b) PHY padding: Append the PHY pad bits to the PSDU. There are no tail bits.

c) Scrambler: Scramble the PHY padded data.

d) LDPC encoder: The scrambled bits are encoded using the LDPC code with the APEP_LENGTH in the TXVECTOR as described in 21.3.10.5.4.

e) Stream parser: The output of the LDPC encoder is rearranged into blocks as described in 21.3.10.6.

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f) Segment parser (if needed): In a 160 MHz or 80+80 MHz transmission, divide the output bits of each stream parser into two frequency subblocks as described in 21.3.10.7. This block is bypassed for 20 MHz, 40 MHz, and 80 MHz VHT PPDU transmissions.

g) Constellation mapper: Map to BPSK, QPSK, 16-QAM, 64-QAM or 256-QAM constellation points as described in 21.3.10.9.

h) LDPC tone mapper: The LDPC tone mapping shall be performed on all LDPC encoded streams as described in 21.3.10.9.2.

i) Segment deparser (if needed): In a 160 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 21.3.10.9.3. This block is bypassed for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz VHT PPDU transmissions.

j) STBC: Apply STBC as described in 21.3.10.9.4.

k) Pilot insertion: Insert pilots following the steps described in 21.3.10.10.

l) CSD: Apply CSD for each space-time stream and frequency segment as described in 21.3.8.3.2.

m) Spatial mapping: Apply the Q matrix as described in 21.3.10.11.1.

n) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 21.3.7.4 and 21.3.7.5.

o) IDFT: In an 80+80 MHz transmission, map each frequency subblock to a separate IDFT. Compute the inverse discrete Fourier transform.

p) Insert GI and apply windowing: Prepend a GI (SHORT_GI or LONG_GI) and apply windowing as described in 21.3.7.4.

q) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 and 21.3.8 for details.

21.3.4.10 Construction of the Data field in a VHT MU PPDU

21.3.4.10.1 General

In an MU transmission, the PPDU encoding process is performed independently on a per-user basis up to the input of the Spatial Mapping block, except that CSD is performed with a knowledge of the space time stream starting index for that user. All user data is combined and mapped to the transmit chains in the Spatial Mapping block.

21.3.4.10.2 Using BCC

A Data field with BCC encoding is constructed using steps a) to k) in 21.3.4.9.1, then applying CSD for a VHT MU PPDU (as described in 21.3.8.3.2).

21.3.4.10.3 Using LDPC

A Data field with LDPC encoding is constructed using steps a) to k) in 21.3.4.9.2, then applying CSD as for a VHT MU PPDU (as described in 21.3.8.3.2).

21.3.4.10.4 Combining to form a VHT MU PPDU

The per-user data is combined as follows:

a) Spatial Mapping: The Q matrix is applied as described in 21.3.10.11.1. The combining of all user data is done in this block.

b) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 21.3.7.4 and 21.3.7.5.

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c) IDFT: Compute the inverse discrete Fourier transform.

d) Insert GI and apply windowing: Prepend a GI (SHORT_GI or LONG_GI) and apply windowing as described in 21.3.7.4.

e) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 and 21.3.8 for details.

21.3.5 VHT modulation and coding scheme (VHT-MCS)

The VHT-MCS is a value that determines the modulation and coding used in the Data field of the PPDU. It is a compact representation that is carried in the VHT-SIG-A field for VHT SU PPDUs and in the VHT-SIG-B field for VHT MU PPDUs. Rate-dependent parameters for the full set of VHT-MCSs are shown in Table 21-29 to Table 21-60 (in 21.5). These tables give rate-dependent parameters for VHT-MCSs with indices 0 to 9, with number of spatial streams from 1 to 8 and bandwidth options of 20 MHz, 40 MHz, 80 MHz, and either 160 MHz or 80+80 MHz. Equal modulation (EQM) is applied to all streams for a particular user.

21.3.6 Timing-related parameters

Refer to Table 19-6 for timing-related parameters for non-VHT formats.

Table 21-5 defines the timing-related parameters for VHT format.

Table 21-5—Timing-related constants

Parameter	CBW20	CBW40	CBW80	CBW80+80	CBW160	Description
N_{SD}	52	108	234	234	468	Number of complex data numbers per frequency segment
N_{SP}	4	6	8	8	16	Number of pilot values per frequency segment
N_{ST}	56	114	242	242	484	Total number of subcarriers per frequency segment. See NOTE.
N_{SR}	28	58	122	122	250	Highest data subcarrier index per frequency segment
N_{Seg}	1	1	1	2	1	Number of frequency segments
Δ_F	312.5 kHz					Subcarrier frequency spacing
T_{DFT}	3.2 μs					IDFT/DFT period
T_{GI}	0.8 μs = T_{DFT}/4					Guard interval duration
T_{GI2}	1.6 μs					Double guard interval

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Table 21-5—Timing-related constants *(continued)*

Parameter	CBW20	CBW40	CBW80	CBW80+80	CBW160	Description
T_{GIS}	0.4 µs = T_{DFT}/8					Short guard interval duration
T_{SYML}	4 µs = T_{DFT} + T_{GI} = 1.25 × T_{DFT}					Long GI symbol interval
T_{SYMS}	3.6 µs = T_{DFT} + T_{GIS} = 1.125 × T_{DFT}					Short GI symbol interval
T_{SYM}	T_{SYML} or T_{SYMS} depending on the GI used (see Table 21-8)					Symbol interval
$T_{L\text{-}STF}$	8 µs = 10 x T_{DFT}/4					Non-HT Short Training field duration
$T_{L\text{-}LTF}$	8 µs = 2 x T_{DFT} + T_{GI2}					Non-HT Long Training field duration
$T_{L\text{-}SIG}$	4 µs = T_{SYML}					Non-HT SIGNAL field duration
$T_{VHT\text{-}SIG\text{-}A}$	8 µs = 2T_{SYML}					VHT Signal A field duration
$T_{VHT\text{-}STF}$	4 µs = T_{SYML}					VHT Short Training field duration
$T_{VHT\text{-}LTF}$	4 µs = T_{SYML}					Duration of each VHT-LTF symbol
$T_{VHT\text{-}SIG\text{-}B}$	4 µs = T_{SYML}					VHT Signal B field duration
$N_{service}$	16					Number of bits in the SERVICE field
N_{tail}	6					Number of tail bits per BCC encoder

NOTE—$N_{ST} = N_{SD} + N_{SP}$

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Table 21-6 defines parameters used frequently in Clause 21.

Table 21-6—Frequently used parameters

Symbol	Explanation
N_{CBPS}, $N_{CBPS,u}$	Number of coded bits per symbol for user u, $u = 0, ..., N_{user}-1$. For a VHT SU PPDU, $N_{CBPS} = N_{CBPS,0}$ For a VHT MU PPDU, N_{CBPS} is undefined
N_{CBPSS}, $N_{CBPSS,u}$	Number of coded bits per symbol per spatial stream. For the VHT-SIG-B field, N_{CBPSS} is common for all users. $N_{CBPSS} = \begin{cases} N_{SD}, \text{ for a 20 MHz, 40 MHz, 80 MHz, and 160 MHz PPDU} \\ 2N_{SD}, \text{ for an 80+80 MHz PPDU} \end{cases}$ for all users. For the Data field, $N_{CBPSS,u}$ equals the number of coded bits per symbol per spatial stream for user u, $u = 0, ..., N_{user}-1$. For the Data field of a VHT SU PPDU, $N_{CBPSS} = N_{CBPSS,0}$ For the Data field of a VHT MU PPDU, N_{CBPSS} is undefined
N_{CBPSSI}, $N_{CBPSSI,u}$	Number of coded bits per symbol per spatial stream per BCC interleaver block. For a VHT SU PPDU, $N_{CBPSSI} = \begin{cases} N_{CBPSS}, \text{ for a 20 MHz, 40 MHz, or 80 MHz PPDU} \\ \frac{N_{CBPSS}}{2}, \text{ for a 160 MHz or 80+80 MHz PPDU} \end{cases}$ For a VHT MU PPDU for user u, $u = 0, ..., N_{user}-1$ $N_{CBPSSI,u} = \begin{cases} N_{CBPSS,u}, \text{ for a 20 MHz, 40 MHz, or 80 MHz PPDU} \\ \frac{N_{CBPSS,u}}{2}, \text{ for a 160 MHz or 80+80 MHz PPDU} \end{cases}$ For a VHT MU PPDU, N_{CBPSSI} is undefined.
N_{DBPS}, $N_{DBPS,u}$	Number of data bits per symbol for user u, $u = 0, ..., N_{user}-1$. For a VHT SU PPDU, $N_{DBPS} = N_{DBPS,0}$ For a VHT MU PPDU, N_{DBPS} is undefined
N_{BPSCS}, $N_{BPSCS,u}$	Number of coded bits per subcarrier per spatial stream for user u, $u = 0, ..., N_{user}-1$. For a VHT SU PPDU, $N_{BPSCS} = N_{BPSCS,0}$ For a VHT MU PPDU, N_{BPSCS} is undefined
N_{RX}	Number of receive chains
N_{user}	For pre-VHT modulated fields, $N_{user} = 1$. For VHT modulated fields, N_{user} represents the number of users in the transmission (equal to the TXVECTOR parameter NUM_USERS).
N_{STS}, $N_{STS,u}$	For pre-VHT modulated fields, $N_{STS,u} = 1$ (see NOTE). For VHT modulated fields, $N_{STS,u}$ is the number of space-time streams for user u, $u = 0, ..., N_{user}-1$. For a VHT SU PPDU, $N_{STS} = N_{STS,0}$. For a VHT MU PPDU, N_{STS} is undefined.

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Table 21-6—Frequently used parameters *(continued)*

Symbol	Explanation
$N_{STS,total}$	For VHT modulated fields, $N_{STS,total}$ is the total number of space-time streams in a PPDU. $N_{STS,\,total} = \sum_{u=0}^{N_{user}-1} N_{STS,\,u}$ For pre-VHT modulated fields, $N_{STS,total}$ is undefined. Note that $N_{STS,total} = N_{STS}$ for a VHT SU PPDU.
N_{SS}, $N_{SS,u}$	Number of spatial streams. For the VHT-SIG-B field, $N_{SS} = 1$ for each user. For the Data field, $N_{SS,u}$ is the number of spatial streams for user u, $u = 0, \ldots, N_{user}-1$. For the Data field of a VHT SU PPDU, $N_{SS} = N_{SS,0}$. For the Data field of a VHT MU PPDU, N_{SS} is undefined.
N_{TX}	Number of transmit chains
N_{ES}, $N_{ES,u}$	The number of BCC encoders. For the VHT-SIG-B field, $N_{ES} = 1$ for each user. For a Data field encoded using BCC, $N_{ES,u}$ is the number of BCC encoders for user u, $u = 0, \ldots, N_{user}-1$. For the Data field encoded using LDPC, $N_{ES} = 1$ for a VHT SU PPDU and $N_{ES,u} = 1$ for a VHT MU PPDU for user u, $u = 0, \ldots N_{user}-1$. For the Data field of a VHT SU PPDU, $N_{ES} = N_{ES,0}$. For the Data field of a VHT MU PPDU, N_{ES} is undefined.
$N_{VHT\text{-}LTF}$	Number of VHT-LTF symbols (see 21.3.8.3.5)
R, R_u	R_u is the coding rate for user u, $u = 0, \ldots, N_{user}-1$. For a VHT SU PPDU, $R = R_0$ For a VHT MU PPDU, R is undefined
M_u	For pre-VHT modulated fields, $M_u = 0$. For VHT modulated fields, $M_0 = 0$ for $u = 0$ and $M_u = \sum_{u'=0}^{u-1} N_{STS,\,u'}$ for $u = 1, \ldots N_{user}-1$.
NOTE—For pre-VHT modulated fields, u is 0 only since $N_{user} = 1$.	

21.3.7 Mathematical description of signals

21.3.7.1 Notation

For a description of the conventions used for the mathematical description of the signals, see 17.3.2.5. In addition, the following notational conventions are used in Clause 21:

$[Q]_{m,\,n}$ indicates the element in row m and column n of matrix Q, where $1 \le m \le N_{row}$ and $1 \le n \le N_{col}$

N_{row} and N_{col} are the number of rows and columns, respectively, of the matrix Q

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$[Q]_{M:N}$ indicates a matrix consisting of columns M to N of matrix Q

21.3.7.2 Subcarrier indices in use

For description on subcarrier indices over which the signal is transmitted for non-HT and HT PPDUs, see 19.3.7.

For a 20 MHz VHT PPDU transmission, the 20 MHz is divided into 64 subcarriers. The signal is transmitted on subcarriers –28 to –1 and 1 to 28, with 0 being the center (DC) subcarrier.

For a 40 MHz VHT PPDU transmission, the 40 MHz is divided into 128 subcarriers. The signal is transmitted on subcarriers –58 to –2 and 2 to 58.

For an 80 MHz VHT PPDU transmission, the 80 MHz is divided into 256 subcarriers. The signal is transmitted on subcarriers –122 to –2 and 2 to 122.

For a 160 MHz VHT PPDU transmission, the 160 MHz is divided into 512 subcarriers. The signal is transmitted on subcarriers –250 to –130, –126 to –6, 6 to 126, and 130 to 250.

For an 80+80 MHz VHT PPDU transmission, each 80 MHz frequency segment is divided into 256 subcarriers. In each frequency segment, the signal is transmitted on subcarriers –122 to –2 and 2 to 122.

21.3.7.3 Channel frequencies

Let

$$f_{c,\,\mathrm{idx0}} = \mathrm{dot11CurrentChannelCenterFrequencyIndex0} \tag{21-1}$$

$$f_{c,\,\mathrm{idx1}} = \mathrm{dot11CurrentChannelCenterFrequencyIndex1} \tag{21-2}$$

$$f_{\mathrm{P20,\,idx}} = \mathrm{dot11CurrentPrimaryChannel} \tag{21-3}$$

$$f_{\mathrm{CH,\,start}} = \mathrm{dot11ChannelStartingFactor} \times 500\ \mathrm{kHz} \tag{21-4}$$

where

dot11CurrentChannelCenterFrequencyIndex0, dot11CurrentChannelCenterFrequencyIndex1, and dot11CurrentPrimaryChannel are defined in Table 21-22.

When dot11CurrentChannelWidth (see Table 21-22) is 20 MHz, $f_{\mathrm{P20,\,idx}} = f_{c,\,\mathrm{idx0}}$. For dot11CurrentChannelWidth greater than 20 MHz, $f_{\mathrm{P20,\,idx}}$ and $f_{c,\,\mathrm{idx0}}$ shall have the relationship specified in Equation (21-5).

$$f_{\mathrm{P20,\,idx}} = f_{c,\,\mathrm{idx0}} - 4 \cdot \left(\frac{N_{\mathrm{20MHz}}}{2} - n_{\mathrm{P20}} \right) + 2 \tag{21-5}$$

where

$$N_{\mathrm{20MHz}} = \begin{cases} 2, \text{ if dot11CurrentChannelWidth indicates 40 MHz} \\ 4, \text{ if dot11CurrentChannelWidth indicates 80 MHz and 80+80 MHz} \\ 8, \text{ if dot11CurrentChannelWidth indicates 160 MHz} \end{cases}$$

n_{P20} is an integer with possible range $0 \le n_{\mathrm{P20}} \le N_{\mathrm{20MHz}} - 1$

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When dot11CurrentChannelWidth is 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz,

— The primary 20 MHz channel is the channel with 20 MHz bandwidth centered at $f_{\text{CH, start}} + 5 \times f_{\text{P20, idx}}$ MHz.
— The secondary 20 MHz channel is the channel with 20 MHz bandwidth centered at $f_{\text{CH, start}} + 5 \times f_{S\text{20, idx}}$, where $f_{S\text{20, idx}}$ is given in Equation (21-6).

$$f_{\text{S20, idx}} = \begin{cases} f_{\text{P20, idx}} + 4, & \text{if } n_{\text{P20}} \text{ is even} \\ f_{\text{P20, idx}} - 4, & \text{if } n_{\text{P20}} \text{ is odd} \end{cases} \quad (21\text{-}6)$$

When dot11CurrentChannelWidth is 80 MHz, 160 MHz, or 80+80 MHz,

— The primary 40 MHz channel is the channel with 40 MHz bandwidth centered at $f_{\text{CH, start}} + 5 \times f_{\text{P40, idx}}$ MHz, where $f_{\text{P40, idx}}$ is given in Equation (21-7).
— The secondary 40 MHz channel is the channel with 40 MHz bandwidth centered at $f_{\text{CH, start}} + 5 \times f_{S\text{40, idx}}$ MHz, where $f_{S\text{40, idx}}$ is given in Equation (21-8).

$$f_{\text{P40, idx}} = f_{c,\,\text{idx0}} - 8 \cdot \left(\frac{N_{\text{20MHz}}}{4} - n_{\text{P40}} \right) + 4 \quad (21\text{-}7)$$

$$f_{\text{S40, idx}} = \begin{cases} f_{\text{P40, idx}} + 8, & \text{if } n_{\text{P40}} \text{ is even} \\ f_{\text{P40, idx}} - 8, & \text{if } n_{\text{P40}} \text{ is odd} \end{cases} \quad (21\text{-}8)$$

where $n_{\text{P40}} = \lfloor n_{\text{P20}} / 2 \rfloor$.

When dot11CurrentChannelWidth is 160 MHz,

— The primary 80 MHz channel is the channel with 80 MHz bandwidth centered at $f_{\text{CH, start}} + 5 \times f_{\text{P80, idx}}$ MHz, where $f_{\text{P80, idx}}$ is given in Equation (21-9).
— The secondary 80 MHz channel is the channel with 80 MHz bandwidth centered at $f_{\text{CH, start}} + 5 \times f_{\text{S80, idx}}$ MHz where $f_{\text{S80, idx}}$ is given in Equation (21-10).

$$f_{\text{P80, idx}} = f_{c,\,\text{idx0}} - 16 \cdot \left(\frac{N_{\text{20MHz}}}{8} - n_{\text{P80}} \right) + 8 \quad (21\text{-}9)$$

$$f_{\text{S80, idx}} = \begin{cases} f_{\text{P80, idx}} + 16, & \text{if } n_{\text{P80}} \text{ is even} \\ f_{\text{P80, idx}} - 16, & \text{if } n_{\text{P80}} \text{ is odd} \end{cases} \quad (21\text{-}10)$$

where $n_{\text{P80}} = \lfloor n_{\text{P20}} / 4 \rfloor$.

When dot11CurrentChannelWidth is 80+80 MHz,

— The primary 80 MHz channel is the channel with 80 MHz bandwidth centered at $f_{\text{CH, start}} + 5 \times f_{\text{P80, idx}}$ MHz, where $f_{\text{P80, idx}} = f_{c,\,\text{idx0}}$.
— The secondary 80 MHz channel is the channel with 80 MHz bandwidth centered at $f_{\text{CH, start}} + 5 \times f_{\text{S80, idx}}$ MHz where $f_{\text{S80, idx}} = f_{c,\,\text{idx1}}$.

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21.3.7.4 Transmitted signal

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the relation shown in Equation (21-11).

$$r_{RF}^{(i_{Seg}, i_{TX})}(t) = \mathrm{Re}\left\{ \frac{1}{\sqrt{N_{Seg}}} r_{\mathrm{PPDU}}^{(i_{Seg}, i_{TX})}(t) \exp(j2\pi f_c^{(i_{Seg})} t) \right\},$$
$$i_{Seg} = 0, \ldots, N_{Seg} - 1; \quad i_{TX} = 1, \ldots, N_{TX} \tag{21-11}$$

where

N_{Seg} represents the number of frequency segments in the transmit signal, as defined in Table 21-5

$r_{\mathrm{PPDU}}^{(i_{Seg}, i_{TX})}(t)$ represents the complex baseband signal of frequency segment i_{Seg} and transmit chain i_{TX}

$f_c^{(i_{Seg})}$ represents the center frequency of the portion of the PPDU transmitted in frequency segment i_{Seg}. Table 21-7 shows $f_c^{(i_{Seg})}$ as a function of the channel starting frequency and dot11CurrentChannelWidth (see Table 21-22) where $f_{\mathrm{P20,\,idx}}$, $f_{\mathrm{P40,\,idx}}$, and $f_{\mathrm{P80,\,idx}}$ are given in Equation (21-4), Equation (21-5), Equation (21-7), and Equation (21-9), respectively.

Table 21-7—Center frequency of the portion of the PPDU transmitted in frequency segment i_{Seg}

dot11CurrentChannelWidth	CH_BANDWIDTH	$f_c^{(i_{Seg})} = f_{\mathrm{CH,\,start}} + 5 \times f_{(i_{Seg})}$	
		$f_{(0)}$	$f_{(1)}$
20 MHz	CBW20	$f_{c,\,\mathrm{idx0}}$	—
40 MHz	CBW20	$f_{\mathrm{P20,\,idx}}$	—
	CBW40	$f_{c,\,\mathrm{idx0}}$	—
80 MHz	CBW20	$f_{\mathrm{P20,\,idx}}$	—
	CBW40	$f_{\mathrm{P40,\,idx}}$	—
	CBW80	$f_{c,\,\mathrm{idx0}}$	—
160 MHz	CBW20	$f_{\mathrm{P20,\,idx}}$	—
	CBW40	$f_{\mathrm{P40,\,idx}}$	—
	CBW80	$f_{\mathrm{P80,\,idx}}$	—
	CBW160	$f_{c,\,\mathrm{idx0}}$	—

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Table 21-7—Center frequency of the portion of the PPDU transmitted in frequency segment i_{Seg} *(continued)*

dot11CurrentChannel Width	CH_BANDWIDTH	$f_c^{(i_{Seg})} = f_{\text{CH, start}} + 5 \times f_{(i_{Seg})}$	
		$f_{(0)}$	$f_{(1)}$
80+80 MHz	CBW20	$f_{\text{P20, idx}}$	—
	CBW40	$f_{\text{P40, idx}}$	—
	CBW80	$f_{\text{P80, idx}}$	—
	CBW80+80	$\min(f_{c,\text{ idx0}}, f_{c,\text{ idx1}})$	$\max(f_{c,\text{ idx0}}, f_{c,\text{ idx1}})$

NOTE—Transmitted signals might have different impairments such as phase offset or phase noise between the two frequency segments, which is not shown in Equation (21-11) for simplicity. See 21.3.17.3.

The transmitted RF signal is derived by upconverting the complex baseband signal, which consists of several fields. The timing boundaries for the various fields are shown in Figure 21-17 where $N_{VHT\text{-}LTF}$ is the number of VHT-LTF symbols and is defined in Table 21-13.

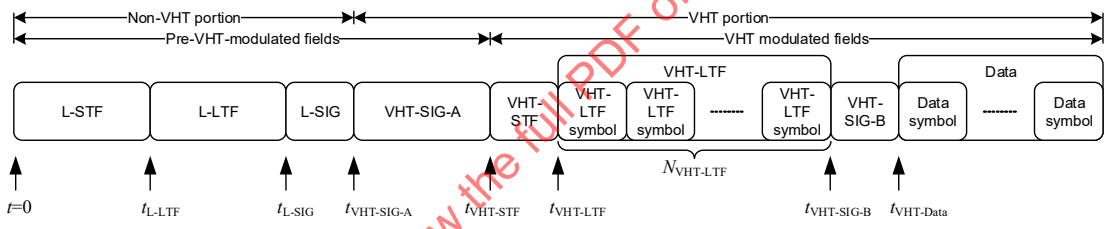

Figure 21-17—Timing boundaries for VHT PPDU fields

The time offset, t_{Field}, determines the starting time of the corresponding field relative to the start of L-STF ($t = 0$).

The signal transmitted on frequency segment i_{Seg} and transmit chain i_{TX} shall be as shown in Equation (21-12):

$$\begin{aligned} r_{\text{PPDU}}^{(i_{Seg}, i_{TX})}(t) = {} & r_{\text{L-STF}}^{(i_{Seg}, i_{TX})}(t) + r_{\text{L-LTF}}^{(i_{Seg}, i_{TX})}(t - t_{\text{L-LTF}}) \\ & + r_{\text{L-SIG}}^{(i_{Seg}, i_{TX})}(t - t_{\text{L-SIG}}) + r_{\text{VHT-SIG-A}}^{(i_{Seg}, i_{TX})}(t - t_{\text{VHT-SIG-A}}) \\ & + r_{\text{VHT-STF}}^{(i_{Seg}, i_{TX})}(t - t_{\text{VHT-STF}}) + r_{\text{VHT-LTF}}^{(i_{Seg}, i_{TX})}(t - t_{\text{VHT-LTF}}) \\ & + r_{\text{VHT-SIG-B}}^{(i_{Seg}, i_{TX})}(t - t_{\text{VHT-SIG-B}}) + r_{\text{VHT-Data}}^{(i_{Seg}, i_{TX})}(t - t_{\text{VHT-Data}}) \end{aligned} \quad (21\text{-}12)$$

where

$0 \le i_{Seg} \le N_{Seg} - 1$

$1 \le i_{TX} \le N_{TX}$

$t_{\text{L-LTF}} = T_{\text{L-STF}}$

$t_{\text{L-SIG}} = t_{\text{L-LTF}} + T_{\text{L-LTF}}$

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$$t_{\text{VHT-SIG-A}} = t_{\text{L-SIG}} + T_{\text{L-SIG}}$$
$$t_{\text{VHT-STF}} = t_{\text{VHT-SIG-A}} + T_{\text{VHT-SIG-A}}$$
$$t_{\text{VHT-LTF}} = t_{\text{VHT-STF}} + T_{\text{VHT-STF}}$$
$$t_{\text{VHT-SIG-B}} = t_{\text{VHT-LTF}} + N_{VHT\text{-}LTF} T_{\text{VHT-LTF}}$$
$$t_{\text{VHT-Data}} = t_{\text{VHT-SIG-B}} + T_{\text{VHT-SIG-B}}$$

Each field, $r_{Field}^{(i_{Seg}, i_{TX})}(t)$, is defined as the summation of one or more subfields, where each subfield is defined to be an inverse discrete Fourier transform as specified in Equation (21-13).

$$r_{\text{Subfield}}^{(i_{Seg}, i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{Field}}^{\text{Tone}} N_{\text{Norm}}}} w_{T_{\text{Subfield}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_{user}-1} \sum_{m=1}^{N_{STS,u}} \left[Q_k^{(i_{Seg})} \right]_{i_{TX}, (M_u + m)} \Upsilon_{k, BW} X_{k,u}^{(i_{Seg}, m)} \exp(j2\pi k \Delta_F (t - T_{\text{GI, Field}} - T_{\text{CS, VHT}}(M_u + m))) \quad (21\text{-}13)$$

This general representation holds for all subfields. The total power of the time domain VHT modulated field signals summed over all transmit chains should not exceed the total power of the time domain pre-VHT modulated field signals summed over all transmit chains. For notational simplicity, the parameter BW is omitted from some bandwidth dependent terms.

In Equation (21-13) the following notions are used:

$N_{\text{Field}}^{\text{Tone}}$ Table 21-8 summarizes the various values of $N_{\text{Field}}^{\text{Tone}}$ as a function of bandwidth per frequency segment.

Table 21-8—Tone scaling factor and guard interval duration values for PHY fields

Field	$N_{\text{Field}}^{\text{Tone}}$ as a function of bandwidth per frequency segment				Guard interval duration
	20 MHz	40 MHz	80 MHz	160 MHz	
L-STF	12	24	48	96	—
L-LTF	52	104	208	416	T_{GI2}
L-SIG	52	104	208	416	T_{GI}
VHT-SIG-A	52	104	208	416	T_{GI}
VHT-STF	12	24	48	96	—
VHT-LTF	56	114	242	484	T_{GI}
VHT-SIG-B	56	114	242	484	T_{GI}
VHT-Data	56	114	242	484	T_{GI} or T_{GIS} (see NOTE 2)
NON_HT_DUP_OFDM-Data (see NOTE 1)	—	104	208	416	T_{GI}

NOTE 1—For notational convenience, NON_HT_DUP_OFDM-Data is used as a label for the Data field of a NON_HT PPDU with format type NON_HT_DUP_OFDM.

NOTE 2—T_{GI} denotes guard interval duration when TXVECTOR parameter GI_TYPE equals LONG_GI, T_{GIS} denotes short guard interval duration when TXVECTOR parameter GI_TYPE equals SHORT_GI.

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N_{Norm} For pre-VHT modulated fields, $N_{\text{Norm}} = N_{TX}$. For VHT modulated fields, $N_{\text{Norm}} = N_{STS,\,total}$ where $N_{STS,\,total}$ is given in Table 21-6.

$w_{T_{\text{Subfield}}}(t)$ is a windowing function. An example function, $w_{T_{\text{Subfield}}}(t)$, is given in 17.3.2.5. T_{Subfield} is $T_{L\text{-}STF}$ for L-STF, $T_{L\text{-}LTF}$ for L-LTF, $T_{L\text{-}SIG}$ for L-SIG, T_{SYML} for VHT-SIG-A, $T_{VHT\text{-}STF}$ for VHT-STF, $T_{VHT\text{-}LTF}$ for VHT-LTF and $T_{VHT\text{-}SIG\text{-}B}$ for VHT-SIG-B. T_{Subfield} is T_{SYM} for VHT-Data, that is T_{SYML} when not using the short guard interval (Short GI field of VHT-SIG-A is 0) and T_{SYMS} when using the short guard interval (Short GI field of VHT-SIG-A is 1).

$Q_k^{(i_{Seg})}$ is the spatial mapping matrix for the subcarrier k in frequency segment i_{Seg}. For pre-VHT modulated fields, $Q_k^{(i_{Seg})}$ is a column vector with N_{TX} elements with element i_{TX} being $\exp(-j2\pi k\Delta_F T_{\text{CS}}^{i_{TX}})$, where $T_{\text{CS}}^{i_{TX}}$ represents the cyclic shift for transmitter chain i_{TX} whose values are given in Table 21-10. For VHT modulated fields, $Q_k^{(i_{Seg})}$ is a matrix with N_{TX} rows and $N_{STS,\,total}$ columns.

$\Upsilon_{k,\,\text{BW}}$ is defined in 21.3.7.5

Δ_F is the subcarrier frequency spacing given in Table 21-5.

$X_{k,\,u}^{(i_{Seg},\,m)}$ is the frequency domain symbol in subcarrier k of user u for frequency segment i_{Seg} of space-time stream m. Some of the $X_{k,\,u}^{(i_{Seg},\,m)}$ within $-N_{SR} \le k \le N_{SR}$ have a value of 0. Examples of such cases include the DC tones, guard tones on each side of the transmit spectrum, as well as the unmodulated tones of L-STF and VHT-STF fields. Note that the multiplication matrices $A_{VHT\text{-}LTF}^k$ and $P_{VHT\text{-}LTF}$ are included in the calculation of $X_{k,\,u}^{(i_{Seg},\,m)}$ for the VHT-LTF and VHT-SIG-B fields, respectively.

$T_{\text{GI, Field}}$ is the guard interval duration used for each OFDM symbol in the field. For L-STF and VHT-STF, $T_{\text{GI, Field}} = T_{\text{GI}}$ but it can be omitted from Equation (21-13) due to the periodic property of L-STF and VHT-STF over every 0.8 μs. For the L-SIG, VHT-SIG-A, VHT-LTF, and VHT-SIG-B fields, $T_{\text{GI, Field}}$ is defined in the "Guard interval duration" column of Table 21-8.

$T_{\text{CS, VHT}}(l)$ For pre-VHT modulated fields, $T_{\text{CS, VHT}}(l) = 0$. For VHT modulated fields, $T_{\text{CS, VHT}}(l)$ represents the cyclic shift per space-time stream, whose value is defined in Table 21-11.

M_u is defined in Table 21-6.

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21.3.7.5 Definition of tone rotation

The function $\Upsilon_{k, \mathrm{BW}}$ is used to represent a rotation of the tones. BW in $\Upsilon_{k, \mathrm{BW}}$ is determined by the TXVECTOR parameter CH_BANDWIDTH as defined in Table 21-9.

Table 21-9—CH_BANDWIDTH and $\Upsilon_{k, \mathrm{BW}}$

CH_BANDWIDTH	$\Upsilon_{k, \mathrm{BW}}$
CBW20	$\Upsilon_{k, 20}$
CBW40	$\Upsilon_{k, 40}$
CBW80	$\Upsilon_{k, 80}$
CBW160	$\Upsilon_{k, 160}$
CBW80+80	$\Upsilon_{k, 80}$ per frequency segment

For a 20 MHz PPDU transmission,

$$\Upsilon_{k, 20} = 1 \tag{21-14}$$

For a 40 MHz PPDU transmission,

$$\Upsilon_{k, 40} = \begin{cases} 1, & k < 0 \\ j, & k \geq 0 \end{cases} \tag{21-15}$$

For an 80 MHz PPDU transmission,

$$\Upsilon_{k, 80} = \begin{cases} 1, & k < -64 \\ -1, & k \geq -64 \end{cases} \tag{21-16}$$

For an 80+80 MHz PPDU transmission, each 80 MHz frequency segment shall use the phase rotation for 80 MHz PPDU transmissions as defined in Equation (21-16).

For a 160 MHz PPDU transmission,

$$\Upsilon_{k, 160} = \begin{cases} 1, & k < -192 \\ -1, & -192 \leq k < 0 \\ 1, & 0 \leq k < 64 \\ -1, & k \geq 64 \end{cases} \tag{21-17}$$

21.3.8 VHT preamble

21.3.8.1 Introduction

A VHT preamble is defined to carry the required information to operate in either single user or multi-user mode. To maintain compatibility with non-VHT STAs, specific non-VHT fields are defined that can be received by non-VHT STAs compliant with Clause 17 or Clause 19. The non-VHT fields are followed by VHT fields specific to VHT STAs.

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21.3.8.2 Non-VHT portion of VHT format preamble

21.3.8.2.1 Cyclic shift for pre-VHT modulated fields

The cyclic shift value $T_{CS}^{i_{TX}}$ for the L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU for transmit chain i_{TX} out of a total of N_{TX} are defined in Table 21-10.

Table 21-10—Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU

$T_{CS}^{i_{TX}}$ values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU									
Total number of transmit chains (N_{TX}) per frequency segment	**Cyclic shift for transmit chain i_{TX} (in units of ns)**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**>8**
1	0	–	–	–	–	–	–	–	–
2	0	–200	–	–	–	–	–	–	–
3	0	–100	–200	–	–	–	–	–	–
4	0	–50	–100	–150	–	–	–	–	–
5	0	–175	–25	–50	–75	–	–	–	–
6	0	–200	–25	–150	–175	–125	–	–	–
7	0	–200	–150	–25	–175	–75	–50	–	–
8	0	–175	–150	–125	–25	–100	–50	–200	–
>8	0	–175	–150	–125	–25	–100	–50	–200	Between –200 and 0

21.3.8.2.2 L-STF definition

The L-STF field for a 20 MHz or 40 MHz transmission is defined by Equation (19-8) and Equation (19-9), respectively, in 19.3.9.3.3. For 80 MHz, the L-STF field is defined by Equation (21-18). Note that these equations do not include the phase rotation per 20 MHz subchannel.

$$S_{-122,122} = \{S_{-58,58}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, S_{-58,58}\} \quad (21\text{-}18)$$

where

$S_{-58,58}$ is defined in Equation (19-9)

For 160 MHz, the L-STF is defined by Equation (21-19).

$$S_{-250,250} = \{S_{-122,122}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, S_{-122,122}\} \quad (21\text{-}19)$$

For an 80+80 MHz transmission, each 80 MHz frequency segment shall use the L-STF pattern for the 80 MHz ($S_{-122,122}$) defined in Equation (21-18).

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The time domain representation of the signal on frequency segment i_{Seg} and transmit chain i_{TX} shall be as specified in Equation (21-20).

$$r_{\text{L-STF}}^{(i_{Seg}, i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{L-STF}}^{\text{Tone}} N_{\text{TX}}}} w_{T_{\text{L-STF}}}(t) \sum_{k=-26}^{26} \Upsilon_{k,\text{BW}} S_k \exp(j2\pi k\Delta_F(t - T_{CS}^{i_{TX}})) \quad (21\text{-}20)$$

where

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain i_{TX} with a value given in Table 21-10

$\Upsilon_{k,\text{BW}}$ is defined by Equation (21-14), Equation (21-15), Equation (21-16). and Equation (21-17)

$N_{\text{L-STF}}^{\text{Tone}}$ has the value given in Table 21-8

21.3.8.2.3 L-LTF definition

For a 20 MHz or 40 MHz transmission, the L-LTF pattern in the VHT preamble is defined by Equation (19-11) and Equation (19-12) in 19.3.9.3.4, respectively. For an 80 MHz transmission, the L-LTF pattern is defined by Equation (21-21). Note that these equations do not include the phase rotation per 20 MHz subchannel.

$$L_{-122,122} = \{L_{-58,58}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, L_{-58,58}\} \quad (21\text{-}21)$$

where

$L_{-58,58}$ is defined in Equation (19-12)

For a 160 MHz transmission, the L-LTF is defined by Equation (21-22). Note that this equation does not include the phase rotations per 20 MHz subchannel.

$$L_{-250,250} = \{L_{-122,122}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, L_{-122,122}\} \quad (21\text{-}22)$$

For an 80+80 MHz transmission, each 80 MHz frequency segment shall use the L-LTF pattern for the 80 MHz L-LTF pattern ($L_{-122,122}$) defined in Equation (21-21).

The time domain representation of the signal on frequency segment i_{Seg} and transmit chain i_{TX} shall be as defined in Equation (21-23).

$$r_{\text{L-LTF}}^{(i_{Seg}, i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{L-LTF}}^{\text{Tone}} N_{\text{TX}}}} w_{T_{\text{L-LTF}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \Upsilon_{k,\text{BW}} L_k \exp(j2\pi k\Delta_F(t - T_{\text{GI2}} - T_{CS}^{i_{TX}})) \quad (21\text{-}23)$$

where

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmitter chain i_{TX} with a value given in Table 21-10

$\Upsilon_{k,\text{BW}}$ is defined by Equation (21-14), Equation (21-15), Equation (21-16). and Equation (21-17)

$N_{\text{L-LTF}}^{\text{Tone}}$ has the value given in Table 21-8

21.3.8.2.4 L-SIG definition

The L-SIG field is used to communicate rate and length information. The structure of the L-SIG field is defined in Figure 17-5.

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In a VHT PPDU, the RATE field shall be set to the value representing 6 Mb/s in the 20 MHz channel spacing column of Table 17-6. In a non-HT duplicate PPDU, the RATE field is defined in 17.3.4.2 using the L_DATARATE parameter in the TXVECTOR.

The LENGTH field shall be set to the value given by Equation (21-24).

$$\text{Length} = \frac{\text{TXTIME} - 20}{4} \times 3 - 3 \tag{21-24}$$

where
TXTIME (in μs) is defined in 21.4.3

The LSB of the binary expression of the Length value shall be mapped to B5. In a non-HT duplicate PPDU, the LENGTH field is defined in 17.3.4.3 using the L_LENGTH parameter in the TXVECTOR.

The Reserved (R) field shall be set to 0.

The Parity (P) field has the even parity of bits 0-16.

The SIGNAL TAIL field shall be set to 0.

The L-SIG field shall be encoded, interleaved, and mapped following the steps described in 17.3.5.6, 17.3.5.7, and 17.3.5.8. The stream of 48 complex numbers generated by these steps is denoted by d_k, $k = 0, \ldots, 47$. Pilots shall be inserted as described in 17.3.5.9. The time domain waveform of the L-SIG field shall be as given by Equation (21-25).

$$r_{\text{L-SIG}}^{(i_{Seg},\, i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{L-SIG}}^{\text{Tone}} N_{TX}}} w_{T_{\text{L-SIG}}}(t) \cdot \sum_{i_{\text{BW}}=0}^{N_{20\text{MHz}}-1} \sum_{k=-26}^{26} \left(\Upsilon_{(k - K_{\text{Shift}}(i_{\text{BW}})),\, \text{BW}}(D_{k,20} + p_0 P_k) \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_F(t - T_{GI} - T_{CS}^{i_{TX}})) \right) \tag{21-25}$$

where
$N_{20\text{MHz}}$ is defined in 21.3.7.3
$K_{\text{Shift}}(i) = (N_{20\text{MHz}} - 1 - 2i) \cdot 32$

$$D_{k,20} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M_{20}^r(k)}, \text{otherwise} \end{cases} \tag{21-26}$$

$$M_{20}^r(k) = \begin{cases} k + 26, -26 \le k \le -22 \\ k + 25, -20 \le k \le -8 \\ k + 24, -6 \le k \le -1 \\ k + 23, 1 \le k \le 6 \\ k + 22, 8 \le k \le 20 \\ k + 21, 22 \le k \le 26 \end{cases} \tag{21-27}$$

P_k is defined in 17.3.5.10
p_0 is the first pilot value in the sequence defined in 17.3.5.10

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$N_{\text{L-SIG}}^{\text{Tone}}$ has the value given in Table 21-8

$\Upsilon_{k,\text{BW}}$ is defined in Equation (21-14), Equation (21-15), Equation (21-16). and Equation (21-17)

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmitter chain i_{TX} with a value given in Table 21-10

NOTE—$M_{20}^{r}(k)$ is a "reverse" function of the function $M(k)$ defined in 17.3.5.10.

21.3.8.3 VHT portion of VHT format preamble

21.3.8.3.1 Introduction

The VHT portion of the VHT format preamble consists of the VHT-SIG-A, VHT-STF, VHT-LTF, and VHT-SIG-B fields.

All numeric fields are transmitted in unsigned format, LSB first.

21.3.8.3.2 Cyclic shift for VHT modulated fields

The cyclic shift values defined in this subclause apply to the VHT-STF, VHT-LTF, VHT-SIG-B, and Data fields of the VHT PPDU. The cyclic shift values defined in 21.3.8.2.1 apply to VHT-SIG-A field in the VHT format preamble.

Throughout the VHT modulated fields of the preamble, cyclic shifts are applied to prevent unintended beamforming when correlated signals are transmitted in multiple space-time streams. The same cyclic shift is also applied to these streams during the transmission of the Data field of the VHT PPDU. The cyclic shift value $T_{CS,VHT}(n)$ for the VHT modulated fields for space-time stream n out of $N_{STS,total}$ total space-time streams is shown in Table 21-11.

Table 21-11—Cyclic shift values for the VHT modulated fields of a PPDU

$T_{CS,VHT}(n)$ values for the VHT modulated fields of a PPDU								
Total number of space-time streams ($N_{STS,total}$)	**Cyclic shift for space-time stream n (ns)**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	0	–	–	–	–	–	–	–
2	0	–400	–	–	–	–	–	–
3	0	–400	–200	–	–	–	–	–
4	0	–400	–200	–600	–	–	–	–
5	0	–400	–200	–600	–350	–	–	–
6	0	–400	–200	–600	–350	–650	–	–
7	0	–400	–200	–600	–350	–650	–100	–
8	0	–400	–200	–600	–350	–650	–100	–750

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In a VHT MU PPDU, the cyclic shifts are applied sequentially across the space-time streams as follows: the cyclic shift of the space-time stream number m of user u is given by $T_{CS,VHT}(M_u + m)$ of the row corresponding to $N_{STS,total}$ in Table 21-11.

21.3.8.3.3 VHT-SIG-A definition

The VHT-SIG-A field carries information required to interpret VHT PPDUs. The structure of the VHT-SIG-A field for the first part (VHT-SIG-A1) is shown in Figure 21-18 and for the second part (VHT-SIG-A2) is shown in Figure 21-19.

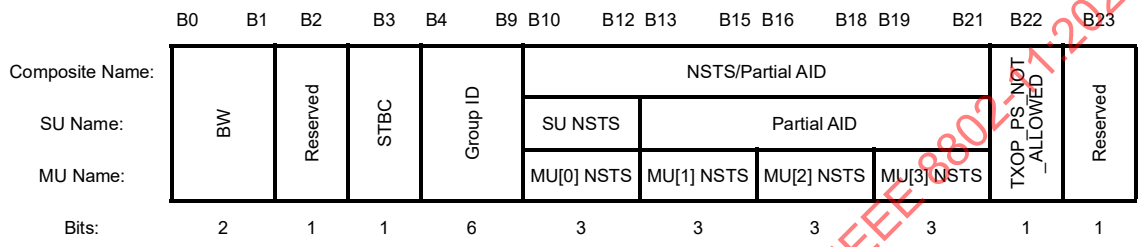

Figure 21-18—VHT-SIG-A1 structure

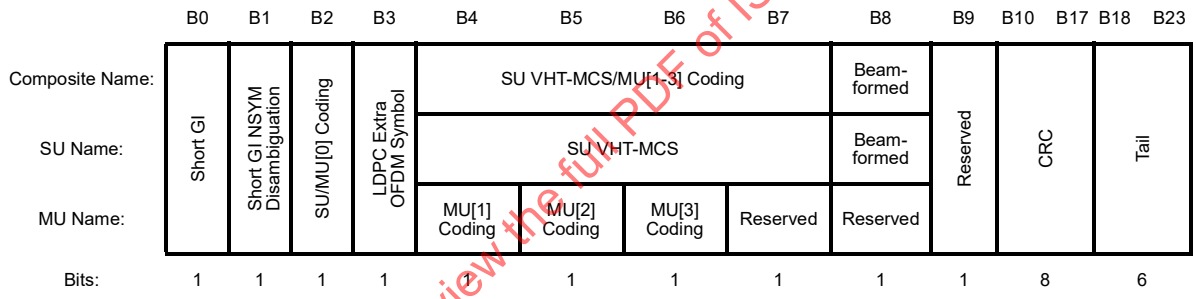

Figure 21-19—VHT-SIG-A2 structure

The VHT-SIG-A field contains the fields listed in Table 21-12. The mapping of the fields is also described in Table 21-12. Note that the mapping of the STBC field, the NSTS/Partial AID field, the SU/MU[0] Coding field, the SU VHT-MCS/MU[1-3] Coding field, and the Beamformed field is different for VHT SU and MU PPDUs.

The VHT-SIG-A field is composed of two parts, VHT-SIG-A1 and VHT-SIG-A2, each containing 24 data bits, as shown in Table 21-12. VHT-SIG-A1 is transmitted before VHT-SIG-A2. The VHT-SIG-A symbols shall be BCC encoded at rate, R = 1/2, be interleaved, be mapped to a BPSK constellation, and have pilots inserted following the steps described in 17.3.5.6, 17.3.5.7, 17.3.5.8, and 17.3.5.9, respectively. The first and second half of the stream of 96 complex numbers generated by these steps (before pilot insertion) is divided into two groups of 48 complex numbers $d_{k,n}, k = 0 \ldots 47$, where $n = 0, 1$, respectively. The first 48 complex numbers form the first symbol of VHT-SIG-A and the second 48 complex numbers form the second symbol of VHT-SIG-A after rotating by 90° counter-clockwise relative to the first symbol. The first symbol of VHT-SIG-A, which does not have the 90° rotation, is used to differentiate VHT PPDUs from HT PPDUs, while the second symbol of VHT-SIG-A, which has the 90° rotation, is used to differentiate VHT PPDUs from non-HT PPDUs.

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Table 21-12—Fields in the VHT-SIG-A field

Two parts of VHT-SIG-A	Bit	Field	Description
VHT-SIG-A1	B0-B1	BW	Set to 0 for 20 MHz, 1 for 40 MHz, 2 for 80 MHz, and 3 for 160 MHz and 80+80 MHz
	B2	Reserved	Reserved. Set to 1.
	B3	STBC	For a VHT SU PPDU: Set to 1 if space-time block coding (see 21.3.10.9.4) is used and set to 0 otherwise. For a VHT MU PPDU: Set to 0.
	B4-B9	Group ID	A value of 0 or 63 indicates a VHT SU PPDU; otherwise, indicates a VHT MU PPDU. (See TXVECTOR parameter GROUP_ID.)
	B10-B21	NSTS/Partial AID	For a VHT MU PPDU: NSTS is divided into 4 user positions of 3 bits each. User position p, where $0 \le p \le 3$, uses bits B($10 + 3p$) to B($12 + 3p$). The number of space-time streams for user u are indicated at user position p = USER_POSITION[u] where u = 0, 1, …, NUM_USERS – 1 and the notation A[b] denotes the value of array A at index b. Zero space-time streams are indicated at positions not listed in the USER_POSITION array. Each user position is set as follows: Set to 0 for 0 space-time streams Set to 1 for 1 space-time stream Set to 2 for 2 space-time streams Set to 3 for 3 space-time streams Set to 4 for 4 space-time streams Values 5-7 are reserved For a VHT SU PPDU: B10-B12 Set to 0 for 1 space-time stream Set to 1 for 2 space-time streams Set to 2 for 3 space-time streams Set to 3 for 4 space-time streams Set to 4 for 5 space-time streams Set to 5 for 6 space-time streams Set to 6 for 7 space-time streams Set to 7 for 8 space-time streams B13-B21 Partial AID: Partial AID provides an abbreviated indication of the intended recipient(s) of the PSDU (see TXVECTOR parameter PARTIAL_AID and 10.19).
	B22	TXOP_PS_NOT_ALLOWED	Set to 0 by VHT AP if it allows non-AP VHT STAs in TXOP power save mode to enter doze state during a TXOP. Set to 1 otherwise. The bit is reserved and set to 1 in VHT PPDUs transmitted by a non-AP VHT STA.
	B23	Reserved	Set to 1

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Table 21-12—Fields in the VHT-SIG-A field *(continued)*

Two parts of VHT-SIG-A	Bit	Field	Description
VHT-SIG-A2	B0	Short GI	Set to 0 if short guard interval is not used in the Data field. Set to 1 if short guard interval is used in the Data field.
	B1	Short GI N_{SYM} Disambiguation	Set to 1 if short guard interval is used and N_{SYM} mod 10 = 9; otherwise, set to 0. N_{SYM} is defined in 21.4.3.
	B2	SU/MU[0] Coding	For a VHT SU PPDU, B2 is set to 0 for BCC, 1 for LDPC. For a VHT MU PPDU, if the MU[0] NSTS field is nonzero, then B2 indicates the coding used for user u with USER_POSITION[u] = 0; set to 0 for BCC and 1 for LDPC. If the MU[0] NSTS field is 0, then this field is reserved and set to 1.
	B3	LDPC Extra OFDM Symbol	Set to 1 if the LDPC PPDU encoding process (if an SU PPDU), or at least one LDPC user's PPDU encoding process (if a VHT MU PPDU), results in an extra OFDM symbol (or symbols) as described in 21.3.10.5.4 and 21.3.10.5.5. Set to 0 otherwise.
	B4-B7	SU VHT-MCS/MU[1-3] Coding	For a VHT SU PPDU: VHT-MCS index For a VHT MU PPDU: If the MU[1] NSTS field is nonzero, then B4 indicates coding for user u with USER_POSITION[u] = 1: set to 0 for BCC, 1 for LDPC. If the MU[1] NSTS field is 0, then B4 is reserved and set to 1. If the MU[2] NSTS field is nonzero, then B5 indicates coding for user u with USER_POSITION[u] = 2: set to 0 for BCC, 1 for LDPC. If the MU[2] NSTS field is 0, then B5 is reserved and set to 1. If the MU[3] NSTS field is nonzero, then B6 indicates coding for user u with USER_POSITION[u] = 3: set to 0 for BCC, 1 for LDPC. If the MU[3] NSTS field is 0, then B6 is reserved and set to 1. B7 is reserved and set to 1
	B8	Beamformed	For a VHT SU PPDU: Set to 1 if a beamforming steering matrix is applied to the waveform in an SU transmission, set to 0 otherwise. For a VHT MU PPDU: Reserved and set to 1 NOTE—If equal to 1 smoothing is not recommended.
	B9	Reserved	Reserved and set to 1
	B10-B17	CRC	CRC calculated as in 19.3.9.4.4 with c7 in B10. Bits 0-23 of HT-SIG1 and bits 0-9 of HT-SIG2 are replaced by bits 0-23 of VHT-SIG-A1 and bits 0-9 of VHT-SIG-A2, respectively.
	B18-B23	Tail	Used to terminate the trellis of the convolutional decoder. Set to 0.

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The time domain waveform for the VHT-SIG-A field in a VHT PPDU shall be as specified in Equation (21-28).

$$r_{\text{VHT-SIG-A}}^{(i_{Seg},\, i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{VHT-SIG-A}}^{\text{Tone}} N_{\text{TX}}}} \sum_{n=0}^{1} w_{T_{SYML}}(t - nT_{SYML}) \cdot \sum_{i_{\text{BW}}=0}^{N_{20\text{MHz}}-1} \left(\sum_{k=-26}^{26} \Upsilon_{(k-K_{\text{Shift}}(i_{\text{BW}})),\,\text{BW}} (j^n D_{k,n,20} + p_{n+1} P_k) \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_F(t - nT_{SYML} - T_{\text{GI}} - T_{CS}^{i_{TX}})) \right) \quad (21\text{-}28)$$

where

$N_{20\text{MHz}}$ and $K_{\text{Shift}}(i)$ are defined in 21.3.8.2.4

$$D_{k,n,20} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M_{20}^r(k),n}, \text{otherwise} \end{cases}$$

$M_{20}^r(k)$ is defined in Equation (21-27)

P_k and p_n are defined in 17.3.5.10

$N_{\text{VHT-SIG-A}}^{\text{Tone}}$ has the value given in Table 21-8

$\Upsilon_{k,\text{BW}}$ is defined in Equation (21-14), Equation (21-15), Equation (21-16). and Equation (21-17)

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmitter chain i_{TX} with a value given in Table 21-10

NOTE—This definition results in a QBPSK modulation on the second symbol of VHT-SIG-A where the constellation of the data tones is rotated by 90° counter-clockwise relative to the first symbol of VHT-SIG-A and relative to the non-HT signal field in VHT PPDUs (Figure 21-20). In VHT PPDUs, the VHT-SIG-A is transmitted with the same number of subcarriers and the same cyclic shifts as the preceding non-HT portion of the preamble.

For an 80+80 MHz transmission, each frequency segment shall use the time domain waveform for 80 MHz transmissions.

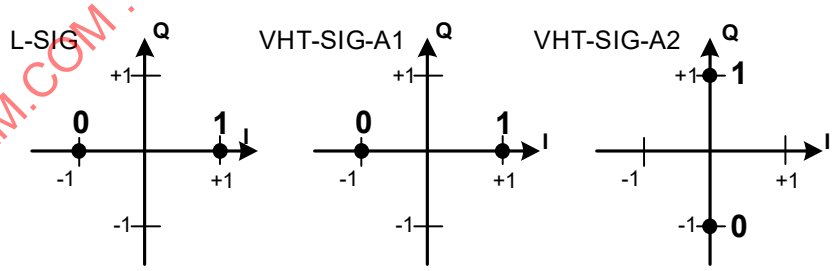

Figure 21-20—Data tone constellation in the VHT PPDU pre-VHT modulated fields

21.3.8.3.4 VHT-STF definition

The main purpose of the VHT-STF field is to improve automatic gain control estimation in a MIMO transmission. The duration of the VHT-STF field is $T_{VHT\text{-}STF}$ regardless of the Short GI field setting in VHT-SIG-A. The frequency domain sequence used to construct the VHT-STF field in a 20 MHz

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transmission is identical to the HT-STF field. In a 40 MHz and an 80 MHz transmission, the VHT-STF field is constructed from the 20 MHz version by frequency shifting a duplicate of it to each 20 MHz subchannel and applying appropriate phase rotations per 20 MHz subchannel.

For a 20 MHz transmission, the frequency domain sequence is given by Equation (21-29).

$$VHTS_{-28,28} = HTS_{-28,28} \tag{21-29}$$

where

$HTS_{-28,28}$ is defined in Equation (19-19)

For a 40 MHz transmission, the frequency domain sequence is given by Equation (21-30).

$$VHTS_{-58,58} = HTS_{-58,58} \tag{21-30}$$

where

$HTS_{-58,58}$ is defined in Equation (19-20)

For an 80 MHz transmission, the frequency domain sequence is given by Equation (21-31).

$$VHTS_{-122,122} = \{VHTS_{-58,58}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, VHTS_{-58,58}\} \tag{21-31}$$

For a 160 MHz transmission, the frequency domain sequence is given by Equation (21-32).

$$VHTS_{-250,250} = \{VHTS_{-122,122}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, VHTS_{-122,122}\} \tag{21-32}$$

NOTE—Equation (21-29), Equation (21-30), Equation (21-31), and Equation (21-32) do not show the phase rotation per 20 MHz subchannel.

For an 80+80 MHz transmission, each 80 MHz frequency segment shall use the VHT-STF pattern for the 80 MHz ($VHTS_{-122,122}$) defined in Equation (21-31).

The time domain representation of the signal on frequency segment i_{Seg} and transmit chain i_{TX} shall be as specified in Equation (21-33).

$$r_{\text{VHT-STF}}^{(i_{Seg}, i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{VHT-STF}}^{\text{Tone}} N_{STS,total}}} w_{T_{\text{VHT-STF}}}(t) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_{user}-1} \sum_{m=1}^{N_{STS,u}} \left(\left[Q_k^{(i_{Seg})} \right]_{i_{TX},(M_u+m)} \Upsilon_{k,\text{BW}} VHTS_k \cdot \exp(j2\pi k \Delta_F (t - T_{\text{CS,VHT}}(M_u + m))) \right) \tag{21-33}$$

where

$N_{\text{VHT-STF}}^{\text{Tone}}$ has the value given in Table 21-8

$T_{\text{CS,VHT}}(n)$ is given in Table 21-11

$Q_k^{(i_{Seg})}$ is defined in 21.3.10.11.1

$\Upsilon_{k,\text{BW}}$ is defined in Equation (21-14), Equation (21-15), Equation (21-16). and Equation (21-17)

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21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-LTF) field provides a means for the receiver to estimate the MIMO channel between the set of constellation mapper outputs (or, if STBC is applied, the STBC encoder outputs) and the receive chains. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT\text{-}LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT\text{-}LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT\text{-}LTF}$ matrix instead of the $P_{VHT\text{-}LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT\text{-}LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS,total}$	$N_{VHT\text{-}LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

Let LTF_{left} and LTF_{right} be the sequences defined in Equation (21-34) and Equation (21-35), respectively.

$$LTF_{\text{left}} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (21\text{-}34)$$

$$LTF_{\text{right}} = \{1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (21\text{-}35)$$

NOTE 1—LTF_{left} is identical to the leftmost 26 elements of Equation (17-8), and LTF_{right} is identical to the rightmost 26 elements of Equation (17-8).

In a 20 MHz transmission, the VHT-LTF sequence transmitted is given by Equation (21-36).

$$\begin{aligned} VHT\text{-}LTF_{-28,28} &= \{1, 1, LTF_{\text{left}}, 0, LTF_{\text{right}}, -1, -1\} \\ &= HT\text{-}LTF_{-28,28} \end{aligned} \quad (21\text{-}36)$$

where

$HT\text{-}LTF_{-28,28}$ is defined in Equation (19-23)

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In a 40 MHz transmission, the VHT-LTF sequence transmitted is given by Equation (21-37).

$$\begin{aligned} VHT\text{-}LTF_{-58,58} &= \{LTF_{\text{left}}, 1, LTF_{\text{right}}, -1, -1, -1, 1, 0, 0, 0, -1, 1, 1, -1, LTF_{\text{left}}, 1, LTF_{\text{right}}\} \\ &= HT\text{-}LTF_{-58,58} \end{aligned} \quad (21\text{-}37)$$

where

$HT\text{-}LTF_{-58,58}$ is defined in Equation (19-24)

In an 80 MHz transmission, the VHT-LTF sequence transmitted is given by Equation (21-38).

$$\begin{aligned} VHT\text{-}LTF_{-122,122} = \{&LTF_{\text{left}}, 1, LTF_{\text{right}}, -1, -1, -1, 1, 1, -1, 1, -1, 1, 1, -1, LTF_{\text{left}}, 1, LTF_{\text{right}}, \\ &1, -1, 1, -1, 0, 0, 0, 1, -1, -1, 1, \\ &LTF_{\text{left}}, 1, LTF_{\text{right}}, -1, -1, -1, 1, 1, -1, 1, -1, 1, 1, -1, LTF_{\text{left}}, 1, LTF_{\text{right}}\} \end{aligned} \quad (21\text{-}38)$$

In a 160 MHz transmission, the VHT-LTF sequence transmitted is given by Equation (21-39).

$$VHT\text{-}LTF_{-250,250} = \{VHT\text{-}LTF_{-122,122}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, VHT\text{-}LTF_{122,122}\} \quad (21\text{-}39)$$

where

$VHT\text{-}LTF_{-122,122}$ is given in Equation (21-38)

NOTE 2—Equation (21-36), Equation (21-37), Equation (21-38), and Equation (21-39) do not show the phase rotation per 20 MHz subchannel.

For a 80+80 MHz transmission, each 80 MHz frequency segment shall use the 80 MHz VHT-LTF sequence, $VHT\text{-}LTF_{-122,122}$, defined in Equation (21-38).

The generation of the time domain VHT-LTF symbols per frequency segment is shown in Figure 21-21 where $A^{k}_{VHT\text{-}LTF}$ is given in Equation (21-40).

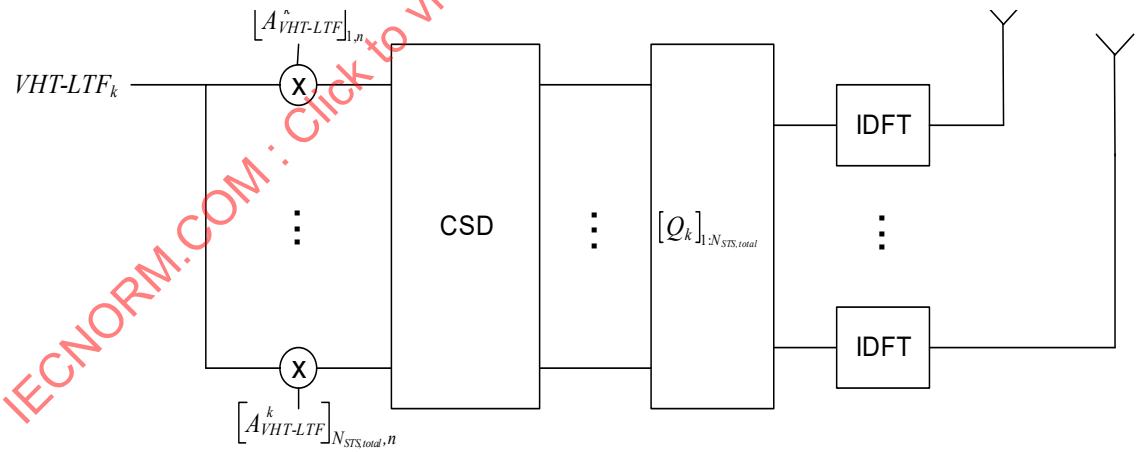

Figure 21-21—Generation of VHT-LTF symbols per frequency segment

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$$A_{VHT\text{-}LTF}^{k} = \begin{cases} R_{VHT\text{-}LTF}, \text{ if } k \in K_{\text{Pilot}} \\ P_{VHT\text{-}LTF}, \text{ otherwise} \end{cases} \quad (21\text{-}40)$$

where

K_{Pilot} is the set of subcarrier indices for the pilot tones:

For a 20 MHz transmission, $K_{\text{Pilot}} = \{\pm 7, \pm 21\}$.

For a 40 MHz transmission, $K_{\text{Pilot}} = \{\pm 11, \pm 25, \pm 53\}$.

For an 80 MHz transmission, $K_{\text{Pilot}} = \{\pm 11, \pm 39, \pm 75, \pm 103\}$.

For a 160 MHz transmission,
$K_{\text{Pilot}} = \{\pm 25, \pm 53, \pm 89, \pm 117, \pm 139, \pm 167, \pm 203, \pm 231\}$.

For an 80+80 MHz transmission, K_{Pilot} for each 80 MHz frequency segment is identical to K_{Pilot} for an 80 MHz transmission.

$R_{VHT\text{-}LTF}$ is a $N_{VHT\text{-}LTF} \times N_{VHT\text{-}LTF}$ matrix whose elements are defined in Equation (21-41).

$$\left[R_{VHT\text{-}LTF}\right]_{m,n} = \left[P_{VHT\text{-}LTF}\right]_{1,n}, 1 \le m, n \le N_{VHT\text{-}LTF} \quad (21\text{-}41)$$

$P_{VHT\text{-}LTF}$ is defined in Equation (21-42)

The time domain representation of the waveform transmitted on frequency segment i_{Seg} of transmit chain i_{TX} shall be as described by Equation (21-42).

$$r_{\text{VHT-LTF}}^{(i_{Seg}, i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{VHT-LTF}}^{\text{Tone}} N_{STS,total}}} \sum_{n=0}^{N_{VHT\text{-}LTF}-1} w_{T_{\text{VHT-LTF}}}(t - nT_{\text{VHT-LTF}}) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_{user}-1} \sum_{m=1}^{N_{STS,u}} \left(\left[Q_k^{(i_{Seg})}\right]_{i_{TX},(M_u+m)} \Upsilon_{k,\text{BW}} \left[A_{VHT\text{-}LTF}^{k}\right]_{(M_u+m),(n+1)} VHT\text{-}LTF_k \cdot \exp(j2\pi k\Delta_F(t - nT_{\text{VHT-LTF}} - T_{\text{GI}} - T_{\text{CS,VHT}}(M_u+m))) \right) \quad (21\text{-}42)$$

where

$N_{\text{VHT-LTF}}^{\text{Tone}}$ has the value given in Table 21-8

$T_{\text{CS,VHT}}(n)$ is given in Table 21-11

$Q_k^{(i_{Seg})}$ is defined in 21.3.10.11.1

$\Upsilon_{k,\text{BW}}$ is defined in Equation (21-14), Equation (21-15), Equation (21-16). and Equation (21-17)

$A_{VHT\text{-}LTF}^{k}$ is defined in Equation (21-40)

$$P_{VHT\text{-}LTF} = \begin{cases} P_{4\times 4}, N_{STS,total} \le 4 \\ P_{6\times 6}, N_{STS,total} = 5, 6 \\ P_{8\times 8}, N_{STS,total} = 7, 8 \end{cases} \quad (21\text{-}43)$$

where

$P_{4\times 4}$ is defined in Equation (19-27)

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The VHT-LTF mapping matrix for six VHT-LTF symbols, $P_{6\times 6}$, is defined in Equation (21-44).

$$P_{6\times 6} = \begin{bmatrix} 1 & -1 & 1 & 1 & 1 & -1 \\ 1 & -w^1 & w^2 & w^3 & w^4 & -w^5 \\ 1 & -w^2 & w^4 & w^6 & w^8 & -w^{10} \\ 1 & -w^3 & w^6 & w^9 & w^{12} & -w^{15} \\ 1 & -w^4 & w^8 & w^{12} & w^{16} & -w^{20} \\ 1 & -w^5 & w^{10} & w^{15} & w^{20} & -w^{25} \end{bmatrix} \quad (21\text{-}44)$$

where

$w = \exp(-j2\pi/6)$

The VHT-LTF mapping matrix for eight VHT-LTF symbols, $P_{8\times 8}$, is defined in Equation (21-45).

$$P_{8\times 8} = \begin{bmatrix} P_{4\times 4} & P_{4\times 4} \\ P_{4\times 4} & -P_{4\times 4} \end{bmatrix} \quad (21\text{-}45)$$

where

$P_{4\times 4}$ is defined in Equation (19-27)

As defined in Table 21-5, the duration of each VHT-LTF symbol is $T_{\text{VHT-LTF}}$ regardless of the Short GI field setting in VHT-SIG-A.

21.3.8.3.6 VHT-SIG-B definition

The VHT-SIG-B field is one symbol and contains 26 bits in a 20 MHz PPDU, 27 bits in a 40 MHz PPDU, and 29 bits in 80 MHz, 160 MHz, and 80+80 MHz PPDUs for each user. The fields in the VHT-SIG-B field are listed in Table 21-14. For example, for an MU transmission using VHT-MCS 5 (0101 in binary) in 20 MHz bandwidth, the VHT-SIG-B field bits are set as follows: B16=1, B17=0, B18=1, and B19=0.

Table 21-14—Fields in the VHT-SIG-B field

Field	VHT MU PPDU Allocation (bits)			VHT SU PPDU Allocation (bits)			Description
	20 MHz	40 MHz	80 MHz, 160 MHz, 80+80 MHz	20 MHz	40 MHz	80 MHz, 160 MHz, 80+80 MHz	
VHT-SIG-B Length	B0-B15 (16)	B0-B16 (17)	B0-B18 (19)	B0-B16 (17)	B0-B18 (19)	B0-B20 (21)	Length of A-MPDU pre-EOF padding in units of four octets
VHT-MCS	B16-B19 (4)	B17-B20 (4)	B19-B22 (4)	N/A	N/A	N/A	
Reserved	N/A	N/A	N/A	B17-B19 (3)	B19-B20 (2)	B21-B22 (2)	All 1s
Tail	B20-B25 (6)	B21-B26 (6)	B23-B28 (6)	B20-B25 (6)	B21-B26 (6)	B23-B28 (6)	All 0s
Total # bits	26	27	29	26	27	29	

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NOTE—Due to the limitations in the maximum A-MPDU length, B19-20 are always 0 for an 80 MHz, 160 MHz, and 80+80 MHz VHT SU PPDU.

The VHT-SIG-B Length field for user u shall be set using Equation (21-46).

$$\text{VHT-SIG-B Length (for user } u \text{ in units of 4 octets)} = \left\lceil \frac{\text{APEP_LENGTH}_u}{4} \right\rceil \quad (21\text{-}46)$$

where

APEP_LENGTH_u is the TXVECTOR parameter APEP_LENGTH for user u (in octets)

The VHT-SIG-B bits for an NDP transmission in various channel widths shall be set as defined in Table 21-15.

Table 21-15—VHT-SIG-B bits (before Tail field) in NDP for various channel widths

Channel width	B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22
20 MHz	0	0	0	0	0	1	1	1	0	1	0	0	0	1	0	0	0	0	1	0	–	–	–
40 MHz	1	0	1	0	0	1	0	1	1	0	1	0	0	0	1	0	0	0	0	1	1	—	–
80 MHz, 160 MHz, or 80+80 MHz	0	1	0	1	0	0	1	1	0	0	1	0	1	1	1	1	1	1	1	0	0	1	0

For a 40 MHz transmission, the VHT-SIG-B bits are repeated twice. For an 80 MHz transmission, the VHT-SIG-B bits are repeated four times and a pad bit appended that is set to 0. For a 160 MHz and 80+80 MHz transmission, the VHT-SIG-B bits are first repeated four times and a pad bit appended that is set to 0 as in the 80 MHz transmission. Then, the resulting 117 bits are repeated again to fill the 234 available bits. The repetition of the VHT-SIG-B bits for various channel width PPDUs is shown in Figure 21-22.

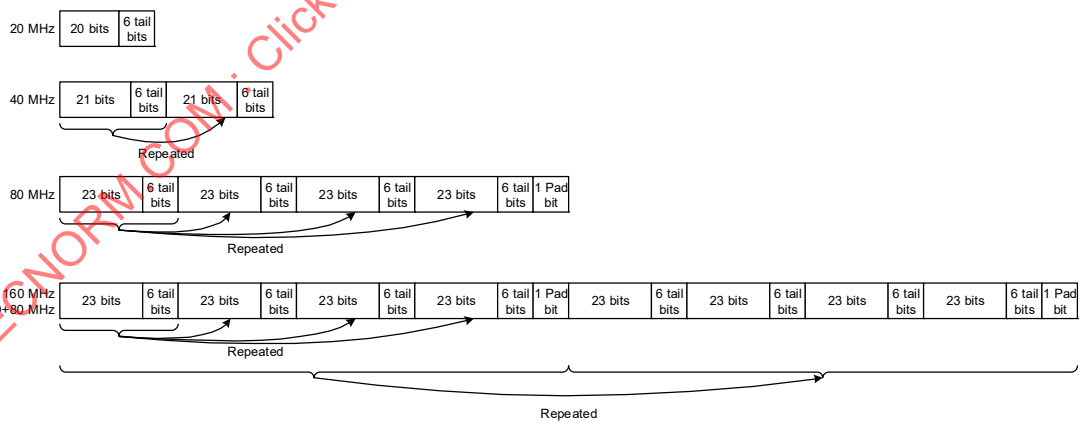

Figure 21-22—VHT-SIG-B bits in 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz transmissions

For each user u, the VHT-SIG-B field shall be BCC encoded at rate R = 1/2 as defined in 17.3.5.6, be segment parsed as defined in 21.3.10.7, be interleaved as defined in 21.3.10.8, be mapped to a BPSK

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constellation as defined in 17.3.5.8, be segment deparsed as defined in 21.3.10.9.3, and have pilots inserted following the steps described in 21.3.10.10. The VHT-SIG-B field constellation points are mapped to $N_{STS,u}$ space-time streams by the user-specific elements of the first column of the $P_{VHT\text{-}LTF}$ matrix, which is defined in 21.3.8.3.5. The total number of data subcarriers and pilot subcarriers are the same as in the Data field. The space-time streams per each frequency segment are input into the CSD block, which is defined in Table 21-11 and follow the same transmission flow as the Data field from there on. The duration of the VHT-SIG-B field is $T_{VHT\text{-}SIG\text{-}B}$, regardless of the value of the TXVECTOR parameter GI_TYPE. The time domain waveform for the VHT-SIG-B field in a VHT PPDU is specified by Equation (21-47).

$$r_{\text{VHT-SIG-B}}^{(i_{Seg}, i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{VHT-SIG-B}}^{\text{Tone}} N_{STS,\,total}}} w_{T_{\text{VHT-SIG-B}}}(t) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_{user}-1} \sum_{m=1}^{N_{STS,u}} \left(\left[Q_k^{(i_{Seg})} \right]_{i_{TX},\,(M_u+m)} \Upsilon_{k,\,\text{BW}} \left(\left[P_{VHT\text{-}LTF} \right]_{(M_u+m),\,1} D_{k,\,BW}^{(i_{Seg},\,u)} + p_3 P_0^k \right) \cdot \exp(j2\pi k \Delta_F (t - T_{\text{GI}} - T_{\text{CS,VHT}}(M_u+m))) \right) \quad (21\text{-}47)$$

where

$N_{\text{VHT-SIG-B}}^{\text{Tone}}$	has the value given in Table 21-8
$T_{\text{CS,VHT}}(n)$	is given in Table 21-11
$Q_k^{(i_{Seg})}$	is defined in 21.3.10.11.1
p_n	is defined in 17.3.5.10
P_n^k	is defined in 21.3.10.10
$\Upsilon_{k,\,\text{BW}}$	is defined in Equation (21-14), Equation (21-15), Equation (21-16). and Equation (21-17)
$P_{VHT\text{-}LTF}$	is given in Equation (21-43)

Let $d_k^{(i_{Seg},\,u)}$ be the stream of complex numbers generated for VHT-SIG-B for user u at subcarrier k (logical index, starting with 0) on frequency segment i_{Seg} (prior to multiplication by $P_{VHT\text{-}LTF}$). For a 20 MHz VHT transmission,

$$D_{k,\,20}^{(i_{Seg},\,u)} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M_{20}^r(k)}^{(i_{Seg},\,u)}, \text{otherwise} \end{cases} \quad (21\text{-}48)$$

$$M_{20}^r(k) = \begin{cases} k+28, -28 \le k \le -22 \\ k+27, -20 \le k \le -8 \\ k+26, -6 \le k \le -1 \\ k+25, 1 \le k \le 6 \\ k+24, 8 \le k \le 20 \\ k+23, 22 \le k \le 28 \end{cases} \quad (21\text{-}49)$$

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For a 40 MHz VHT transmission,

$$D_{k,40}^{(i_{Seg},u)} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 25, \pm 53 \\ d_{M_{40}^r(k)}^{(i_{Seg},u)}, \text{otherwise} \end{cases} \quad (21\text{-}50)$$

$$M_{40}^r(k) = \begin{cases} k+58, -58 \le k \le -54 \\ k+57, -52 \le k \le -26 \\ k+56, -24 \le k \le -12 \\ k+55, -10 \le k \le -2 \\ k+52, 2 \le k \le 10 \\ k+51, 12 \le k \le 24 \\ k+50, 26 \le k \le 52 \\ k+49, 54 \le k \le 58 \end{cases} \quad (21\text{-}51)$$

For an 80 MHz VHT transmission,

$$D_{k,80}^{(i_{Seg},u)} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 39, \pm 75, \pm 103 \\ d_{M_{80}^r(k)}^{(i_{Seg},u)}, \text{otherwise} \end{cases} \quad (21\text{-}52)$$

$$M_{80}^r(k) = \begin{cases} k+122, -122 \le k \le -104 \\ k+121, -102 \le k \le -76 \\ k+120, -74 \le k \le -40 \\ k+119, -38 \le k \le -12 \\ k+118, -10 \le k \le -2 \\ k+115, 2 \le k \le 10 \\ k+114, 12 \le k \le 38 \\ k+113, 40 \le k \le 74 \\ k+112, 76 \le k \le 102 \\ k+111, 104 \le k \le 122 \end{cases} \quad (21\text{-}53)$$

For a 160 MHz VHT transmission,

$$D_{k,160}^{(i_{Seg},u)} = \begin{cases} 0, k = 0, \pm 1, \pm 2, \pm 3, \pm 4, \pm 5, \pm 25, \pm 53, \pm 89, \pm 117, \pm 127, \pm 128, \pm 129, \pm 139, \pm 167, \pm 203, \pm 231 \\ d_{M_{160}^r(k)}^{(i_{Seg},u)}, \text{otherwise} \end{cases} \quad (21\text{-}54)$$

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$$M^{r}_{160}(k) = \begin{cases} k+250, -250 \le k \le -232 \\ k+249, -230 \le k \le -204 \\ k+248, -202 \le k \le -168 \\ k+247, -166 \le k \le -140 \\ k+246, -138 \le k \le -130 \\ k+243, -126 \le k \le -118 \\ k+242, -116 \le k \le -90 \\ k+241, -88 \le k \le -54 \\ k+240, -52 \le k \le -26 \\ k+239, -24 \le k \le -6 \\ k+228, 6 \le k \le 24 \\ k+227, 26 \le k \le 52 \\ k+226, 54 \le k \le 88 \\ k+225, 90 \le k \le 116 \\ k+224, 118 \le k \le 126 \\ k+221, 130 \le k \le 138 \\ k+220, 140 \le k \le 166 \\ k+219, 168 \le k \le 202 \\ k+218, 204 \le k \le 230 \\ k+217, 232 \le k \le 250 \end{cases} \quad (21\text{-}55)$$

For an 80+80 MHz VHT transmission, each frequency segment shall follow the 80 MHz VHT transmission format as specified in Equation (21-52) and Equation (21-53).

21.3.9 Transmission of NON_HT and HT PPDUs with multiple transmit chains

21.3.9.1 Transmission of 20 MHz NON_HT PPDUs with more than one transmit chain

A VHT STA that transmits a NON_HT PPDU shall apply the cyclic shifts defined in Table 21-10 to the preamble and Data field.

21.3.9.2 Transmission of HT PPDUs with more than four transmit chains

A VHT STA that transmits an HT PPDU with FORMAT equal to HT_MF shall apply the cyclic shifts defined in Table 21-10 for the non-HT portion of the PPDU, including the HT-SIG field.

21.3.10 Data field

21.3.10.1 General

The number of OFDM symbols in the Data field is determined by the Length field in L-SIG [see Equation (21-24)], the preamble duration and the setting of the Short GI field in VHT-SIG-A (see 21.3.8.3.3).

When BCC encoding is used, the Data field shall consist of the SERVICE field, the PSDU, the PHY pad bits, and the tail bits ($N_{tail}N_{ES}$ bits for SU and $N_{tail}N_{ES,u}$ bits for each user u in MU). When LDPC encoding is used, the Data field shall consist of the SERVICE field, the PSDU, and the PHY pad bits. No tail bits are present when LDPC encoding is used.

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The padding flow is as follows. The MAC delivers a PSDU that fills the available octets in the Data field of the PPDU for each user *u*. The PHY determines the number of pad bits to add and appends them to the PSDU. The number of pad bits added will always be 0 to 7 per user. When user *u* of a VHT MU PPDU uses BCC encoding, the number of pad bits is calculated using Equation (21-56). In the case of SU ignore *u* in Equation (21-56).

$$N_{PAD,u} = N_{SYM}N_{DBPS,u} - 8 \cdot \text{PSDU_LENGTH}_u - N_{service} - N_{tail}N_{ES,u} \quad (21\text{-}56)$$

where

PSDU_LENGTH_u	is defined in 21.4.3
N_{SYM}	is the number of symbols in the Data field and is given by Equation (21-111) for a VHT SU PPDU and by Equation (21-67) for a VHT MU PPDU

For an SU PPDU, if LDPC encoding is used then the PHY padding bits are calculated using Equation (21-57).

$$N_{PAD} = N_{SYM,init}N_{DBPS} - 8 \cdot \text{PSDU_LENGTH} - N_{service} \quad (21\text{-}57)$$

where

PSDU_LENGTH	is defined in 21.4.3
$N_{SYM,init}$	is given by Equation (21-62)

For a VHT MU PPDU, if LDPC encoding is used for user *u* then the PHY padding bits are calculated using Equation (21-58).

$$N_{PAD,u} = N_{\text{SYM_max_init}}N_{DBPS,u} - 8 \cdot \text{PSDU_LENGTH}_u - N_{service} \quad (21\text{-}58)$$

where

PSDU_LENGTH_u	is defined in 21.4.3
$N_{\text{SYM_max_init}}$	is given by Equation (21-65)

The Data field of the VHT PPDU contains data for one or more users. For a VHT MU PPDU, the data processing, from scrambling to constellation mapping shall happen on a per-user basis. In the following subclauses, this process is described from a single user's point of view.

21.3.10.2 SERVICE field

The SERVICE field is as shown in Table 21-16.

Table 21-16—SERVICE field

Bits	Field	Description
B0-B6	Scrambler Initialization	Set to 0
B7	Reserved	Set to 0
B8-B15	CRC	CRC calculated over VHT-SIG-B (excluding tail bits)

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21.3.10.3 CRC calculation for VHT-SIG-B

The CRC calculation and insertion is illustrated in Figure 21-23.

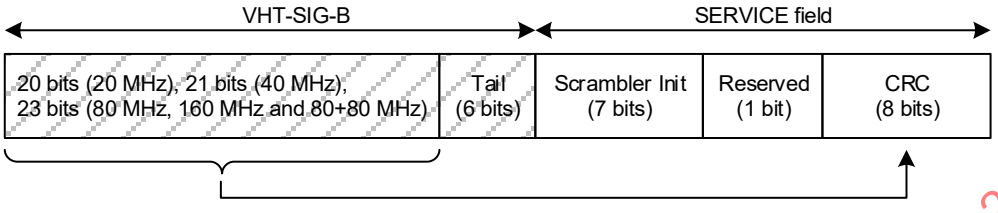

Figure 21-23—VHT-SIG-B and SERVICE field relationship

The value of the CRC field shall be the 1s complement of Equation (21-59).

$$crc(D) = (M(D) \oplus I(D))D^8 \bmod G(D) \tag{21-59}$$

where

$M(D) = m_0 D^{N-1} + m_1 D^{N-2} + \ldots + m_{N-2} D + m_{N-1}$

N is the number of bits over which the CRC is generated; 20 for 20 MHz, 21 for 40 MHz, and 23 for 80 MHz/160 MHz/80+80 MHz

m_i is bit i of VHT-SIG-B

$I(D) = \sum_{i=N-8}^{N-1} D^i$ are initialized values that are added modulo 2 to the first 8 bits of VHT-SIG-B

$G(D) = D^8 + D^2 + D + 1$ is the CRC generating polynomial

$crc(D) = c_0 D^7 + c_1 D^6 + \ldots + c_6 D + c_7$

Figure 19-8 shows the operation of the CRC. First, the shift register is reset to all 1s. The bits are then passed through the XOR operation at the input. When the last bit has entered, the output is generated by shifting the bits out of the shift register, c_7 first, through an inverter.

As an example, if bits $\{m_0, \ldots m_{22}\}$ are given by {1 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1}, the CRC bits $\{c_7, \ldots c_0\}$ are {0 0 0 1 1 1 0 0}.

The CRC field is transmitted with c_7 first. Hence, c_7 is mapped to B8 of the SERVICE field, c_6 is mapped to B9, …, and c_0 is mapped to B15 of the SERVICE field.

21.3.10.4 Scrambler

The SERVICE, PSDU, and PHY pad parts of the Data field shall be scrambled by the scrambler defined in 17.3.5.5. The Clause 17 TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT are not present; therefore, the initial state of the scrambler is set to a pseudorandom nonzero seed. Different users in a VHT MU PPDU may use different pseudorandom nonzero seeds.

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21.3.10.5 Coding

21.3.10.5.1 General

The Data field shall be encoded using either the binary convolutional code (BCC) defined in 21.3.10.5.2 and 21.3.10.5.3 or the low-density parity check (LDPC) code defined in 21.3.10.5.4. The encoder is selected by the SU/MU[0] Coding, MU[1] Coding, MU[2] Coding, or MU[3] Coding fields in VHT-SIG-A, as defined in 21.3.8.3.3. When BCC FEC encoding is used, the number of encoders is determined by rate-dependent parameters as defined in 21.5. The operation of the BCC FEC is described in 21.3.10.5.2 and 21.3.10.5.3. The operation of the LDPC coder is described in 21.3.10.5.4. Support for the reception of a BCC encoded Data field is mandatory.

21.3.10.5.2 BCC encoder parsing operation

If multiple encoders are used, the scrambled SERVICE, PSDU, and PHY pad bits are divided between the encoders by sending bits to different encoders in a round robin manner. Bit i to encoder j of user u, denoted $x_{i,u}^{(j)}$, is as specified in Equation (21-60).

$$x_{i,u}^{(j)} = \begin{cases} b_{N_{ES}\cdot i+j,u}; & 0 \le i < N_{SYM}\dfrac{N_{DBPS,u}}{N_{ES,u}} - N_{tail}, \quad 0 \le j \le N_{ES,u} - 1 \\ 0; & N_{SYM}\dfrac{N_{DBPS,u}}{N_{ES,u}} - N_{tail} \le i < N_{SYM}\dfrac{N_{DBPS,u}}{N_{ES,u}}, \quad 0 \le j \le N_{ES,u} - 1 \end{cases} \tag{21-60}$$

where

$b_{k,u}$ is bit k of the scrambled SERVICE, PSDU, and pad bits of user u

N_{SYM} is the number of symbols in the Data field and is given by Equation (21-111) for a VHT SU PPDU and by Equation (21-67) for a VHT MU PPDU

NOTE—Tail bits with value 0 are being appended to each BCC encoder parser output sequence in Equation (21-60).

21.3.10.5.3 BCC coding and puncturing

The BCC encoder parser output sequences of user u $\{x_{i,u}^{(j)}\}$, $0 \le i < N_{SYM}N_{DBPS,u}/N_{ES,u}$, $0 \le j \le N_{ES,u} - 1$ each of which is separately encoded by a rate R = ½ convolutional encoder defined in 17.3.5.6. After encoding, the encoded data is punctured by the method defined in 17.3.5.6 (except for rate 5/6), to achieve the rate selected by the modulation and coding scheme. In the case that rate 5/6 coding is selected, the puncturing scheme will be the same as described in 19.3.11.6.

21.3.10.5.4 LDPC coding

For a VHT SU PPDU using LDPC coding to encode the Data field, the LDPC code and encoding process described in 19.3.11.7 shall be used with the following modifications. First, all bits in the Data field including the scrambled SERVICE, PSDU, and pad bits are encoded. Thus, N_{pld} for VHT PPDUs shall be computed using Equation (21-61) instead of Equation (19-35).

$$N_{pld} = N_{SYM,init}N_{DBPS} \tag{21-61}$$

where

$N_{SYM,init}$ is given by Equation (21-62)

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$$N_{SYM,\,init} = m_{STBC} \times \left\lceil \frac{8 \cdot \text{APEP_LENGTH} + N_{service}}{m_{STBC} \cdot N_{DBPS}} \right\rceil \tag{21-62}$$

where

m_{STBC} is equal to 2 when STBC is used, and 1 otherwise

APEP_LENGTH is the TXVECTOR parameter APEP_LENGTH

Following the calculation of N_{pld}, N_{avbits} shall be computed using Equation (21-63) instead of Equation (19-36).

$$N_{avbits} = N_{SYM,\,init} N_{CBPS} \tag{21-63}$$

In addition, if N_{SYM} computed in Equation (19-41) in step d) of 19.3.11.7.5 is greater than $N_{SYM,\,init}$, then the LDPC Extra OFDM Symbol field of VHT-SIG-A shall be set to 1. Otherwise, the LDPC Extra OFDM Symbol field of VHT-SIG-A shall be set to 0.

LDPC codes used in VHT MU PPDUs shall also follow the definitions in 19.3.11.7. Refer to 21.3.10.5.5 for a description of the LDPC encoding process for VHT MU PPDUs.

21.3.10.5.5 Encoding process for VHT MU PPDUs

For a VHT MU PPDU, first compute the initial number of OFDM symbols for each user using Equation (21-64).

$$N_{\text{SYM_init},\,u} = \begin{cases} \left\lceil \dfrac{8 \cdot \text{APEP_LENGTH}_u + N_{service} + N_{tail} \cdot N_{ES,\,u}}{N_{DBPS,\,u}} \right\rceil & \text{when user } u \text{ uses BCC} \\ \left\lceil \dfrac{8 \cdot \text{APEP_LENGTH}_u + N_{service}}{N_{DBPS,\,u}} \right\rceil & \text{when user } u \text{ uses LDPC} \end{cases} \tag{21-64}$$

where

APEP_LENGTH_u is the TXVECTOR parameter APEP_LENGTH for user u

Based on the above equation, compute the largest initial number of symbols over all users using Equation (21-65).

$$N_{\text{SYM_max_init}} = \max\{N_{\text{SYM_init},\,u}\}_{u=0}^{N_{user}-1} \tag{21-65}$$

Then, for each user u that uses LDPC in the VHT MU PPDU, the final number of symbols in the Data field ($N_{SYM,u}$) shall be computed as follows. First, perform step a) in 19.3.11.7.5 with the exception that N_{pld} is computed using Equation (21-66) instead of Equation (19-35).

$$N_{pld} = N_{\text{SYM_max_init}} N_{DBPS,\,u} \tag{21-66}$$

Then, perform steps b) to d) in 19.3.11.7.5 with N_{CBPS} and R replaced with $N_{CBPS,u}$ and R_u, respectively. $N_{SYM,u}$ for user u shall then be equal to the value of N_{SYM} obtained at the end of step d) using Equation (19-41).

The purpose of going through steps a) to d) in 19.3.11.7.5 in the above paragraph is to compute $N_{SYM,u}$. Thus, at this stage $N_{SYM,u}$ for each user may be calculated without actually encoding the data using LDPC.

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For BCC users, $N_{SYM,u} = N_{\text{SYM_init},u}$.

Then, compute the number of symbols in the Data field using Equation (21-67).

$$N_{SYM} = \max\{N_{SYM,u}\}_{u=0}^{N_{user}-1} \quad (21\text{-}67)$$

When constructing the Data field for user u encoded using LDPC code, the MAC follows the padding procedure described in 10.12.6 and delivers a PSDU that contains PSDU_LENGTH$_u$ octets (see 21.4.3). The PHY follows the padding procedure described in 21.3.10.1 to fill $N_{\text{SYM_max_init}}$ symbols, where $N_{\text{SYM_max_init}}$ is defined in Equation (21-65). Then, for each user, all bits in the Data field including the scrambled SERVICE, PSDU, and pad bits shall be encoded using the LDPC encoding process specified in 19.3.11.7.5 with the following modifications. First, N_{pld} shall be computed using Equation (21-66) instead of Equation (19-35). Also, replace N_{CBPS} and R with $N_{CBPS,u}$ and R_u, respectively. Next, step d) in 19.3.11.7.5 is replaced with step d) below:

d) If N_{SYM} computed in Equation (21-67) is equal to $N_{\text{SYM_max_init}}$, then the number of bits to be punctured, N_{punc}, from the codewords after encoding is computed as shown in Equation (19-38).

   If N_{SYM} computed in Equation (21-67) is greater than $N_{\text{SYM_max_init}}$, then the number of bits to be punctured, N_{punc}, from the codewords after encoding is computed using Equation (19-39) and Equation (19-40). Note also that N_{avbits} has now been updated in Equation (19-39) in this case.

   The punctured bits shall be equally distributed over all N_{CW} codewords with the first $\text{rem}(N_{punc}, N_{CW})$ codewords punctured 1 bit more than the remaining codewords. Define $N_{ppcw} = \lfloor N_{punc}/N_{CW} \rfloor$. When $N_{ppcw} > 0$, the puncturing is performed by discarding parity bits $p_{n-k-N_{ppcw}-1}, \ldots, p_{n-k-1}$ of the first $\text{rem}(N_{punc}, N_{CW})$ codewords and discarding parity bits $p_{n-k-N_{ppcw}}, \ldots, p_{n-k-1}$ of the remaining codewords after encoding.

When constructing the Data field for users encoded using BCC, the MAC follows the padding procedure described in 10.12.6 and delivers a PSDU that contains PSDU_LENGTH$_u$ octets. The PHY follows the padding procedure described in 21.3.10.1 to fill up N_{SYM} symbols computed in Equation (21-67). Then, for each user, all bits in the Data field including the scrambled SERVICE, PSDU, and pad bits shall be encoded using the BCC encoding process specified in 21.3.10.5.2 and 21.3.10.5.3. Note that this process results in the BCC tail bits being placed at the very end of the PPDU.

In addition, if N_{SYM} computed in Equation (21-67) is greater than $N_{\text{SYM_max_init}}$ computed in Equation (21-65), then the LDPC Extra OFDM Symbol field of VHT-SIG-A2 shall be set to 1. Otherwise, the LDPC Extra OFDM Symbol field of VHT-SIG-A2 shall be set to 0.

21.3.10.6 Stream parser

After coding and puncturing, the data bit streams at the output of the FEC encoders are processed in groups of N_{CBPS} bits. Each of these groups is rearranged into N_{SS} blocks of N_{CBPSS} bits ($N_{SS,u}$ blocks of $N_{CBPSS,u}$ bits in the case of an MU transmission). This operation is referred to as *stream parsing* and is described in this subclause.

The description is given in terms of an SU transmission. For MU transmissions, the rearrangements are carried out in the same way per user.

The number of bits assigned to a single axis (real or imaginary) of a constellation point in a spatial stream is denoted by Equation (21-68).

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$$s = \max\left\{1, \frac{N_{BPSCS}}{2}\right\} \tag{21-68}$$

The sum of these over all streams is $S = N_{SS} \cdot s$

Consecutive blocks of s bits are assigned to different spatial streams in a round robin fashion.

Let

$$N_{\text{Block}} = \left\lfloor \frac{N_{CBPS}}{N_{ES} \cdot S} \right\rfloor \tag{21-69}$$

and

$$M = \frac{N_{CBPS} - N_{\text{Block}} \cdot N_{ES} \cdot S}{s \cdot N_{ES}} \tag{21-70}$$

For the first $N_{\text{Block}} \cdot N_{ES} \cdot S$ bits of each OFDM symbol, S bits from the output of first encoder are divided among all spatial streams, s bits per stream. Then, S bits from the output of next encoder are used, and so on. If N_{CBPS} is greater than $N_{\text{Block}} \cdot N_{ES} \cdot S$, then for the last $N_{CBPS} - N_{\text{Block}} \cdot N_{ES} \cdot S$ bits of each OFDM symbol, $M \cdot s$ bits from the output of the first encoder are fed into spatial streams 1 to M (s bits per spatial stream), and then $M \cdot s$ bits from the output of the next encoder are used for spatial stream $M+1$ to $[(2M-1) \bmod N_{SS}] + 1$, and so on, where $z \bmod t$ is the remainder resulting from the division of integer z by integer t.

The following equations are an equivalent description to the above procedure. Bit i at the output of encoder j is assigned to input bit k of spatial stream i_{SS} where

$$j = \begin{cases} \left\lfloor \frac{k}{s} \right\rfloor \bmod N_{ES}, & k = 0, 1, \ldots, N_{\text{Block}} \cdot N_{ES} \cdot s - 1 \\ \left\lfloor \frac{L}{M} \right\rfloor, & k = N_{\text{Block}} \cdot N_{ES} \cdot s, \ldots, N_{CBPSS} - 1 \end{cases} \tag{21-71}$$

and

$$i = \begin{cases} (i_{SS}-1)s + S \cdot \left\lfloor \frac{k}{N_{ES} \cdot s} \right\rfloor + k \bmod s, & k = 0, 1, \ldots, N_{\text{Block}} \cdot N_{ES} \cdot s - 1 \\ (L \bmod M) \cdot s + N_{\text{Block}} \cdot S + k \bmod s, & k = N_{\text{Block}} \cdot N_{ES} \cdot s, \ldots, N_{CBPSS} - 1 \end{cases} \tag{21-72}$$

where

$i_{SS} = 1, 2, \ldots, N_{SS}$

$i = 0, 1, \ldots, N_{CBPS}/N_{ES} - 1$

$j = 0, 1, \ldots, N_{ES} - 1$

$k = 0, 1, \ldots, N_{CBPSS} - 1$

$L = \left\lfloor \frac{k'}{s} \right\rfloor N_{SS} + (i_{SS} - 1)$

$k' = k - N_{\text{Block}} \cdot N_{ES} \cdot s$

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NOTE—N_{CBPS} is greater than $N_{\text{Block}} \cdot N_{ES} \cdot S$ in only the following cases:

a) 160 MHz and 80+80 MHz, $N_{SS} = 5$, VHT-MCS = 5
b) 160 MHz and 80+80 MHz, $N_{SS} = 5$, VHT-MCS = 6
c) 160 MHz and 80+80 MHz, $N_{SS} = 7$, VHT-MCS = 5
d) 160 MHz and 80+80 MHz, $N_{SS} = 7$, VHT-MCS = 6

21.3.10.7 Segment parser

The description in this subclause is given in terms of an SU transmission. For MU transmissions, the rearrangements are carried out in the same way per user.

For a 160 MHz or an 80+80 MHz transmission, the output bits of each stream parser are first divided into blocks of N_{CBPSS} bits ($N_{CBPSS,u}$ bits in the case of an MU transmission). Then, each block is further divided into two frequency subblocks of $N_{CBPSS}/2$ bits as shown in Equation (21-73).

$$y_{k,l} = x_{2s \cdot N_{ES}\left\lfloor \frac{k}{s \cdot N_{ES}} \right\rfloor + l \cdot s \cdot N_{ES} + k \bmod (s \cdot N_{ES})}, \quad k = 0, 1, \ldots, \frac{N_{CBPSS}}{2} - 1 \tag{21-73}$$

where

x_m is the m th bit of a block of N_{CBPSS} bits, m= 0 to $N_{CBPSS} - 1$
l is the frequency subblock index, $l = 0, 1$
$y_{k,l}$ is bit k of the frequency subblock l
s is defined in Equation (21-68)

If N_{CBPSS} is not divisible by $2s \cdot N_{ES}$, then apply the segment parsing method described in Equation (21-73) for $\lfloor N_{CBPSS}/(2s \cdot N_{ES}) \rfloor$ sets of $2s \cdot N_{ES}$ segment parser input bits. At this point, each stream parser output has $2s \cdot N_{res}$ ($N_{res} = \frac{N_{CBPSS} \bmod (2s \cdot N_{ES})}{2s} < N_{ES}$, integer) residue bits. Then, the residue bits are divided into subsets of s bits, with each subset being assigned to different subblock ($l = 0, 1$) in a round robin fashion. The first s bits are assigned to the subblock with index $l = 0$. Repeat N_{res} times (until all bits are distributed to the two subblocks). That is, if N_{CBPSS} is not divisible by $2s \cdot N_{ES}$, each block is further divided into two subblocks of $N_{CBPSS}/2$ bits as shown in Equation (21-74).

$$y_{k,l} = \begin{cases} x_{2s \cdot N_{ES}\left\lfloor \frac{k}{s \cdot N_{ES}} \right\rfloor + l \cdot s \cdot N_{ES} + k \bmod (s \cdot N_{ES})}, & k = 0, 1, \ldots, \lfloor N_{CBPSS}/(2s \cdot N_{ES}) \rfloor \cdot s \cdot N_{ES} - 1 \\ x_{2s \cdot N_{ES}\left\lfloor \frac{k}{s \cdot N_{ES}} \right\rfloor + 2s \cdot \left\lfloor \frac{k \bmod (s \cdot N_{ES})}{s} \right\rfloor + l \cdot s + k \bmod s}, & k = \lfloor N_{CBPSS}/(2s \cdot N_{ES}) \rfloor \cdot s \cdot N_{ES}, \ldots, \frac{N_{CBPSS}}{2} - 1 \end{cases} \tag{21-74}$$

Segment parser is bypassed for a 20 MHz, 40 MHz, or 80 MHz VHT PPDU transmission, i.e., as specified in Equation (21-75).

$$y_{k,l} = x_k, \quad k = 0, 1, \ldots, N_{CBPSS} - 1 \tag{21-75}$$

where

l is the frequency subblock index. $l = 0$ for a 20, 40 or 80 MHz VHT PPDU transmission.
$y_{k,l}$ is bit k of the frequency subblock l
x_m is bit m of a block of N_{CBPSS} bits, $m = 0$ to $N_{CBPSS} - 1$

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21.3.10.8 BCC interleaver

For ease of explanation, the operation of the interleaver is described for the SU case. For user u of an MU transmission, the interleaver operates in the same way on the output bits for the user from the stream parser by replacing N_{SS}, N_{CBPSS}, N_{CBPSSI}, and N_{BPSCS} with $N_{SS,u}$, $N_{CBPSS,u}$, $N_{CBPSSI,u}$, and $N_{BPSCS,u}$, respectively. That is, the operation of the interleaver is the same as if the transmission were an SU one, consisting of bits from only that user.

This subclause describes the interleaver used in the case of BCC encoding. The interleaver described in this subclause shall be bypassed in the case of LDPC encoding.

In a 20 MHz, 40 MHz, or 80 MHz VHT PPDU transmission, the bits at the output of the stream parser are processed in groups of N_{CBPS} bits. Each of these groups is divided into N_{SS} blocks of N_{CBPSS} bits, and each block shall be interleaved by an interleaver based on the Clause 17 interleaver. In a 160 MHz or an 80+80 MHz VHT PPDU transmission, each frequency subblock of $N_{CBPSS}/2$ output bits from the segment parser is interleaved by the interleaver for 80 MHz defined in this subclause. This interleaver, which is based on entering the data in rows, and reading it out in columns, has a different number of columns N_{COL} and rows N_{ROW} for different bandwidths. The values of N_{COL} and N_{ROW} are given in Table 21-17.

Table 21-17—Number of rows and columns in the interleaver

Parameter	20 MHz	40 MHz	80 MHz
N_{COL}	13	18	26
N_{ROW}	$4 \times N_{BPSCS}$	$6 \times N_{BPSCS}$	$9 \times N_{BPSCS}$
N_{ROT} ($N_{SS} \leq 4$)	11	29	58
N_{ROT} ($N_{SS} > 4$)	6	13	28

After the operations based on the Clause 17 interleaver have been applied and if more than one spatial stream exists, a third operation called *frequency rotation* is applied to the additional spatial streams. The parameter for the frequency rotation is N_{ROT}. The values of N_{ROT} are given in Table 21-17.

An additional parameter is the spatial stream index $i_{SS} = 1, 2, \ldots, N_{SS}$. The output of the third operation is a function of the spatial stream index.

The interleaving is defined using three permutations. The first permutation is given by the rule shown in Equation (21-76).

$$i = N_{ROW}(k \bmod N_{COL}) + \left\lfloor \frac{k}{N_{COL}} \right\rfloor, k = 0, 1, \ldots, N_{CBPSSI} - 1 \quad (21\text{-}76)$$

The second permutation is defined by the rule shown in Equation (21-77).

$$j = s\left\lfloor \frac{i}{s} \right\rfloor + \left(i + N_{CBPSSI} - \left\lfloor \frac{N_{COL} \cdot i}{N_{CBPSSI}} \right\rfloor\right) \bmod s, \quad i = 0, 1, \ldots, N_{CBPSSI} - 1 \quad (21\text{-}77)$$

where

s is defined in Equation (21-68)

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If $2 \le N_{SS} \le 4$, a frequency rotation is applied to the output of the second permutation as shown in Equation (21-78).

$$r = \left\{ j - \left[(2(i_{SS} - 1)) \bmod 3 + 3 \left\lfloor \frac{i_{SS} - 1}{3} \right\rfloor \right] \cdot N_{ROT} \cdot N_{BPSCS} \right\} \bmod N_{CBPSSI}, \quad (21\text{-}78)$$

$$j = 0, 1, \ldots, N_{CBPSSI} - 1$$

where

$i_{SS} = 1, 2, \ldots, N_{SS}$ is the spatial steam index on which this interleaver is operating

If $N_{SS} > 4$, a frequency rotation is applied to the output of the second permutation as shown in Equation (21-79).

$$r = \{ j - J(i_{SS}) \cdot N_{ROT} \cdot N_{BPSCS} \} \bmod N_{CBPSSI}, j = 0, 1, \ldots, N_{CBPSSI} - 1 \quad (21\text{-}79)$$

where

$i_{SS} = 1, 2, \ldots, N_{SS}$ is the spatial steam index on which this interleaver is operating, and $J(i_{SS})$ is an integer as defined in Table 21-18.

Table 21-18—$J(i_{SS})$ values

i_{SS}	$J(i_{SS})$
1	0
2	5
3	2
4	7
5	3
6	6
7	1
8	4

The deinterleaver uses the following three operations to perform the inverse permutations. Let r denote the index of the bit in the received block (per spatial stream). The first operation reverses the third (frequency rotation) permutation of the interleaver. When $N_{SS} = 1$, this reversal is performed by $j = r$ ($r = 0, 1, \ldots, N_{CBPSSI} - 1$). When $2 \le N_{SS} \le 4$, this reversal is performed by as shown in Equation (21-80).

$$j = \left\{ r + \left[(2(i_{SS} - 1)) \bmod 3 + 3 \left\lfloor \frac{i_{SS} - 1}{3} \right\rfloor \right] \cdot N_{ROT} \cdot N_{BPSCS} \right\} \bmod N_{CBPSSI}, \quad (21\text{-}80)$$

$$r = 0, 1, \ldots, N_{CBPSSI} - 1$$

When $N_{SS} > 4$, this reversal is performed by Equation (21-81).

$$j = \{ r + J(i_{SS}) \cdot N_{ROT} \cdot N_{BPSCS} \} \bmod N_{CBPSSI}, \quad r = 0, 1, \ldots, N_{CBPSSI} - 1 \quad (21\text{-}81)$$

where

$J(i_{SS})$ is defined in Table 21-18

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The second operation defined by Equation (21-82) reverses the second permutation in the interleaver.

$$i = s\left\lfloor \frac{j}{s} \right\rfloor + \left(j + \left\lfloor \frac{N_{COL} \cdot j}{N_{CBPSSI}} \right\rfloor\right) \bmod s, \quad j = 0, 1, \ldots, N_{CBPSSI} - 1 \tag{21-82}$$

where

s is defined in Equation (21-68)

The third operation defined in Equation (21-83) reverses the first permutation of the interleaver.

$$k = N_{COL} \cdot i - (N_{CBPSSI} - 1)\left\lfloor \frac{i}{N_{ROW}} \right\rfloor, \quad i = 0, 1, \ldots, N_{CBPSSI} - 1 \tag{21-83}$$

21.3.10.9 Constellation mapping

21.3.10.9.1 General

The mapping between bits at the output of the interleaver and complex constellation points for BPSK, QPSK, 16-QAM, and 64-QAM follows the rules defined in 17.3.5.8. For 256-QAM, the mapping is shown in Figure 21-24 through Figure 21-27.

The bit string convention in Figure 21-24 through Figure 21-27 follows the bit string convention outlined in 17.3.5.8.

The streams of complex numbers in frequency subblock l for user u are denoted as follows:

$d_{k,i,n,l,u}$; $k = 0, 1, \ldots, N_{SD} - 1$ for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz; (21-84)

$k = 0, 1, \ldots, \frac{N_{SD}}{2} - 1$ for 160 MHz;

$i = 1, \ldots, N_{SS,u}$;

$n = 0, 1, \ldots, N_{SYM} - 1$;

$l = 0$ for 20 MHz, 40 MHz, and 80 MHz;

$l = 0, 1$ for 160 MHz and 80+80 MHz;

$u = 0, \ldots, N_{user} - 1$

The normalization factor, K_{MOD}, for 256-QAM is $1/\sqrt{170}$.

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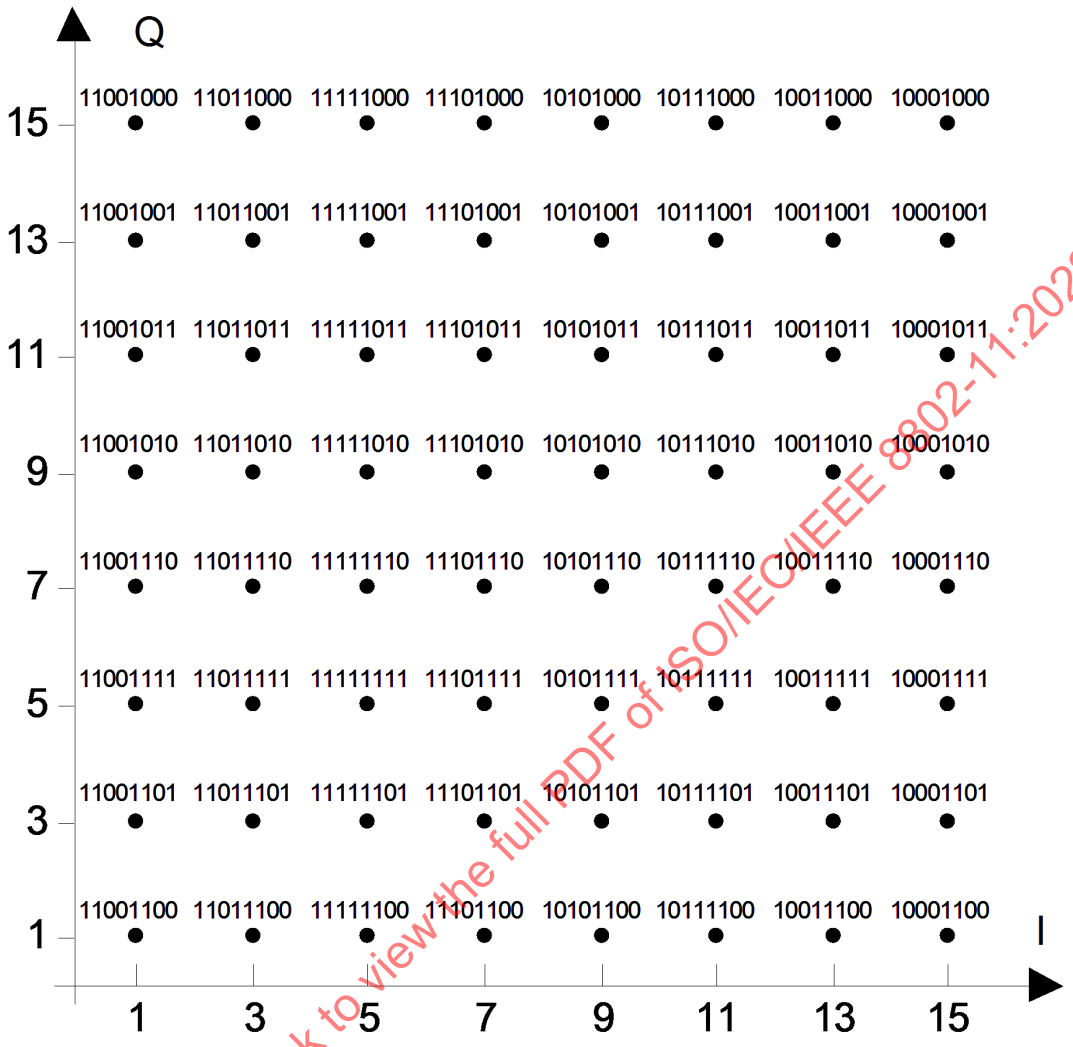

Figure 21-24—Constellation bit encoding for 256-QAM (1st quadrant)

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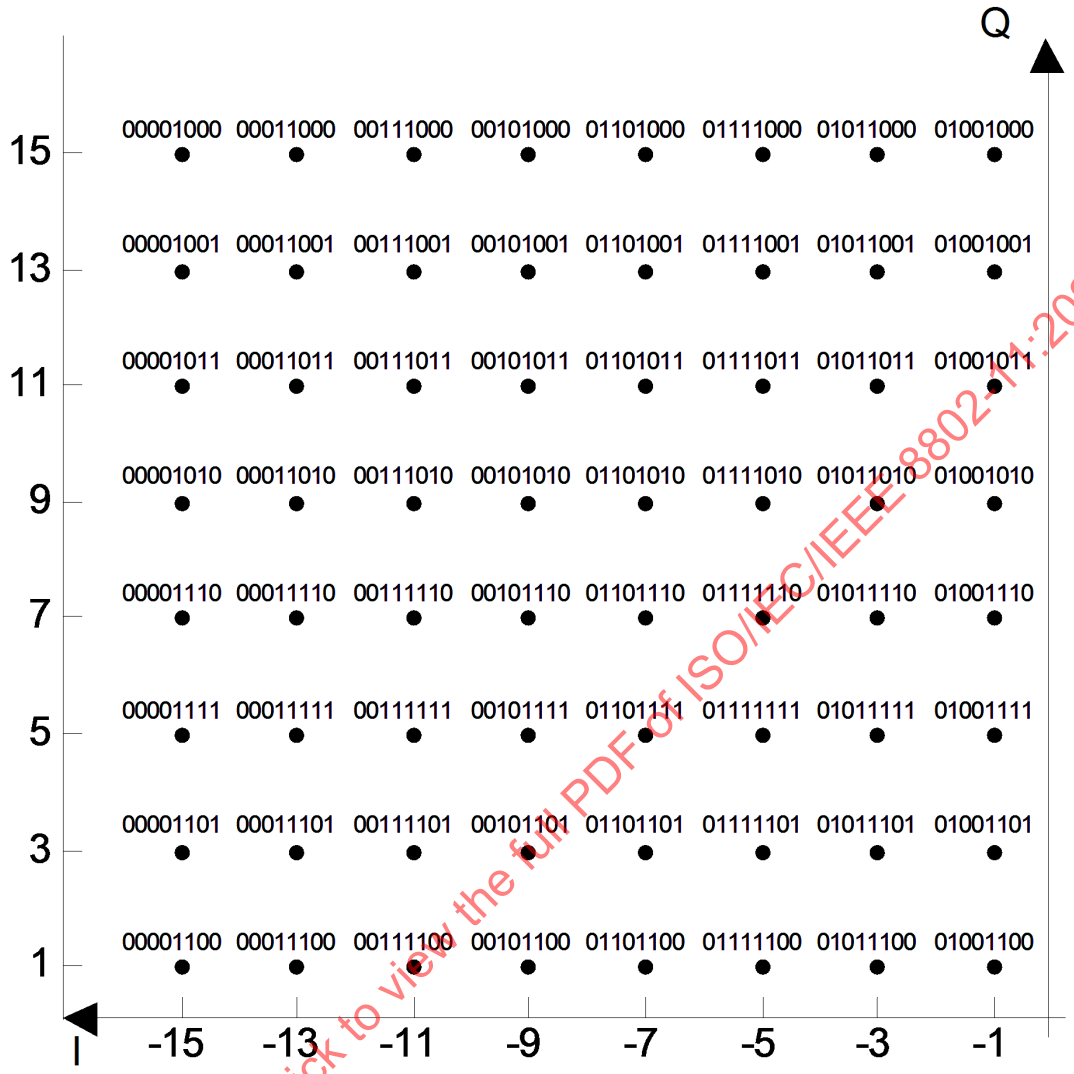

Figure 21-25—Constellation bit encoding for 256-QAM (2nd quadrant)

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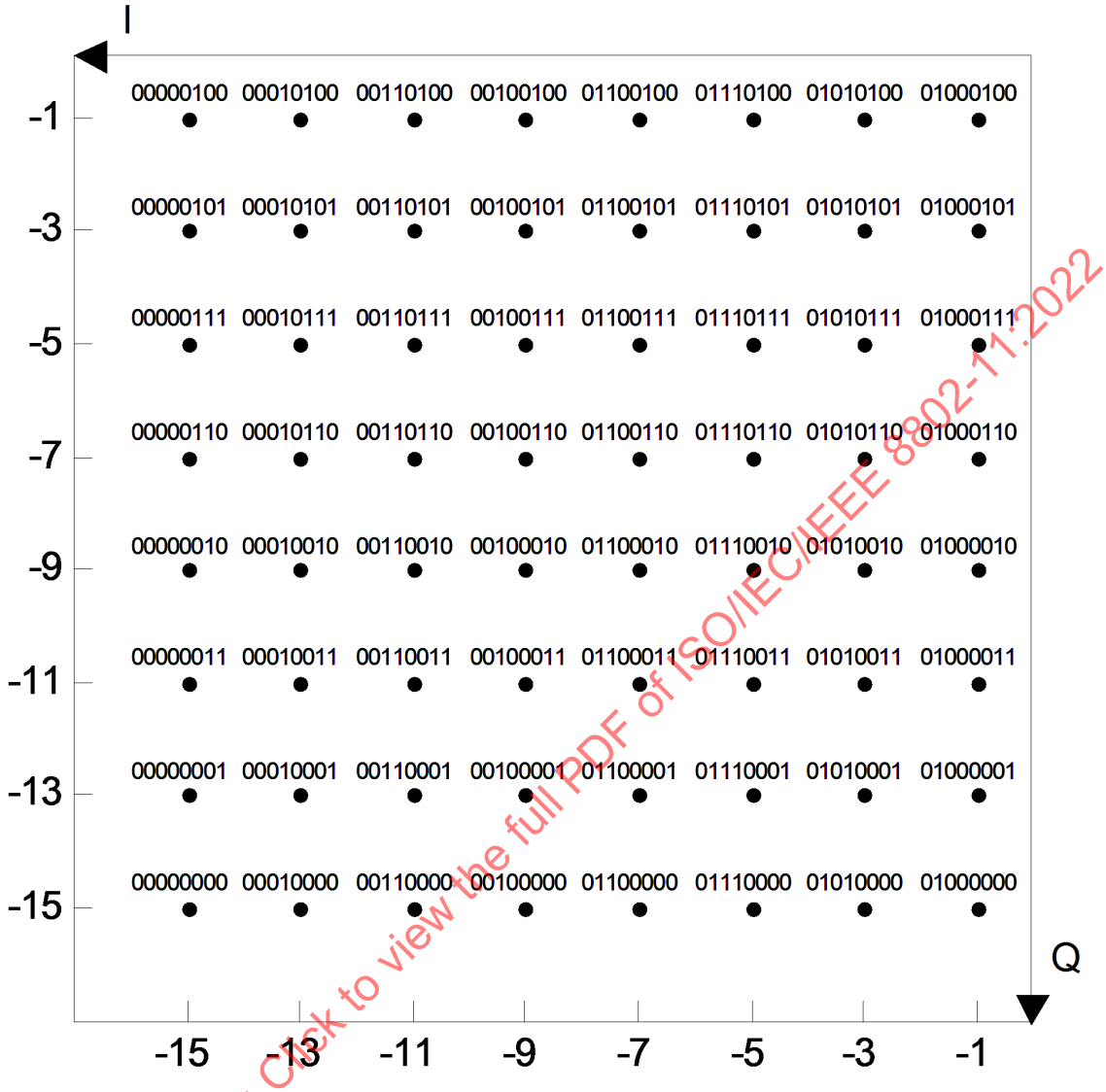

Figure 21-26—Constellation bit encoding for 256-QAM (3rd quadrant)

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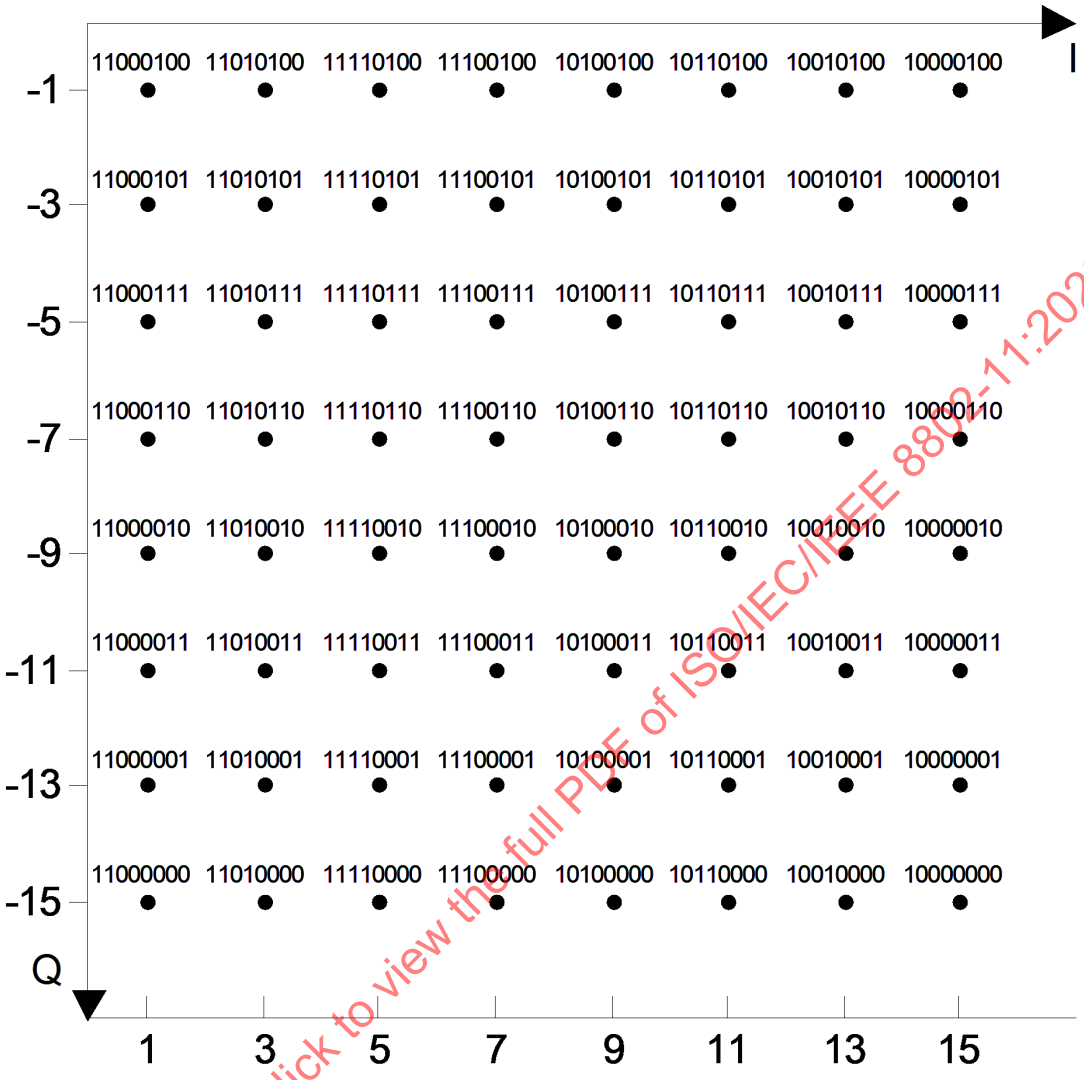

Figure 21-27—Constellation bit encoding for 256-QAM (4th quadrant)

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21.3.10.9.2 LDPC tone mapping

The LDPC tone mapping shall be performed on all LDPC encoded streams as described in this subclause and using an LDPC tone-mapping distance parameter D_{TM}. D_{TM} is constant for each bandwidth and its value for different bandwidths is given in Table 21-19. LDPC tone mapping shall not be performed on streams that are encoded using BCC.

Table 21-19—LDPC tone mapping distance for each bandwidth

Parameter	20 MHz	40 MHz	80 MHz	160 MHz, 80+80 MHz
D_{TM}	4	6	9	9

For a VHT PPDU transmission, the LDPC tone mapping for LDPC-coded streams corresponding to user u is done by permuting the stream of complex numbers generated by the constellation mappers [see Equation (21-84)] to obtain

$$d''_{t(k),\,i,\,n,\,l,\,u} = d'_{k,\,i,\,n,\,l,\,u};\quad k = 0, 1, \ldots, N_{SD} - 1 \text{ for 20 MHz, 40 MHz, 80 MHz and 80+80 MHz;} \tag{21-85}$$

$$k = 0, 1, \ldots, \frac{N_{SD}}{2} - 1 \text{ for 160 MHz;}$$

$$i = 1, \ldots, N_{SS,\,u};$$

$$n = 0, 1, \ldots, N_{SYM} - 1;$$

$$l = 0 \text{ for 20 MHz, 40 MHz, and 80 MHz;}$$

$$l = 0, 1 \text{ for 160 MHz and 80+80 MHz;}$$

$$u = 0, \ldots, N_{user} - 1$$

where

$$t(k) = \begin{cases} D_{TM}\left(k \bmod \dfrac{N_{SD}}{D_{TM}}\right) + \left\lfloor \dfrac{k \cdot D_{TM}}{N_{SD}} \right\rfloor, & \text{for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz} \\ D_{TM}\left(k \bmod \dfrac{N_{SD}/2}{D_{TM}}\right) + \left\lfloor \dfrac{k \cdot D_{TM}}{N_{SD}/2} \right\rfloor, & \text{for 160 MHz} \end{cases} \tag{21-86}$$

As a result of the LDPC tone mapping operation above, each two consecutively generated complex constellation numbers $d'_{k,\,i,\,n,\,l,\,u}$ and $d'_{k+1,\,i,\,n,\,l,\,u}$ will be transmitted on two data tones that are separated by at least $D_{TM} - 1$ other data tones. Note that the operation above is equivalent to block-interleaving the complex numbers $d'_{0,\,i,\,n,\,l,\,u}, \ldots, d'_{N_{SD}-1,\,i,\,n,\,l,\,u}$ for each i, n, and u using a matrix with D_{TM} rows and N_{SD}/D_{TM} (for 20 MHz, 40 MHz, 80 MHz, or 80+80 MHz) or $\dfrac{N_{SD}}{2 \cdot D_{TM}}$ (for 160 MHz) columns, where $d'_{0,\,i,\,n,\,l,\,u}, \ldots, d'_{N_{SD}-1,\,i,\,n,\,l,\,u}$ are written row-wise into the matrix, and $d''_{0,\,i,\,n,\,l,\,u}, \ldots, d''_{N_{SD}-1,\,i,\,n,\,l,\,u}$ are read column-wise from the matrix.

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NOTE—LDPC tone mapping is performed separately for the upper and lower 80 MHz frequency subblocks of a 160 MHz or 80+80 MHz transmission as indicated by the frequency subblock index l in Equation (21-85) and Equation (21-86).

Since LDPC tone mapping is not performed on BCC-coded streams, for BCC-coded streams, the following applies:

$$d''_{k,i,n,l,u} = d'_{k,i,n,l,u};\quad k = 0, 1, \ldots, N_{SD} - 1 \text{ for 20 MHz, 40 MHz, 80 MHz and 80+80 MHz;} \tag{21-87}$$

$$k = 0, 1, \ldots, \frac{N_{SD}}{2} - 1 \text{ for 160 MHz;}$$

$$i = 1, \ldots, N_{SS,u};$$

$$n = 0, 1, \ldots, N_{SYM} - 1;$$

$$l = 0 \text{ for 20 MHz, 40 MHz, and 80 MHz;}$$

$$l = 0, 1 \text{ for 160 MHz and 80+80 MHz;}$$

$$u = 0, \ldots, N_{user} - 1$$

21.3.10.9.3 Segment deparser

In a 160 MHz VHT PPDU transmission, the two frequency subblocks at the output of the LDPC tone mapper for LDPC or constellation mapper for BCC are combined into one frequency segment as shown in Equation (21-88).

$$d^{(i_{Seg})}_{k,i,n,u} = \begin{cases} d''_{k,i,n,0,u}, & \text{if } 0 \le k \le \frac{N_{SD}}{2} - 1 \\ d''_{k-N_{SD}/2,i,n,1,u}, & \text{if } \frac{N_{SD}}{2} \le k \le N_{SD} - 1 \end{cases}, \quad i_{Seg} = 0 \tag{21-88}$$

In a 20 MHz, 40 MHz, or 80 MHz VHT PPDU transmission, the segment deparsing is not performed. Hence,

$$d^{(i_{Seg})}_{k,i,n,u} = d''_{k,i,n,0,u}, \quad 0 \le k \le N_{SD} - 1, \quad i_{Seg} = 0 \tag{21-89}$$

In an 80+80 MHz VHT PPDU transmission, the segment deparsing is not performed. Hence,

$$d^{(i_{Seg})}_{k,i,n,u} = d''_{k,i,n,i_{Seg},u}, \quad 0 \le k \le N_{SD} - 1, \quad i_{Seg} = 0, 1 \tag{21-90}$$

NOTE—As per Table 21-7, $f_c^{(0)}$ (center frequency for frequency segment i_{Seg}=0) is always less than $f_c^{(1)}$ in case of 80+80 MHz VHT PPDU transmissions. Hence, $d''_{k,i,n,0,u}$ (frequency subblock 0) is always transmitted in the frequency segment lower in frequency, while $d''_{k,i,n,1,u}$ (frequency subblock 1) is always transmitted in the frequency segment higher in frequency.

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21.3.10.9.4 Space-time block coding

This subclause defines a set of optional robust transmission techniques that are applicable only when using STBC coding for VHT SU PPDUs. In this case, $N_{SS,0}$ spatial streams are mapped to $N_{STS,0}$ space-time streams. These techniques are based on STBC. When the VHT-SIG-A STBC field is 1, a symbol operation shall occur between the constellation mapper and the spatial mapper as defined in this subclause. STBC shall not be applied in a VHT MU PPDU. Hence, the user subscript u is 0 in this subclause.

If STBC is applied, the stream of complex numbers, $d^{(i_{Seg})}_{k,\,i,\,n,\,0}$; $k = 0, \ldots, N_{SD}-1$; $i = 1, \ldots, N_{SS,\,0}$; $n = 0, \ldots, N_{SYM}-1$, generated by the segment deparser, is the input to the STBC encoder, which produces as output the stream of complex numbers $\tilde{d}^{(i_{Seg})}_{k,\,i_{STS},\,n,\,0}$; $k = 0, \ldots, N_{SD}-1$; $i_{STS} = 1, \ldots, N_{STS,\,0}$; $n = 0, \ldots, N_{SYM}-1$. For given values of k and i, STBC processing operates on the complex modulation symbols in sequential pairs of OFDM symbols so that the value of $\tilde{d}^{(i_{Seg})}_{k,\,2i-1,\,2m,\,0}$ and $\tilde{d}^{(i_{Seg})}_{k,\,2i,\,2m,\,0}$ depend on $d^{(i_{Seg})}_{k,\,i,\,2m,\,0}$ and $d^{(i_{Seg})}_{k,\,i,\,2m+1,\,0}$. Also, $\tilde{d}^{(i_{Seg})}_{k,\,2i-1,\,2m+1,\,0}$ and $\tilde{d}^{(i_{Seg})}_{k,\,2i,\,2m+1,\,0}$ depend on $d^{(i_{Seg})}_{k,\,i,\,2m,\,0}$ and $d^{(i_{Seg})}_{k,\,i,\,2m+1,\,0}$. This is defined in Table 21-20. Note that the segment index i_{Seg} is omitted in Table 21-20 for simplicity.

Table 21-20—Constellation mapper output to spatial mapper input for STBC

N_{STS}	N_{SS}	i_{STS}	$\tilde{d}_{k,\,i_{STS},\,2m,\,0}$	$\tilde{d}_{k,\,i_{STS},\,2m+1,\,0}$
2	1	1	$d_{k,\,1,\,2m,\,0}$	$d_{k,\,1,\,2m+1,\,0}$
		2	$-d^{*}_{k,\,1,\,2m+1,\,0}$	$d^{*}_{k,\,1,\,2m,\,0}$
4	2	1	$d_{k,\,1,\,2m,\,0}$	$d_{k,\,1,\,2m+1,\,0}$
		2	$-d^{*}_{k,\,1,\,2m+1,\,0}$	$d^{*}_{k,\,1,\,2m,\,0}$
		3	$d_{k,\,2,\,2m,\,0}$	$d_{k,\,2,\,2m+1,\,0}$
		4	$-d^{*}_{k,\,2,\,2m+1,\,0}$	$d^{*}_{k,\,2,\,2m,\,0}$
6	3	1	$d_{k,\,1,\,2m,\,0}$	$d_{k,\,1,\,2m+1,\,0}$
		2	$-d^{*}_{k,\,1,\,2m+1,\,0}$	$d^{*}_{k,\,1,\,2m,\,0}$
		3	$d_{k,\,2,\,2m,\,0}$	$d_{k,\,2,\,2m+1,\,0}$
		4	$-d^{*}_{k,\,2,\,2m+1,\,0}$	$d^{*}_{k,\,2,\,2m,\,0}$
		5	$d_{k,\,3,\,2m,\,0}$	$d_{k,\,3,\,2m+1,\,0}$
		6	$-d^{*}_{k,\,3,\,2m+1,\,0}$	$d^{*}_{k,\,3,\,2m,\,0}$

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Table 21-20—Constellation mapper output to spatial mapper input for STBC *(continued)*

N_{STS}	N_{SS}	i_{STS}	$\tilde{d}_{k, i_{STS}, 2m, 0}$	$\tilde{d}_{k, i_{STS}, 2m+1, 0}$
8	4	1	$d_{k, 1, 2m, 0}$	$d_{k, 1, 2m+1, 0}$
		2	$-d^*_{k, 1, 2m+1, 0}$	$d^*_{k, 1, 2m, 0}$
		3	$d_{k, 2, 2m, 0}$	$d_{k, 2, 2m+1, 0}$
		4	$-d^*_{k, 2, 2m+1, 0}$	$d^*_{k, 2, 2m, 0}$
		5	$d_{k, 3, 2m, 0}$	$d_{k, 3, 2m+1, 0}$
		6	$-d^*_{k, 3, 2m+1, 0}$	$d^*_{k, 3, 2m, 0}$
		7	$d_{k, 4, 2m, 0}$	$d_{k, 4, 2m+1, 0}$
		8	$-d^*_{k, 4, 2m+1, 0}$	$d^*_{k, 4, 2m, 0}$

If STBC is not applied, $\tilde{d}^{(i_{Seg})}_{k, i, n, 0} = d^{(i_{Seg})}_{k, i, n, 0}$ and $N_{STS, 0} = N_{SS, 0}$.

NOTE—When STBC is applied, an odd number of space-time streams is not allowed, and $N_{STS, 0} = 2N_{SS, 0}$.

21.3.10.10 Pilot subcarriers

In a 20 MHz transmission, four pilot tones shall be inserted in subcarriers $k \in \{-21, -7, 7, 21\}$. The pilot mapping P^k_n for subcarrier k for symbol n shall be as specified in Equation (21-91).

$$\begin{aligned} P^{\{-21,-7,7,21\}}_n &= \{\Psi^{(1)}_{1, n \bmod 4}, \Psi^{(1)}_{1, (n+1) \bmod 4}, \Psi^{(1)}_{1, (n+2) \bmod 4}, \Psi^{(1)}_{1, (n+3) \bmod 4}\} \\ P^{k \notin \{-21,-7,7,21\}}_n &= 0 \end{aligned} \tag{21-91}$$

where

$\Psi^{(1)}_{1, m}$ is given by the $N_{STS} = 1$ row of Table 19-19

In a 40 MHz transmission, six pilot tones shall be inserted in subcarriers –53, –25, –11, 11, 25, and 53. The pilot mapping P^k_n for subcarrier k for symbol n shall be as specified in Equation (21-92).

$$\begin{aligned} P^{\{-53,-25,-11,11,25,53\}}_n &= \{\Psi^{(1)}_{1, n \bmod 6}, \Psi^{(1)}_{1, (n+1) \bmod 6}, \ldots, \Psi^{(1)}_{1, (n+5) \bmod 6}\} \\ P^{k \notin \{-53,-25,-11,11,25,53\}}_n &= 0 \end{aligned} \tag{21-92}$$

where

$\Psi^{(1)}_{1, m}$ is given by the $N_{STS} = 1$ row of Table 19-20

In an 80 MHz transmission, eight pilot tones shall be inserted in subcarriers –103, –75, –39, –11, 11, 39, 75, and 103. The pilot mapping P^k_n for subcarrier k for symbol n shall be as specified in Equation (21-93).

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$$P_n^{\{-103,-75,-39,-11,11,39,75,103\}} = \{\Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \ldots, \Psi_{(n+7) \bmod 8}\}$$
$$P_n^{k \notin \{-103,-75,-39,-11,11,39,75,103\}} = 0 \quad (21\text{-}93)$$

where

Ψ_m is defined in Table 21-21

Table 21-21—Pilot values for 80 MHz transmission

Ψ_0	Ψ_1	Ψ_2	Ψ_3	Ψ_4	Ψ_5	Ψ_6	Ψ_7
1	1	1	–1	–1	1	1	1

In a 160 MHz transmission, the 80 MHz pilot mapping is replicated in the two 80 MHz subchannels of the 160 MHz transmission. Specifically, 16 pilot tones shall be inserted in subcarriers –231, –203, –167, –139, –117, –89, –53, –25, 25, 53, 89, 117, 139, 167, 203, and 231. The pilot mapping P_n^k for subcarrier k for symbol n shall be as specified in Equation (21-94).

$$P_n^{\{-231,-203,-167,-139,-117,-89,-53,-25,25,53,89,117,139,167,203,231\}} \quad (21\text{-}94)$$
$$= \{\Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8}, \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8},$$
$$\Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8}, \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8}\}$$
$$P_n^{k \notin \{-231,-203,-167,-139,-117,-89,-53,-25,25,53,89,117,139,167,203,231\}} = 0$$

where

Ψ_m is given in Table 21-21

In an 80+80 MHz transmission, each frequency segment shall follow the 80 MHz pilot tone allocation and values defined for 80 MHz transmission as specified in Equation (21-93) and Table 21-21.

The above pilot mapping shall be copied to all space-time streams before the space-time stream cyclic shifts are applied.

21.3.10.11 OFDM modulation

21.3.10.11.1 Transmission in VHT format

The time domain waveform of the Data field of a VHT PPDU from frequency segment i_{Seg} and transmit chain i_{TX}, $1 \le i_{TX} \le N_{TX}$ shall be as defined in Equation (21-95).

$$r_{\text{VHT-Data}}^{(i_{Seg}, i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{VHT-Data}}^{\text{Tone}} N_{STS,\,total}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{\text{SYM}}}(t - nT_{SYM}) \quad (21\text{-}95)$$
$$\cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_{user}-1} \sum_{m=1}^{N_{STS,u}} \left(\left[Q_k^{(i_{Seg})} \right]_{i_{TX}, (M_u+m)} \Upsilon_{k,\,\text{BW}} (\tilde{D}_{k,m,n,BW}^{(i_{Seg},u)} + p_{n+4} P_n^k) \right.$$
$$\left. \cdot \exp(j2\pi k \Delta_F (t - nT_{SYM} - T_{\text{GI, Data}} - T_{\text{CS,VHT}}(M_u + m))) \right)$$

where

p_n is defined in 17.3.5.10

P_n^k is defined in 21.3.10.10

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$\Upsilon_{k,\mathrm{BW}}$ is defined in Equation (21-14), Equation (21-15), Equation (21-16). and Equation (21-17)

$\tilde{D}^{(i_{Seg},u)}_{k,m,n,BW}$ is the transmitted constellation for user u at subcarrier k, space-time stream m, and Data field OFDM symbol n and is defined in Equation (21-96) to Equation (21-99)

$N^{\mathrm{Tone}}_{\mathrm{VHT\text{-}Data}}$ has the value given in Table 21-8

$T_{\mathrm{CS,VHT}}(n)$ is given in Table 21-11

$T_{\mathrm{GI,\,Data}}$ is the guard interval duration. $T_{\mathrm{GI,\,Data}} = T_{\mathrm{GI}}$ when not using the short guard interval (Short GI field of VHT-SIG-A2 is 0) and $T_{\mathrm{GI,\,Data}} = T_{\mathrm{GIS}}$ when using the short guard interval (Short GI field of VHT-SIG-A2 is 1). T_{GI} and T_{GIS} are given in Table 21-5

In a 20 MHz VHT transmission,

$$\tilde{D}^{(i_{Seg},u)}_{k,m,n,20} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ \tilde{d}^{(i_{Seg})}_{M^r_{20}(k),m,n,u}, \text{otherwise} \end{cases} \quad (21\text{-}96)$$

where

$M^r_{20}(k)$ is defined in Equation (21-49)

In a 40 MHz VHT transmission,

$$\tilde{D}^{(i_{Seg},u)}_{k,m,n,40} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 25, \pm 53 \\ \tilde{d}^{(i_{Seg})}_{M^r_{40}(k),m,n,u}, \text{otherwise} \end{cases} \quad (21\text{-}97)$$

where

$M^r_{40}(k)$ is defined in Equation (21-51)

In an 80 MHz transmission,

$$\tilde{D}^{(i_{Seg},u)}_{k,m,n,80} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 39, \pm 75, \pm 103 \\ \tilde{d}^{(i_{Seg})}_{M^r_{80}(k),m,n,u}, \text{otherwise} \end{cases} \quad (21\text{-}98)$$

where

$M^r_{80}(k)$ is defined in Equation (21-53)

In a 160 MHz transmission,

$$\tilde{D}^{(i_{Seg},u)}_{k,m,n,160} = \begin{cases} 0, k = 0, \pm 1, \pm 2, \pm 3, \pm 4, \pm 5, \pm 25, \pm 53, \pm 89, \pm 117, \pm 127, \pm 128, \pm 129, \pm 139, \pm 167, \pm 203, \pm 231 \\ \tilde{d}^{(i_{Seg})}_{M^r_{160}(k),m,n,u}, \text{otherwise} \end{cases} \quad (21\text{-}99)$$

where

$M^r_{160}(k)$ is defined in Equation (21-55)

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In an 80+80 MHz transmission, each frequency segment shall follow the 80 MHz VHT subcarrier mapping as specified in Equation (21-98) and Equation (21-53).

$Q_k^{(i_{Seg})}$ is a spatial mapping/steering matrix with N_{TX} rows and $N_{STS,total}$ columns for subcarrier k in frequency segment i_{Seg}. $Q_k^{(i_{Seg})}$ may be frequency dependent. Refer to the examples of Q_k listed in 19.3.11.11.2 for examples of $Q_k^{(i_{Seg})}$ that could be used for VHT SU PPDUs. Note that implementations are not restricted to the spatial mapping matrix examples listed in 19.3.11.11.2 and the number of transmit chains N_{TX} could be greater than 4. For VHT SU PPDUs to which beamforming is applied, $Q_k^{(i_{Seg})}$ is a beamforming steering matrix and is derived from the TXVECTOR parameter EXPANSION_MAT. For VHT MU PPDUs, $Q_k^{(i_{Seg})}$ is the DL-MU-MIMO steering matrix and is derived from the TXVECTOR parameter EXPANSION_MAT. The beamforming steering matrices and DL-MU-MIMO steering matrices are implementation specific.

21.3.10.12 Non-HT duplicate transmission

When the TXVECTOR parameter FORMAT is NON_HT and the TXVECTOR parameter NON_HT_MODULATION is NON_HT_DUP_OFDM, the transmitted PPDU is a non-HT duplicate. Non-HT duplicate transmission is used to transmit to non-HT OFDM STAs, HT STAs, or VHT STAs that may be present in a part of a 40 MHz, 80 MHz, or 160 MHz channel (see Table 21-2). The VHT-SIG-A, VHT-STF, VHT-LTF, and VHT-SIG-B fields are not transmitted. The L-STF, L-LTF, and L-SIG fields shall be transmitted in the same way as in the VHT transmission, with the exceptions for the Rate and Length fields which shall follow 17.3.4.

In a 40 MHz non-HT duplicate transmission, the Data field shall be as defined by Equation (19-61).

For 80 MHz and 160 MHz non-HT duplicate transmissions, the Data field shall be as defined by Equation (21-100).

$$r_{\text{non-HT},BW}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{\text{NON_HT_DUP_OFDM-Data}}^{\text{Tone}}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{i_{BW}=0}^{N_{20\text{MHz}}-1} \left(\sum_{k=-26}^{26} \Upsilon_{(k-K_{\text{Shift}}(i_{BW})),BW}(D_{k,n} + p_{n+1}P_k) \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{BW}))\Delta_F(t - nT_{SYM} - T_{GI} - T_{\text{CS}}^{i_{TX}})) \right) \quad (21\text{-}100)$$

where

$N_{20\text{MHz}}$ and $K_{\text{Shift}}(i)$	are defined in 21.3.8.2.4
P_k and p_n	are defined in 17.3.5.10
$D_{k,n}$	is defined in Equation (21-26)
$\Upsilon_{k,BW}$	is defined in Equation (21-16) and Equation (21-17)
$T_{\text{CS}}^{i_{TX}}$	represents the cyclic shift for transmitter chain i_{TX} with a value given in Table 21-10
$N_{\text{NON_HT_DUP_OFDM-Data}}^{\text{Tone}}$	has the value given in Table 21-8

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In an 80+80 MHz non-HT duplicate transmission, data transmission in each frequency segment shall be as defined for an 80 MHz non-HT duplicate transmission in Equation (21-100).

21.3.11 SU-MIMO and DL-MU-MIMO Beamforming

21.3.11.1 General

SU-MIMO and DL-MU-MIMO beamforming are techniques used by a STA with multiple antennas (the beamformer) to steer signals using knowledge of the channel to improve throughput. With SU-MIMO beamforming all space-time streams in the transmitted signal are intended for reception at a single STA. With DL-MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs.

For SU-MIMO beamforming, the steering matrix Q_k can be determined from the beamforming feedback matrix V_k that is sent back to the beamformer by the beamformee using the compressed beamforming feedback matrix format as defined in 19.3.12.3.6. The feedback report format is described in 9.4.1.49.

For DL-MU-MIMO beamforming, the receive signal vector in subcarrier k at beamformee u, $\boldsymbol{y}_{k,u} = [y_{k,0}, y_{k,1}, \ldots, y_{k,N_{RX_u}-1}]^T$, is shown in Equation (21-101), where $\boldsymbol{x}_k = [\boldsymbol{x}_{k,0}^T, \boldsymbol{x}_{k,1}^T, \ldots, \boldsymbol{x}_{k,N_{user}-1}^T]^T$ denotes the transmit signal vector in subcarrier k for all N_{user} beamformees, with $\boldsymbol{x}_{k,u} = [x_{k,0}, x_{k,1}, \ldots, x_{k,N_{STS,u}-1}]^T$ being the transmit signal for beamformee u.

$$\boldsymbol{y}_{k,u} = \boldsymbol{H}_{k,u} \times [Q_{k,0}, Q_{k,1}, \ldots, Q_{k,N_{user}-1}] \times \boldsymbol{x}_k + \boldsymbol{n} \quad (21\text{-}101)$$

where

$\boldsymbol{H}_{k,u}$ is the channel matrix from the beamformer to beamformee u in subcarrier k with dimensions $N_{RX_u} \times N_{TX}$

N_{RX_u} is the number of receive antennas at beamformee u

$Q_{k,u}$ is a steering matrix for beamformee u in subcarrier k with dimensions $N_{TX} \times N_{STS_u}$

N_{user} is the number of VHT MU PPDU recipients (see Table 21-6)

$\boldsymbol{n}$ is a vector of additive noise and may include interference

The DL-MU-MIMO steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \ldots, Q_{k,N_{user}-1}]$ can be determined by the beamformer using the beamforming feedback matrices for subcarrier k from beamformee u, $V_{k,u,}$ and SNR information for subcarrier k from beamformee u, $SNR_{k,u}$, where $u = 0, 1, \ldots, N_{user} - 1$. The steering matrix that is computed (or updated) using new beamforming feedback matrices and new SNR information from some or all of participating beamformees might replace the existing steering matrix Q_k for the next DL-MU-MIMO data transmission. The beamformee group for the MU transmission is signaled using the Group ID field in VHT-SIG-A (see 21.3.8.3.3 and 21.3.11.4).

21.3.11.2 Beamforming Feedback Matrix *V*

Upon receipt of a VHT NDP sounding PPDU, the beamformee shall remove the space-time stream CSD in Table 21-11 from the measured channel before computing a set of matrices for feedback to the beamformer. The beamforming feedback matrix, $V_{k,u}$, found by the beamformee u for subcarrier k shall be compressed in the form of angles using the method described in 19.3.12.3.6. The angles, $\phi(k,u)$ and $\psi(k,u)$, are quantized according to Table 9-74. The number of bits for quantization is chosen by the beamformee, based on the indication from the beamformer as to whether the feedback is requested for SU-MIMO beamforming or

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DL-MU-MIMO beamforming. The compressed beamforming feedback using 19.3.12.3.6 is the only Clause 21 beamforming feedback format defined.

The beamformee shall generate the beamforming feedback matrices with the number of rows (Nr) equal to the N_{STS} of the NDP.

After receiving the angle information, $\phi(k,u)$ and $\psi(k,u)$, the beamformer reconstructs $V_{k,u}$ using Equation (19-79). For SU-MIMO beamforming, the beamformer can use this $V_{k,0}$ matrix to determine the steering matrix Q_k. For DL-MU-MIMO beamforming, the beamformer may calculate a steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \ldots, Q_{k,N_{user}-1}]$ using $V_{k,u}$ and $SNR_{k,u}$ $(0 \le u \le N_{user} - 1)$ in order to suppress crosstalk between participating beamformees. The method used by the beamformer to calculate the steering matrix Q_k is implementation specific.

The beamformee decides the tone grouping and codebook size to be used in the beamforming feedback matrix V. A beamformer shall support all tone groups and codebook sizes.

21.3.11.3 Maximum Number of Total Spatial Streams in VHT MU PPDUs

An MU beamformee capable STA shall support reception of VHT MU PPDUs with the total number of space-time streams across the N_user users being less than or equal to the value indicated in the Maximum $N_{STS,total}$ subfield of the Supported VHT-MCS and NSS Set field of the VHT Capabilities element.

21.3.11.4 Group ID

A value in the Group ID field in VHT-SIG-A (see 21.3.8.3.3) in the range 1 to 62 indicates a VHT MU PPDU. Prior to transmitting a VHT MU PPDU, group assignments have been established by the AP for DL-MU-MIMO capable STAs using the Group ID Management frame as defined in 9.6.22.3.

After the PHY is configured using the PHYCONFIG_VECTOR parameter GROUP_ID_MANAGEMENT, the following lookup tables are populated:

a) Group ID to Membership Status, denoted by MembershipStatusInGroupID[g] for $1 \le g \le 62$
b) Group ID to User Position, denoted by UserPositionInGroupID[g] for $1 \le g \le 62$

When a STA receives a VHT MU PPDU where the Group ID field in VHT-SIG-A has the value k and where MembershipStatusInGroupID[k] is equal to 1, then the number of space-time streams for that STA is indicated in the MU[UserPositionInGroupID[k]] NSTS field in VHT-SIG-A. The space-time streams of different users are ordered in accordance to user position values, i.e., the space-time streams for the user in user position 0 come first, followed by the space-time streams for the user in position 1, followed by the space-time streams for the user in position 2, and followed by the space-time streams for the user in position 3.

A STA is also able to identify the space-time streams intended for other STAs that act as interference. VHT-LTF symbols in the VHT MU PPDU are used to measure the channel for the space-time streams intended for the STA and can also be used to measure the channel for the interfering space-time streams. To successfully demodulate the space-time streams intended for the STA, the STA may use the channel state information for all space-time streams to reduce the effect of interfering space-time streams.

If a STA finds that it is not a member of the group, or the STA is a member of the group but the corresponding MU NSTS field in VHT-SIG-A indicates that there are zero space-time streams for the STA in the PPDU, then the STA may elect to not process the remainder of the PPDU.

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21.3.12 VHT preamble format for sounding PPDUs

NDP is the only VHT sounding format.

The format of a VHT NDP is shown in Figure 21-28.

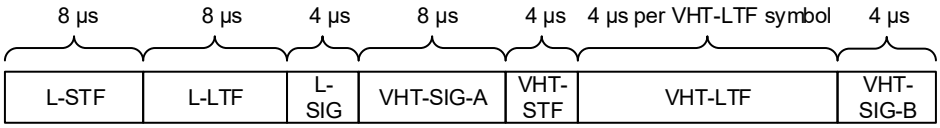

Figure 21-28—VHT NDP format

NOTE—The number of VHT-LTF symbols in the NDP is determined by the SU NSTS field in VHT-SIG-A.

The VHT NDP has the following properties:

— Uses the VHT PPDU format but without the Data field.
— Is a VHT SU PPDU as indicated by the VHT-SIG-A field.
— Has the data bits of the VHT-SIG-B field set to a fixed bit pattern (see 21.3.8.3.6).

21.3.13 Regulatory requirements

Wireless LANs (WLANs) implemented in accordance with this standard are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The PHY specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regulations are subject to revision or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PHY specification. Regulatory requirements that do not affect interoperability are not addressed in this standard. Implementers are referred to the regulatory sources in Annex D for further information. Operation in countries within defined regulatory domains might be subject to additional or alternative national regulations.

21.3.14 Channelization

A VHT channel is specified by the four PLME MIB fields specified in Table 21-22.

Given dot11CurrentChannelCenterFrequencyIndex0 and dot11CurrentChannelCenterFrequencyIndex1, the respective channel center frequency is given by Equation (21-102).

$$\text{Channel center frequency [MHz]} = \text{Channel starting frequency} + 5 \times \text{dot11CurrentChannelCenterFrequencyIndex} \quad (21\text{-}102)$$

where

Channel starting frequency is given by the operating class (Annex E)

dot11CurrentChannelCenterFrequencyIndex is either dot11CurrentChannelCenterFrequencyIndex0 or dot11CurrentChannelCenterFrequencyIndex1

The center frequency of the primary 20 MHz channel is given by Equation (21-103).

$$\text{Primary 20 MHz channel center frequency [MHz]} = \text{Channel starting frequency} + 5 \times \text{dot11CurrentPrimaryChannel} \quad (21\text{-}103)$$

where

Channel starting frequency is defined as dot11ChannelStartingFactor × 500 kHz.

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Table 21-22—Fields to specify VHT channels

Field	Meaning
dot11CurrentChannelWidth	Channel width. Possible values represent 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz channels.
dot11CurrentChannelCenterFrequencyIndex0	For a 20 MHz, 40 MHz, 80 MHz, or 160 MHz channel, denotes the channel center frequency. For an 80+80 MHz channel, denotes the center frequency of the frequency segment 0, which is the frequency segment containing the primary channel. Valid range is 1 to 200. See Equation (21-102).
dot11CurrentChannelCenterFrequencyIndex1	For an 80+80 MHz channel, denotes the center frequency of the frequency segment 1, which is the frequency segment that does not contain the primary channel. Valid range is 1 to 200. See Equation (21-102). For a 20 MHz, 40 MHz, 80 MHz, or 160 MHz channel, set to 0.
dot11CurrentPrimaryChannel	Denotes the location of the primary 20 MHz channel. Valid range is 1 to 200. See Equation (21-103).

A channel center frequency of 5 GHz shall be indicated by dot11ChannelStartingFactor = 8000 and dot11CurrentPrimaryChannel = 200.

For an 80+80 MHz channel, any two channels that would each be allowed as 80 MHz channels and whose center frequencies are separated by greater than 80 MHz (difference between dot11CurrentChannelCenterFrequencyIndex0 and dot11CurrentChannelCenterFrequencyIndex1 corresponds to a frequency difference greater than 80 MHz) may be used.

For example, a channel specified by

Channel starting frequency = 5000 MHz
dot11CurrentChannelWidth = 80 MHz
dot11CurrentChannelCenterFrequencyIndex0 = 42
dot11CurrentPrimaryChannel = 36

is an 80 MHz channel with a center frequency of 5210 MHz and the primary 20 MHz channel centered at 5180 MHz.

A channel specified by

Channel starting frequency = 5000 MHz
dot11CurrentChannelWidth = 160 MHz
dot11CurrentChannelCenterFrequencyIndex0 = 50
dot11CurrentPrimaryChannel = 56

is a 160 MHz channel with a center frequency of 5250 MHz and the primary 20 MHz channel centered at 5280 MHz.

A channel specified by

Channel starting frequency = 5000 MHz
dot11CurrentChannelWidth = 80+80 MHz
dot11CurrentChannelCenterFrequencyIndex0 =155
dot11CurrentChannelCenterFrequencyIndex1 = 106
dot11CurrentPrimaryChannel = 161

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is an 80+80 MHz channel in which frequency segment 0 has 80 MHz bandwidth and center frequency of 5775 MHz. Frequency segment 1 also has 80 MHz bandwidth and center frequency of 5530 MHz. The primary 20 MHz channel is centered at 5805 MHz.

21.3.15 Slot time

The slot time for the VHT PHY shall be 9 μs for 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz channel spacing.

21.3.16 Transmit and receive port impedance

Transmit and receive antenna connector impedance for each transmit and receive antenna is defined in 17.3.8.7.

21.3.17 VHT transmit specification

21.3.17.1 Transmit spectrum mask

NOTE 1—In the presence of additional regulatory restrictions, the device has to meet both the regulatory requirements and the mask defined in this subclause.

NOTE 2—Transmit spectral mask figures in this subclause are not drawn to scale.

NOTE 3—For rules regarding TX center frequency leakage levels, see 21.3.17.4.2. The spectral mask requirements in this subclause do not apply to the RF LO.

For a 20 MHz mask PPDU of non-HT, HT or VHT format the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 9 and 11 MHz, 11 and 20 MHz, and 20 and 30 MHz shall be linearly interpolated in dB domain from the requirements for 9 MHz, 11 MHz, 20 MHz, and 30 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –53 dBm/MHz at any frequency offset. Figure 21-29 shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –53 dBm/MHz.

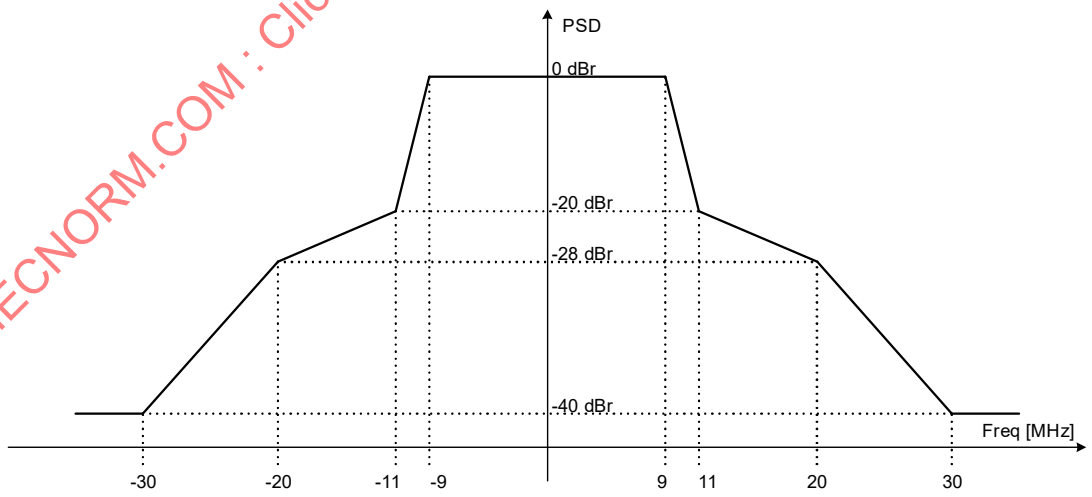

Figure 21-29—Example transmit spectral mask for 20 MHz mask PPDU

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For a 40 MHz mask PPDU of non-HT, non-HT duplicate, HT or VHT format, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 38 MHz, –20 dBr at 21 MHz frequency offset, –28 dBr at 40 MHz frequency offset, and –40 dBr at 60 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 19 and 21 MHz, 21 and 40 MHz, and 40 and 60 MHz shall be linearly interpolated in dB domain from the requirements for 19 MHz, 21 MHz, 40 MHz, and 60 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –56 dBm/MHz at any frequency offset greater than 19 MHz. Figure 21-30 shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –56 dBm/MHz.

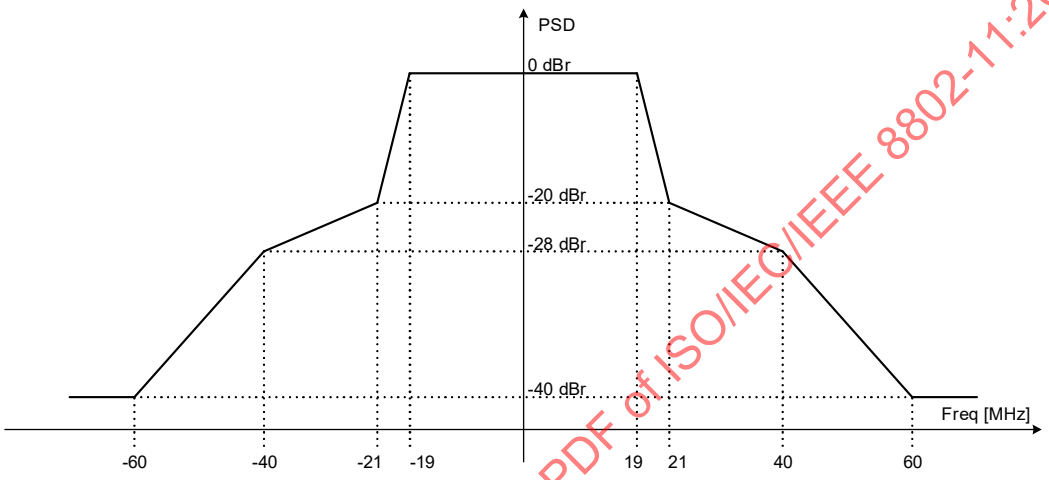

Figure 21-30—Example transmit spectral mask for 40 MHz mask PPDU

For an 80 MHz mask PPDU of non-HT, non-HT duplicate, HT or VHT format, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 78 MHz, –20 dBr at 41 MHz frequency offset, –28 dBr at 80 MHz frequency offset, and –40 dBr at 120 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 39 and 41 MHz, 41 and 80 MHz, and 80 and 120 MHz shall be linearly interpolated in dB domain from the requirements for 39 MHz, 41 MHz, 80 MHz, and 120 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectrum mask and –59 dBm/MHz at any frequency offset. Figure 21-31 shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –59 dBm/MHz.

For a 160 MHz mask PPDU of non-HT, non-HT duplicate, HT or VHT format, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 158 MHz, –20 dBr at 81 MHz frequency offset, –28 dBr at 160 MHz frequency offset, and –40 dBr at 240 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 79 and 81 MHz, 81 and 160 MHz, and 160 and 240 MHz shall be linearly interpolated in dB domain from the requirements for 79 MHz, 81 MHz, 160 MHz, and 240 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectrum mask and –59 dBm/MHz at any frequency offset. Figure 21-32 shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –59 dBm/MHz.

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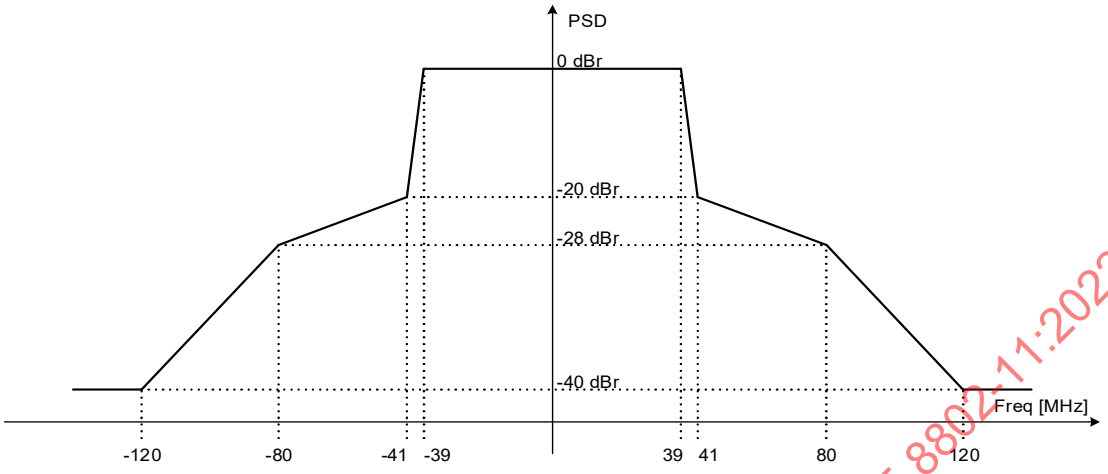

Figure 21-31—Example transmit spectral mask for 80 MHz mask PPDU

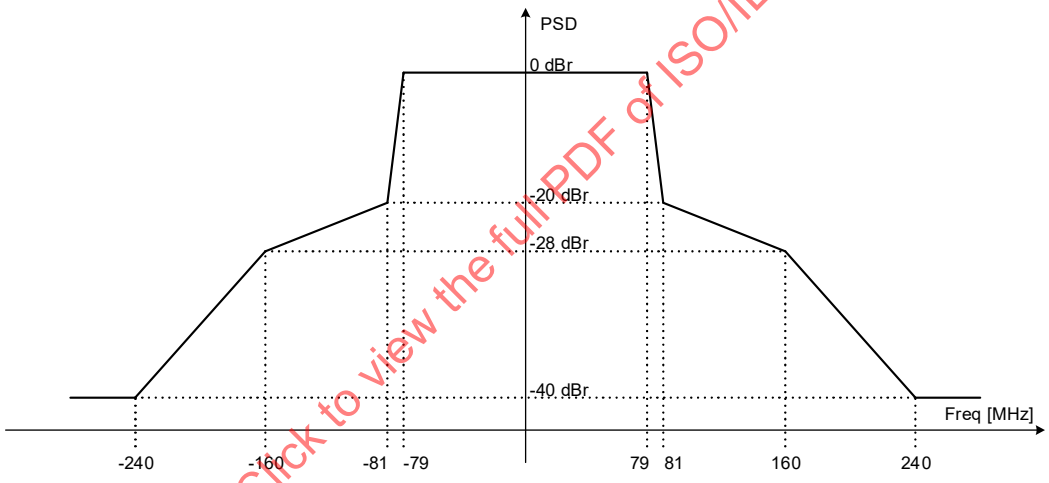

Figure 21-32—Example transmit spectral mask for 160 MHz mask PPDU

For an 80+80 MHz mask PPDU of non-HT duplicate or VHT format, the overall transmit spectral mask is constructed in the following manner. First, the 80 MHz interim spectral mask is placed on each of the two 80 MHz frequency segments. Then, for each frequency at which both of the 80 MHz interim spectral masks have values greater than –40 dBr and less than –20 dBr, the sum of the two interim mask values (summed in linear domain) shall be taken as the overall spectral mask value. Next, for each frequency at which neither of the two 80 MHz interim masks have values greater than or equal to –20 dBr and less than or equal to 0 dBr, the higher value of the two interim masks shall be taken as the overall interim spectral value. Finally, for any frequency region where the mask value has not been defined yet, linear interpolation (in dB domain) between the nearest two frequency points with the interim spectral mask value defined shall be used to define the interim spectral mask value. The transmit spectrum shall not exceed the maximum of the interim transmit spectrum mask and –59 dBm/MHz at any frequency offset. Figure 21-33 shows an example of a transmit spectral mask for a noncontiguous transmission using two 80 MHz channels where the center frequency of the two 80 MHz channels are separated by 160 MHz and the –40 dBr spectrum level is above –59 dBm/MHz.

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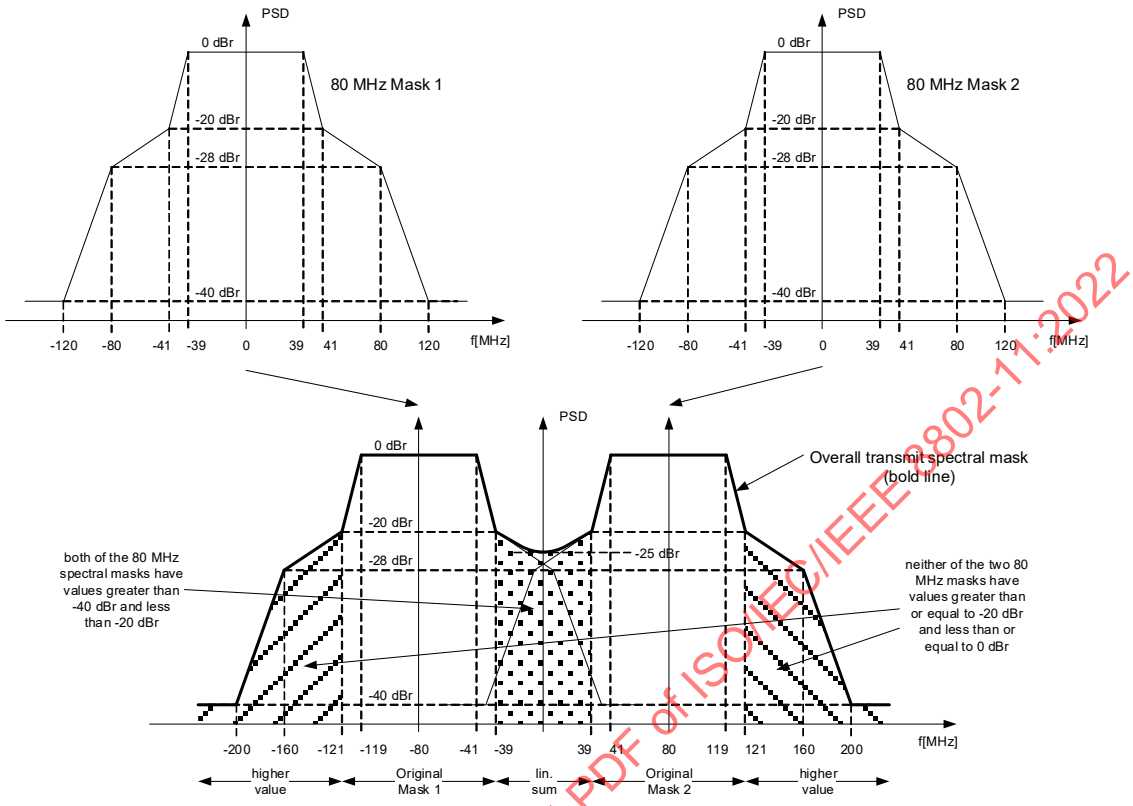

Figure 21-33—Example transmit spectral mask for 80+80 MHz mask PPDU

Different center frequency separation between the two 80 MHz frequency segments of the spectral mask as well as different peak levels of each 80 MHz frequency segment of the spectral mask are possible, in which case a similar procedure in determining the spectral mask as in Figure 21-33 is followed.

The transmit spectral mask for noncontiguous transmissions using two nonadjacent 80 MHz channels is applicable only in regulatory domains that allow for such transmissions.

Measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

21.3.17.2 Spectral flatness

Spectral flatness measurements shall be conducted using BPSK modulated PPDUs. Demodulate the PPDUs according to the following (or equivalent) procedure:

a) Start of PPDU shall be detected.
b) Transition from L-STF to L-LTF shall be detected and fine timing shall be established.
c) Coarse and fine frequency offsets shall be estimated.
d) Symbols in a PPDU shall be derotated according to estimated frequency offset.
e) For each VHT-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and derotate the subcarrier values according to the estimated phase.
f) For each of the data OFDM symbols: transform the symbol into subcarrier received values.

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The spectral flatness test shall be performed over at least 20 PPDUs. The PPDUs under test shall be at least 16 data OFDM symbols long.

Evaluate spectral flatness using the subcarrier received values or the magnitude of the channel estimation.

Let $E_{i,\,avg}$ denote the magnitude of the channel estimation on subcarrier i or the average constellation energy of a BPSK modulated subcarrier i in a VHT data symbol.

In a contiguous non-HT duplicate or VHT transmission having a bandwidth listed in Table 21-23, $E_{i,\,avg}$ of each of the subcarriers with indices listed as tested subcarrier indices shall not deviate by more than the specified maximum deviation in Table 21-23 from the average of $E_{i,\,avg}$ over subcarrier indices listed as averaging subcarrier indices. Averaging of $E_{i,\,avg}$ is done in the linear domain.

Table 21-23—Maximum transmit spectral flatness deviations

Format	Bandwidth of transmission (MHz)	Averaging subcarrier indices	Tested subcarrier indices	Maximum deviation (dB)
VHT	20	–16 to –1 and +1 to +16	–16 to –1 and +1 to +16	± 4
			–28 to –17 and +17 to +28	+4/–6
	40	–42 to –2 and +2 to +42	–42 to –2 and +2 to +42	± 4
			–58 to –43 and +43 to +58	+4/–6
	80	–84 to –2 and +2 to +84	–84 to –2 and +2 to +84	± 4
			–122 to –85 and +85 to +122	+4/–6
	160	–172 to –130, –126 to –44, +44 to +126, and +130 to +172	–172 to –130, –126 to –44, +44 to +126, and +130 to +172	± 4
			–250 to –173, –43 to –6, +6 to +43, and +173 to +250	+4/–6
non-HT duplicate	40	–42 to –33, –31 to –6, +6 to +31, and +33 to +42	–42 to –33, –31 to –6, +6 to +31, and +33 to +42	± 4
			–43 to –58 and +43 to +58	+4/–6
	80	–84 to –70, –58 to –33, –31 to –6, +6 to +31, +33 to +58, +70 to +84	–84 to –70,–58 to –33, –31 to –6, +6 to +31, +33 to +58, +70 to +84	± 4
			–122 to –97, –95 to –85 and +85 to +95, +97 to +122	+4/–6
	160	–172 to –161, –159 to –134, –122 to –97, –95 to –70, –58 to –44, +44 to +58, +70 to +95, +97 to +122, +134 to +159, +161 to +172	–172 to –161, –159 to –134, –122 to –97, –95 to –70, –58 to –44, +44 to +58, +70 to +95, +97 to +122, +134 to +159, +161 to +172	± 4
			–250 to –225, –223 to –198, –186 to –173, –43 to –33, –31 to –6, +6 to +31, +33 to +43, +173 to +186, +198 to +223, +225 to +250	+4/–6

In an 80+80 MHz transmission, each segment shall meet the spectral flatness requirement for an 80 MHz transmission.

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For the spectral flatness test, the transmitting STA shall be configured to use a spatial mapping matrix Q_k (see 21.3.10.11) with flat frequency response. Each output port under test of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The requirements apply to 20 MHz, 40 MHz, 80 MHz, and 160 MHz contiguous transmissions as well as 80+80 MHz transmissions.

21.3.17.3 Transmit center frequency and symbol clock frequency tolerance

The symbol clock frequency and transmit center frequency tolerance shall be ± 20 ppm. The transmit center frequency and the symbol clock frequency for all transmit antennas and frequency segments shall be derived from the same reference oscillator. Transmit signals with the TXVECTOR parameter CH_BANDWIDTH set to CBW160 or CBW80+80 may be generated using two separate RF LOs, one for each of the lower and upper 80 MHz frequency portions.

NOTE—The signal phase of the two 80 MHz frequency portions might not be correlated.

21.3.17.4 Modulation accuracy

21.3.17.4.1 Introduction to modulation accuracy tests

Transmit modulation accuracy specifications are described in 21.3.17.4.2 and 21.3.17.4.3. The test method is described in 21.3.17.4.4.

21.3.17.4.2 Transmit center frequency leakage

TX LO leakage shall meet the following requirements for all formats and bandwidths except 80+80 MHz where the RF LO falls outside both frequency segments:

— When the RF LO is in the center of the transmitted PPDU BW, the power measured at the center of transmission BW using resolution BW 312.5 kHz shall not exceed the maximum of the average power per-subcarrier of the transmitted PPDU and –20 dBm, or equivalently, $max(P - 10\log 10(N_{ST}), -20)$, where P is the transmit power per antenna in dBm, and N_{ST} is defined in Table 21-5.

— When the RF LO is not at the center of the transmitted PPDU BW, the power measured at the location of the RF LO using resolution BW 312.5 kHz shall not exceed the maximum of –32 dB relative to the total transmit power and –20 dBm, or equivalently $max(P - 32, -20)$, where P is the transmit power per antenna in dBm.

For an 80+80 MHz transmission where the RF LO falls outside both frequency segments, the RF LO shall follow the spectral mask requirements as defined in 21.3.17.1.

The transmit center frequency leakage is specified per antenna.

21.3.17.4.3 Transmitter constellation error

The relative constellation RMS error, calculated by first averaging over subcarriers, frequency segments, VHT PPDUs, and spatial streams [see Equation (19-89)] shall not exceed a data-rate dependent value according to Table 21-24. The number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized testing instrumentation input ports. In the test, $N_{SS} = N_{STS}$ (no STBC) shall be used and no beamforming steering matrix shall be used. Each output port of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The requirements apply to 20 MHz, 40 MHz, 80 MHz, and 160 MHz contiguous transmissions as well as 80+80 MHz noncontiguous transmissions.

For non-HT duplicate transmissions, requirements defined in 17.3.9.7.4 apply to each 20 MHz subchannel.

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Table 21-24—Allowed relative constellation error versus constellation size and coding rate

Modulation	Coding rate	Relative constellation error (dB)
BPSK	1/2	–5
QPSK	1/2	–10
QPSK	3/4	–13
16-QAM	1/2	–16
16-QAM	3/4	–19
64-QAM	2/3	–22
64-QAM	3/4	–25
64-QAM	5/6	–27
256-QAM	3/4	–30
256-QAM	5/6	–32

21.3.17.4.4 Transmitter modulation accuracy (EVM) test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signals into a stream of complex samples at sampling rate greater than or equal to the bandwidth of the signal being transmitted; except that

— For non-HT duplicate transmissions, each 20 MHz subchannel may be tested independently while all subchannels are being transmitted and

— For noncontiguous transmissions, each frequency segment may be tested independently while both segments are being transmitted.

In this case, transmit modulation accuracy of each segment shall meet the required value in Table 21-24 using only the subcarriers within the corresponding segment.

The instrument shall have sufficient accuracy in terms of I/Q arm amplitude and phase balance, DC offsets, phase noise, and analog to digital quantization noise. A possible embodiment of such a setup is converting the signals to a low IF frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components. The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or equivalent procedure:

a) Start of PPDU shall be detected.
b) Transition from L-STF to L-LTF shall be detected and fine timing shall be established.
c) Coarse and fine frequency offsets shall be estimated.
d) Symbols in a PPDU shall be derotated according to estimated frequency offset.
e) For each VHT-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and derotate the subcarrier values according to the estimated phase.
f) Estimate the complex channel response coefficient for each of the subcarriers and each of the transmit streams.

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g) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, derotate the subcarrier values according to the estimated phase, group the results from all of the receiver chains in each subcarrier to a vector, and multiply the vector by a zero-forcing equalization matrix generated from the estimated channel.

h) For each data-carrying subcarrier in each spatial stream, find the closest constellation point and compute the Euclidean distance from it.

i) Compute the average across PPDUs of the RMS of all errors per PPDU as given by Equation (19-89).

NOTE—In the case the transmit modulation accuracy test is performed simultaneously for the two frequency segments of the 80+80 MHz transmissions, N_{ST} in Equation (19-89) represents the total number of subcarriers of both 80 MHz frequency segments.

The test shall be performed over at least 20 PPDUs [N_f as defined in Equation (19-89)]. The PPDUs under test shall be at least 16 data OFDM symbols long. Random data shall be used for the symbols.

21.3.17.5 Time of Departure accuracy

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is

$20 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{20\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW20

$40 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{40\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW40

$80 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{80\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW80

$160 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{160\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW160 or CBW80+80

where

f_H is the nominal center frequency in Hz of the highest channel in the channel set

f_L is the nominal center frequency in Hz of the lowest channel in the channel set, the channel set is the set of channels upon which frames providing measurements are transmitted, the channel set comprises channels uniformly spaced across $f_H - f_L \leq 50$ MHz

— FIRST_TRANSITION_FIELD is L-STF.

— SECOND_TRANSITION_FIELD is L-LTF.

— TRAINING_FIELD is L-LTF windowed in a manner which should approximate the windowing described in 17.3.2.5 with TTR = 100 ns.

— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns.

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

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21.3.18 VHT receiver specification

For tests in this subclause, the input levels are measured at the antenna connector and are referenced as the average power per receive antenna. The number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized Device Under Test input ports. Each output port of the transmitting STA shall be connected through a cable to one input port of the Device Under Test.

21.3.18.1 Receiver minimum input sensitivity

The packet error ratio (PER) shall be less than 10% for a PSDU length of 4096 octets with the rate-dependent input levels listed in Table 21-25. The test in this subclause and the minimum sensitivity levels specified in Table 21-25 apply only to non-STBC modes, 800 ns GI, BCC, and VHT PPDUs.

Table 21-25—Receiver minimum input level sensitivity

Modulation	Rate (R)	Minimum sensitivity (20 MHz PPDU) (dBm)	Minimum sensitivity (40 MHz PPDU) (dBm)	Minimum sensitivity (80 MHz PPDU) (dBm)	Minimum sensitivity (160 MHz or 80+80 MHz PPDU) (dBm)
BPSK	1/2	–82	–79	–76	–73
QPSK	1/2	–79	–76	–73	–70
QPSK	3/4	–77	–74	–71	–68
16-QAM	1/2	–74	–71	–68	–65
16-QAM	3/4	–70	–67	–64	–61
64-QAM	2/3	–66	–63	–60	–57
64-QAM	3/4	–65	–62	–59	–56
64-QAM	5/6	–64	–61	–58	–55
256-QAM	3/4	–59	–56	–53	–50
256-QAM	5/6	–57	–54	–51	–48

21.3.18.2 Adjacent channel rejection

Adjacent channel rejection for W MHz channels (where W is 20, 40, 80 or 160) shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 21-25 and raising the power of the interfering signal of W MHz bandwidth until 10% PER is caused for a PSDU length of 4096 octets. The difference in power between the signals in the interfering channel and the desired channel is the corresponding adjacent channel rejection. The center frequency of the adjacent channel shall be placed W MHz away from the center frequency of the desired signal.

Adjacent channel rejection for 80+80 MHz channels shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 21-25. Then, an interfering signal of 80 MHz bandwidth is introduced, where the center frequency of the interfering signal is placed 80 MHz away from the center frequency of the frequency segment lower in frequency of the desired signal. The power of the interfering signal is raised until 10% PER is caused for a PSDU length of 4096 octets. Let ΔP_1

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be the power difference between the interfering and desired signal. Next, the interfering signal of 80 MHz bandwidth is moved to a frequency where the center frequency of the interfering signal is 80 MHz away from the center frequency of the frequency segment higher in frequency of the desired signal. The power of the interfering signal is raised until 10% PER is caused for a PSDU length of 4096 octets. Let ΔP_2 be the power difference between the interfering and desired signal. The smaller value between ΔP_1 and ΔP_2 is the corresponding adjacent channel rejection.

The interfering signal in the adjacent channel shall be a signal compliant with the VHT PHY, unsynchronized with the signal in the channel under test, and shall have a minimum duty cycle of 50%. The corresponding rejection shall be no less than specified in Table 21-26.

The test in this subclause and the adjacent sensitivity levels specified in Table 21-26 apply only to non-STBC modes, 800 ns GI, BCC, and VHT PPDUs.

Table 21-26—Minimum required adjacent and nonadjacent channel rejection levels

Modulation	Rate (R)	Adjacent channel rejection (dB)		Nonadjacent channel rejection (dB)	
		20/40/80/ 160 MHz Channel	80+80 MHz Channel	20/40/80/ 160 MHz Channel	80+80 MHz Channel
BPSK	1/2	16	13	32	29
QPSK	1/2	13	10	29	26
QPSK	3/4	11	8	27	24
16-QAM	1/2	8	5	24	21
16-QAM	3/4	4	1	20	17
64-QAM	2/3	0	–3	16	13
64-QAM	3/4	–1	–4	15	12
64-QAM	5/6	–2	–5	14	11
256-QAM	3/4	–7	–10	9	6
256-QAM	5/6	–9	–12	7	4

The measurement of adjacent channel rejection for 160 MHz operation in a regulatory domain is required only if such a frequency band plan is permitted in that regulatory domain.

21.3.18.3 Nonadjacent channel rejection

Nonadjacent channel rejection for W MHz channels (where W is 20, 40, 80, or 160) shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 21-25, and raising the power of the interfering signal of W MHz bandwidth until a 10% PER occurs for a PSDU length of 4096 octets. The difference in power between the signals in the interfering channel and the desired channel is the corresponding nonadjacent channel rejection. The nonadjacent channel rejection shall be met with any nonadjacent channels located at least $2\times W$ MHz away from the center frequency of the desired signal.

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Nonadjacent channel rejection for 80+80 MHz channels shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 21-25. Then, an interfering signal of 80 MHz bandwidth is introduced, where the center frequency of the interfering signal is placed at least 160 MHz away from the center frequency of the frequency segment lower in frequency of the desired signal. The center frequency of the interfering signal shall also be at least 160 MHz away from the center frequency of the frequency segment higher in frequency of the desired signal. The power of the interfering signal is raised until 10% PER is caused for a PSDU length of 4096 octets. Let ΔP_1 be the power difference between the interfering and desired signal. Next, the interfering signal of 80 MHz bandwidth is moved to a frequency where the center frequency of the interfering signal is at least 160 MHz away from the center frequency of the frequency segment higher in frequency of the desired signal. The center frequency of the interfering signal shall also be at least 160 MHz away from the center frequency of the frequency segment lower in frequency of the desired signal. The power of the interfering signal is raised until 10% PER is caused for a PSDU length of 4096 octets. Let ΔP_2 be the difference in power between the signals in the interfering channel and the desired channel. The smaller value between ΔP_1 and ΔP_2 is the corresponding nonadjacent channel rejection.

The interfering signal in the nonadjacent channel shall be a signal compliant with the VHT PHY, unsynchronized with the signal in the channel under test, and shall have a minimum duty cycle of 50%. The corresponding rejection shall be no less than specified in Table 21-26.

The test in this subclause and the nonadjacent sensitivity levels specified in Table 21-26 apply only to non-STBC modes, 800 ns GI, BCC, and VHT PPDUs.

The measurement of nonadjacent channel rejection for 160 MHz operation in a regulatory domain is required only if such a frequency band plan is permitted in that regulatory domain.

21.3.18.4 Receiver maximum input level

The receiver shall provide a maximum PER of 10% at a PSDU length of 4096 octets, for a maximum input level of –30 dBm, measured at each antenna for any baseband VHT modulation.

21.3.18.5 CCA sensitivity

21.3.18.5.1 General

The thresholds in this subclause are compared with the signal level at each receiving antenna.

21.3.18.5.2 CCA sensitivity for operating classes requiring CCA-ED

For the operating classes requiring CCA-Energy Detect (CCA-ED), the PHY shall also indicate a medium busy condition when CCA-ED detects a channel busy condition.

For improved spectrum sharing, CCA-ED is required in some bands. The behavior class indicating CCA-ED is given in Table D-2. The operating classes requiring the corresponding CCA-ED behavior class are given in E-1. The PHY of a STA that is operating within an operating class that requires CCA-ED shall operate with CCA-ED.

CCA-ED shall detect a channel busy condition when the received signal strength exceeds the CCA-ED threshold as given by dot11OFDMEDThreshold for the primary 20 MHz channel, dot11OFDMEDThreshold for the secondary 20 MHz channel (if present), dot11OFDMEDThreshold + 3 dB for the secondary 40 MHz channel (if present), and dot11OFDMEDThreshold + 6 dB for the secondary 80 MHz channel (if present). The CCA-ED thresholds for the operating classes requiring CCA-ED are subject to the criteria in D.2.5.

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NOTE—The requirement to detect a channel busy condition as stated in 21.3.18.5.3 and 21.3.18.5.4 is a mandatory energy detect requirement on all Clause 21 receivers. Support for CCA-ED is an additional requirement that relates specifically to the sensitivities described in D.2.5.

21.3.18.5.3 CCA sensitivity for signals occupying the primary 20 MHz channel

A VHT STA with a *W* MHz operating channel width shall detect, with >90% probability, the start of a PPDU that occupies at least the primary 20 MHz channel in an otherwise idle *W* MHz operating channel width, and issue a PHY-CCA.indication(BUSY, {primary}) primitive within a period of aCCATime (see 21.4.4) if one of the following conditions is met:

— The start of a non-HT PPDU as defined in 17.3.10.6.
— The start of an HT PPDU as defined in 19.3.19.5.
— The start of a non-HT duplicate or VHT PPDU for which the power measured within the primary 20 MHz channel is or above –82 dBm.

The CCA signal shall be held busy (PHY-CCA.indication(BUSY, {primary}) primitive) for the duration of the PPDU.

The receiver shall issue a PHY-CCA.indication(BUSY, {primary}) primitive for any signal that exceeds a threshold equal to 20 dB above the minimum modulation and coding rate sensitivity (–82 + 20 = –62 dBm) in the primary 20 MHz channel within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the receiver shall not issue a PHY-CCA.indication(BUSY,{secondary}), PHY-CCA.indication(BUSY,{secondary40}), PHY-CCA.indication(BUSY,{secondary80}), or PHY-CCA.indication(IDLE) primitive while the threshold continues to be exceeded.

21.3.18.5.4 CCA sensitivity for signals not occupying the primary 20 MHz channel

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary}) primitive if the conditions for issuing PHY-CCA.indication(BUSY, {primary}) primitive are not present and one of the following conditions are present in an otherwise idle 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz operating channel width:

— Any signal within the secondary 20 MHz channel at or above a threshold of –62 dBm within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the PHY shall not issue a PHY-CCA.indication(BUSY,{secondary40}), PHY-CCA.indication(BUSY,{secondary80}), or PHY-CCA.indication(IDLE) primitive while the threshold continues to be exceeded.
— A 20 MHz NON_HT, HT_MF, HT_GF or VHT PPDU detected in the secondary 20 MHz channel at or above –72 dBm with >90% probability within a period aCCAMidTime (see 21.4.4).

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary40}) primitive if the conditions for issuing a PHY-CCA.indication(BUSY, {primary}) and PHY-CCA.indication(BUSY, {secondary}) primitive are not present and one of the following conditions are present in an otherwise idle 80 MHz, 160 MHz, or 80+80 MHz operating channel width:

— Any signal within the secondary 40 MHz channel at or above a threshold of –59 dBm within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the PHY shall not issue a PHY-CCA.indication(BUSY, {secondary80}) primitive or PHY-CCA.indication(IDLE) primitive while the threshold continues to be exceeded.
— A 40 MHz non-HT duplicate, HT_MF, HT_GF or VHT PPDU detected in the secondary 40 MHz channel at or above –72 dBm with >90% probability within a period aCCAMidTime (see 21.4.4).
— A 20 MHz non-HT, HT_MF, HT_GF or VHT PPDU detected in any 20 MHz subchannel of the secondary 40 MHz channel at or above –72 dBm with >90% probability within a period aCCAMidTime.

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The PHY shall issue a PHY-CCA.indication(BUSY, {secondary80}) primitive if the conditions for PHYCCA.indication(BUSY, {primary}), PHY-CCA.indication(BUSY, {secondary}), and PHY-CCA.indication(BUSY, {secondary40}) primitive are not present and one of the following conditions are present in an otherwise idle 160 MHz or 80+80 MHz operating channel width:

— Any signal within the secondary 80 MHz channel at or above –56 dBm.

— An 80 MHz non-HT duplicate or VHT PPDU detected in the secondary 80 MHz channel at or above –69 dBm with >90% probability within a period aCCAMidTime (see 21.4.4).

— A 40 MHz non-HT duplicate, HT_MF, HT_GF or VHT PPDU detected in any 40 MHz subchannel of the secondary 80 MHz channel at or above –72 dBm with >90% probability within a period aCCAMidTime.

— A 20 MHz NON_HT, HT_MF, HT_GF or VHT PPDU detected in any 20 MHz subchannel of the secondary 80 MHz channel at or above –72 dBm with >90% probability within a period aCCAMidTime.

21.3.18.6 RSSI

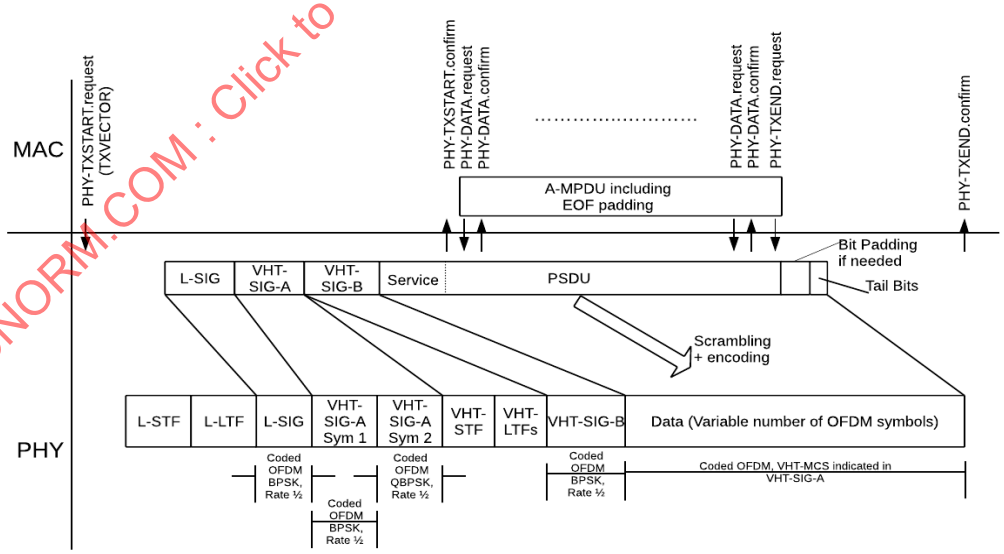
The RSSI parameter returned in the RXVECTOR shall be calculated during the reception of the VHT-LTFs and shall be a monotonically increasing function of the received power.

21.3.19 PHY transmit procedure

There are two paths for the transmit PHY procedure:

— The first path, for which typical transmit procedures are shown in Figure 21-34, is selected if the FORMAT parameter of the PHY-TXSTART.request(TXVECTOR) primitive is VHT. These transmit procedures do not describe the operation of optional features, such as LDPC, STBC or MU.

— The second path is to follow the transmit procedure in Clause 17 if the FORMAT parameter of the PHY-TXSTART.request(TXVECTOR) primitive is NON_HT and the NON_HT_MODULATION parameter is set to NON_HT_DUP_OFDM except that the signal referred to in Clause 17 is instead generated simultaneously on each of the 20 MHz channels that are indicated by the CH_BANDWIDTH parameter as defined in 21.3.8 and 21.3.10.12.



NOTE—This procedure does not describe the operation of optional features, such as MU-MIMO, LDPC or STBC.

Figure 21-34—PHY transmit procedure for SU transmission

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NOTE 1—For a VHT MU PPDU the A-MPDU is per user in the MAC sublayer and the VHT-STF, VHT-LTFs, VHT-SIG-B, and Data are per user in the PHY in Figure 21-34, with the number of VHT-LTF symbols depending on the total number of space-time streams across all users.

NOTE 2—The transmit procedure for NON_HT format where NON_HT_MODULATION is OFDM is specified in 21.2.5.2. The transmit procedure for HT_MF and HT_GF formats is specified in 21.2.5.3.

In both paths, in order to transmit data, the MAC generates a PHY-TXSTART.request primitive, which causes the PHY entity to enter the transmit state. Further, the PHY is set to operate at the appropriate frequency through station management via the PLME, as specified in 21.4. Other transmit parameters, such as VHT-MCS Coding types and transmit power, are set via the PHY SAP using the PHY-TXSTART.request(TXVECTOR) primitive, as described in 21.2.2. The remainder of the clause applies to the first path.

The PHY indicates the state of the primary channel and other channels (if any) via the PHY-CCA.indication primitive (see 21.3.18.5 and 8.3.5.12). Transmission of the PPDU shall be initiated by the PHY after receiving the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request primitive are specified in Table 21-1.

Transmission of the PHY preamble may start if TIME_OF_DEPARTURE_REQUESTED is false, and shall start immediately if TIME_OF_DEPARTURE_REQUESTED is true, based on the parameters passed in the PHY-TXSTART.request primitive.

If all of the following conditions are met:

— If dot11TODImplemented and dot11TODActivated are true or if dot11TimingMsmtActivated is true,
— The TXVECTOR parameter TIME_OF_DEPARTURE_REQUESTED is true,

then the PHY shall issue a PHY-TXSTART.confirm primitive to the MAC, forwarding the TIME_OF_DEPARTURE corresponding to the time when the first frame energy is sent by the transmitting port and TIME_OF_DEPARTURE_ClockRate parameter within the TXSTATUS. If dot11TimingMsmtActivated is true, then the PHY shall forward the value of TX_START_OF_FRAME_OFFSET in the TXSTATUS.

After the PHY preamble transmission is started, the PHY entity immediately initiates data scrambling and data encoding. The encoding method for the Data field is based on the FEC_CODING, CH_BANDWIDTH, NUM_STS, STBC, MCS, and NUM_USERS parameter of the TXVECTOR, as described in 21.3.2.

The SERVICE field and PSDU are encoded as described in 21.3.3. The data shall be exchanged between the MAC and the PHY through a series of PHY-DATA.request(DATA) primitives issued by the MAC, and PHY-DATA.confirm primitives issued by the PHY. Zero to seven PHY padding bits are appended to the PSDU to make the number of bits in the coded PSDU an integer multiple of the number of coded bits per OFDM symbol.

Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. PSDU transmission is terminated by receiving a PHY-TXEND.request primitive. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY. In an SU transmission, normal termination occurs after the transmission of the final bit of the last PSDU octet, according to the number of OFDM symbols indicated by N_{SYM} (see 21.4.3).

In the PHY, the GI or short GI is inserted in every data OFDM symbol as a countermeasure against delay spread.

When the PPDU transmission is completed the PHY entity enters the receive state.

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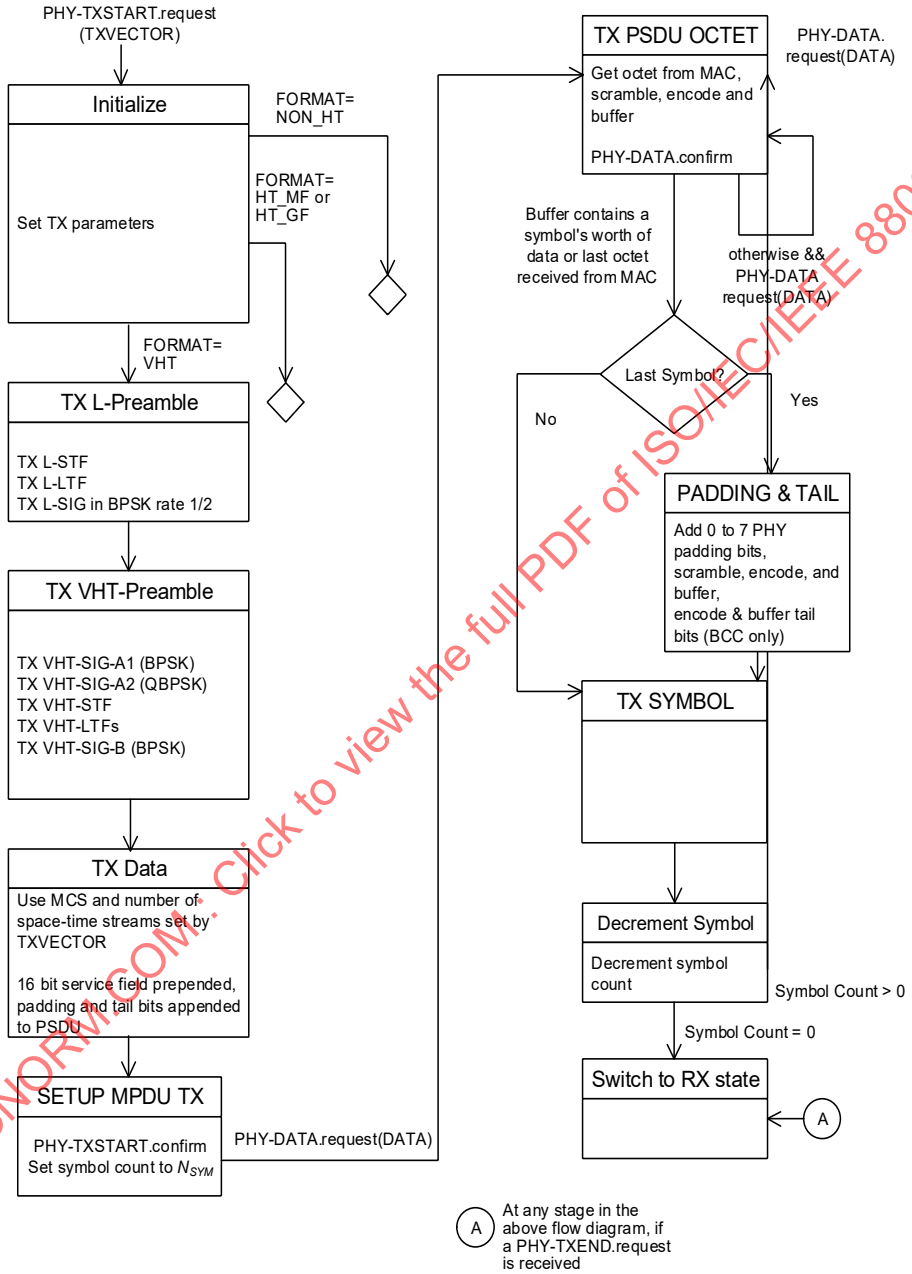
A typical state machine implementation of the transmit PHY for an SU transmission is provided in Figure 21-35. Request (.request) and confirmation (.confirm) primitives are issued once per state as shown. This state machine does not describe the operation of optional features, such as multi-user, LDPC or STBC. If the TXVECTOR parameter FORMAT is equal to NON_HT, refer to the transmit procedure and state machine in 17.3.11. If the TXVECTOR parameter FORMAT is equal to HT_MF or HT_GF, refer to the transmit procedure and state machine in 19.3.20.



NOTE—This state machine does not describe the operation of optional features, such as MU-MIMO, LDPC or STBC.

Figure 21-35—PHY transmit state machine for SU transmission

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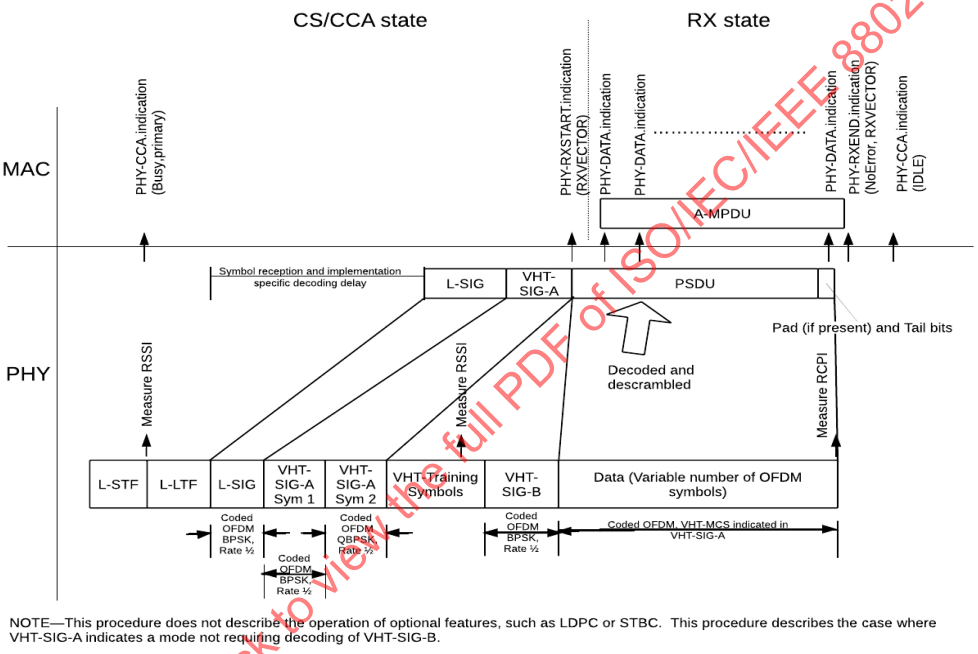
21.3.20 PHY receive procedure

A typical PHY receive procedure is shown in Figure 21-36 for VHT format. A typical state machine implementation of the receive PHY is given in Figure 21-37. This receive procedure and state machine do not describe the operation of optional features, such as LDPC or STBC. If the detected format indicates a NON_HT PPDU format (denoted "Not VHT-SIG-A" in Figure 21-37), refer to the receive procedure and state machine in 17.3.12. If the detected format indicates an HT PPDU format (denoted "HT_SIG (HT GF preamble)" and "HT_SIG (HT MF preamble)" in Figure 21-37), refer to the receive procedure and state machine in 19.3.21. Further, through station management (via the PLME) the PHY is set to the appropriate frequency, as specified in 21.4. The PHY has also been configured with group information (i.e., group membership and position in group) so that it can receive data intended for the STA. Other receive parameters, such as RSSI and indicated DATARATE, may be accessed via the PHY SAP.



NOTE—This procedure does not describe the operation of optional features, such as LDPC or STBC. This procedure describes the case where VHT-SIG-A indicates a mode not requiring decoding of VHT-SIG-B.

Figure 21-36—PHY receive procedure for SU transmission

Upon receiving the transmitted PHY preamble overlapping the primary 20 MHz channel, the PHY measures a receive signal strength. The PHY indicates this activity to the MAC by issuing a PHY-CCA.indication primitive. A PHY-CCA.indication(BUSY, channel-list) primitive is also issued as an initial indication of reception of a signal as specified in 21.3.18.5. The channel-list parameter of the PHY-CCA.indication primitive is absent when the operating channel width is 20 MHz. The channel-list parameter is present and includes the entry primary when the operating channel width is 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz.

The PHY shall not issue a PHY-RXSTART.indication primitive in response to a PPDU that does not overlap the primary 20 MHz channel.

The PHY includes the most recently measured RSSI value in the PHY-RXSTART.indication(RXVECTOR) primitive issued to the MAC.

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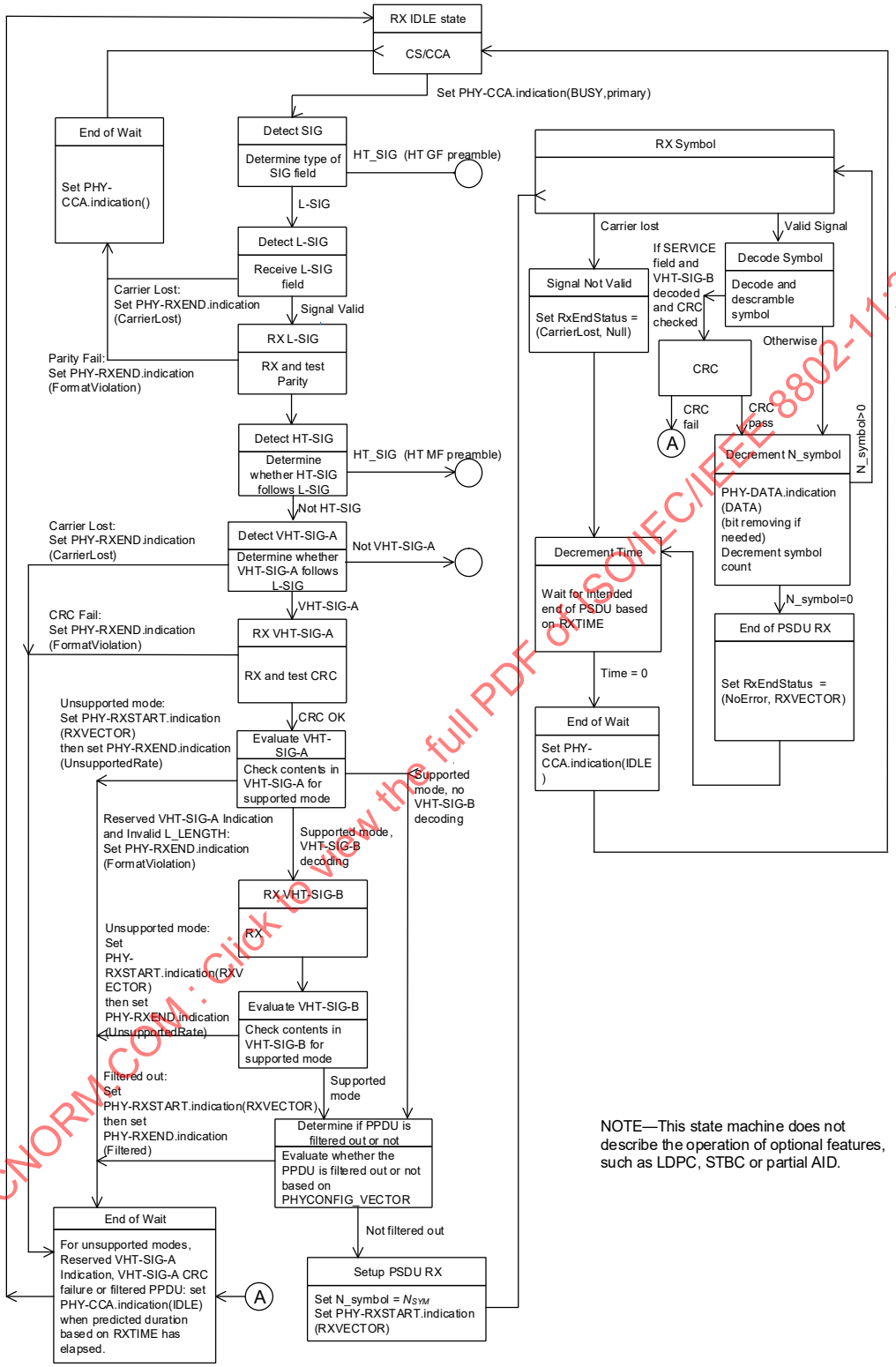

Figure 21-37—PHY receive state machine

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After the PHY-CCA.indication(BUSY, channel-list) primitive is issued, the PHY entity shall begin receiving the training symbols and searching for L-SIG in order to set the maximum duration of the data stream. If the check of the L-SIG parity bit is not valid, a PHY-RXSTART.indication primitive is not issued, and instead the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive. If a valid L-SIG parity bit is indicated, the VHT PHY shall maintain PHY-CCA.indication(BUSY, channel-list) primitive for the predicted duration of the transmitted PPDU, as defined by RXTIME in Equation (21-105), for all supported modes, unsupported modes, Reserved VHT-SIG-A Indication, invalid VHT-SIG-A CRC and invalid L-SIG Length field value. The L-SIG Length field value of a VHT PPDU is invalid if it is not divisible by 3. Reserved VHT-SIG-A Indication is defined as a VHT-SIG-A with Reserved bits equal to 0 or MU[u] NSTS fields (u = 0, 1, 2, 3) set to 5-7 or Short GI field set to 0 and Short GI NSYM Disambiguation field set to 1, or a combination of VHT-MCS and N_{STS} not included in 21.5 or any other VHT-SIG-A field bit combinations that do not correspond to modes of PHY operation defined in Clause 21. If the VHT-SIG-A indicates an unsupported mode, the PHY shall issue a PHY-RXEND.indication(UnsupportedRate) primitive. If the VHT-SIG-A indicates an invalid CRC or Reserved VHT-SIG-A Indication or if the L-SIG Length field is invalid, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive.

After receiving a valid L-SIG and VHT-SIG-A indicating a supported mode, the PHY entity shall begin receiving the VHT-STF, VHT-LTFs and VHT-SIG-B. If the received group ID in VHT-SIG-A has a value indicating a VHT SU PPDU (see 10.19), the PHY entity may choose not to decode VHT-SIG-B. If VHT-SIG-B is not decoded, subsequent to an indication of a valid VHT-SIG-A CRC, a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued.

Subsequently, if dot11TimingMsmtActivated is true, a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued and RX_START_OF_FRAME_OFFSET parameter within the RXVECTOR shall be forwarded (see 20.2.2).

NOTE—The RX_START_OF_FRAME_OFFSET value is used as described in 6.3.55 in order to estimate when the start of the preamble for the incoming frame was detected on the medium at the receive antenna connector.

The RXVECTOR associated with this primitive includes the parameters specified in Table 21-1.

If the Group ID field in VHT-SIG-A has a value indicating a VHT MU PPDU (see 10.19), the PHY, in a STA that is MU beamformee capable, shall decode VHT-SIG-B. If the VHT-SIG-B indicates an unsupported mode, the PHY shall issue the error condition PHY-RXEND.indication(UnsupportedRate) primitive.

If VHT-SIG-B was decoded the PHY may check the VHT-SIG-B CRC in the SERVICE field. If the VHT-SIG-B CRC in the SERVICE field is not checked a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. The RXVECTOR associated with this primitive includes the parameters specified in Table 21-1.

The PHY optionally filters out the PPDU based on the GroupID, MU[0-3] NSTS and Partial AID fields of VHT-SIG-A and the contents of the PHYCONFIG_VECTOR as follows:

The PHY shall not filter out the PPDU if one of the following is true:

— (g = 0) and (l_{00} is true) and (*partialaid* is included in PARTIAL_AID_LIST_GID00)

— (g = 63) and (l_{63} is true) and (*partialaid* is included in PARTIAL_AID_LIST_GID63)

— ($1 \le g \le 62$) and (MembershipStatusInGroupID[g] = 1) and (n_{STS}[UserPositionInGroupID[g]] > 0)

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— where
  — l_{NN} is the one of the LISTEN_TO_GID*NN* parameters of the PHYCONFIG_VECTOR
  — MembershipStatusInGroupID[g] is the Membership Status Array field of the GROUP_ID_MANAGEMENT parameter of the PHYCONFIG_VECTOR for group g
  — g is the value of the GroupID field of VHT-SIG-A
  — $n_{STS}[u]$ is the value of the MU[u] NSTS field of VHT-SIG-A
  — UserPositionInGroupID[g] is the User Position Array field of the GROUP_ID_MANAGEMENT parameter of the PHYCONFIG_VECTOR for group g
  — *partialaid* is the value of the Partial AID field of VHT-SIG-A
— Otherwise, the PHY may filter out the PPDU.

If the PPDU is filtered out, the PHY shall issue a PHY-RXEND.indication(Filtered) primitive.

Following training and signal fields, the Data field shall be received. The number of symbols in the Data field is determined by Equation (21-104).

$$N_{SYM} = \begin{cases} N'_{SYM} - 1, \text{ if Short GI = 1 and Short GI NSYM Disambiguation = 1} \\ N'_{SYM}, \text{ otherwise} \end{cases} \quad (21\text{-}104)$$

where

$$N'_{SYM} = \left\lfloor \frac{\text{RXTIME} - \left(\begin{array}{l} T_{\text{L-STF}} + T_{\text{L-LTF}} + T_{\text{L-SIG}} + T_{\text{VHT-SIG-A}} + \\ T_{\text{VHT-STF}} + N_{VHT\text{-}LTF} T_{\text{VHT-LTF}} + T_{\text{VHT-SIG-B}} \end{array} \right)}{T_{SYM}} \right\rfloor$$

$$\text{RXTIME}(\mu s) = \left\lceil \frac{\text{LENGTH} + 3}{3} \right\rceil \cdot 4 + 20 \quad (21\text{-}105)$$

where LENGTH is the LENGTH field in L-SIG.

The value of the PSDU_LENGTH parameter returned in the RXVECTOR using BCC encoding is calculated using Equation (21-106).

$$\text{PSDU_LENGTH} = \left\lfloor \frac{N_{SYM} N_{DBPS} - N_{service} - N_{tail} \cdot N_{ES}}{8} \right\rfloor \quad (21\text{-}106)$$

For a VHT SU PPDU, the SU/MU[0] Coding field of VHT-SIG-A2 indicates the type of coding. The PHY entity shall use an LDPC decoder to decode the C-PSDU if this bit is 1; otherwise, BCC decoding shall be used. For an MU transmission, the SU/MU[0] Coding, MU[1] Coding, MU[2] Coding and MU[3] Coding fields of VHT-SIG-A2 indicate the type of coding for user u with USER_POSITION[u] = 0, 1, 2, and 3, respectively. The PHY entity shall use an LDPC decoder to decode the C-PSDU for the respective user if its bit for its C-PSDU is 1. BCC decoding shall be used otherwise. When an LDPC decoder is to be used, $N_{SYM,init}$ is obtained from Equation (21-107).

$$N_{SYM,\,init} = \begin{cases} N_{SYM,\,init}, \text{ if LDPC Extra OFDM Symbol = 0} \\ N_{SYM,\,init} - 1, \text{ if LDPC Extra OFDM Symbol = 1 and STBC = 0} \\ N_{SYM,\,init} - 2, \text{ if LDPC Extra OFDM Symbol = 1 and STBC = 1} \end{cases} \quad (21\text{-}107)$$

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where
LDPC Extra OFDM Symbol and STBC are fields in VHT-SIG-A (see Table 21-12)

The value of the PSDU_LENGTH parameter returned in the RXVECTOR using LDPC encoding is calculated using Equation (21-108).

$$\text{PSDU_LENGTH} = \left\lfloor \frac{N_{SYM,init} N_{DBPS} - N_{service}}{8} \right\rfloor \quad (21\text{-}108)$$

The value of the PSDU_LENGTH parameter returned in the RXVECTOR for an NDP is 0.

If VHT-SIG-B is decoded and the VHT-SIG-B CRC in the SERVICE field is checked and not valid, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive. If the VHT-SIG-B field is decoded and the VHT-SIG-B CRC field is checked and valid, a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. The RXVECTOR associated with this primitive includes the parameters specified in Table 21-1.

If signal loss occurs during reception prior to completion of the PSDU reception, the error condition shall be reported to the MAC using a PHY-RXEND.indication(CarrierLost) primitive. After waiting for the intended end of the PSDU as determined by Equation (21-105), the PHY shall generate a PHY-CCA.indication(IDLE) primitive and return to RX IDLE state.

The received PSDU bits are assembled into octets, decoded, and presented to the MAC using a series of PHY-DATA.indication(DATA) primitive exchanges. Any final bits that cannot be assembled into a complete octet are considered pad bits and discarded. After the reception of the final bit of the last PSDU octet, and possible padding and tail bits, the receiver shall be returned to the RX IDLE state, as shown in Figure 21-37. A PHY-RXEND.indication(NoError) primitive shall be issued on entry to the RX IDLE state.

21.4 VHT PLME

21.4.1 PLME SAP sublayer management primitives

Table 21-27 lists the MIB attributes that may be accessed by the PHY entities and the intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.5.

Table 21-27—VHT PHY MIB attributes

Managed object	Default value/ range	Operational semantics
dot11PHYOperationTable		
dot11PHYType	vht(9)	Static
dot11PHYTxPowerTable		
dot11NumberSupportedPowerLevelsImplemented	Implementation dependent	Static
dot11TxPowerLevel1	Implementation dependent	Static
dot11TxPowerLevel2	Implementation dependent	Static

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Table 21-27—VHT PHY MIB attributes *(continued)*

Managed object	Default value/ range	Operational semantics
dot11TxPowerLevel3	Implementation dependent	Static
dot11TxPowerLevel4	Implementation dependent	Static
dot11TxPowerLevel5	Implementation dependent	Static
dot11TxPowerLevel6	Implementation dependent	Static
dot11TxPowerLevel7	Implementation dependent	Static
dot11TxPowerLevel8	Implementation dependent	Static
dot11CurrentTxPowerLevel	Implementation dependent	Static
dot11TxPowerLevelExtended	Implementation dependent	Static
dot11CurrentTxPowerLevelExtended	Implementation dependent	Static
dot11PHYHTTable		
dot11CurrentPrimaryChannel	Implementation dependent	Dynamic
dot11CurrentSecondaryChannel	Implementation dependent	Dynamic
dot11FortyMHzOperationImplemented	false/Boolean	Static
dot11FortyMHzOperationActivated	false/Boolean	Dynamic
dot11NumberOfSpatialStreamsImplemented	Implementation dependent	Static
dot11NumberOfSpatialStreamsActivated	Implementation dependent	Dynamic
dot11HTGreenfieldOptionImplemented	false/Boolean	Static
dot11HTGreenfieldOptionActivated	false/Boolean	Dynamic
dot11ShortGIOptionInTwentyImplemented	false/Boolean	Static
dot11ShortGIOptionInTwentyActivated	false/Boolean	Dynamic
dot11ShortGIOptionInFortyImplemented	false/Boolean	Static
dot11ShortGIOptionInFortyActivated	false/Boolean	Dynamic
dot11LDPCCodingOptionImplemented	false/Boolean	Static
dot11LDPCCodingOptionActivated	false/Boolean	Dynamic
dot11TxSTBCOptionImplemented	false/Boolean	Static

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Table 21-27—VHT PHY MIB attributes *(continued)*

Managed object	Default value/ range	Operational semantics
dot11TxSTBCOptionActivated	false/Boolean	Dynamic
dot11RxSTBCOptionImplemented	false/Boolean	Static
dot11RxSTBCOptionActivated	false/Boolean	Dynamic
dot11BeamFormingOptionImplemented	false/Boolean	Static
dot11BeamFormingOptionActivated	false/Boolean	Dynamic
dot11PHYVHTTable		
dot11CurrentChannelWidth	Implementation dependent	Dynamic
dot11CurrentChannelCenterFrequencyIndex0	Implementation dependent	Dynamic
dot11CurrentChannelCenterFrequencyIndex1	Implementation dependent	Dynamic
dot11VHTChannelWidthOptionImplemented	Implementation dependent	Static
dot11VHTShortGIOptionIn80Implemented	false/Boolean	Static
dot11VHTShortGIOptionIn80Activated	false/Boolean	Dynamic
dot11VHTShortGIOptionIn160and80p80Implemented	false/Boolean	Static
dot11VHTShortGIOptionIn160and80p80Activated	false/Boolean	Dynamic
dot11VHTLDPCCodingOptionImplemented	false/Boolean	Static
dot11VHTLDPCCodingOptionActivated	false/Boolean	Dynamic
dot11VHTTxSTBCOptionImplemented	false/Boolean	Static
dot11VHTTxSTBCOptionActivated	false/Boolean	Dynamic
dot11VHTRxSTBCOptionImplemented	false/Boolean	Static
dot11VHTRxSTBCOptionActivated	false/Boolean	Dynamic
dot11VHTMaxNTxChainsImplemented	Implementation dependent	Static
dot11VHTMaxNTxChainsActivated	Implementation dependent	Dynamic
dot11TransmitBeamformingConfigTable		
dot11ReceiveStaggerSoundingOptionImplemented	false/Boolean	Static
dot11TransmitStaggerSoundingOptionImplemented	false/Boolean	Static
dot11ReceiveNDPOptionImplemented	false/Boolean	Static
dot11TransmitNDPOptionImplemented	false/Boolean	Static
dot11ImplicitTransmitBeamformingOptionImplemented	false/Boolean	Static
dot11CalibrationOptionImplemented	Implementation dependent	Static

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Table 21-27—VHT PHY MIB attributes *(continued)*

Managed object	Default value/ range	Operational semantics
dot11ExplicitCSITransmitBeamformingOptionImplemented	false/Boolean	Static
dot11ExplicitNonCompressedBeamformingMatrixOptionImplemented	false/Boolean	Static
dot11ExplicitTransmitBeamformingCSIFeedbackOptionImplemented	Implementation dependent	Static
dot11ExplicitNoncompressedBeamformingFeedbackOptionImplemented	Implementation dependent	Static
dot11ExplicitCompressedBeamformingFeedbackOptionImplemented	Implementation dependent	Static
dot11NumberBeamFormingCSISupportAntenna	Implementation dependent	Static
dot11NumberNonCompressedBeamformingMatrixSupportAntenna	Implementation dependent	Static
dot11NumberCompressedBeamformingMatrixSupportAntenna	Implementation dependent	Static
dot11VHTTransmitBeamformingConfigTable		
dot11VHTSUBeamformeeOptionImplemented	false/Boolean	Static
dot11VHTSUBeamformerOptionImplemented	false/Boolean	Static
dot11VHTMUBeamformeeOptionImplemented	false/Boolean	Static
dot11VHTMUBeamformerOptionImplemented	false/Boolean	Static
dot11VHTNumberSoundingDimensions	Implementation dependent	Static
dot11VHTBeamformeeNTxSupport	Implementation dependent	Static

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21.4.2 PHY MIB

VHT PHY MIB attributes are defined in Annex C with specific values defined in Table 21-27. The "Operational semantics" column in Table 21-27 contains two types: static and dynamic.

— Static MIB attributes are fixed and cannot be modified for a given PHY implementation.
— Dynamic MIB attributes are interpreted according to the MAX-ACCESS field of the MIB attribute.

When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.

21.4.3 TXTIME and PSDU_LENGTH calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated for a VHT PPDU using Equation (21-109) for short GI and Equation (21-110) for long GI.

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$$\text{TXTIME} = T_{\text{LEG_PREAMBLE}} + T_{\text{L-SIG}} + T_{\text{VHT-SIG-A}} + T_{\text{VHT_PREAMBLE}} + T_{\text{VHT-SIG-B}} + T_{SYML} \times \left\lceil \frac{T_{SYMS} \times N_{SYM}}{T_{SYML}} \right\rceil \quad (21\text{-}109)$$

$$\text{TXTIME} = T_{\text{LEG_PREAMBLE}} + T_{\text{L-SIG}} + T_{\text{VHT-SIG-A}} + T_{\text{VHT_PREAMBLE}} + T_{\text{VHT-SIG-B}} + T_{SYML} \times N_{SYM} \quad (21\text{-}110)$$

where

$T_{\text{LEG_PREAMBLE}} = T_{\text{L-STF}} + T_{\text{L-LTF}}$

$T_{\text{VHT_PREAMBLE}} = T_{\text{VHT-STF}} + N_{VHT\text{-}LTF} T_{\text{VHT-LTF}}$

T_{SYML}, T_{SYMS}, $T_{\text{VHT-SIG-A}}$, $T_{\text{VHT-SIG-B}}$, $T_{\text{L-STF}}$, $T_{\text{VHT-STF}}$, $T_{\text{L-LTF}}$, and $T_{\text{VHT-LTF}}$ are defined in Table 21-5

$N_{VHT\text{-}LTF}$ is defined in Table 21-13

For an NDP, there is no Data field and $N_{SYM} = 0$.

For a VHT SU PPDU using BCC encoding, the total number of data symbols in the Data field is given by Equation (21-111).

$$N_{SYM} = m_{\text{STBC}} \times \left\lceil \frac{8 \cdot \text{APEP_LENGTH} + N_{service} + N_{tail} \cdot N_{ES}}{m_{\text{STBC}} \cdot N_{DBPS}} \right\rceil \quad (21\text{-}111)$$

where

m_{STBC} is equal to 2 when STBC is used, and 1 otherwise

For a VHT SU PPDU using LDPC encoding, the total number of data symbols in the Data field, N_{SYM}, is given in 21.3.10.5.4 (computed using Equation (19-41) in step d) of 19.3.11.7.5).

For a VHT MU PPDU, the total number of data symbols in the Data field, N_{SYM}, is given by Equation (21-67).

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for a VHT SU PPDU using BCC encoding is calculated using Equation (21-112).

$$\text{PSDU_LENGTH} = \left\lfloor \frac{N_{SYM} N_{DBPS} - N_{service} - N_{tail} \cdot N_{ES}}{8} \right\rfloor \quad (21\text{-}112)$$

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for a VHT SU PPDU using LDPC encoding is calculated using Equation (21-113).

$$\text{PSDU_LENGTH} = \left\lfloor \frac{N_{SYM,init} N_{DBPS} - N_{service}}{8} \right\rfloor \quad (21\text{-}113)$$

where

$N_{SYM,init}$ is given by Equation (21-62)

The value of the PSDU_LENGTH parameter for user u returned in the PLME-TXTIME.confirm primitive and in the RXVECTOR for a VHT MU PPDU is calculated using Equation (21-114).

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$$\text{PSDU_LENGTH}_u = \begin{cases} \left\lfloor \dfrac{N_{SYM} N_{DBPS,u} - N_{service} - N_{tail} \cdot N_{ES,u}}{8} \right\rfloor & \text{when BCC is used for user } u \\ \left\lfloor \dfrac{N_{\text{SYM_max_init}} N_{DBPS,u} - N_{service}}{8} \right\rfloor & \text{when LDPC is used for user } u \end{cases} \quad (21\text{-}114)$$

where

N_{SYM} is given by Equation (21-67)

$N_{\text{SYM_max_init}}$ is given by Equation (21-65)

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for an NDP is 0.

21.4.4 VHT PHY

The static VHT PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, shall be as shown in Table 19-25 unless otherwise listed in Table 21-28. The definitions for these characteristics are given in 6.5.4.

Table 21-28—VHT PHY characteristics

Characteristics	Value
aCCAMidTime	25 µs
aPPDUMaxTime	5.484 ms
aPSDUMaxLength	4 692 480 octets (see NOTE 1)
aRxPHYStartDelay	36 + 4 × the maximum possible value for $N_{VHT\text{-}LTF}$ supported + 4 (see NOTE 2)
aAPEPMaxLengthVHTMU20	262 140 octets (see NOTE 3)
aAPEPMaxLengthVHTMU40	524 284 octets (see NOTE 3)
aAPEPMaxLengthVHTMU80orMore	2 097 148 octets (see NOTE 3 and NOTE 4)

NOTE 1—This is the maximum length in octets for a VHT SU PPDU with a bandwidth of 160 MHz or 80+80 MHz, VHT-MCS 9, and 8 spatial streams, and limited by 1504 possible Short GI data symbols in aPPDUMaxTime. This is the maximum PSDU length a VHT PHY could support assuming no restrictions in MAC. See 10.3.2 and 9.2.4.7.1 for additional restrictions on the maximum number of octets the MAC could support.

NOTE 2—This value arises from the time to the end of VHT-SIG-B (see Figure 21-4) plus the need to decode the first symbol of the Data field in order to extract the SERVICE field and check the CRC it contains.

NOTE 3—This value is derived inversely from Equation (21-46) using corresponding VHT-SIG-B Length in Table 21-14.

NOTE 4—This value is larger than the constraint by the Maximum A-MPDU Length Exponent of 7 and the maximum A-MPDU length will be limited by the Maximum A-MPDU Length Exponent (see 10.12.2 and 10.13).

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21.5 Parameters for VHT-MCSs

The rate-dependent parameters for 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz N_{SS} = 1, …, 8 are given in Table 21-29 to Table 21-60. Support for 400 ns GI is optional in all cases. Support for VHT-MCS 8 and 9 (when valid) is optional in all cases. A VHT STA shall support single spatial stream VHT-MCSs within the range VHT-MCS 0 to VHT-MCS 7 for all channel widths for which it has indicated support regardless of the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported VHT-MCS and NSS Set field. When more than one spatial stream is supported, the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported VHT-MCS and NSS Set field may result in a reduced VHT-MCS range (cut-off) for N_{SS} = 2, …, 8 . Support for 20 MHz, 40 MHz, and 80 MHz with N_{SS} = 1 is mandatory. Support for 20 MHz, 40 MHz, and 80 MHz with N_{SS} = 2, …, 8 is optional. Support for 160 MHz and 80+80 MHz with N_{SS} = 1, …, 8 is optional. N_{ES} values were chosen to yield an integer number of punctured blocks for each BCC encoder per OFDM symbol.

Table 21-29 to Table 21-32, Table 21-37 to Table 21-40, Table 21-45 to Table 21-48, and Table 21-53 to Table 21-56 define VHT-MCSs not only for SU transmission but also for user u of MU transmission. In the case of VHT-MCSs for MU transmission, the parameters, N_{SS}, R, N_{BPSCS}, N_{CBPS}, N_{DBPS}, and N_{ES} are replaced with $N_{SS,u}$, R_u, $N_{BPSCS,u}$, $N_{CBPS,u}$, $N_{DBPS,u}$, and $N_{ES,u}$, respectively. Note that the 400 ns GI rate values are rounded to 1 decimal place.

Table 21-29—VHT-MCSs for mandatory 20 MHz, N_{SS} = 1

VHT-MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI (see NOTE)
0	BPSK	1/2	1	52	4	52	26	1	6.5	7.2
1	QPSK	1/2	2	52	4	104	52	1	13.0	14.4
2	QPSK	3/4	2	52	4	104	78	1	19.5	21.7
3	16-QAM	1/2	4	52	4	208	104	1	26.0	28.9
4	16-QAM	3/4	4	52	4	208	156	1	39.0	43.3
5	64-QAM	2/3	6	52	4	312	208	1	52.0	57.8
6	64-QAM	3/4	6	52	4	312	234	1	58.5	65.0
7	64-QAM	5/6	6	52	4	312	260	1	65.0	72.2
8	256-QAM	3/4	8	52	4	416	312	1	78.0	86.7
9	Not valid									

NOTE—Support of 400 ns GI is optional on transmit and receive.

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Table 21-30—VHT-MCSs for optional 20 MHz, N_{SS} = 2

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	52	4	104	52	1	13.0	14.4
1	QPSK	1/2	2	52	4	208	104	1	26.0	28.9
2	QPSK	3/4	2	52	4	208	156	1	39.0	43.3
3	16-QAM	1/2	4	52	4	416	208	1	52.0	57.8
4	16-QAM	3/4	4	52	4	416	312	1	78.0	86.7
5	64-QAM	2/3	6	52	4	624	416	1	104.0	115.6
6	64-QAM	3/4	6	52	4	624	468	1	117.0	130.0
7	64-QAM	5/6	6	52	4	624	520	1	130.0	144.4
8	256-QAM	3/4	8	52	4	832	624	1	156.0	173.3
9	Not valid									

Table 21-31—VHT-MCSs for optional 20 MHz, N_{SS} = 3

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	52	4	156	78	1	19.5	21.7
1	QPSK	1/2	2	52	4	312	156	1	39.0	43.3
2	QPSK	3/4	2	52	4	312	234	1	58.5	65.0
3	16-QAM	1/2	4	52	4	624	312	1	78.0	86.7
4	16-QAM	3/4	4	52	4	624	468	1	117.0	130.0
5	64-QAM	2/3	6	52	4	936	624	1	156.0	173.3
6	64-QAM	3/4	6	52	4	936	702	1	175.5	195.0
7	64-QAM	5/6	6	52	4	936	780	1	195.0	216.7
8	256-QAM	3/4	8	52	4	1248	936	1	234.0	260.0
9	256-QAM	5/6	8	52	4	1248	1040	1	260.0	288.9

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Table 21-32—VHT-MCSs for optional 20 MHz, N_{SS} = 4

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	52	4	208	104	1	26.0	28.9
1	QPSK	1/2	2	52	4	416	208	1	52.0	57.8
2	QPSK	3/4	2	52	4	416	312	1	78.0	86.7
3	16-QAM	1/2	4	52	4	832	416	1	104.0	115.6
4	16-QAM	3/4	4	52	4	832	624	1	156.0	173.3
5	64-QAM	2/3	6	52	4	1248	832	1	208.0	231.1
6	64-QAM	3/4	6	52	4	1248	936	1	234.0	260.0
7	64-QAM	5/6	6	52	4	1248	1040	1	260.0	288.9
8	256-QAM	3/4	8	52	4	1664	1248	1	312.0	346.7
9	Not valid									

Table 21-33—VHT-MCSs for optional 20 MHz, N_{SS} = 5

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	52	4	260	130	1	32.5	36.1
1	QPSK	1/2	2	52	4	520	260	1	65.0	72.2
2	QPSK	3/4	2	52	4	520	390	1	97.5	108.3
3	16-QAM	1/2	4	52	4	1040	520	1	130.0	144.4
4	16-QAM	3/4	4	52	4	1040	780	1	195.0	216.7
5	64-QAM	2/3	6	52	4	1560	1040	1	260.0	288.9
6	64-QAM	3/4	6	52	4	1560	1170	1	292.5	325.0
7	64-QAM	5/6	6	52	4	1560	1300	1	325.0	361.1
8	256-QAM	3/4	8	52	4	2080	1560	1	390.0	433.3
9	Not valid									

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Table 21-34—VHT-MCSs for optional 20 MHz, N_{SS} = 6

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	52	4	312	156	1	39.0	43.3
1	QPSK	1/2	2	52	4	624	312	1	78.0	86.7
2	QPSK	3/4	2	52	4	624	468	1	117.0	130.0
3	16-QAM	1/2	4	52	4	1248	624	1	156.0	173.3
4	16-QAM	3/4	4	52	4	1248	936	1	234.0	260.0
5	64-QAM	2/3	6	52	4	1872	1248	1	312.0	346.7
6	64-QAM	3/4	6	52	4	1872	1404	1	351.0	390.0
7	64-QAM	5/6	6	52	4	1872	1560	1	390.0	433.3
8	256-QAM	3/4	8	52	4	2496	1872	1	468.0	520.0
9	256-QAM	5/6	8	52	4	2496	2080	1	520.0	577.8

Table 21-35—VHT-MCSs for optional 20 MHz, N_{SS} = 7

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	52	4	364	182	1	45.5	50.6
1	QPSK	1/2	2	52	4	728	364	1	91.0	101.1
2	QPSK	3/4	2	52	4	728	546	1	136.5	151.7
3	16-QAM	1/2	4	52	4	1456	728	1	182.0	202.2
4	16-QAM	3/4	4	52	4	1456	1092	1	273.0	303.3
5	64-QAM	2/3	6	52	4	2184	1456	1	364.0	404.4
6	64-QAM	3/4	6	52	4	2184	1638	1	409.5	455.0
7	64-QAM	5/6	6	52	4	2184	1820	1	455.0	505.6
8	256-QAM	3/4	8	52	4	2912	2184	2	546.0	606.7
9	Not valid									

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Table 21-36—VHT-MCSs for optional 20 MHz, N_{SS} = 8

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	52	4	416	208	1	52.0	57.8
1	QPSK	1/2	2	52	4	832	416	1	104.0	115.6
2	QPSK	3/4	2	52	4	832	624	1	156.0	173.3
3	16-QAM	1/2	4	52	4	1664	832	1	208.0	231.1
4	16-QAM	3/4	4	52	4	1664	1248	1	312.0	346.7
5	64-QAM	2/3	6	52	4	2496	1664	1	416.0	462.2
6	64-QAM	3/4	6	52	4	2496	1872	1	468.0	520.0
7	64-QAM	5/6	6	52	4	2496	2080	1	520.0	577.8
8	256-QAM	3/4	8	52	4	3328	2496	2	624.0	693.3
9	Not valid									

Table 21-37—VHT-MCSs for mandatory 40 MHz, N_{SS} = 1

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI (See NOTE)
0	BPSK	1/2	1	108	6	108	54	1	13.5	15.0
1	QPSK	1/2	2	108	6	216	108	1	27.0	30.0
2	QPSK	3/4	2	108	6	216	162	1	40.5	45.0
3	16-QAM	1/2	4	108	6	432	216	1	54.0	60.0
4	16-QAM	3/4	4	108	6	432	324	1	81.0	90.0
5	64-QAM	2/3	6	108	6	648	432	1	108.0	120.0
6	64-QAM	3/4	6	108	6	648	486	1	121.5	135.0
7	64-QAM	5/6	6	108	6	648	540	1	135.0	150.0
8	256-QAM	3/4	8	108	6	864	648	1	162.0	180.0
9	256-QAM	5/6	8	108	6	864	720	1	180.0	200.0

NOTE—Support of 400 ns GI is optional on transmit and receive.

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Table 21-38—VHT-MCSs for optional 40 MHz, N_{SS} = 2

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	108	6	216	108	1	27.0	30.0
1	QPSK	1/2	2	108	6	432	216	1	54.0	60.0
2	QPSK	3/4	2	108	6	432	324	1	81.0	90.0
3	16-QAM	1/2	4	108	6	864	432	1	108.0	120.0
4	16-QAM	3/4	4	108	6	864	648	1	162.0	180.0
5	64-QAM	2/3	6	108	6	1296	864	1	216.0	240.0
6	64-QAM	3/4	6	108	6	1296	972	1	243.0	270.0
7	64-QAM	5/6	6	108	6	1296	1080	1	270.0	300.0
8	256-QAM	3/4	8	108	6	1728	1296	1	324.0	360.0
9	256-QAM	5/6	8	108	6	1728	1440	1	360.0	400.0

Table 21-39—VHT-MCSs for optional 40 MHz, N_{SS} = 3

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	108	6	324	162	1	40.5	45.0
1	QPSK	1/2	2	108	6	648	324	1	81.0	90.0
2	QPSK	3/4	2	108	6	648	486	1	121.5	135.0
3	16-QAM	1/2	4	108	6	1296	648	1	162.0	180.0
4	16-QAM	3/4	4	108	6	1296	972	1	243.0	270.0
5	64-QAM	2/3	6	108	6	1944	1296	1	324.0	360.0
6	64-QAM	3/4	6	108	6	1944	1458	1	364.5	405.0
7	64-QAM	5/6	6	108	6	1944	1620	1	405.0	450.0
8	256-QAM	3/4	8	108	6	2592	1944	1	486.0	540.0
9	256-QAM	5/6	8	108	6	2592	2160	1	540.0	600.0

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Table 21-40—VHT-MCSs for optional 40 MHz, N_{SS} = 4

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	108	6	432	216	1	54.0	60.0
1	QPSK	1/2	2	108	6	864	432	1	108.0	120.0
2	QPSK	3/4	2	108	6	864	648	1	162.0	180.0
3	16-QAM	1/2	4	108	6	1728	864	1	216.0	240.0
4	16-QAM	3/4	4	108	6	1728	1296	1	324.0	360.0
5	64-QAM	2/3	6	108	6	2592	1728	1	432.0	480.0
6	64-QAM	3/4	6	108	6	2592	1944	1	486.0	540.0
7	64-QAM	5/6	6	108	6	2592	2160	1	540.0	600.0
8	256-QAM	3/4	8	108	6	3456	2592	2	648.0	720.0
9	256-QAM	5/6	8	108	6	3456	2880	2	720.0	800.0

Table 21-41—VHT-MCSs for optional 40 MHz, N_{SS} = 5

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	108	6	540	270	1	67.5	75.0
1	QPSK	1/2	2	108	6	1080	540	1	135.0	150.0
2	QPSK	3/4	2	108	6	1080	810	1	202.5	225.0
3	16-QAM	1/2	4	108	6	2160	1080	1	270.0	300.0
4	16-QAM	3/4	4	108	6	2160	1620	1	405.0	450.0
5	64-QAM	2/3	6	108	6	3240	2160	1	540.0	600.0
6	64-QAM	3/4	6	108	6	3240	2430	2	607.5	675.0
7	64-QAM	5/6	6	108	6	3240	2700	2	675.0	750.0
8	256-QAM	3/4	8	108	6	4320	3240	2	810.0	900.0
9	256-QAM	5/6	8	108	6	4320	3600	2	900.0	1000.0

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Table 21-42—VHT-MCSs for optional 40 MHz, N_{SS} = 6

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	108	6	648	324	1	81.0	90.0
1	QPSK	1/2	2	108	6	1296	648	1	162.0	180.0
2	QPSK	3/4	2	108	6	1296	972	1	243.0	270.0
3	16-QAM	1/2	4	108	6	2592	1296	1	324.0	360.0
4	16-QAM	3/4	4	108	6	2592	1944	1	486.0	540.0
5	64-QAM	2/3	6	108	6	3888	2592	2	648.0	720.0
6	64-QAM	3/4	6	108	6	3888	2916	2	729.0	810.0
7	64-QAM	5/6	6	108	6	3888	3240	2	810.0	900.0
8	256-QAM	3/4	8	108	6	5184	3888	2	972.0	1080.0
9	256-QAM	5/6	8	108	6	5184	4320	2	1080.0	1200.0

Table 21-43—VHT-MCSs for optional 40 MHz, N_{SS} = 7

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	108	6	756	378	1	94.5	105.0
1	QPSK	1/2	2	108	6	1512	756	1	189.0	210.0
2	QPSK	3/4	2	108	6	1512	1134	1	283.5	315.0
3	16-QAM	1/2	4	108	6	3024	1512	1	378.0	420.0
4	16-QAM	3/4	4	108	6	3024	2268	2	567.0	630.0
5	64-QAM	2/3	6	108	6	4536	3024	2	756.0	840.0
6	64-QAM	3/4	6	108	6	4536	3402	2	850.5	945.0
7	64-QAM	5/6	6	108	6	4536	3780	2	945.0	1050.0
8	256-QAM	3/4	8	108	6	6048	4536	3	1134.0	1260.0
9	256-QAM	5/6	8	108	6	6048	5040	3	1260.0	1400.0

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Table 21-44—VHT-MCSs for optional 40 MHz, N_{SS} = 8

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	108	6	864	432	1	108.0	120.0
1	QPSK	1/2	2	108	6	1728	864	1	216.0	240.0
2	QPSK	3/4	2	108	6	1728	1296	1	324.0	360.0
3	16-QAM	1/2	4	108	6	3456	1728	1	432.0	480.0
4	16-QAM	3/4	4	108	6	3456	2592	2	648.0	720.0
5	64-QAM	2/3	6	108	6	5184	3456	2	864.0	960.0
6	64-QAM	3/4	6	108	6	5184	3888	2	972.0	1080.0
7	64-QAM	5/6	6	108	6	5184	4320	2	1080.0	1200.0
8	256-QAM	3/4	8	108	6	6912	5184	3	1296.0	1440.0
9	256-QAM	5/6	8	108	6	6912	5760	3	1440.0	1600.0

Table 21-45—VHT-MCSs for mandatory 80 MHz, N_{SS} = 1

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI (See NOTE)
0	BPSK	1/2	1	234	8	234	117	1	29.3	32.5
1	QPSK	1/2	2	234	8	468	234	1	58.5	65.0
2	QPSK	3/4	2	234	8	468	351	1	87.8	97.5
3	16-QAM	1/2	4	234	8	936	468	1	117.0	130.0
4	16-QAM	3/4	4	234	8	936	702	1	175.5	195.0
5	64-QAM	2/3	6	234	8	1404	936	1	234.0	260.0
6	64-QAM	3/4	6	234	8	1404	1053	1	263.3	292.5
7	64-QAM	5/6	6	234	8	1404	1170	1	292.5	325.0
8	256-QAM	3/4	8	234	8	1872	1404	1	351.0	390.0
9	256-QAM	5/6	8	234	8	1872	1560	1	390.0	433.3

NOTE—Support of 400 ns GI is optional on transmit and receive.

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Table 21-46—VHT-MCSs for optional 80 MHz, N_{SS} = 2

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	234	8	468	234	1	58.5	65.0
1	QPSK	1/2	2	234	8	936	468	1	117.0	130.0
2	QPSK	3/4	2	234	8	936	702	1	175.5	195.0
3	16-QAM	1/2	4	234	8	1872	936	1	234.0	260.0
4	16-QAM	3/4	4	234	8	1872	1404	1	351.0	390.0
5	64-QAM	2/3	6	234	8	2808	1872	1	468.0	520.0
6	64-QAM	3/4	6	234	8	2808	2106	1	526.5	585.0
7	64-QAM	5/6	6	234	8	2808	2340	2	585.0	650.0
8	256-QAM	3/4	8	234	8	3744	2808	2	702.0	780.0
9	256-QAM	5/6	8	234	8	3744	3120	2	780.0	866.7

Table 21-47—VHT-MCSs for optional 80 MHz, N_{SS} = 3

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	234	8	702	351	1	87.8	97.5
1	QPSK	1/2	2	234	8	1404	702	1	175.5	195.0
2	QPSK	3/4	2	234	8	1404	1053	1	263.3	292.5
3	16-QAM	1/2	4	234	8	2808	1404	1	351.0	390.0
4	16-QAM	3/4	4	234	8	2808	2106	1	526.5	585.0
5	64-QAM	2/3	6	234	8	4212	2808	2	702.0	780.0
6	Not valid									
7	64-QAM	5/6	6	234	8	4212	3510	2	877.5	975.0
8	256-QAM	3/4	8	234	8	5616	4212	2	1053.0	1170.0
9	256-QAM	5/6	8	234	8	5616	4680	3	1170.0	1300.0

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Table 21-48—VHT-MCSs for optional 80 MHz, N_{SS} = 4

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	234	8	936	468	1	117.0	130.0
1	QPSK	1/2	2	234	8	1872	936	1	234.0	260.0
2	QPSK	3/4	2	234	8	1872	1404	1	351.0	390.0
3	16-QAM	1/2	4	234	8	3744	1872	1	468.0	520.0
4	16-QAM	3/4	4	234	8	3744	2808	2	702.0	780.0
5	64-QAM	2/3	6	234	8	5616	3744	2	936.0	1040.0
6	64-QAM	3/4	6	234	8	5616	4212	2	1053.0	1170.0
7	64-QAM	5/6	6	234	8	5616	4680	3	1170.0	1300.0
8	256-QAM	3/4	8	234	8	7488	5616	3	1404.0	1560.0
9	256-QAM	5/6	8	234	8	7488	6240	3	1560.0	1733.3

Table 21-49—VHT-MCSs for optional 80 MHz, N_{SS} = 5

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	234	8	1170	585	1	146.3	162.5
1	QPSK	1/2	2	234	8	2340	1170	1	292.5	325.0
2	QPSK	3/4	2	234	8	2340	1755	1	438.8	487.5
3	16-QAM	1/2	4	234	8	4680	2340	2	585.0	650.0
4	16-QAM	3/4	4	234	8	4680	3510	2	877.5	975.0
5	64-QAM	2/3	6	234	8	7020	4680	3	1170.0	1300.0
6	64-QAM	3/4	6	234	8	7020	5265	3	1316.3	1462.5
7	64-QAM	5/6	6	234	8	7020	5850	3	1462.5	1625.0
8	256-QAM	3/4	8	234	8	9360	7020	4	1755.0	1950.0
9	256-QAM	5/6	8	234	8	9360	7800	4	1950.0	2166.7

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Table 21-50—VHT-MCSs for optional 80 MHz, N_{SS} = 6

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	234	8	1404	702	1	175.5	195.0
1	QPSK	1/2	2	234	8	2808	1404	1	351.0	390.0
2	QPSK	3/4	2	234	8	2808	2106	1	526.5	585.0
3	16-QAM	1/2	4	234	8	5616	2808	2	702.0	780.0
4	16-QAM	3/4	4	234	8	5616	4212	2	1053.0	1170.0
5	64-QAM	2/3	6	234	8	8424	5616	3	1404.0	1560.0
6	64-QAM	3/4	6	234	8	8424	6318	3	1579.5	1755.0
7	64-QAM	5/6	6	234	8	8424	7020	4	1755.0	1950.0
8	256-QAM	3/4	8	234	8	11 232	8424	4	2106.0	2340.0
9	Not valid									

Table 21-51—VHT-MCSs for optional 80 MHz, N_{SS} = 7

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	234	8	1638	819	1	204.8	227.5
1	QPSK	1/2	2	234	8	3276	1638	1	409.5	455.0
2	QPSK	3/4	2	234	8	3276	2457	3	614.3	682.5
3	16-QAM	1/2	4	234	8	6552	3276	2	819.0	910.0
4	16-QAM	3/4	4	234	8	6552	4914	3	1228.5	1365.0
5	64-QAM	2/3	6	234	8	9828	6552	4	1638.0	1820.0
6	Not valid									
7	64-QAM	5/6	6	234	8	9828	8190	6	2047.5	2275.0
8	256-QAM	3/4	8	234	8	13 104	9828	6	2457.0	2730.0
9	256-QAM	5/6	8	234	8	13 104	10 920	6	2730.0	3033.3

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Table 21-52—VHT-MCSs for optional 80 MHz, N_{SS} = 8

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	234	8	1872	936	1	234.0	260.0
1	QPSK	1/2	2	234	8	3744	1872	1	468.0	520.0
2	QPSK	3/4	2	234	8	3744	2808	2	702.0	780.0
3	16-QAM	1/2	4	234	8	7488	3744	2	936.0	1040.0
4	16-QAM	3/4	4	234	8	7488	5616	3	1404.0	1560.0
5	64-QAM	2/3	6	234	8	11 232	7488	4	1872.0	2080.0
6	64-QAM	3/4	6	234	8	11 232	8424	4	2106.0	2340.0
7	64-QAM	5/6	6	234	8	11 232	9360	6	2340.0	2600.0
8	256-QAM	3/4	8	234	8	14 976	11 232	6	2808.0	3120.0
9	256-QAM	5/6	8	234	8	14 976	12 480	6	3120.0	3466.7

Table 21-53—VHT-MCSs for optional 160 MHz and 80+80 MHz, N_{SS} = 1

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	$N_{SD} \cdot N_{Seg}$	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	468	16	468	234	1	58.5	65.0
1	QPSK	1/2	2	468	16	936	468	1	117.0	130.0
2	QPSK	3/4	2	468	16	936	702	1	175.5	195.0
3	16-QAM	1/2	4	468	16	1872	936	1	234.0	260.0
4	16-QAM	3/4	4	468	16	1872	1404	1	351.0	390.0
5	64-QAM	2/3	6	468	16	2808	1872	1	468.0	520.0
6	64-QAM	3/4	6	468	16	2808	2106	1	526.5	585.0
7	64-QAM	5/6	6	468	16	2808	2340	2	585.0	650.0
8	256-QAM	3/4	8	468	16	3744	2808	2	702.0	780.0
9	256-QAM	5/6	8	468	16	3744	3120	2	780.0	866.7

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Table 21-54—VHT-MCSs for optional 160 MHz and 80+80 MHz, N_{SS} = 2

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	$N_{SD} \cdot N_{Seg}$	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	468	16	936	468	1	117.0	130.0
1	QPSK	1/2	2	468	16	1872	936	1	234.0	260.0
2	QPSK	3/4	2	468	16	1872	1404	1	351.0	390.0
3	16-QAM	1/2	4	468	16	3744	1872	1	468.0	520.0
4	16-QAM	3/4	4	468	16	3744	2808	2	702.0	780.0
5	64-QAM	2/3	6	468	16	5616	3744	2	936.0	1040.0
6	64-QAM	3/4	6	468	16	5616	4212	2	1053.0	1170.0
7	64-QAM	5/6	6	468	16	5616	4680	3	1170.0	1300.0
8	256-QAM	3/4	8	468	16	7488	5616	3	1404.0	1560.0
9	256-QAM	5/6	8	468	16	7488	6240	3	1560.0	1733.3

Table 21-55—VHT-MCSs for optional 160 MHz and 80+80 MHz, N_{SS} = 3

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	$N_{SD} \cdot N_{Seg}$	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	468	16	1404	702	1	175.5	195.0
1	QPSK	1/2	2	468	16	2808	1404	1	351.0	390.0
2	QPSK	3/4	2	468	16	2808	2106	1	526.5	585.0
3	16-QAM	1/2	4	468	16	5616	2808	2	702.0	780.0
4	16-QAM	3/4	4	468	16	5616	4212	2	1053.0	1170.0
5	64-QAM	2/3	6	468	16	8424	5616	3	1404.0	1560.0
6	64-QAM	3/4	6	468	16	8424	6318	3	1579.5	1755.0
7	64-QAM	5/6	6	468	16	8424	7020	4	1755.0	1950.0
8	256-QAM	3/4	8	468	16	11 232	8424	4	2106.0	2340.0
9	Not valid									

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Table 21-56—VHT-MCSs for optional 160 MHz and 80+80 MHz, N_{SS} = 4

VHT-MCS Index	Modulation	R	N_{BPSCS}	$N_{SD} \cdot N_{Seg}$	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	468	16	1872	936	1	234.0	260.0
1	QPSK	1/2	2	468	16	3744	1872	1	468.0	520.0
2	QPSK	3/4	2	468	16	3744	2808	2	702.0	780.0
3	16-QAM	1/2	4	468	16	7488	3744	2	936.0	1040.0
4	16-QAM	3/4	4	468	16	7488	5616	3	1404.0	1560.0
5	64-QAM	2/3	6	468	16	11 232	7488	4	1872.0	2080.0
6	64-QAM	3/4	6	468	16	11 232	8424	4	2106.0	2340.0
7	64-QAM	5/6	6	468	16	11 232	9360	6	2340.0	2600.0
8	256-QAM	3/4	8	468	16	14 976	11 232	6	2808.0	3120.0
9	256-QAM	5/6	8	468	16	14 976	12 480	6	3120.0	3466.7

Table 21-57—VHT-MCSs for optional 160 MHz and 80+80 MHz, N_{SS} = 5

VHT-MCS Index	Modulation	R	N_{BPSCS}	$N_{SD} \cdot N_{Seg}$	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	468	16	2340	1170	1	292.5	325.0
1	QPSK	1/2	2	468	16	4680	2340	2	585.0	650.0
2	QPSK	3/4	2	468	16	4680	3510	2	877.5	975.0
3	16-QAM	1/2	4	468	16	9360	4680	3	1170.0	1300.0
4	16-QAM	3/4	4	468	16	9360	7020	4	1755.0	1950.0
5	64-QAM	2/3	6	468	16	14 040	9360	5	2340.0	2600.0
6	64-QAM	3/4	6	468	16	14 040	10 530	5	2632.5	2925.0
7	64-QAM	5/6	6	468	16	14 040	11 700	6	2925.0	3250.0
8	256-QAM	3/4	8	468	16	18 720	14 040	8	3510.0	3900.0
9	256-QAM	5/6	8	468	16	18 720	15 600	8	3900.0	4333.3

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Table 21-58—VHT-MCSs for optional 160 MHz and 80+80 MHz, N_{SS} = 6

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	$N_{SD} \cdot N_{Seg}$	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	468	16	2808	1404	1	351.0	390.0
1	QPSK	1/2	2	468	16	5616	2808	2	702.0	780.0
2	QPSK	3/4	2	468	16	5616	4212	2	1053.0	1170.0
3	16-QAM	1/2	4	468	16	11 232	5616	3	1404.0	1560.0
4	16-QAM	3/4	4	468	16	11 232	8424	4	2106.0	2340.0
5	64-QAM	2/3	6	468	16	16 848	11 232	6	2808.0	3120.0
6	64-QAM	3/4	6	468	16	16 848	12 636	6	3159.0	3510.0
7	64-QAM	5/6	6	468	16	16 848	14 040	8	3510.0	3900.0
8	256-QAM	3/4	8	468	16	22 464	16 848	8	4212.0	4680.0
9	256-QAM	5/6	8	468	16	22 464	18 720	9	4680.0	5200.0

Table 21-59—VHT-MCSs for optional 160 MHz and 80+80 MHz, N_{SS} = 7

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	$N_{SD} \cdot N_{Seg}$	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	468	16	3276	1638	1	409.5	455.0
1	QPSK	1/2	2	468	16	6552	3276	2	819.0	910.0
2	QPSK	3/4	2	468	16	6552	4914	3	1228.5	1365.0
3	16-QAM	1/2	4	468	16	13 104	6552	4	1638.0	1820.0
4	16-QAM	3/4	4	468	16	13 104	9828	6	2457.0	2730.0
5	64-QAM	2/3	6	468	16	19 656	13 104	7	3276.0	3640.0
6	64-QAM	3/4	6	468	16	19 656	14 742	7	3685.5	4095.0
7	64-QAM	5/6	6	468	16	19 656	16 380	9	4095.0	4550.0
8	256-QAM	3/4	8	468	16	26 208	19 656	12	4914.0	5460.0
9	256-QAM	5/6	8	468	16	26 208	21 840	12	5460.0	6066.7

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Table 21-60—VHT-MCSs for optional 160 MHz and 80+80 MHz, N_{SS} = 8

VHT-MCS Index	Modulation	*R*	N_{BPSCS}	$N_{SD} \cdot N_{Seg}$	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)	
									800 ns GI	400 ns GI
0	BPSK	1/2	1	468	16	3744	1872	1	468.0	520.0
1	QPSK	1/2	2	468	16	7488	3744	2	936.0	1040.0
2	QPSK	3/4	2	468	16	7488	5616	3	1404.0	1560.0
3	16-QAM	1/2	4	468	16	14 976	7488	4	1872.0	2080.0
4	16-QAM	3/4	4	468	16	14 976	11 232	6	2808.0	3120.0
5	64-QAM	2/3	6	468	16	22 464	14 976	8	3744.0	4160.0
6	64-QAM	3/4	6	468	16	22 464	16 848	8	4212.0	4680.0
7	64-QAM	5/6	6	468	16	22 464	18 720	9	4680.0	5200.0
8	256-QAM	3/4	8	468	16	29 952	22 464	12	5616.0	6240.0
9	256-QAM	5/6	8	468	16	29 952	24 960	12	6240.0	6933.3

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22. Television very high throughput (TVHT) PHY specification

22.1 Introduction

22.1.1 Introduction to the TVHT PHY

Clause 22 specifies the PHY entity for a television very high throughput (TVHT) orthogonal frequency division multiplexing (OFDM) system.

Three basic channel units (BCUs) are defined as 6 MHz, 7 MHz, or 8 MHz, depending on the regulatory domain, and denoted in the rest of this clause as a BCU or TVHT_W. Many of the terms used in this clause refer to different bands, depending on the regulatory domain. These terms include

— TVHT_2W, which represents two contiguous BCUs (12 MHz, 14 MHz, or 16 MHz)
— TVHT_W+W, which represents two noncontiguous BCU (6+6 MHz, 7+7 MHz, or 8+8 MHz)
— TVHT_4W, which represents four contiguous BCUs (24 MHz, 28 MHz, or 32 MHz)
— TVHT_2W+2W, which represents two noncontiguous frequency segments, each of which is composed of two BCUs (12+12 MHz, 14+14 MHz, or 16+16 MHz)

The TVHT PHY is based on the VHT PHY, as defined in 21.3, 21.4, and 21.5, and on Clause 17.

All TVHT transmissions in one BCU shall use the VHT PHY parameters for 40 MHz channel defined in 21.3, 21.4, and 21.5 with a sampling clock change to fit into each of the BCU bandwidths and with the number of encoders (N_{ES}) always being 1 (for SU-MIMO and per user in MU-MIMO).

Table 22-8 describes the sampling clock for each of the BCUs and the basic PHY parameters for transmission over one BCU.

For all VHT PPDUs and non-HT PPDUs in TVWS band, timing-related parameters shall be used as defined in Table 22-5 and Table 22-8; frequently used parameters shall be used as defined in Table 22-6 and Table 22-9; phase rotation parameter $\Upsilon_{k,\mathrm{BW}}$ shall be replaced by $\Upsilon_{k,\mathrm{M}}$, which is defined in Table 22-12; and cyclic shift parameters shall be used as defined in 22.3.8.3.2.

As shown in Table 22-8, the design is based on defining 144 OFDM tones in the 6 MHz and 8 MHz channel units and using up to tone 58 on each side of the DC tone for data and pilots, exactly matching the VHT 40 MHz PHY parameters. The 7 MHz channel unit is split into 168 tones to maintain the same tone spacing and PHY design as used for 6 MHz channels (note the ratio of 168 to 144 is identical to the ratio of 7 to 6). The choice of 144 and not 128 was made to reduce the PHY channel BW from 6 MHz to 5 1/3 MHz in order to allow sharper filtering to achieve 55 dB ACLR.

The TVHT PHY defines the following transmission modes that incorporate transmission on one, two, or four BCUs:

a) Mandatory transmission mode - one BCU (TVHT_MODE_1)
b) Optional transmission modes - multi-BCUs
   1) Two contiguous BCUs (TVHT_MODE_2C)
   2) Two noncontiguous BCUs (TVHT_MODE_2N)
   3) Four contiguous BCUs (TVHT_MODE_4C)
   4) Two noncontiguous frequency segments, each of which comprises two contiguous BCUs (TVHT_MODE_4N)

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The tone spacing, DFT duration, and other timing parameters remain unchanged for all optional modes compared with the definition in Table 22-8.

The number of occupied tones in each BCU of any optional mode is the same as the number defined in Table 22-8.

The location of the occupied tones in each BCU of any optional mode is shown in Table 22-9.

The DATA encoding process for multi-BCUs transmission is similar to one BCU transmission and is defined in 22.3.10.

A TVHT STA shall support the following features:

- TVHT_MODE_1 (one BCU)
- Single spatial stream MCSs 0 to 7 (transmit and receive)
- BCC coding
- Normal and short guard interval (transmit and receive)

A TVHT STA may support the following features:

- TVHT_MODE_2C, TVHT_MODE_2N, TVHT_MODE_4C, or TVHT_MODE_4N (two or four BCUs)
- Two or more spatial streams (transmit and receive)
- Beamforming sounding (by sending a VHT NDP)
- Respond to transmit beamforming sounding (provide compressed beamforming feedback)
- STBC (transmit and receive)
- LDPC (transmit and receive)
- VHT MU PPDUs (transmit and receive)
- MCSs 8 and 9 (transmit and receive)

22.1.2 Scope of TVHT PHY services

The services provided to the MAC by the TVHT PHY consist of a protocol function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. These STAs support a TVHT PHY.

22.1.3 TVHT PHY functions

22.1.3.1 General

See 21.1.3.1 with “TVHT” replacing “VHT”.

22.1.3.2 PHY management entity (PLME)

See 21.1.3.2.

22.1.3.3 Service specification method

See 21.1.3.3 with “TVHT” replacing “VHT”.

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22.1.4 PPDU formats

The structure of the PPDU transmitted by a TVHT STA is determined by the TXVECTOR parameters as defined in 22.2.2.

The FORMAT parameter determines the overall structure of the PPDU and includes the following:

— Non-HT format (NON_HT), based on Clause 17. Support for non-HT format is mandatory.
— VHT format (VHT). Support for TVHT_W VHT format is mandatory.

22.2 TVHT PHY service interface

22.2.1 Introduction

See 21.2.1.

22.2.2 TXVECTOR and RXVECTOR parameters

The TXVECTOR and RXVECTOR parameters are defined in Table 22-1.

The TXVECTOR parameter FORMAT shall be set to NON_HT or VHT. When the TXVECTOR parameter FORMAT equals NON_HT, then NON_HT_MODULATION shall be set to NON_HT_DUP_OFDM.

When the TXVECTOR parameter FORMAT equals NON_HT, the TXVECTOR parameter L_DATARATE indicates the data rate used to transmit the PSDU in Mb/s. The allowed values are 6 Mb/s, 9 Mb/s, 12 Mb/s, 18 Mb/s, 24 Mb/s, 36 Mb/s, 48 Mb/s, and 54 Mb/s divided by 7.5 for 6 MHz and 7 MHz unit channels and by 5.625 for 8 MHz channels.

When the TXVECTOR parameter FORMAT equals VHT, the TXVECTOR parameter CH_BANDWIDTH indicates the channel width of the transmitted PPDU:

Enumerated type:

— TVHT_W for one BCU
— TVHT_2W for two contiguous BCUs
— TVHT_W+W for two noncontiguous BCUs
— TVHT_4W for four contiguous BCUs
— TVHT_2W+2W for two noncontiguous frequency segments, each of which comprises two contiguous BCUs

Note that TVHT_W represents the broadcast channel bandwidth for the regulatory domain, e.g., TVHT_W is 6 MHz, 7 MHz, or 8 MHz. TVHT_2W represents two contiguous BCUs with the same regulatory domain, e.g., TVHT_2W is 12 MHz, 14 MHz, or 16 MHz.

When the TXVECTOR parameter FORMAT equals NON_HT, the TXVECTOR parameter CH_BANDWIDTH indicates the channel width of the transmitted PPDU on transmission and the estimated channel width of the received PPDU on reception:

Enumerated type:

— TVHT_W, TVHT_2W, TVHT_W+W, TVHT_4W, TVHT_2W+2W

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When the TXVECTOR parameter FORMAT equals VHT, the TXVECTOR parameter NUM_STS indicates the number of space-time streams: range 1 to 4 for SU, 1 to 3 per user for MU. NUM_STS summed over all users shall be less than or equal to 4. The TXVECTOR parameter NUM_STS is not present when the TXVECTOR parameter FORMAT equals to NON_HT.

Table 22-1—TXVECTOR and RXVECTOR parameters

Parameter	Condition	Value	TXVECTOR	RXVECTOR
FORMAT		Determines the format of the PPDU. Enumerated type: NON_HT indicates non-HT duplicated PPDU format. In this case, the modulation is determined by the NON_HT_MODULATION parameter. VHT indicates VHT format.	Y	Y
NON_HT_MODULATION	FORMAT is NON_HT	In TXVECTOR, indicates the format type of the transmitted non-HT PPDU. In RXVECTOR, indicates the estimated format type of the received non-HT PPDU. Enumerated type: NON_HT_DUP_OFDM indicates non-HT duplicate format.	Y	Y
	Otherwise	Not present	N	N
L_LENGTH	FORMAT is NON_HT	Indicates the length of the PSDU in octets in the range 1 to 4095. This value is used by the PHY to determine the number of octet transfers that occur between the MAC and the PHY.	Y	Y
	FORMAT is VHT	Not present NOTE—The Length field of the L-SIG in VHT PPDUs is defined in Equation (22-9) using the scaling factor defined in 22.3.8.2.1.	N	N
L_DATARATE	FORMAT is NON_HT	Indicates the data rate used to transmit the PSDU in Mb/s. The allowed values are 6, 9, 12, 18, 24, 36, 48, and 54 divided by 7.5 for 6 MHz and 7 MHz unit channels and by 5.625 for 8 MHz channels.	Y	Y
	FORMAT is VHT	Not present NOTE—The RATE field in the L-SIG field in a VHT PPDU is set to the value representing 6/*X* Mb/s in TVWS band "Modulation BPSK and Coding rate 1/2" row of Table 22-4.	N	N
N_TX	FORMAT is VHT	Indicates the number of transmit chains.	Y	N
	Otherwise	Not present	N	N

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Table 22-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
EXPANSION_MAT_TYPE	FORMAT is VHT and EXPANSION_MAT is present.	Set to COMPRESSED_SV	Y	N
	Otherwise	See corresponding entry in Table 19-1		
EXPANSION_MAT	FORMAT is VHT	Contains a vector in the number of selected subcarriers containing feedback matrices as defined in 22.3.11.2 based on the channel measured during the training symbols of a previous VHT NDP.	M U	N
	Otherwise	See corresponding entry in Table 19-1		
CHAN_MAT_TYPE	FORMAT is VHT and PSDU_LENGTH equals zero	Set to COMPRESSED_SV NOTE—This parameter is present only for TVHT NDPs.	N	Y
	FORMAT is VHT and PSDU_LENGTH is greater than zero	Not present	N	N
	Otherwise	See corresponding entry in Table 19-1		
CHAN_MAT	FORMAT is VHT and PSDU_LENGTH equals zero	Contains a set of compressed beamforming feedback matrices as defined in 21.3.11.2 based on the channel measured during the training symbols of the received VHT NDP.	N	Y
	FORMAT is VHT and PSDU_LENGTH is greater than zero	Not present	N	N
	Otherwise	See corresponding entry in Table 19-1		
DELTA_SNR	FORMAT is VHT	Contains an array of delta SNR values as defined in 9.4.1.52 based on the channel measured during the training symbols of the received VHT NDP. NOTE—In the RXVECTOR this parameter is present only for VHT NDPs for MU sounding.	M U	Y
	Otherwise	Not present	N	N

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Table 22-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
SNR	FORMAT is VHT	Contains an array of measures of the received SNR for each spatial stream. SNR indications of 8 bits are supported. SNR shall be the sum of the decibel values of SNR per tone divided by the number of tones represented in each stream as described in 9.4.1.50.	N	Y
	Otherwise	See corresponding entry in Table 19-1		
NO_SIG_EXTN	FORMAT is VHT	Not present	N	N
	Otherwise	See corresponding entry in Table 19-1		
FEC_CODING	FORMAT is HT	Indicates which FEC encoding is used. Enumerated type: BCC_CODING indicates binary convolutional code. LDPC_CODING indicates low-density parity check code.	M U	Y
	Otherwise	See corresponding entry in Table 19-1		
STBC	FORMAT is VHT	Indicates whether STBC is used. 0 indicates no STBC ($N_{STS}=N_{SS}$ in the Data field). 1 indicates STBC is used ($N_{STS}=2N_{SS}$ in the Data field).	Y	Y
	Otherwise	See corresponding entry in Table 19-1		
GI_TYPE	FORMAT is VHT	Indicates whether a short guard interval is used in the transmission of the Data field of the PPDU. Enumerated type: LONG_GI indicates short GI is not used in the Data field of the PPDU. SHORT_GI indicates short GI is used in the Data field of the PPDU.	Y	Y
	Otherwise	Not present	N	N
TXPWR_LEVEL_INDEX	FORMAT is VHT	The allowed values for the TXPWR_LEVEL_INDEX parameter are in the range 1 to $N/2$, where N is the number of octets in dot11TxPowerLevelExtended. This parameter is used to indicate which of the available transmit output power levels defined in dot11TxPowerLevelExtended shall be used for the current transmission.	Y	N
	Otherwise	See corresponding entry in Table 19-1		

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Table 22-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
RSSI	FORMAT is VHT	The allowed values for the RSSI parameter are in the range 0 to 255. This parameter is a measure by the PHY of the power observed at the antenna connector used to receive the current PPDU measured during the reception of the TVHT-LTF field. RSSI is intended to be used in a relative manner, and it is a monotonically increasing function of the received power.	N	Y
	Otherwise	See corresponding entry in Table 19-1		
MCS	FORMAT is VHT	Indicates the modulation and coding scheme used in the transmission of the PPDU. Integer: range 0 to 9	M U	Y
	Otherwise	See corresponding entry in Table 19-1		
REC_MCS	FORMAT is VHT	Indicates the MCS that the STA's receiver recommends.	N	O
	Otherwise	Not present	N	N
CH_BANDWIDTH	FORMAT is VHT	Indicates the channel width of the transmitted PPDU: Enumerated type: TVHT_W for one BCU TVHT_2W for two contiguous BCUs TVHT_W+W for two noncontiguous BCUs TVHT_4W for four contiguous BCUs TVHT_2W+2W for two noncontiguous frequency segments, each of which comprises two contiguous BCUs	Y	Y
	FORMAT is NON_HT	In TXVECTOR, indicates the channel width of the transmitted PPDU. In RXVECTOR, indicates the estimated channel width of the received PPDU. Enumerated type: TVHT_W, TVHT_2W, TVHT_W+W, TVHT_4W, TVHT_2W+2W if NON_HT_MODULATION equals NON_HT_DUP_OFDM	Y	Y
DYN_BANDWIDTH_IN_NON_HT	FORMAT is NON_HT	In TXVECTOR, if present, indicates whether the transmitter is capable of Static or Dynamic bandwidth operation. In RXVECTOR, if valid, indicates whether the transmitter is capable of Static or Dynamic bandwidth operation. Enumerated type: Static if the transmitter is capable of Static bandwidth operation Dynamic if the transmitter is capable of Dynamic bandwidth operation NOTE—In the RXVECTOR, the validity of this parameter is determined by the MAC based on the contents of the received MPDU.	O	Y
	Otherwise	Not present	N	N

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Table 22-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
CH_BANDWIDTH_IN_NON_HT	FORMAT is NON_HT	In TXVECTOR, if present, indicates the channel width of the transmitted PPDU, which is signaled via the scrambling sequence. In RXVECTOR, if valid, indicates the channel width of the received PPDU, which is signaled via the scrambling sequence. Enumerated type: TVHT_W, TVHT_2W, TVHT_W+W, TVHT_4W, TVHT_2W+2W. NOTE—In the RXVECTOR, the validity of this parameter is determined by the MAC based on the contents of the received MPDU.	O	Y
	Otherwise	Not present	N	N
APEP_LENGTH	FORMAT is VHT	If equal to 0, indicates a TVHT NDP for both RXVECTOR and TXVECTOR. If greater than zero, in the TXVECTOR, indicates the number of octets in the range 1 to 1 048 575 in the A-MPDU pre-EOF padding (see 10.12.2) carried in the PSDU. If greater than zero, in the RXVECTOR, is the value obtained from the VHT-SIG-B Length field multiplied by 4.	M U	O
	Otherwise	Not present	N	N
PSDU_LENGTH	FORMAT is VHT	Indicates the number of octets in the VHT PSDU in the range 0 to 1 065 600 octets. A value of 0 indicates a VHT NDP.	N	Y
	Otherwise	Not present	N	N
USER_POSITION	FORMAT is VHT and 1 ≤ GROUP_ID ≤ 62	Index for user in MU transmission. Integer: range 0 to 3. NOTE—The entries in the USER_POSITION array are in ascending order.	M U	O
	Otherwise	Not present	N	N
NUM_STS	FORMAT is VHT	Indicates the number of space-time streams. Integer: range 1 to 4 for SU, 1 to 3 per user in the TXVECTOR, and 0 to 4 in the RXVECTOR for MU. NUM_STS summed over all users is between 1 and 4.	M U	Y
	Otherwise	Not present	N	N
GROUP_ID	FORMAT is VHT	Indicates the group ID. Integer: range 0 to 63 (see Table 22-12) A value of 0 or 63 indicates a VHT SU PPDU. A value in the range 1 to 62 indicates a VHT MU PPDU.	Y	Y
	Otherwise	Not present	N	N

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Table 22-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
PARTIAL_AID	FORMAT is VHT and GROUP_ID is 0 or 63	Provides an abbreviated indication of the intended recipient(s) of the PSDU (see 10.19). Integer: range 0 to 511.	Y	Y
	Otherwise	Not present	N	N
NUM_USERS	FORMAT is VHT	Indicates the number of users with nonzero space-time streams. Integer: range 1 to 4.	Y	N
	Otherwise	Not present	N	N
BEAMFORMED	FORMAT is VHT and GROUP_ID is 0 or 63	Set to 1 if a beamforming steering matrix is applied to the waveform in an SU transmission. Set to 0 otherwise. NOTE—When BEAMFORMED is set to 1, smoothing is not recommended.	Y	O
	Otherwise	Not present	N	N
TXOP_PS_NOT_ALLOWED	FORMAT is VHT	Indicates whether a TVHT AP allows non-AP TVHT STAs in TXOP power save mode to enter doze state during the TXOP. 0 indicates that the TVHT AP allows non-AP TVHT STAs to enter doze state during a TXOP. 1 indicates that the TVHT AP does not allow non-AP TVHT STAs to enter doze state during a TXOP.	Y	Y
	Otherwise	Not present	N	N
TIME_OF_DEPARTURE_REQUESTED		Boolean value: true indicates that the MAC entity requests that the PHY entity measures and reports time of departure parameters corresponding to the time when the first PPDU energy is sent by the transmitting port. false indicates that the MAC entity requests that the PHY entity neither measures nor reports time of departure parameters.	O	N

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Table 22-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
RX_START_OF_FRAME_OFFSET	dot11TimingMsmtActivated is true	0 to 2^{32}– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble corresponding to the incoming frame arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC.	N	Y
	Otherwise	Not present	N	N

NOTE 1—In the TXVECTOR and RXVECTOR columns, the following apply:
Y = Present;
N = Not present;
O = Optional;
MU indicates that the parameter is present once for a VHT SU PPDU and present per user for a VHT MU PPDU. Parameters specified to be present per user are conceptually supplied as an array of values indexed by *u*, where *u* takes values 0 to NUM_USERS – 1.

NOTE 2—On reception, where valid, the CH_BANDWIDTH_IN_NON_HT parameter is likely to be a more reliable indication of subformat and channel width than the NON_HT_MODULATION and CH_BANDWIDTH parameters, since for non-HT or non-HT duplicate frames, CH_BANDWIDTH is a receiver estimate of the bandwidth, whereas CH_BANDWIDTH_IN_NON_HT is the signaled bandwidth.

22.2.3 Effects of CH_BANDWIDTH parameter on PPDU format

Table 22-2 shows the PPDU format as a function of the CH_BANDWIDTH and FORMAT parameters.

Table 22-2—PPDU format as a function of CH_BANDWIDTH parameter

FORMAT	CH_BANDWIDTH	PPDU format
VHT	TVHT_W	The STA transmits a VHT PPDU in TVWS bands (when FORMAT is VHT) with TVHT_MODE_1.
VHT	TVHT_2W	The STA transmits a VHT PPDU in TVWS bands (when FORMAT is VHT) with TVHT_MODE_2C.
VHT	TVHT_4W	The STA transmits a VHT PPDU in TVWS bands (when FORMAT is VHT) with TVHT_MODE_4C.
VHT	TVHT_W+W	The STA transmits a VHT PPDU in TVWS bands (when FORMAT is VHT) with TVHT_MODE_2N.
VHT	TVHT_2W+2W	The STA transmits a VHT PPDU in TVWS bands (when FORMAT is VHT) with TVHT_MODE_4N.

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Table 22-2—PPDU format as a function of CH_BANDWIDTH parameter *(continued)*

FORMAT	CH_BANDWIDTH	PPDU format
NON_HT	TVHT_W	The STA transmits a NON_HT PPDU with NON_HT_MODULATION set to NON_HT_DUP_OFDM using one TVHT_W channel as defined in 22.3.10.12. If the BSS bandwidth is wider than TVHT_W, then the transmission shall use the primary TVHT_W channel.
NON_HT	TVHT_2W	The STA transmits a NON_HT PPDU with NON_HT_MODULATION set to NON_HT_DUP_OFDM using two adjacent TVHT_W channels as defined in 22.3.10.12. If the BSS bandwidth is wider than TVHT_2W, then the transmission shall use the primary TVHT_2W channel.
NON_HT	TVHT_4W	The STA transmits a NON_HT PPDU with NON_HT_MODULATION set to NON_HT_DUP_OFDM using four adjacent TVHT_W channels as defined in 22.3.10.12.
NON_HT	TVHT_W+W	The STA transmits a NON_HT PPDU with NON_HT_MODULATION set to NON_HT_DUP_OFDM using two nonadjacent frequency segments, with each frequency segment consisting of single TVHT_W channels as defined in 22.3.10.12.
NON_HT	TVHT_2W+2W	The STA transmits a NON_HT PPDU with NON_HT_MODULATION set to NON_HT_DUP_OFDM using two nonadjacent frequency segments, with each frequency segment consisting of two adjacent TVHT_W channels as defined in 22.3.10.12.

22.2.4 Support for NON_HT and HT formats

Transmission of HT PPDUs is not supported in Clause 22. Except for Non-HT duplicate transmission defined in 22.3.10.12, transmission of NON_HT is not supported in Clause 22.

Non-HT duplicate transmission is based on Clause 17, unless otherwise stated in Clause 22.

Non-HT PPDU format is same as in Figure 17-1. Overview of the PPDU encoding process is defined in 17.3.2.2 except for following modifications:

Modulation-dependent parameters for Non-HT duplicate mode in TVWS band is defined in Table 22-3. Timing related parameters are defined in Table 22-5. t_{SIGNAL} in Equation (17-2) is equal to 16 multiplied by X µs, and t_{DATA} in Equation (17-2) is equal to 20 multiplied by X µs where X is 7.5 for 6 MHz and 7 MHz unit channels and X is 5.625 for 8 MHz channels.

The timings for preamble are multiplied by X where X is 7.5 for 6 MHz and 7 MHz unit channels and X is 5.625 for 8 MHz channels.

Constructions of L-STF, L-LTF, and L-SIG are same as in 22.3.4.2, 22.3.4.3, and 22.3.4.4 except for the value field parameters in L-SIG.

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Table 22-3—Modulation-dependent parameters for Non-HT duplicate mode in TVWS band

Modulation	Coding rate (R)	Coded bits per subcarrier (N_{BPSC})	Coded bits per OFDM symbol (N_{CBPS})	Data bits per OFDM symbol (N_{DBPS})	Data rate (Mb/s) (TVWS band)
BPSK	1/2	1	48	24	6/X (see NOTE)
BPSK	3/4	1	48	36	9/X (see NOTE)
QPSK	1/2	2	96	48	12/X (see NOTE)
QPSK	3/4	2	96	72	18/X (see NOTE)
16-QAM	1/2	4	192	96	24/X (see NOTE)
16-QAM	3/4	4	192	144	36/X (see NOTE)
64-QAM	2/3	6	288	192	48/X (see NOTE)
64-QAM	3/4	6	288	216	54/X (see NOTE)
NOTE—In TVWS band, X depends on regulatory domain, i.e., 7.5 for 6 MHz and 7 MHz unit channels and 5.625 for 8 MHz channels.					

Interpretation of the bits R1-R4 in the SIGNAL field is modified as in Table 22-4.

Table 22-4—RATE field in L-SIG

R1-R4	Modulation	Coding rate
1101	BPSK	1/2
1111	BPSK	3/4
0101	QPSK	1/2
0111	QPSK	3/4
1001	16-QAM	1/2
1011	16-QAM	3/4
0001	64-QAM	2/3
0011	64-QAM	3/4

Table 22-5 and Table 22-6 define the timing-related parameters for Non-HT format and location of occupied tones.

Other timing parameters are derived as in Table 17-5 using the definition of T_{FFT} in Table 22-5. Table 22-6 defines the number of occupied tones and their location in all transmission modes. Zero denotes the DC tone of any contiguous segment.

Refer to Table 21-6 for parameters definition. The definitions in the table are applicable to Clause 22 with the exception that in each transmission mode in Clause 22 $N_{CBPSSI} = N_{CBPSS}$ for SU and MU PPDUs.

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Table 22-5—Timing-related constants in Non-HT PPDU

Parameter	6 MHz	7 MHz	8 MHz	Description
N_{SD}	96	96	96	Number of complex data numbers per BCU
N_{SP}	8	8	8	Number of pilot values per BCU
N_{ST}	104	104	104	Total number of subcarriers per BCU
N_{SR}	58	58	58	Highest data subcarrier index per BCU
Δ_F	$\frac{6\text{ MHz}}{144} = 41\frac{2}{3}$ kHz	$\frac{7\text{ MHz}}{168} = 41\frac{2}{3}$ kHz	$\frac{8\text{ MHz}}{144} = 55\frac{5}{9}$ kHz	Subcarrier frequency spacing
T_{DFT}	24 μs	24 μs	18 μs	IDFT/DFT period
T_{GI}	6 μs = T_{DFT}/4	6 μs = T_{DFT}/4	4.5 μs = T_{DFT}/4	Guard interval duration
T_{GIS}	3 μs = T_{DFT}/8	3 μs = T_{DFT}/8	2.25 μs = T_{DFT}/8	Short guard interval duration

Table 22-6—Tone location in Non-HT PPDU

Parameter	TVHT_MODE_1	TVHT_MODE_2C	TVHT_MODE_2N	TVHT_MODE_4C	TVHT_MODE_4N	Description
N_{ST}	104	104	104	104	104	Total number of occupied subcarriers per BCU
N_{TT}	104	208	208	416	416	Total number of occupied subcarriers across all BCUs
Subcarrier index	–58 to –33, –31 to –6, +6 to +31, and +33 to +58	–130 to –105, –103 to –78, –66 to –41, –39 to –14, +14 to +39, +41 to +66, +78 to +103, and +105 to +130	–58 to –33, –31 to –6, +6 to +31, and +33 to +58 for each BCU	–274 to –249, –247 to –222, –210 to –185, –183 to –158, –130 to –105, –103 to –78, –66 to –41, –39 to –14, +14 to +39, +41 to +66, +78 to +103, +105 to +130, +158 to +183, +185 to +210, +222 to +247, and +249 to +274	–130 to –105, –103 to –78, –66 to –41, –39 to –14, +14 to +39, +41 to +66, +78 to +103, and +105 to +130 for each BCU	Location of occupied subcarriers for 6 MHz and 8 MHz channel units

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Table 22-6—Tone location in Non-HT PPDU *(continued)*

Parameter	TVHT_ MODE_1	TVHT_ MODE_2C	TVHT_ MODE_2N	TVHT_ MODE_4C	TVHT_ MODE_4N	Description
Subcarrier index	–58 to –33, –31 to –6, +6 to +31, and +33 to +58	–142 to –117, –115 to –90, –78 to –53, –51 to –26, +26 to +51, +53 to +78, +90 to +115, and +117 to +142	–58 to –33, –31 to –6, +6 to +31, and +33 to +58 for each BCU	–310 to –285, –283 to –258, –246 to –221, –219 to –194, –142 to –117, –115 to –90, –78 to –53, –51 to –26, +26 to +51, +53 to +78, +90 to +115, +117 to +142, +194 to +219, +221 to +246, +258 to +283, and +285 to +310	–142 to –117, –115 to –90, –78 to –53, –51 to –26, +26 to +51, +53 to +78, +90 to +115, and +117 to +142 for each BCU	Location of occupied subcarriers for 7 MHz

22.3 TVHT PHY sublayer

22.3.1 Introduction

See 21.3.1.

22.3.2 VHT PPDU format in TVWS bands

A single PPDU format is defined for this PHY: the VHT PPDU format in TVWS bands. Figure 22-1 shows the VHT PPDU format in TVWS bands, with the timing parameters (8 μs and 4 μs) in Figure 21-4 replaced by numbers from Table 22-8.

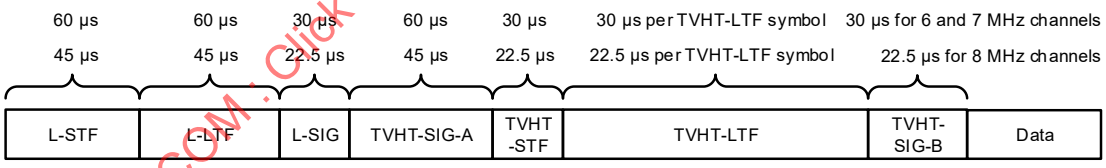

Figure 22-1—VHT PPDU format in TVWS bands

The fields of the VHT PPDU format in TVWS bands are summarized in Table 22-7.

The TVHT-SIG-A, TVHT-STF, TVHT-LTF, and TVHT-SIG-B fields exist only in VHT PPDU in TVWS bands. In a TVHT NDP, the Data field is not present. The number of symbols in the TVHT-LTF field, $N_{TVHT\text{-}LTF}$, can be 1, 2, or 4 and is determined by the total number of space-time streams across all users being transmitted in the VHT PPDU in TVWS bands (see Table 21-13).

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Table 22-7—Fields of the VHT PPDU in TVWS bands

Field	Description
L-STF	Non-HT Short Training field
L-LTF	Non-HT Long Training field
L-SIG	Non-HT SIGNAL field
TVHT-SIG-A	TVHT Signal A field
TVHT-STF	TVHT Short Training field
TVHT-LTF	TVHT Long Training field
TVHT-SIG-B	TVHT Signal B field
Data	The Data field includes the PSDU

22.3.3 Transmitter block diagram

The transmit process for the L-SIG and TVHT-SIG-A fields of a VHT PPDU using one BCU is shown in Figure 21-5, with "TVHT" replacing "VHT" and with bandwidth corrected according to TVHT bandwidth.

The transmit process for generating the TVHT-SIG-B field of a VHT SU PPDU and VHT MU PPDU using one frequency segment is shown in Figure 21-5 and Figure 21-7, respectively, with "TVHT" replacing "VHT" and with bandwidth corrected according to TVHT bandwidth.

The transmit process for generating the Data field of an SU PPDU in TVHT_MODE_1, TVHT_MODE_2C, or TVHT_MODE_4C with BCC and LDPC encodings, using one BCU, is shown Figure 21-10 and Figure 21-11, respectively, with "TVHT" replacing "VHT" and with bandwidth corrected according to TVHT bandwidth. Single BCC encoder shall be assumed in Figure 21-10.

The transmit process for generating the Data field of an MU PPDU in TVHT_MODE_1, TVHT_MODE_2C, or TVHT_MODE_4C with BCC and LDPC encoding is shown in Figure 21-12, with "TVHT" replacing "VHT" and with bandwidth corrected according to TVHT bandwidth. In the case of BCC encoding, single BCC encoder shall be assumed in Figure 21-12.

Figure 22-2 and Figure 22-3 show the transmit process for generating the Data field of a TVHT_MODE_2N or TVHT_MODE_4N SU PPDU with BCC and LDPC encoding, respectively, where the subcarrier allocation block allocates the subcarriers for the two IDFTs in each transmit path by the subcarrier mapper as described in 22.3.10.11.

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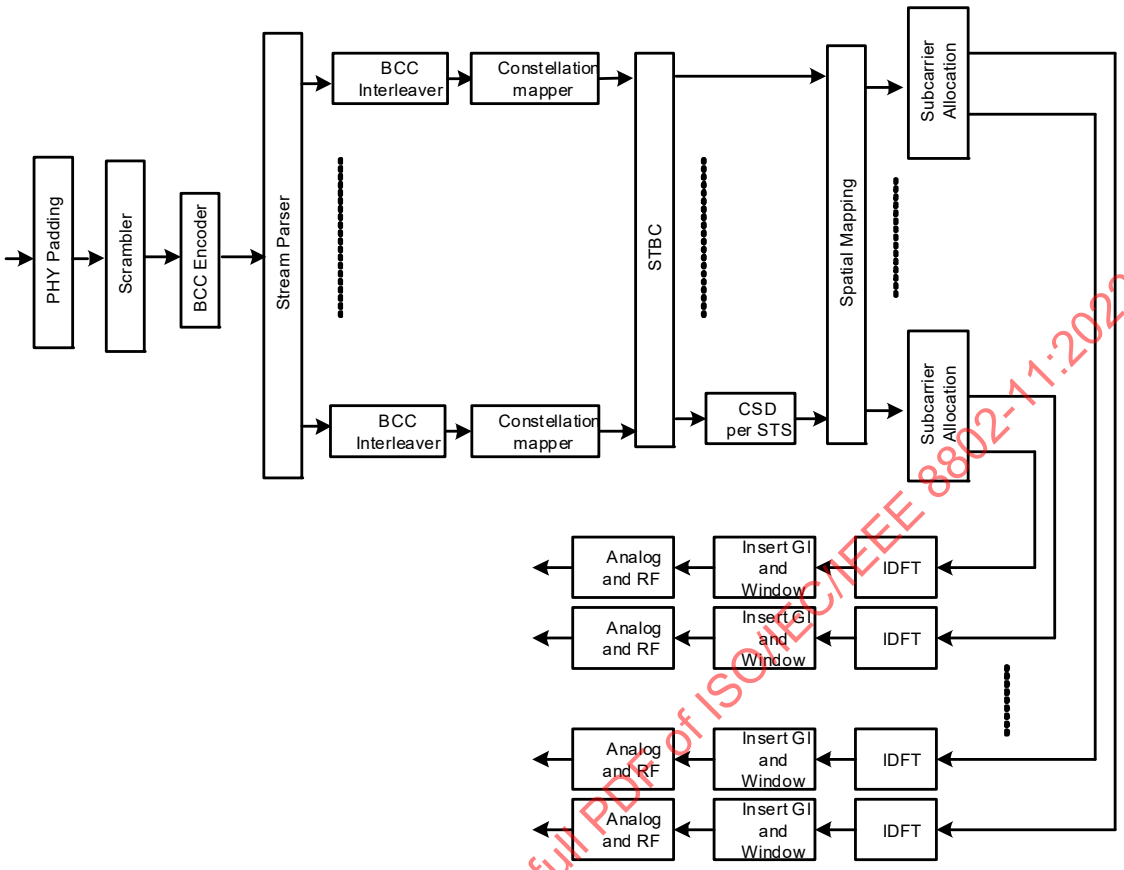

Figure 22-2—Transmitter block diagram for the Data field of a TVHT_MODE_2N or TVHT_MODE_4N SU PPDU with BCC encoding

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22.3.4 Overview of the PPDU encoding process

22.3.4.1 General

This subclause provides an overview of the VHT PPDU in TVWS bands encoding process.

22.3.4.2 Construction of L-STF

Construct the L-STF field as defined in 22.3.8.2.2 following the procedure in 21.3.4.2 reading "Clause 22" for references to "Clause 21" except the following:

c) Duplication and phase rotation: Duplicate the L-STF over the BCUs of the CH_BANDWIDTH. Apply appropriate phase rotation as defined in 22.3.7.

22.3.4.3 Construction of the L-LTF

Construct the L-LTF field as defined in L-LTF definition following the procedure in 21.3.4.3 reading "Clause 22" for references to "Clause 21" except the following:

c) Duplication and phase rotation: Duplicate the L-LTF over the BCUs of the CH_BANDWIDTH. Apply appropriate phase rotation as defined in 22.3.7.

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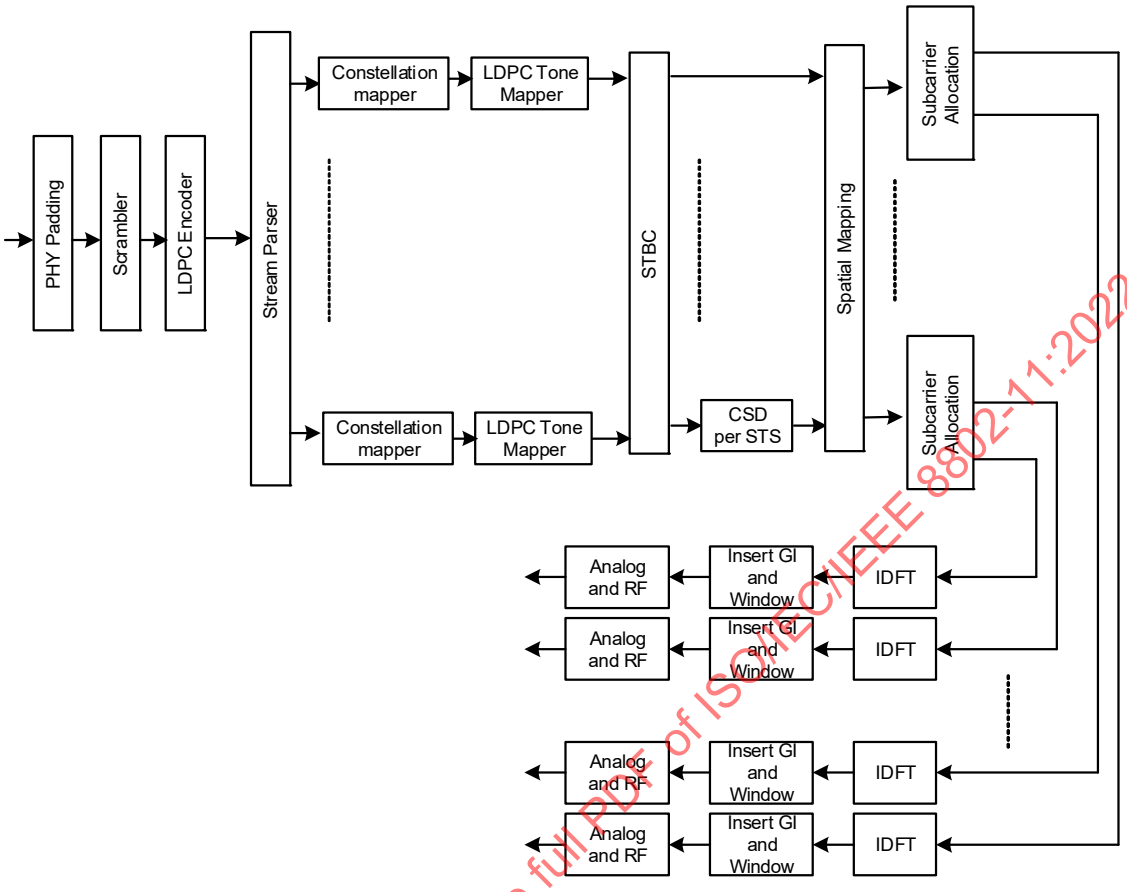

Figure 22-3—Transmitter block diagram for the Data field of a TVHT_MODE_2N or TVHT_MODE_4N SU PPDU with LDPC encoding

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22.3.4.4 Construction of L-SIG

Construct the L-SIG field as the SIGNAL field defined by 22.3.8.2.4 following the procedure in 21.3.4.4 reading "Clause 22" for references to "Clause 21" except the following:

a) For a VHT PPDU in TVWS bands, set the RATE subfield in the SIGNAL field R1-R4 to 1101. Set the Length, Parity, and Tail bits in the SIGNAL field as defined in 22.3.8.2.4. Add calculated one bit parity and N_{tail} bits into the L-SIG symbol.

f) Duplication and phase rotation: Duplicate the L-SIG field over the BCUs of the CH_BANDWIDTH. Apply appropriate phase rotation as defined in 22.3.7.

22.3.4.5 Construction of TVHT-SIG-A

The TVHT-SIG-A field consists of two symbols, TVHT-SIG-A1 and TVHT-SIG-A2, constructed as defined in 22.3.8.3.3 following the procedure in 21.3.4.5 reading "Clause 22" for references to "Clause 21" except the following:

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e) Pilot insertion: Insert pilots following the steps defined in 22.3.10.10.

f) Duplication and phase rotation: Duplicate TVHT-SIG-A1 and TVHT-SIG-A2 over of the BCUs of the CH_BANDWIDTH. Apply the appropriate phase rotation as defined in 22.3.7.

i) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as defined in 22.3.7.

22.3.4.6 Construction of TVHT-STF

Construct the TVHT-STF field for each BCU as defined in 22.3.8.3.4 with channel bandwidth being 40 MHz, following the procedure in 21.3.4.6 reading "Clause 22" for references to "Clause 21" except the following:

b) Phase rotation: Apply appropriate phase rotation as defined in 22.3.7.

f) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as defined in 22.3.7.

In multiple BCU transmissions TVHT_MODE_2C, TVHT_MODE_2N, TVHT_MODE_4C, and TVHT_MODE_4N, the TVHT-STF subcarriers of one BCU are repeated in each BCU with an appropriate phase rotation factor being applied as described in 22.3.8.3.4.

22.3.4.7 Construction of TVHT-LTF

Construct the TVHT-LTF field for each BCU as defined in 22.3.8.3.5 with channel bandwidth being 40 MHz, following the procedure in 21.3.4.7 reading "Clause 22" for references to "Clause 21" except the following:

b) Phase rotation: Apply appropriate phase rotation as defined in 22.3.7.

g) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as defined in 22.3.7.

In multiple BCU transmissions TVHT_MODE_2C, TVHT_MODE_2N, TVHT_MODE_4C, and TVHT_MODE_4N, the TVHT-LTF subcarriers of one BCU are repeated in each BCU with an appropriate phase rotation factor being applied as described in 22.3.8.3.5.

22.3.4.8 Construction of TVHT-SIG-B

The TVHT-SIG-B field is constructed per-user for each BCU as defined in 21.3.4.8 with channel bandwidth being 40 MHz, reading "Clause 22" for references to "Clause 21" except the following:

i) Pilot insertion: Insert pilots following the steps defined in 22.3.10.10.

m) Phase rotation: Apply the appropriate phase rotations as defined in 22.3.7.

o) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as defined in 22.3.7.

In multiple BCU transmissions TVHT_MODE_2C, TVHT_MODE_2N, TVHT_MODE_4C, and TVHT_MODE_4N, the TVHT-SIG-B subcarriers of one BCU are repeated in each BCU with an appropriate phase rotation factor being applied as described in 22.3.8.3.6.

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22.3.4.9 Construction of the Data field in an SU PPDU

22.3.4.9.1 Using BCC

The construction of the Data field in a VHT SU PPDU with BCC encoding proceeds as defined in 21.3.4.9.1 reading "Clause 22" for references to "Clause 21" except the following:

d) BCC encoder: Only one encoder is used.

f) Segment parser is omitted.

i) Segment deparser is omitted.

l) CSD: Apply CSD for each space-time stream and frequency segment as described in 22.3.8.3.2.

n) Phase rotation: Apply the appropriate phase rotations as defined in 22.3.7.

o) IDFT: When in TVHT_MODE_2N or VHT_MODE_4N, allocate the subcarriers for the two IDFTs in each transmit path as described in 22.3.10.11.

p) Insert GI and apply windowing: Prepend a GI (SHORT_GI or LONG_GI) and apply windowing as defined in 22.3.7.

22.3.4.9.2 Using LDPC

The construction of the Data field in a VHT SU PPDU with LDPC encoding proceeds as defined in 21.3.4.9.2 reading "Clause 22" for references to "Clause 21" except the following:

f) Segment parser is omitted.

i) Segment deparser is omitted.

l) CSD: Apply CSD for each space-time stream and frequency segment as described in 22.3.8.3.2.

n) Phase rotation: Apply the appropriate phase rotations as defined in 22.3.7. When in TVHT_MODE_2N or VHT_MODE_4N, allocate the subcarriers for the two IDFTs in each transmit path as described in 21.3.10.11.1.

o) IDFT: When in TVHT_MODE_2N or VHT_MODE_4N, allocate the subcarriers for the two IDFTs in each transmit path as described in 22.3.10.11.

p) Insert GI and apply windowing: Prepend a GI (SHORT_GI or LONG_GI) and apply windowing as defined in 22.3.7.

22.3.4.10 Construction of the Data field in an MU PPDU

22.3.4.10.1 General

See 21.3.4.10.1.

22.3.4.10.2 Using BCC

A Data field with BCC encoding is constructed using the process defined in 22.3.4.9.1 before the spatial mapping block and repeated for each user that uses BCC encoding.

22.3.4.10.3 Using LDPC

A Data field with LDPC encoding is constructed using the process defined in 22.3.4.9.2 before the spatial mapping block and repeated for each user that uses LDPC encoding.

22.3.4.10.4 Combining to form an MU PPDU

The per-user data is combined as defined in 21.3.4.10.4 except the following:

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a) Spatial mapping: The Q matrix is applied as defined in 22.3.10.11. The combining of all user data is done in this block.

b) Phase rotation: Apply the appropriate phase rotations as defined in 22.3.7.

d) Insert GI and apply windowing: Prepend a GI (SHORT_GI or LONG_GI) and apply windowing as defined in 22.3.7.

e) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7 and 22.3.8 for details.

22.3.5 Modulation and coding scheme (MCS)

The MCS is a value that determines the modulation and coding used in the Data field of the PPDU. It is a compact representation that is carried in the TVHT-SIG-A field for SU PPDUs and in the TVHT-SIG-B field for MU PPDUs. Rate-dependent parameters for the full set of MCSs are shown in Table 22-26 to Table 22-37 (in 22.5). These tables give rate-dependent parameters for MCSs with indices 0 to 9, with number of spatial streams from 1 to 4 and bandwidth options of one, two, or four BCUs. Equal modulation (EQM) is applied to all streams for a particular user.

Table 22-26 to Table 22-29 show rate-dependent parameters for MCSs for one to four streams for one BCU operation. Table 22-30 to Table 22-33 show rate-dependent parameters for MCSs for one to four streams for dual BCU operation. Table 22-34 to Table 22-37 show rate-dependent parameters for MCSs for one to four streams for quad BCU operation.

22.3.6 Timing-related parameters

Table 22-8 and Table 22-9 define the timing-related parameters for VHT format and location of occupied tones in TVWS bands.

Table 22-8—Timing-related parameters

Parameter	6 MHz	7 MHz	8 MHz	Description
N_{SD}	108	108	108	Number of complex data numbers per BCU
N_{SP}	6	6	6	Number of pilot values per BCU
N_{ST}	114	114	114	Total number of subcarriers per BCU
N_{SR}	58	58	58	Highest data subcarrier index per BCU
Δ_F	$\frac{6\text{ MHz}}{144} = 41\frac{2}{3}$ kHz	$\frac{7\text{ MHz}}{168} = 41\frac{2}{3}$ kHz	$\frac{8\text{ MHz}}{144} = 55\frac{5}{9}$ kHz	Subcarrier frequency spacing
T_{DFT}	24 μs	24 μs	18 μs	IDFT/DFT period
T_{GI}	6 μs = T_{DFT}/4	6 μs = T_{DFT}/4	4.5 μs = T_{DFT}/4	Guard interval duration

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Table 22-9—Tone location

Parameter	TVHT_ MODE_1	TVHT_ MODE_2C	TVHT_ MODE_2N	TVHT_ MODE_4C	TVHT_ MODE_4N	Description
N_{ST}	114	114	114	114	114	Total number of occupied subcarriers per BCU
N_{TT}	114	228	228	456	456	Total number of occupied subcarriers across all BCUs
Subcarrier index	–58 to –2 and +2 to +58	–130 to –74, –70 to –14, +14 to +70, and +74 to +130	–58 to –2 and +2 to +58 for each BCU	–274 to –218, –214 to –158, –130 to –74, –70 to –14, +14 to +70, +74 to +130, +158 to +214, and +218 to +274	–130 to –74, –70 to –14, +14 to +70, and +74 to +130 for each BCU	Location of occupied subcarriers for 6 MHz and 8 MHz channel units
Subcarrier index	–58 to –2 and +2 to +58	–142 to –86, –82 to –26, +26 to +82, and +86 to +142	–58 to –2 and +2 to +58 for each BCU	–310 to –254, –250 to –194, –142 to –86, –82 to –26, +26 to +82, +86 to +142, +194 to +250, and +254 to +310	–142 to –86, –82 to –26, +26 to +82, and +86 to +142 for each BCU	Location of occupied subcarriers for 7 MHz

The rest of the timing parameters are derived as in Table 21-5 using the definition of T_{DFT} in Table 22-8. Table 22-9 defines the number of occupied tones and their location in all transmission modes. Zero denotes the DC tone of any contiguous segment.

Refer to Table 21-6 for the frequency parameters. The definitions in the table are applicable to Clause 22 with the exception that in each transmission mode in Clause 22 $N_{CBPSSI} = N_{CBPSS}$ for SU and MU PPDUs.

22.3.7 Mathematical description of signals

For a description of the conventions used for the mathematical description of the signals, see 17.3.2.5.

For all VHT PPDU in TVWS bands transmission modes the signal is transmitted on subcarriers as defined in Table 22-9.

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Let

$f_{c,\text{idx0}}$ = dot11CurrentTVHTChannelCenterFrequencyIndex0 (see Table 22-17)

$f_{c,\text{idx1}}$ = dot11CurrentTVHTChannelCenterFrequencyIndex1 (see Table 22-17)

$f_{\text{PW, idx}}$ = dot11CurrentPrimaryChannel (see Table 22-17), where TVHT_W refers to a BCU of 6 MHz, 7 MHz, or 8 MHz

$f_{\text{CH, start}}$ = Channel starting frequency given in the operation class (E.1)

When dot11CurrentTVHTChannelWidth is TVHT_W, TVHT_2W, TVHT_W+W, TVHT_4W, or TVHT_2W+2W, $f_{PW,idx}$ and $f_{c,idx1}$ shall have the relationship specified in Equation (22-1).

$$f_{\text{PW, idx}} = f_{c,\text{idx0}} + n_{\text{PW}} \tag{22-1}$$

where

$$N_{PW} = \begin{cases} 1 \text{ in TVHT_W and TVHT_W+W} \\ 2 \text{ in TVHT_2W and TVHT_2W+2W} \\ 4 \text{ in TVHT_4W} \end{cases}$$

n_{PW} is an integer with possible range $0 \le n_{\text{PW}} \le N_{PW} - 1$

When dot11CurrentTVHTChannelWidth is TVHT_W, TVHT_2W, TVHT_W+W, TVHT_4W, or TVHT_2W+2W,

— The primary TVHT_W channel is the channel with TVHT_W bandwidth centered at $f_{\text{CH, start}}$ + TVHT_W × $f_{\text{PW, idx}}$, where $f_{\text{PW, idx}}$ is given in Equation (22-1).

When dot11CurrentTVHTChannelWidth is TVHT_2W, TVHT_4W, or TVHT_2W+2W,

— The secondary TVHT_W channel is the channel with TVHT_W bandwidth centered at $f_{\text{CH, start}}$ + TVHT_W × $f_{\text{SW, idx}}$, where $f_{\text{SW, idx}}$ is given in Equation (22-2).

$$f_{\text{SW, idx}} = \begin{cases} f_{\text{PW, idx}} + 1, & \text{if } n_{\text{PW}} \text{ is even} \\ f_{\text{PW, idx}} - 1, & \text{if } n_{\text{PW}} \text{ is odd} \end{cases} \tag{22-2}$$

When dot11CurrentTVHTChannelWidth is TVHT_W+W,

— The secondary TVHT_W channel is the channel with TVHT_W bandwidth centered at $f_{\text{CH, start}}$ + TVHT_W × $f_{\text{SW, idx}}$, where $f_{\text{SW, idx}}$ is given in Equation (22-3).

$$f_{\text{SW, idx}} = f_{c,\text{idx1}} \tag{22-3}$$

When dot11CurrentTVHTChannelWidth is TVHT_2W, TVHT_4W, or TVHT_2W+2W,

— The primary TVHT_2W channel is the channel with TVHT_2W bandwidth centered at $f_{\text{CH, start}}$ + TVHT_W × $f_{\text{P2W, idx}}$ + 0.5 × TVHT_W MHz, where $f_{\text{P2W, idx}}$ is given in Equation (22-4).

— The secondary TVHT_2W channel is the channel with TVHT_2W bandwidth centered at $f_{\text{CH, start}}$ + TVHT_W × $f_{S2W,\text{idx}}$ + 0.5 × TVHT_W MHz, where $f_{S2W,\text{idx}}$ is given in Equation (22-5).

$$f_{\text{P2W, idx}} = f_{c,\text{idx0}} + 2 \times n_{\text{P2W}} \quad 0 \le n_{\text{P2W}} \le N_{P2W} - 1 \quad N_{P2W} = \begin{cases} 1 \text{ in TVHT_2W and TVHT_2W+2W} \\ 2 \text{ in TVHT_4W} \end{cases} \tag{22-4}$$

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When dot11CurrentTVHTChannelWidth is TVHT_4W,

— The secondary TVHT_2W channel is the channel with TVHT_2W bandwidth centered at $f_{\text{CH, start}} + \text{TVHT_W} \times f_{S2W, \text{idx}} + 0.5 \times \text{TVHT_W}$ MHz, where $f_{S2W, \text{idx}}$ is given in Equation (22-5).

$$f_{\text{S2W, idx}} = \begin{cases} f_{\text{P2W, idx}} + 2, & \text{if } n_{\text{P2W}} \text{ is even} \\ f_{\text{P2W, idx}} - 2, & \text{if } n_{\text{P2W}} \text{ is odd} \end{cases} \quad (22\text{-}5)$$

When dot11CurrentTVHTChannelWidth is TVHT_2W+2W,

— The secondary TVHT_2W channel is the channel with TVHT_2W bandwidth centered at $f_{\text{CH, start}} + \text{TVHT_W} \times f_{S2W, \text{idx}} + 0.5 \times \text{TVHT_W}$ MHz, where $f_{S2W, \text{idx}}$ is given in Equation (22-3).

The transmitted signal is defined in complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the relation shown in Equation (21-11) in Clause 21.

$f_c^{(i_{Seg})}$ represents the center frequency of the PPDU transmitted in frequency segment i_{Seg} in each transmission mode in Clause 22.

Note that in TVHT_MODE_2C and TVHT_MODE_4C, the gap between the center frequencies of the adjacent segments is as shown in Table 22-9.

Table 22-10 shows $f_c^{(i_{Seg})}$ as a function of dot11CurrentTVHTChannelWidth.

Table 22-10—Center frequency of a PPDU transmitted in frequency segment i_{Seg}

dot11CurrentTVHTChannelWidth	CH_BANDWIDTH	$f_c^{(i_{Seg})} = f_{\text{CH, start}} + \text{TVHT_W} \times f_{(i_{Seg})} + \textit{Correction}$	
		$(f_{(0)}, \textit{Correction})$	$(f_{(1)}, \textit{Correction})$
TVHT_W	TVHT_W	$(f_{c, \text{idx0}}, 0)$	—
TVHT_2W	TVHT_W	$(f_{\text{PW, idx}}, 0)$	—
	TVHT_2W	$(f_{c, \text{idx0}}, 0.5 \times \text{TVHT_W})$	—
TVHT_W+W	TVHT_W	$(f_{\text{PW, idx}}, 0)$	
	TVHT_W+W	$(f_{c, \text{idx0}}, 0)$	$(f_{c, \text{idx1}}, 0)$
TVHT_4W	TVHT_W	$(f_{\text{PW, idx}}, 0)$	—
	TVHT_2W	$(f_{\text{P2W, idx}}, 0.5 \times \text{TVHT_W})$	—
	TVHT_4W	$(f_{c, \text{idx0}}, 1.5 \times \text{TVHT_W})$	—
TVHT_2W+2W	TVHT_W	$(f_{c, \text{idx0}}, 0)$	
	TVHT_2W	$(f_{c, \text{idx0}}, 0.5 \times \text{TVHT_W})$	
	TVHT_2W+2W	$(f_{c, \text{idx0}}, 0.5 \times \text{TVHT_W})$	$(f_{c, \text{idx1}}, 0.5 \times \text{TVHT_W})$

NOTE—Transmitted signals in TVHT_MODE_2N and TVHT_MODE_4N might have different impairments such as phase offset or phase noise between the two frequency segments in TVHT_MODE_2N or TVHT_MODE_4N, which is not shown in Equation (21-11) for simplicity. See 22.3.17.3.

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The transmitted RF signal is derived by upconverting the complex baseband signal, which consists of several fields. The signal transmitted on frequency segment i_{Seg} of transmit chain i_{TX} is described by Equation (21-12) in 21.3.7. The timing boundaries for the various fields are shown in Figure 21-17.

Each field is defined as the summation of one or more subfields, where each subfield is defined to be an inverse discrete Fourier transform as specified in Equation (21-13) and where references to Table 21-5, Table 21-6, Table 21-8, Table 21-9, Table 21-10, and Table 21-11 are replaced by the corresponding descriptions in Clause 22 including Table 22-8, Table 22-9, Table 22-11, and Table 22-12.

Table 22-11 summarizes the various values of $N_{\text{Field}}^{\text{Tone}}$ as a function of number of BCUs (TVHT_MODE_1 has one BCU, TVHT_MODE_2C and TVHT_MODE_2N have two BCUs, and TVHT_MODE_4C and TVHT_MODE_4N have four BCUs).

Table 22-11—Tone scaling factor and guard interval duration values for PHY fields

Field	$N_{\text{Field}}^{\text{Tone}}$ as a function of the number of BCUs			Guard interval duration
	One	Two	Four	
L-STF	24	48	96	—
L-LTF	104	208	416	T_{GI2}
L-SIG	104	208	416	T_{GI}
TVHT-SIG-A	104	208	416	T_{GI}
TVHT-STF	24	48	96	-
TVHT-LTF	114	228	456	T_{GI}
TVHT-SIG-	114	228	456	T_{GI}
VHT-Data	114	228	484	T_{GI} or T_{GIS} (see NOTE 2)
NON_HT_DUP_OFDM-Data (see NOTE 1)	104	208	416	T_{GI}

NOTE 1—For notational convenience, NON_HT_DUP_OFDM-Data is used as a label for the Data field of a NON_HT PPDU with format type NON_HT_DUP_OFDM.

NOTE 2—T_{GI} denotes guard interval duration when TXVECTOR parameter GI_TYPE equals LONG_GI, T_{GIS} denotes short guard interval duration when TXVECTOR parameter GI_TYPE equals SHORT_GI.

In addition, the parameter $\Upsilon_{k,\text{BW}}$ in Equation (21-13) is replaced by $\Upsilon_{k,\text{M}}$ as defined in Table 22-12.

Table 22-12—Transmission mode and Gamma sub$_{k,M}$

Transmission mode	$\Upsilon_{k,\text{M}}$
TVHT_MODE_1, TVHT_MODE_2N	$\Upsilon_{k,1}$ per segment
TVHT_MODE_2C, TVHT_MODE_4N	$\Upsilon_{k,2}$ per two contiguous segments
TVHT_MODE_4C	$\Upsilon_{k,4}$

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For TVHT_MODE_1 and TVHT_MODE_2N PPDU transmission,

$$\Upsilon_{k,1} = \begin{cases} 1, & k < 0 \\ j, & k \geq 0 \end{cases} \quad (22\text{-}6)$$

For TVHT_MODE_2C and TVHT_MODE_4N PPDU transmission,

$$\Upsilon_{k,2} = \begin{cases} 1, & k < -72 \text{ for 6 MHz and 8 MHz channels, } k < -84 \text{ for 7 MHz channels} \\ -1, & k \geq -72 \text{ for 6 MHz and 8 MHz channels, } k \geq -84 \text{ for 7 MHz channels} \end{cases} \quad (22\text{-}7)$$

For TVHT_MODE_4C PPDU transmission,

$$\Upsilon_{k,4} = \begin{cases} 1, & k < -216 \text{ for 6 MHz and 8 MHz channels, } k < -252 \text{ for 7 MHz channels} \\ -1, & -216 \leq k < 0 \text{ for 6 MHz and 8 MHz channels, } -252 \leq k < 0 \text{ for 7 MHz channels} \\ 1, & 0 \leq k < 72 \text{ for 6 MHz and 8 MHz channels, } 0 \leq k < 84 \text{ for 7 MHz channels} \\ -1, & k \geq 72 \text{ for 6 MHz and 8 MHz channels, } k \geq 84 \text{ for 7 MHz channels} \end{cases} \quad (22\text{-}8)$$

22.3.8 TVHT preamble

22.3.8.1 Introduction

A TVHT preamble is defined to carry the required information to operate in either single user or multi-user mode.

22.3.8.2 Non-TVHT portion of TVHT format preamble

22.3.8.2.1 Cyclic shift definition for pre-TVHT modulated fields

The cyclic shift value $T_{CS}^{i_{TX}}$ for the L-STF, L-LTF, L-SIG, and TVHT-SIG-A fields of the PPDU for transmit chain i_{TX} out of a total of N_{TX} is defined in Table 21-10 with a scaling factor to account for the change in sampling clock frequency. The CSD delay values shall be multiplied by the corresponding correction values for the 6 MHz, 7 MHz, and 8 MHz channels, respectively.

The scaling factor for transmissions over 6 MHz and 7 MHz channels is 7.5.

The scaling factor for transmissions over 8 MHz channels is 5.625.

As an example, the CSD value for antenna-2 with 2-transmit antennas is –200 ns, and the corresponding CSD value for 6 MHz channels is –1.5 μs.

22.3.8.2.2 L-STF definition

The L-STF field for each BCU in any transmission mode is defined by Equation (19-9) in 19.3.9.3.3.

The time domain representation of the signal on BCU i_{Seg} in transmit chain i_{TX} is specified in Equation (21-20), where $\Upsilon_{k,\mathrm{BW}}$ is replaced by $\Upsilon_{k,\mathrm{M}}$ as defined in Table 22-12 and where N_{SR} and Δ_F are defined in Table 22-8.

22.3.8.2.3 L-LTF definition

The L-LTF field for each BCU in any transmission mode is defined by Equation (19-12) in 19.3.9.3.4.

Note that these equations do not include the phase rotations as defined in Table 22-12.

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The time domain representation of the signal in transmit chain i_{TX} is specified in Equation (21-23), where $\Upsilon_{k,\mathrm{BW}}$ is replaced by $\Upsilon_{k,\mathrm{M}}$ as defined in Table 22-12 and where N_{SR} is defined in Table 22-8.

22.3.8.2.4 L-SIG definition

The L-SIG field is used to communicate data rate and length information. The structure of the L-SIG field is defined in Figure 17-5.

In a VHT PPDU, the RATE field shall be set to the value corresponding to 6 Mb/s in the 20 MHz channel spacing column of Table 17-6.

In a NON_HT_DUP PPDU, the RATE field is defined in 17.3.4.2 using the L_DATARATE parameter in the TXVECTOR.

The LENGTH field shall be set to the value given by Equation (22-9).

$$\text{LENGTH} = [(\text{TXTIME} - (20 \times \text{scaling factor}))/(4 \times \text{scaling factor})] \times 3 - 3 \quad (22\text{-}9)$$

where the scaling factor is defined in 22.3.8.2.1 and TXTIME is defined in 22.4.3. In a non-HT duplicate PPDU, the LENGTH field is defined in 17.3.4.3 using the L_LENGTH parameter in the TXVECTOR.

The time domain waveform of the L-SIG field in each BCU is specified in Equation (21-25) using $N_{20\mathrm{MHz}} = 2$, where $\Upsilon_{k,\mathrm{BW}}$ is replaced by $\Upsilon_{k,\mathrm{M}}$ as defined in Table 22-12 and where the rest of the parameters are specified in 22.3.7.

22.3.8.3 TVHT portion of TVHT format preamble

22.3.8.3.1 Introduction

The TVHT portion of the VHT format preamble consists of the TVHT-SIG-A, TVHT-STF, TVHT-LTF, and TVHT-SIG-B fields.

Notational conventions are specified in 21.3.8.3.1.

22.3.8.3.2 Cyclic shift for TVHT modulated fields

The definition, application, and CSD values are defined in 21.3.8.3.2 with scaling factors as defined in 22.3.8.2.1.

22.3.8.3.3 TVHT-SIG-A definition

The TVHT-SIG-A field carries information required to interpret VHT PPDU in TVWS bands and is defined in 21.3.8.3.3.

The time domain waveform of the TVHT-SIG-A field in each BCU is specified in Equation (21-28), where $N_{20\mathrm{MHz}} = 2$ and where the rest of the parameters are specified in 22.3.7.

Fields in the TVHT-SIG-A fields are the same as in Table 21-12 except for the description B0-B1 (BW) and B10-B21 in TVHT-SIG-A1. Description of B0-B1 is specified in Table 22-13.

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Table 22-13—B0-B1 (BW) in TVHT-SIG-A1

B0-B1	TVHT_MODE
00	Not used
10	TVHT_MODE_1
01	TVHT_MODE_2C and TVHT_MODE_2N
11	TVHT_MODE_4C and TVHT_MODE_4N

Description of B10-B21 (N_{STS}/Partial AID) is specified as follows:

For an MU PPDU:

N_{STS} is divided into 4 user positions of 3 bits each. User position p, where $0 \le p \le 3$, uses bits B(10+3p)-B(12+3p). The number of space-time streams for user u is indicated at user position p = USER_POSITION[u] where u = 0, 1, ..., NUM_USER – 1 and where the notation A[b] denotes the value of array A at index b. Zero space-time streams are indicated at positions not listed in the USER_POSITION array.

Set to 0 for 0 space-time streams
Set to 1 for 1 space-time stream
Set to 2 for 2 space-time streams
Set to 3 for 3 space-time streams
Values 4 to 7 are reserved

For an SU PPDU:

B10-B12

Set to 0 for 1 space-time stream
Set to 1 for 2 space-time streams
Set to 2 for 3 space-time streams
Set to 3 for 4 space-time streams
Values 4 to 7 are reserved

B13-B21

Partial AID: Set to the value of the TXVECTOR parameter PARTIAL_AID. Partial AID provides an abbreviated indication of the intended recipient(s) of the PSDU (see 10.19).

22.3.8.3.4 TVHT-STF definition

The TVHT-STF field for each BCU in any transmission mode is defined by Equation (21-30) in 21.3.8.3.4.

The time domain waveform of the TVHT-STF field in each BCU is specified in Equation (21-33), where $\Upsilon_{k,\mathrm{BW}}$ is replaced by $\Upsilon_{k,\mathrm{M}}$ as defined in Table 22-12 and where N_{SR} is defined in Table 22-8.

22.3.8.3.5 TVHT-LTF definition

The TVHT-LTF field is defined in 21.3.8.3.5.

The TVHT-LTF sequence transmitted for each BCU in any transmission mode is defined by Equation (21-37).

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The time domain waveform of the TVHT-LTF field in each BCU is specified in Equation (21-42), where $\Upsilon_{k,\mathrm{BW}}$ is replaced by $\Upsilon_{k,\mathrm{M}}$ as defined in Table 22-12 and where N_{SR} is defined in Table 22-8.

22.3.8.3.6 TVHT-SIG-B definition

The TVHT-SIG-B field for each BCU in any transmission mode is defined in 21.3.8.3.6 for 40 MHz bandwidth.

The 27 TVHT-SIG-B bits are first repeated twice, then BCC encoded, interleaved, and made into constellations as described by Figure 21-22 and the corresponding text in 21.3.8.3.6. If the channel bandwidth of the current PPDU is TVHT_W, then the IDFT is conducted as defined in 21.3.8.3.6.

The time domain waveform for the TVHT-SIG-B field in each BCU in a VHT PPDU is the same as Equation (21-47) with channel bandwidth being 40 MHz. If the channel bandwidth of the current PPDU is larger than TVHT_W, then the TVHT-SIG-B subcarriers as described above are repeated in each BCU, with appropriate phase rotation factors $\Upsilon_{k,\mathrm{M}}$ being applied as shown in Table 22-12, before conducting IDFT.

22.3.9 Transmission of NON_HT and HT PPDUs with multiple antennas

A TVHT STA that transmits a NON_HT PPDU shall apply the cyclic shifts defined in 22.3.8.2.1 for L-STF, L-LTF, and L-SIG fields of the PPDU.

22.3.10 Data field

22.3.10.1 General

See 21.3.10.1, with “TVHT” replacing “VHT”.

22.3.10.2 SERVICE field

See 21.3.10.2, with “TVHT” replacing “VHT”.

22.3.10.3 CRC calculation for TVHT-SIG-B

The CRC calculation and insertion is illustrated in Figure 21-23.

The value of the CRC field shall be the 1s complement of Equation (21-59) with the values of N set to 21 for all Modes.

22.3.10.4 Scrambler

See 21.3.10.4 with “TVHT” replacing “VHT”.

22.3.10.5 Coding

See 21.3.10.5 with “TVHT” replacing “VHT”.

22.3.10.6 Stream parser

After coding and puncturing, the data bit streams at the output of the FEC encoders are processed in groups of N_{CBPS} bits. Each of these groups is rearranged into N_{SS} blocks of N_{CBPSS} bits ($N_{SS,u}$ blocks of $N_{CBPSS,u}$ bits in the case of an MU transmission). This operation is referred to as *stream parsing* and is described in 21.3.10.6.

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22.3.10.7 Segment parser

The segment parser as described in 21.3.10.7 is not used in Clause 22. All modes of operation use a common interleaver in the case of BCC or use a common tone mapper in the case of LDPC.

22.3.10.8 BCC interleaver

The BCC interleaver and deinterleaver for one BCU (TVHT_MODE_1) is defined in 21.3.10.8 for 40 MHz.

The BCC interleaver and deinterleaver for TVHT_MODE_2C, TVHT_MODE_2N, TVHT_MODE_4C, and TVHT_MODE_4N reuse the same formulas as described in 21.3.10.8 for 40 MHz with new values for N_{COL} , N_{ROW}, and N_{ROT} as defined in Table 22-14.

Table 22-14—Number of rows and columns in the interleaver

Parameter	TVHT_MODE_1	TVHT_MODE_2C, TVHT_MODE_2N	TVHT_MODE_4C, TVHT_MODE_4N
N_{COL}	18	27	48
N_{ROW}	$6 \times N_{BPSCS}$	$8 \times N_{BPSCS}$	$9 \times N_{BPSCS}$
N_{ROT} ($N_{SS} \leq 4$)	29	46	78

22.3.10.9 Constellation mapping

22.3.10.9.1 General

The mapping between bits at the output of the interleaver and complex constellation points is as described in 21.3.10.9.1.

The streams of complex numbers in frequency subblock l for user u are denoted

$d_{k,i,n,l,u}$; $k = 0, 1, \ldots, N_{SD}-1$; $i = 1, \ldots, N_{SS,u}$; $n = 0, 1, \ldots, N_{SYM}-1$;
$l = 0$ for all transmission modes.

22.3.10.9.2 LDPC tone mapping

The LDPC tone mapping for one BCU (TVHT_MODE_1) is defined in 21.3.10.9.2 for 40 MHz.

The LDPC tone mapping for TVHT_MODE_2C, TVHT_MODE_2N, TVHT_MODE_4C, and TVHT_MODE_4N reuses the same formulas as described in 21.3.10.9.2 for 40 MHz with values for D_{TM} as defined in Table 22-15.

Table 22-15—LDPC Tone Mapping Distance for each transmission mode

Parameter	TVHT_MODE_1	TVHT_MODE_2C, TVHT_MODE_2N	TVHT_MODE_4C, TVHT_MODE_4N
D_{TM}	6	8	9

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For all Clause 22 transmission Modes, the LDPC tone mapping for LDPC-coded streams corresponding to user u is done by permuting the stream of complex numbers

$$d'_{k,i,n,l,u};\quad k = 0, 1, \ldots, N_{SD} - 1;\quad i = 1, \ldots, N_{SS,u};\quad n = 0, 1, \ldots, N_{SYM} - 1;\quad l = 0 \text{ for all transmission modes.}$$

generated by the constellation mappers, to obtain

$$d'_{t(k),i,n,l,u};\quad k = 0, 1, \ldots, N_{SD} - 1;\quad i = 1, \ldots, N_{SS,u};\quad n = 0, 1, \ldots, N_{SYM} - 1;\quad l = 0 \text{ for all transmission modes.}$$

where

$$t(k) = D_{TM}\left(k \bmod \frac{N_{SD}}{D_{TM}}\right) + \left\lfloor \frac{k \times D_{TM}}{N_{SD}} \right\rfloor \quad \text{for all transmission modes}$$

22.3.10.9.3 Segment deparser

The segment deparser is not used in Clause 22 as no segment parser is used in Clause 22.

22.3.10.9.4 Space-time block coding

See 21.3.10.9.4 with “TVHT” replacing “VHT”.

22.3.10.10 Pilot subcarriers

For TVHT_MODE_1 transmission, six pilot tones shall be inserted in subcarriers –53, –25, –11, 11, 25, and 53. The pilots are generated as described in 21.3.10.10 for 40 MHz transmission.

When multiple BCUs are used (TVHT_MODE_2C, TVHT_MODE_2N, TVHT_MODE_4C, and TVHT_MODE_4N), each BCU shall use the same pilot tones, which are generated as described in 21.3.10.10 for 40 MHz transmission.

22.3.10.11 OFDM modulation transmission in VHT format

For TVHT transmissions, the signal from transmit chain i_{TX}, $1 \le i_{TX} \le N_{TX}$ shall be as specified in Equation (21-95), where $\Upsilon_{k,\mathrm{BW}}$ is replaced by $\Upsilon_{k,\mathrm{M}}$ as defined in Table 22-12 and where N_{SR} and Δ_F are defined in Table 22-8.

For TVHT_MODE_1 transmission, parameters shall be selected to be the same with 40 MHz VHT transmission as defined in 21.3.10.11.1.

For multi-segment transmissions TVHT_MODE_2C and TVHT_MODE_4C, each frequency segment shall follow the waveform as described in Equation (21-95), and the data and pilot subcarriers are allocated to the IDFT block according to the subcarrier mapping as specified in Table 22-9 in consecutive order from the lowest subcarrier to the highest subcarrier.

For multi-segment transmissions TVHT_MODE_2N and TVHT_MODE_4N, each frequency segment shall follow the waveform as described in Equation (21-95), and the data and pilot subcarriers are allocated by the subcarrier allocation block, as shown in Figure 22-2, to the two IDFT blocks according to the subcarrier mapping as specified in Equation (21-95) and Table 22-9 in consecutive order from the lowest subcarrier to the highest subcarrier in each of the two frequency segments, the lower half of the subcarriers are mapped to the IDFT corresponding to the lower frequency segment, and the upper half of the subcarriers are mapped to the IDFT corresponding to the upper frequency segment.

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22.3.10.12 Non-HT duplicate transmission

When the TXVECTOR parameter FORMAT is NON_HT and the TXVECTOR parameter NON_HT_MODULATION is NON_HT_DUP_OFDM, the transmitted PPDU shall be a non-HT duplicate. Multiple BCUs non-HT duplicate transmission is used to transmit to TVHT STAs that may be present in a part of a channel.

For non-HT duplicate transmission, the Data field shall be as defined in 21.3.10.12, with "TVHT" replacing "VHT" and with references to "Clause 22" replacing references to "Clause 21", using the parameter values defined in Table 22-16. The Data field shall be as defined by Equation (21-100) with following modifications. $N_{20\text{MHz}}$ is defined in Table 22-16. $K_{\text{Shift}}(i)$ in Equation (21-100) is replaced by $K_{\text{Shift}}(i) = (N_{20\text{MHz}} - 1 - 2i) \times 32 + 8 \cdot \lfloor N_{20\text{MHz}}/4 \rfloor + 8 \times \lfloor N_{20\text{MHz}}/8 \rfloor - (16 \times \lfloor i/2 \rfloor)$

$T_{\text{CS}}^{i_{TX}}$ represents the cyclic shift of the transmit chain i_{TX} and is defined in 22.3.8.2.1. $N_{\text{NON_HT_DUP_OFDM-Data}}^{\text{Tone}}$ is defined in Table 22-16.

Table 22-16—Parameters for Non-HT duplicate transmissions

Parameter	TVHT_MODE_1	TVHT_MODE_2C	TVHT_MODE_2N	TVHT_MODE_4C	TVHT_MODE_4N
$N_{20\text{MHz}}$	2	4	2	8	4
$N_{\text{NON_HT_DUP_OFDM-Data}}^{\text{Tone}}$	104	208	104	416	208

In addition, the parameter $\Upsilon_{k,BW}$ is replaced by $\Upsilon_{k,M}$ as defined in Table 22-12. For a noncontiguous TVHT_W+W or TVHT_2W+2W non-HT duplicate transmission, data transmission in each frequency segment shall be as defined for a TVHT_W or TVHT_2W non-HT duplicate transmission, respectively.

22.3.11 SU-MIMO and MU-MIMO Beamforming

22.3.11.1 General

SU-MIMO and DL-MU-MIMO beamforming in TVWS band is used as defined in 21.3.11.1 reading "Clause 22" for references to "Clause 21" except for feedback report format described in 9.4.1.50.

22.3.11.2 Beamforming Feedback Matrix V

Beamforming Feedback Matrix V is constructed as defined in 21.3.11.2 reading "Clause 22" for reference to "Clause 21" except for CSD values defined in 22.3.8.3.2.

22.3.11.3 Group ID

See 21.3.11.4 with "TVHT" replacing "VHT".

22.3.12 TVHT preamble format for sounding PPDUs

The format of a VHT NDP in TVWS bands is constructed as defined Figure 22-1.

NOTE—The number of TVHT-LTF symbols in the NDP is determined by the SU N_{STS} field in TVHT-SIG-A.

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The TVHT NDP has the following properties:

— Uses the TVHT PPDU format but without the Data field.
— Is a TVHT SU PPDU as indicated by the TVHT-SIG-A field.
— Has the data bits of the TVHT-SIG-B field set to a fixed bit pattern (see 22.3.8.3.6).

22.3.13 Regulatory requirements

See 21.3.13.

22.3.14 Channelization

A TVHT channel is specified by the four PLME MIB fields specified in Table 22-17.

Table 22-17—Fields to specify TVHT channels

Field	Meaning
dot11CurrentTVHTChannelWidth	Channel width. Possible values represent TVHT_W, TVHT_2W, TVHT_W+W, TVHT_4W, TVHT_2W+2W.
dot11CurrentTVHTChannelCenterFrequencyIndex0	In TVHT_MODE_1, TVHT_MODE_2C, and TVHT_MODE_4C operation denotes the center frequency of the lowest TV channel. In TVHT_MODE_2N and TVHT_MODE_4N operation, denotes the center frequency of the lowest TV channel in the frequency segment that contains the primary channel. Valid range is 1 to 200. See Equation (22-10).
dot11CurrentTVHTChannelCenterFrequencyIndex1	In TVHT_MODE_2N and TVHT_MODE_4N operation, denotes the center frequency of the lowest TV channel in the frequency segment that does not contain the primary channel. Valid range is 1 to 200. See Equation (22-10). Undefined for TVHT_MODE_1, TVHT_MODE_2C, and TVHT_MODE_4C operation.
dot11CurrentPrimaryChannel	Denotes the location of the primary TVHT_W channel. Valid range is 1 to 200. See Equation (22-11).

Given dot11CurrentTVHTChannelCenterFrequencyIndex0 and dot11CurrentTVHTChannelCenterFrequencyIndex1, the respective channel center frequency is given by Equation (22-10).

$$\text{Channel center frequency [MHz]} = \text{Channel starting frequency} + \text{TVHT_W} \times \text{dot11CurrentChannelCenterFrequencyIndex} + \text{ChannelCenterFrequencyCorrection} \quad (22\text{-}10)$$

where

Channel starting frequency is given by the Operating Class (E.1)

dot11CurrentTVHTChannelCenterFrequencyIndex is either
dot11CurrentTVHTChannelCenterFrequencyIndex0 or
dot11CurrentTVHTChannelCenterFrequencyIndex1 and

ChannelCenterFrequencyCorrection is
0 for TVHT_MODE_1 and TVHT_MODE_2N
0.5 × TVHT_W for TVHT_MODE_2C and TVHT+MODE_4N
1.5 × TVHT_W for TVHT_MODE_4C.

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NOTE—Channel starting frequency is the frequency that results in the regulatory domain's channel number being the RLAN channel number, i.e., the center frequency of the channel for index 0. For example, the center frequency of U.S. TV channel 2 is 57 MHz. The center frequency of U.S. TV channel 2 is obtained by Equation (22-10) as follows:

Channel center frequency [MHz] = Channel starting frequency + TVHT_W × dot11CurrentTVHTChannelCenterFrequencyIndex + ChannelCenterFrequencyCorrection = (0.045 × 1000) + 6 × 2 + 0 = 57 MHz.

The center frequency of the primary TVHT_W channel is given by Equation (22-11).

Primary channel center frequency [MHz]
= Channel starting frequency + TVHT_W × dot11CurrentPrimaryChannel (22-11)

where
Channel starting frequency is given by the Operating Class (see E.1)

For TVHT_MODE_2N operation, any two nonidentical channels may be used.

For TVHT_MODE_4N operation, any two channels that would each be allowed as TVHT_2W channels and whose center frequencies are separated by greater than TVHT_2W (difference between dot11CurrentTVHTChannelCenterFrequencyIndex0 and dot11CurrentTVHTChannelCenterFrequencyIndex1 corresponds to a frequency difference greater than 2) may be used.

For example, in the United States, a channel specified by

dot11CurrentTVHTChannelWidth = TVHT_2W (12 MHz)
dot11CurrentTVHTChannelCenterFrequencyIndex0 = 15
dot11CurrentPrimaryChannel = 16

is a 12 MHz channel with a center frequency of 482 MHz and the primary 6 MHz channel centered at 485 MHz.

A channel specified by

dot11CurrentTVHTChannelWidth = TVHT_4W (24 MHz)
dot11CurrentTVHTChannelCenterFrequencyIndex0 = 14
dot11CurrentPrimaryChannel = 17

is a 24 MHz channel with a center frequency of 482 MHz and the primary 6 MHz channel centered at 491 MHz.

A channel specified by

dot11CurrentTVHTChannelWidth = TVHT_2W+2W (12+12 MHz)
dot11CurrentTVHTChannelCenterFrequencyIndex0 =15
dot11CurrentTVHTChannelCenterFrequencyIndex1 = 40
dot11CurrentPrimaryChannel = 16

is an 12+12 MHz channel in which frequency segment 0 has 12 MHz bandwidth and center frequency of 482 MHz. Frequency segment 1 also has 12 MHz bandwidth and center frequency of 632 MHz. The primary 6 MHz channel is centered at 485 MHz.

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22.3.15 Slot time

The slot time for the TVHT PHY shall be 24 µs for 6 MHz and 7 MHz channel units and 20 µs for 8 MHz channel units.

22.3.16 Transmit and receive port impedance

Transmit and receive antenna connector impedance for each transmit and receive antenna is defined in 17.3.8.7.

22.3.17 TVHT transmit specification

22.3.17.1 Transmit spectrum mask

For transmission in TVHT_MODE_1, TVHT_MODE_2C, and TVHT_MODE_4C, the transmit spectral mask shall be as described for 40 MHz mask PPDU in 21.3.17.1 with the frequency axis multiplied by the frequency scaling factor as defined in Table 22-18.

Table 22-18—Spectral mask frequency scaling factor for contiguous transmission

Mode	Scaling for 6 MHz channels	Scaling for 7 MHz channels	Scaling for 8 MHz channels
TVHT_MODE_1	6 / 40	7 / 40	8 / 40
TVHT_MODE_2C	12 / 40	14 / 40	16 / 40
TVHT_MODE_4C	24 / 40	28 / 40	32 / 40

For transmission in mode TVHT_MODE_4N, the transmit spectral mask shall be as described for 80+80 MHz mask PPDU in 21.3.17.1 with the frequency axis multiplied by the frequency scaling factor as defined in Table 22-19.

Table 22-19—Spectral mask frequency scaling factor for TVHT_MODE_4N

Mode	Scaling for 6 MHz channels	Scaling for 7 MHz channels	Scaling for 8 MHz channels
TVHT_MODE_4N	12 / 80	14 / 80	16 / 80

NOTE 1—In the presence of additional regulatory restrictions, the device has to meet both the regulatory requirements (measured as defined in the relevant regulation) and the mask defined in this subclause.

NOTE 2—For rules regarding TX center frequency leakage levels, see 22.3.17.4.2.

For a TVHT_W+W mask PPDU of VHT or non-HT duplicate format, the overall transmit spectral mask is constructed in the following manner. First, the 40 MHz interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 38 MHz, –20 dBr at 21 MHz frequency offset, –28 dBr at 40 MHz frequency offset, and –40 dBr at 60 MHz frequency offset and above. The 40 MHz interim transmit spectral mask for frequency offsets in between 19 MHz and 21 MHz, 21 MHz and 40 MHz, and 40 MHz and 60 MHz shall be linearly interpolated in dB domain from the requirements

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for 19 MHz, 21 MHz, 40 MHz, and 60 MHz frequency offsets. Then the 40 MHz interim spectral mask frequency points are scaled as defined in Table 22-20 to produce a TVHT_W interim spectral mask. Then, the TVHT_W interim spectral mask is placed on each of the two segments to produce the TVHT_W+W interim spectral mask. Then, for each frequency at which both of the TVHT_W interim spectral masks have values greater than –40 dBr and less than –20 dBr, the sum of the two TVHT_W interim mask values (summed in linear domain) shall be taken as the overall TVHT_W+W interim spectral mask value. Next, for each frequency at which neither of the two TVHT_W interim masks has values greater than or equal to –20 dBr and less than or equal to 0 dBr, the higher value of the two interim masks shall be taken as the overall TVHT_W+W interim mask spectral value. Finally, for any frequency region where the TVHT_W+W interim mask value has not been defined yet, linear interpolation (in dB domain) between the nearest two frequency points with the TVHT_W+W interim spectral mask value defined shall be used to define the TVHT_W+W interim spectral mask value. The transmit spectrum shall not exceed the maximum of the TVHT_W+W interim transmit spectrum mask and –59 dBm/MHz at any frequency offset.

Table 22-20—Spectral mask frequency scaling factor for TVHT_MODE_2N

Mode	Scaling for 6 MHz channels	Scaling for 7 MHz channels	Scaling for 8 MHz channels
TVHT_MODE_2N	6 / 40	7 / 40	8 / 40

Example transmit spectral mask for a TVHT_W+W mask PPDU for BCU of 6 MHz and spacing of 12 MHz is shown in Figure 22-4.

22.3.17.2 Spectral flatness

Spectral flatness measurements shall be conducted using BPSK modulated PPDUs. See 22.3.17.4.4 for the demodulation procedure of the PPDUs as well as the number of PPDUs and OFDM symbols to be used for testing.

Let $E_{i,\,avg}$ denote the average constellation energy of a BPSK modulated subcarrier i in a TVHT data symbol.

For TVHT_MODE_1 contiguous non-HT duplicate or TVHT transmission having a bandwidth listed in Table 22-21, $E_{i,\,avg}$ of each of the subcarriers with indices listed as tested subcarrier indices shall not deviate by more than the specified maximum deviation in Table 22-21 from the average of $E_{i,\,avg}$ over subcarrier indices listed as averaging subcarrier indices. Averaging of $E_{i,\,avg}$ is done in the linear domain.

Table 22-21—Maximum transmit spectral flatness deviations

Format	Bandwidth of transmission (MHz)	Averaging subcarrier indices	Tested subcarrier indices	Maximum deviation (dB)
VHT	TVHT_W	–42 to –2 and +2 to +42	–42 to –2 and +2 to +42	± 4
			–58 to –43 and +43 to +58	+4/–6
non-HT duplicate	TVHT_W	–42 to –33, –31 to –6, +6 to +31, and +33 to +42	–42 to –33, –31 to –6, +6 to +31, and +33 to +42	± 4
			–43 to –58 and +43 to +58	+4/–6

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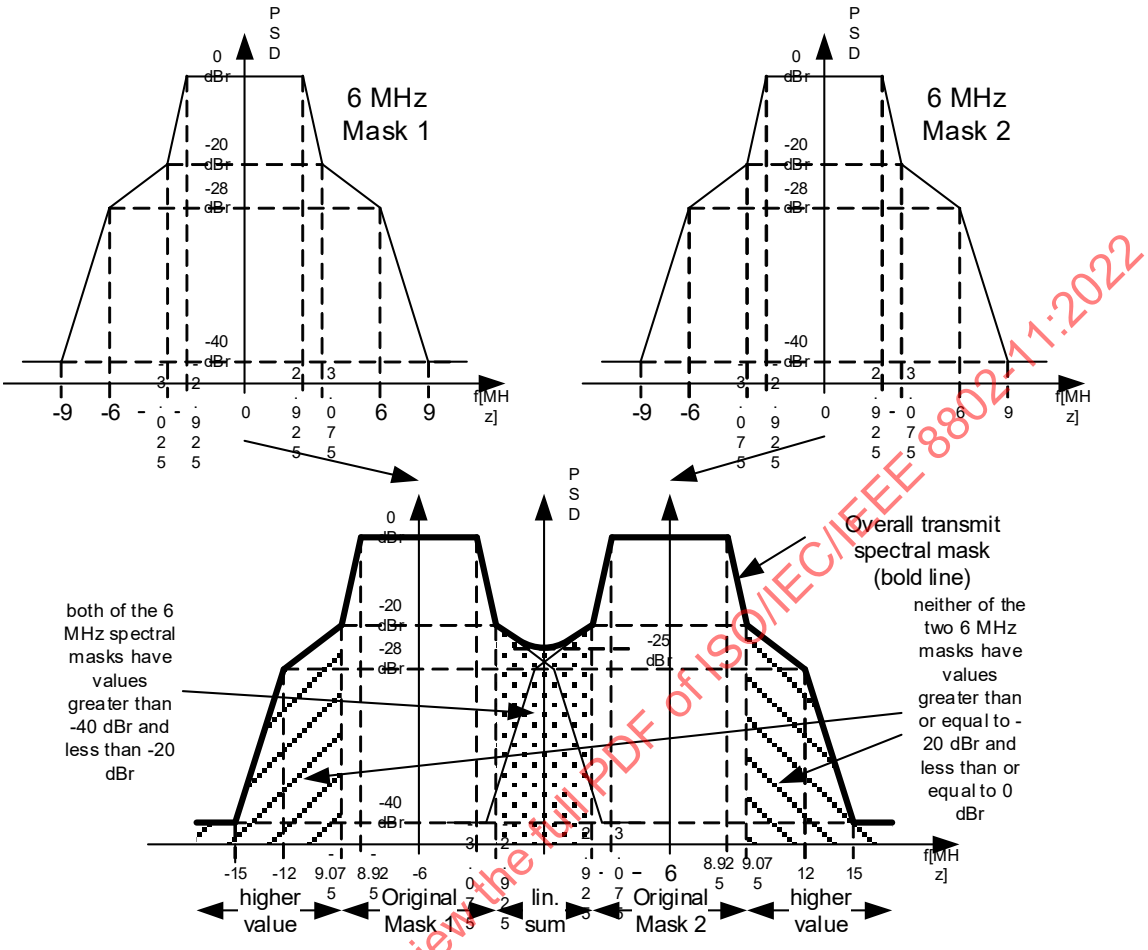

Figure 22-4—Example transmit spectral mask for an 6+6 MHz mask PPDU

For transmissions consisting of multiple contiguous or noncontiguous BCUs, each BCU shall meet the spectral flatness requirement for TVHT_MODE_1 transmission.

For the spectral flatness test, the transmitting STA shall be configured to use a spatial mapping matrix Q_k (see 22.3.10.11) with flat frequency response. Each output port under test of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation.

22.3.17.3 Transmit center frequency and symbol clock frequency tolerance

The transmitter center frequency tolerance shall be ± 25 ppm. Carrier (LO) and symbol clock frequencies for the all transmit chains and BCUs shall be derived from the same reference oscillator.

NOTE—For multichannel operation, the signal phase of each BCU might be uncorrelated.

The symbol clock frequency tolerance shall be ± 25 ppm. The transmit center frequency and the symbol clock frequency for all transmit antennas and contiguous BCUs shall be derived from the same reference oscillator.

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22.3.17.4 Modulation accuracy

22.3.17.4.1 Introduction to modulation accuracy tests

Transmit modulation accuracy specifications are defined in 22.3.17.4.2 and 22.3.17.4.3. The test method is described in 21.3.17.4.4.

22.3.17.4.2 Transmit center frequency leakage

For transmissions using all formats except noncontiguous where the RF LO falls outside both BCUs, TX LO leakage shall meet the following requirements:

— When the RF LO is in the center of the transmitted PPDU BW, the power measured at the center of transmission BW using resolution BW (6/144 or 8/144) MHz shall not exceed the average power per subcarrier of the transmitted PPDU, or equivalently $(P - 10\log 10(N_{ST}))$, where P is the transmit power per antenna in dBm and N_{ST} is defined in Table 22-8.

— When the RF LO is not at the center of the transmitted PPDU BW, the power measured at the location of the RF LO using resolution BW (6/144 or 8/144) MHz shall not exceed the maximum of –32 dB relative to the total transmit power and –20 dBm, or equivalently $max(P - 32, -20)$, where P is the transmit power per antenna in dBm.

For transmissions using TVHT_MODE_2N and TVHT_MODE_4N, where the RF LO falls outside both BCUs, the RF LO shall follow the spectral mask requirements as defined in 22.3.17.1.

22.3.17.4.3 Transmitter constellation error

For all modes defined in TVHT PHY, the requirements for transmit constellation RMS error are same as defined in 21.3.17.4.3.

For non-HT duplicate transmissions, requirements defined in 17.3.9.7.4 apply to all parts of the channel bandwidth. The channel bandwidth is determined by the TXVECTOR parameter CH_BANDWIDTH.

22.3.17.4.4 Transmitter modulation accuracy (EVM) test

For the transmit modulation accuracy test, the same methodology as that defined in 21.3.17.4.4 shall be applied per BCU (termed frequency segment in Clause 21). The channel bandwidth is determined by the TXVECTOR parameter CH_BANDWIDTH.

22.3.17.5 Time of Departure accuracy

For Time of Departure accuracy test, the test parameters defined in 21.3.17.5 shall be used for evaluation of TOD except the channel bandwidth, TTR and TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH. The channel bandwidth is determined by TXVECTOR parameter CH_BANDWIDTH in 22.2.2. TTR and TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH shall be multiplied by the corresponding scaling factor for the 6 MHz, 7 MHz, and 8 MHz channels, where the scaling factor is defined in 22.3.8.2.1.

22.3.18 TVHT receiver specification

22.3.18.1 General

See 21.3.18.

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22.3.18.2 Receiver minimum input sensitivity

The packet error ratio (PER) shall be less than 10% for a PSDU length of 4096 octets with the rate-dependent input levels listed in Table 22-22. The test in this subclause and the minimum sensitivity levels specified in Table 22-22 apply only to non-STBC modes, long GI, BCC, and VHT PPDU in TVWS bands.

Table 22-22—Receiver minimum input level sensitivity

Modulation	Rate (R)	Minimum sensitivity (dBm)					
		6 or 7 MHz (TVHT_ MODE_1)	12/14 MHz (TVHT_ MODE_2C) or 6+6/7+7 MHz (TVHT_ MODE_2N)	24/28 MHz (TVHT_ MODE_4C or 12+12/ 14+14 MHz (TVHT_ MODE_4N)	8 MHz (TVHT_ MODE_1)	16 MHz (TVHT_ MODE_2C) or 8+8 MHz (TVHT_ MODE_2N)	32 MHz (TVHT_ MODE_4C) or 16+16/ 16+16 MHz (TVHT_ MODE_4N)
BPSK	1/2	–88	–85	–82	–87	–84	–81
QPSK	1/2	–85	–82	–79	–84	–81	–78
QPSK	3/4	–83	–80	–77	–82	–79	–76
16-QAM	1/2	–80	–77	–74	–79	–76	–73
16-QAM	3/4	–76	–73	–70	–75	–72	–69
64-QAM	2/3	–72	–69	–66	–71	–68	–65
64-QAM	3/4	–71	–68	–65	–70	–67	–64
64-QAM	5/6	–70	–67	–64	–69	–66	–63
256-QAM	3/4	–65	–62	–59	–64	–61	–58
256-QAM	5/6	–63	–60	–57	–62	–59	–56

22.3.18.3 Adjacent channel rejection

Adjacent channel rejection for TVHT_MODE_1, TVHT_MODE_2C, and TVHT_MODE_4C follow the definition in the first paragraph of 21.3.18.2 and use the values in Table 22-23.

Adjacent channel rejection for TVHT_MODE_2N (TVHT_W+W) and TVHT_MODE_4N (TVWT_2W+2W) follows the definition in the second paragraph of 21.3.18.2, where “80 MHz” is replaced by “TVHT_W” for TVHT_MODE_2N and “TVHT_2W” for TVHT_MODE_4N, and uses the values in Table 22-23.

The definitions in the rest of 21.3.18.2 apply to Clause 22 using the values in Table 22-23.

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Table 22-23—Minimum required adjacent and nonadjacent channel rejection levels

Modulation	Rate (R)	Adjacent channel rejection (dB)		Nonadjacent channel rejection (dB)	
		6 MHz, 7 MHz, 8 MHz, 12 MHz (TVHT_MODE_2C), 14 MHz (TVHT_MODE_2C), 16 MHz (TVHT_MODE_2C), 24 MHz (TVHT_MODE_4C), 28 MHz (TVHT_MODE_4C), 32 MHz (TVHT_MODE_4C)	6+6 MHz (TVHT_MODE_2N), 7+7 MHz (TVHT_MODE_2N), 8+8 MHz (TVHT_MODE_2N), 12+12 MHz (TVHT_MODE_4N), 14+14 MHz (TVHT_MODE_4N), 16+16 MHz (TVHT_MODE_4N)	6 MHz, 7 MHz, 8 MHz, 12 MHz (TVHT_MODE_2C), 14 MHz (TVHT_MODE_2C), 16 MHz (MTVHT_MODE_2C), 24 MHz (TVHT_MODE_4C), 28 MHz (TVHT_MODE_4C), 32 MHz (TVHT_MODE_4C)	6+6 MHz (TVHT_MODE_2N), 7+7 MHz (TVHT_MODE_2N), 8+8 MHz (TVHT_MODE_2N), 12+12 MHz (TVHT_MODE_4N), 14+14 MHz (TVHT_MODE_4N), 16+16 MHz (TVHT_MODE_4N)
BPSK	1/2	16	13	32	29
QPSK	1/2	13	10	29	26
QPSK	3/4	11	8	27	24
16-QAM	1/2	8	5	24	21
16-QAM	3/4	4	1	20	17
64-QAM	2/3	0	–3	16	13
64-QAM	3/4	–1	–4	15	12
64-QAM	5/6	–2	–5	14	11
256-QAM	3/4	–7	–10	9	6
256-QAM	5/6	–9	–12	7	4

22.3.18.4 Nonadjacent channel rejection

Nonadjacent channel rejection for TVHT_MODE_1, TVHT_MODE_2C, and TVHT_MODE_4C channels follows the definition in the first paragraph of 21.3.18.3 and use the values in Table 22-23.

Nonadjacent channel rejection for TVHT_MODE_2N (TVHT_W+W) and TVHT_MODE_4N (TVWT_2W+2W) follows the definition in the second paragraph of 21.3.18.3, where “80 MHz” is replaced by “TVHT_W” for TVHT_MODE_2N and “TVHT_2W” for TVHT_MODE_4N, and uses the values in Table 22-23.

The definitions in the rest of 21.3.18.3 apply to Clause 22 using the values in Table 22-23.

22.3.18.5 Receiver maximum input level

The receiver shall provide a maximum PER of 10% at a PSDU length of 4096 octets, for a maximum input level of –20 dBm, measured at each antenna for any baseband TVHT modulation.

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22.3.18.6 CCA sensitivity

22.3.18.6.1 General

The thresholds in this subclause are compared with the signal level at each receiving antenna.

22.3.18.6.2 CCA sensitivity for operating classes requiring CCA-ED

For the operating classes requiring CCA-Energy Detect (CCA-ED), the PHY shall also indicate a medium busy condition when CCA-ED detects a channel busy condition.

For improved spectrum sharing, CCA-ED is required in some bands. The behavior class indicating CCA-ED is given in Table D-2. The operating classes requiring the corresponding CCA-ED behavior class are given in E.1. The PHY of a STA that is operating within an operating class that requires CCA-ED shall operate with CCA-ED.

CCA-ED shall detect a channel busy condition when the received signal strength exceeds the CCA-ED threshold as given by dot11OFDMEDThreshold for the primary TVHT_W channel, dot11OFDMEDThreshold for the secondary TVHT_W channel (if present) and dot11OFDMEDThreshold + 3 dB for the secondary TVHT_2W channel (if present). The CCA-ED thresholds for the operating classes requiring CCA-ED are subject to the criteria in D.2.5.

NOTE—The requirement to detect a channel busy condition as stated in 22.3.18.6.3 and 22.3.18.6.4 is a mandatory energy detect requirement on all Clause 22 receivers. Support for CCA-ED is an additional requirement that relates specifically to the sensitivities described in D.2.5.

22.3.18.6.3 CCA sensitivity for signals occupying the primary channel

The PHY shall issue a PHY-CCA.indication(BUSY, {primary}) primitive if one of the conditions listed in Table 22-24 is met in an otherwise idle TVHT_W (TVHT_MODE_1), TVHT_2W (TVHT_MODE_2C), TVHT_4W (TVHT_MODE_4C), TVHT_W+W (TVHT_MODE_2N), and TVHT_2W+2W (TVHT_MODE_4N) operating channel width. With >90% probability, the PHY shall detect the start of a PPDU that occupies at least the primary TVHT_W channel under the conditions listed in Table 22-24 within a period of aCCATime (see 22.4.4) and hold the CCA signal busy [PHY-CCA.indication(BUSY, channel-list)] for the duration of the PPDU.

Table 22-24—Conditions for CCA BUSY on the primary channel

Frequency segment width	Conditions
6 MHz	The start of a 6 MHz non-HT duplicate or VHT PPDU in TVWS bands in the primary 6 MHz channel at or above –88 dBm.
7 MHz	The start of a 7 MHz non-HT duplicate or VHT PPDU in TVWS bands in the primary 7 MHz channel at or above –88 dBm.
8 MHz	The start of a 8 MHz non-HT duplicate or VHT PPDU in TVWS bands in the primary 8 MHz channel at or above –87 dBm.

The receiver shall issue a PHY-CCA.indication(BUSY, {primary}) primitive for any signal that exceeds a threshold equal to 20 dB above the minimum modulation and coding rate sensitivity (–88 + 20 = –68 dBm in the case of 6 MHz channel) in the primary TVHT_W channel within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the receiver shall not issue a PHY-CCA.indication(BUSY,{secondary}), PHY-CCA.indication(BUSY,{secondaryTVHT_2W}), or PHY-CCA.indication(IDLE) primitive while the threshold continues to be exceeded.

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22.3.18.6.4 CCA sensitivity for signals not occupying the primary channel

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary}) primitive if the conditions for issuing a PHY-CCA.indication(BUSY, {primary}) primitive are not present and one of the following conditions is present in an otherwise idle TVHT_2W (TVHT_MODE_2C), TVHT_4W (TVHT_MODE_4C), TVHT_W+W (TVHT_MODE_2N), and TVHT_2W+2W (TVHT_MODE_4N) operating channel width:

— Any signal within the secondary channel at or above a threshold (–68 dBm for 6 MHz, –68 dBm for 7 MHz, and –67 dBm for 8 MHz) within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the PHY shall not issue a PHY-CCA.indication(BUSY,{secondaryTVHT_2W}) or PHY-CCA.indication(IDLE) primitive while the threshold continues to be exceeded.

— A TVHT_W non-HT duplicate or VHT PPDU in TVWS bands detected in the secondary channel at or above a threshold (–81 dBm for 6 MHz, –81 dBm for 7 MHz, and –80 dBm for 8 MHz) with >90% probability within a period aCCAMidTime (see 22.4.4).

The PHY shall issue a PHY-CCA.indication(BUSY, {secondaryTVHT_2W}) primitive if the conditions for issuing a PHY-CCA.indication(BUSY, {primary}) primitive and a PHY-CCA.indication(BUSY, {secondary}) primitive are not present and one of the following conditions is present in an otherwise idle TVHT_4W (TVHT_MODE_4C) and TVHT_2W+2W (TVHT_MODE_4N) operating channel width:

— Any signal within the secondary TVHT_2W channel at or above a threshold (–65 dBm for 12 MHz, –65 dBm for 14 MHz, and –64 dBm for 16 MHz) within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the PHY shall not issue a PHY-CCA.indication(IDLE) primitive while the threshold continues to be exceeded.

— A TVHT_2W non-HT duplicate or VHT PPDU in TVWS bands detected in the secondary TVHT_2W channel at or above a threshold (–78 dBm for 6+6 MHz, –78 dBm for 7+7 MHz, and –77 dBm for 8+8 MHz or 16 MHz) with >90% probability within a period aCCAMidTime (see 22.4.4).

— A TVHT_W non-HT duplicate or VHT PPDU in TVWS bands detected in any TVHT_W subchannel of the secondary TVHT_2W channel at or above a threshold (–81 dBm for 6 MHz, –81 dBm for 7 MHz, and –80 dBm for 8 MHz) with >90% probability within a period aCCAMidTime.

22.3.18.7 RSSI

See 21.3.18.6 with "TVHT" replacing "VHT".

22.3.19 PHY transmit procedure

See 21.3.19 with "TVHT" replacing "VHT".

22.3.20 PHY receive procedure

See 21.3.20 with "TVHT" replacing "VHT".

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22.4 TVHT PLME

22.4.1 PLME SAP sublayer management primitives

See 21.4.1 with "TVHT" replacing "VHT".

22.4.2 PHY MIB

See 21.4.2 with "tvht(10)" replacing "vht(9)", "TVHT" replacing "VHT", and "In4W" replacing "In80" and with the removal of "dot11VHTShortGIOptionIn160and80p80Implemented" and "dot11VHTShortGIOptionIn160and80p80Activated".

22.4.3 TXTIME and PSDU_LENGTH calculation

See 21.4.3 with "TVHT" replacing "VHT".

22.4.4 TVHT PHY

The static TVHT PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, shall be as shown in Table 19-25, unless otherwise listed in Table 22-25. The definitions for these characteristics are given in 6.5.4.

Table 22-25—TVHT PHY characteristics

Characteristics	Value
aSlotTime	24 μs (BCUs: 6 MHz or 7 MHz) plus any coverage-class-dependent aAirPropagationTime (see Table 9-95) 20 μs (BCUs: 8 MHz) plus any coverage-class-dependent aAirPropagationTime (see Table 9-95)
aSIFSTime	120 μs (BCUs: 6 MHz or 7 MHz) 90 μs (BCUs: 8 MHz)
aSignalExtension	0 μs
aCCATime	< 15 μs (6 MHz or 7 MHz) < 11.25 μs (8 MHz)
aCCAMidTime	< 94 μs (6 MHz or 7 MHz) < 70 μs (8 MHz)
aAirPropagationTime	As indicated by the coverage class (see 10.22.5)
aPPDUMaxTime	20 ms
aPSDUMaxLength	1 401 120 octets (see NOTE 1)
aRxPHYStartDelay	(36 + 4 × the maximum possible value for $N_{VHT-LTF}$ supported + 4) × 7.5 (6 and 7 MHz channels) or 5.625 (8 MHz channels) (see NOTE 2)

NOTE 1—This is the maximum length in octets for SU PPDUs with a bandwidth of 32 MHz or 16+16 MHz, MCS 9 and 4 spatial streams, limited by 973 possible Short GI data symbols in aPPDUMaxTime.

NOTE 2—This value arises from the time to the end of TVHT-SIG-B (see Figure 22-1) plus the need to decode the first symbol of the Data field in order to extract the SERVICE field and check the CRC it contains.

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22.5 Parameters for TVHT-MCSs

The rate-dependent parameters for one BCU mode (6 MHz, 7 MHz, and/or 8 MHz) and corresponding two and four BCU modes with $N_{SS} = 1, \ldots, 4$ are given in Table 22-26 to Table 22-37. Support for MCS 8 and 9 (when valid) is optional in all cases. A TVHT STA shall support single spatial stream MCSs within the range MCS 0 to MCS 7 for all channel widths for which it has indicated support regardless of the Tx or Rx Highest Supported Data Rate subfield values in the TVHT Supported MCS Set field. When more than one spatial stream is supported, the Tx or Rx Highest Supported Data Rate subfield values in the TVHT Supported MCS Set field may result in a reduced MCS range (cut-off) for $N_{SS} = 2, \ldots, 4$. Support for 6 MHz, 7 MHz, or 8 MHz with $N_{SS} = 1$ is mandatory. Support for 6 MHz, 7 MHz, and 8 MHz with $N_{SS} = 2, \ldots, 4$ is optional. Support for two BCU modes with 12 MHz, 14 MHz, and 16 MHz or with 6+6 MHz, 7+7 MHz, and 8+8 MHz with $N_{SS} = 1, \ldots, 4$ is optional. Support for four BCU modes with 24 MHz, 28 MHz, and 32 MHz or with 12+12 MHz, 14+14 MHz, and 16+16 MHz with $N_{SS} = 1, \ldots, 4$ is optional. N_{ES} values were chosen to yield an integer number of punctured blocks per OFDM symbol. Note that N_{ES} values are 1 for all Clause 22 modulations.

Table 22-26 to Table 22-37 define TVHT-MCSs not only for SU transmission but also for user u of MU transmission. In the case of TVHT-MCSs for MU transmission, the parameters, N_{SS}, R, N_{BPSCS}, N_{CBPS}, and N_{DBPS} are replaced with $N_{SS,u}$, R_u, $N_{BPSCS,u}$, $N_{CBPS,u}$, and $N_{DBPS,u}$, respectively.

In the MCS parameter tables that follow, data rates for a 400 ns GI are rounded to 1 decimal place.

Table 22-26—TVHT-MCSs for TVHT_MODE_1, $N_{SS} = 1$

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) for 6 MHz or 7 MHz		Data rate (Mb/s) for 8 MHz	
								6.0 µs GI	3.0 µs GI	4.5 µs GI	2.25 µs GI
0	BPSK	1/2	1	108	6	108	54	1.8	2.0	2.4	2.7
1	QPSK	1/2	2	108	6	216	108	3.6	4.0	4.8	5.3
2	QPSK	3/4	2	108	6	216	162	5.4	6.0	7.2	8.0
3	16-QAM	1/2	4	108	6	432	216	7.2	8.0	9.6	10.7
4	16-QAM	3/4	4	108	6	432	324	10.8	12.0	14.4	16.0
5	64-QAM	2/3	6	108	6	648	432	14.4	16.0	19.2	21.3
6	64-QAM	3/4	6	108	6	648	486	16.2	18.0	21.6	24.0
7	64-QAM	5/6	6	108	6	648	540	18.0	20.0	24.0	26.7
8	256-QAM	3/4	8	108	6	864	648	21.6	24.0	28.8	32.0
9	256-QAM	5/6	8	108	6	864	720	24.0	26.7	32.0	35.6

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Table 22-27—TVHT-MCSs for TVHT_MODE_1, N_{SS} = 2

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) for 6 MHz or 7 MHz		Data rate (Mb/s) for 8 MHz	
								6.0 µs GI	3.0 µs GI	4.5 µs GI	2.25 µs GI
0	BPSK	1/2	1	108	6	216	108	3.6	4.0	4.8	5.3
1	QPSK	1/2	2	108	6	432	216	7.2	8.0	9.6	10.7
2	QPSK	3/4	2	108	6	432	324	10.8	12.0	14.4	16.0
3	16-QAM	1/2	4	108	6	864	432	14.4	16.0	19.2	21.3
4	16-QAM	3/4	4	108	6	864	648	21.6	24.0	28.8	32.0
5	64-QAM	2/3	6	108	6	1296	864	28.8	32.0	38.4	42.7
6	64-QAM	3/4	6	108	6	1296	972	32.4	36.0	43.2	48.0
7	64-QAM	5/6	6	108	6	1296	1080	36.0	40.0	48.0	53.3
8	256-QAM	3/4	8	108	6	1728	1296	43.2	48.0	57.6	64.0
9	256-QAM	5/6	8	108	6	1728	1440	48.0	53.3	64.0	71.1

Table 22-28—TVHT-MCSs for TVHT_MODE_1, N_{SS} = 3

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) for 6 MHz or 7 MHz		Data rate (Mb/s) for 8 MHz	
								6.0 µs GI	3.0 µs GI	4.5 µs GI	2.25 µs GI
0	BPSK	1/2	1	108	6	324	162	5.4	6.0	7.2	8.0
1	QPSK	1/2	2	108	6	648	324	10.8	12.0	14.4	16.0
2	QPSK	3/4	2	108	6	648	486	16.2	18.0	21.6	24.0
3	16-QAM	1/2	4	108	6	1296	648	21.6	24.0	28.8	32.0
4	16-QAM	3/4	4	108	6	1296	972	32.4	36.0	43.2	48.0
5	64-QAM	2/3	6	108	6	1944	1296	43.2	48.0	57.6	64.0
6	64-QAM	3/4	6	108	6	1944	1458	48.6	54.0	64.8	72.0
7	64-QAM	5/6	6	108	6	1944	1620	54.0	60.0	72.0	80.0
8	256-QAM	3/4	8	108	6	2592	1944	64.8	72.0	86.4	96.0
9	256-QAM	5/6	8	108	6	2592	2160	72.0	80.0	96.0	106.7

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Table 22-29—TVHT-MCSs for TVHT_MODE_1, N_{SS} = 4

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) for 6 MHz or 7 MHz		Data rate (Mb/s) for 8 MHz	
								6.0 µs GI	3.0 µs GI	4.5 µs GI	2.25 µs GI
0	BPSK	1/2	1	108	6	432	216	7.2	8.0	9.6	10.7
1	QPSK	1/2	2	108	6	864	432	14.4	16.0	19.2	21.3
2	QPSK	3/4	2	108	6	864	648	21.6	24.0	28.8	32.0
3	16-QAM	1/2	4	108	6	1728	864	28.8	32.0	38.4	42.7
4	16-QAM	3/4	4	108	6	1728	1296	43.2	48.0	57.6	64.0
5	64-QAM	2/3	6	108	6	2592	1728	57.6	64.0	76.8	85.3
6	64-QAM	3/4	6	108	6	2592	1944	64.8	72.0	86.4	96.0
7	64-QAM	5/6	6	108	6	2592	2160	72.0	80.0	96.0	106.7
8	256-QAM	3/4	8	108	6	3456	2592	86.4	96.0	115.2	128.0
9	256-QAM	5/6	8	108	6	3456	2880	96.0	106.7	128.0	142.2

Table 22-30—TVHT-MCSs for TVHT_MODE_2C and TVHT_MODE_2N, N_{SS} = 1

MCS Index	Modulation	R	N_{BPSCS}	$N_{SD} \cdot N_{Seg}$	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) for 6 MHz or 7 MHz		Data rate (Mb/s) for 8 MHz	
								6.0 µs GI	3.0 µs GI	4.5 µs GI	2.25 µs GI
0	BPSK	1/2	1	216	12	216	108	3.6	4.0	4.8	5.3
1	QPSK	1/2	2	216	12	432	216	7.2	8.0	9.6	10.7
2	QPSK	3/4	2	216	12	432	324	10.8	12.0	14.4	16.0
3	16-QAM	1/2	4	216	12	864	432	14.4	16.0	19.2	21.3
4	16-QAM	3/4	4	216	12	864	648	21.6	24.0	28.8	32.0
5	64-QAM	2/3	6	216	12	1296	864	28.8	32.0	38.4	42.7
6	64-QAM	3/4	6	216	12	1296	972	32.4	36.0	43.2	48.0
7	64-QAM	5/6	6	216	12	1296	1080	36.0	40.0	48.0	53.3
8	256-QAM	3/4	8	216	12	1728	1296	43.2	48.0	57.6	64.0
9	256-QAM	5/6	8	216	12	1728	1440	48.0	53.3	64.0	71.1

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Table 22-31—TVHT-MCSs for TVHT_MODE_2C and TVHT_MODE_2N, N_{SS} = 2

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}· N_{Seg}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) for 6 MHz or 7 MHz		Data rate (Mb/s) for 8 MHz	
								6.0 µs GI	3.0 µs GI	4.5 µs GI	2.25 µs GI
0	BPSK	1/2	1	216	12	432	216	7.2	8.0	9.6	10.7
1	QPSK	1/2	2	216	12	864	432	14.4	16.0	19.2	21.3
2	QPSK	3/4	2	216	12	864	648	21.6	24.0	28.8	32.0
3	16-QAM	1/2	4	216	12	1728	864	28.8	32.0	38.4	42.7
4	16-QAM	3/4	4	216	12	1728	1296	43.2	48.0	57.6	64.0
5	64-QAM	2/3	6	216	12	2592	1728	57.6	64.0	76.8	85.3
6	64-QAM	3/4	6	216	12	2592	1944	64.8	72.0	86.4	96.0
7	64-QAM	5/6	6	216	12	2592	2160	72.0	80.0	96.0	106.7
8	256-QAM	3/4	8	216	12	3456	2592	86.4	96.0	115.2	128.0
9	256-QAM	5/6	8	216	12	3456	2880	96.0	106.7	128.0	142.2

Table 22-32—TVHT-MCSs for TVHT_MODE_2C and TVHT_MODE_2N, N_{SS} = 3

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}· N_{Seg}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) for 6 MHz or 7 MHz		Data rate (Mb/s) for 8 MHz	
								6.0 µs GI	3.0 µs GI	4.5 µs GI	2.25 µs GI
0	BPSK	1/2	1	216	12	648	324	10.8	12.0	14.4	16.0
1	QPSK	1/2	2	216	12	1296	648	21.6	24.0	28.8	32.0
2	QPSK	3/4	2	216	12	1296	972	32.4	36.0	43.2	48.0
3	16-QAM	1/2	4	216	12	2592	1296	43.2	48.0	57.6	64.0
4	16-QAM	3/4	4	216	12	2592	1944	64.8	72.0	86.4	96.0
5	64-QAM	2/3	6	216	12	3888	2592	86.4	96.0	115.2	128.0
6	64-QAM	3/4	6	216	12	3888	2916	97.2	108.0	129.6	144.0
7	64-QAM	5/6	6	216	12	3888	3240	108.	120.0	144.0	160.0
8	256-QAM	3/4	8	216	12	5184	3888	129.6	144.0	172.8	192.0
9	256-QAM	5/6	8	216	12	5184	4320	144.0	160.0	192.0	213.3

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Table 22-33—TVHT-MCSs for TVHT_MODE_2C and TVHT_MODE_2N, N_{SS} = 4

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}· N_{Seg}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) for 6 MHz or 7 MHz		Data rate (Mb/s) for 8 MHz	
								6.0 µs GI	3.0 µs GI	4.5 µs GI	2.25 µs GI
0	BPSK	1/2	1	216	12	864	432	14.4	16.0	19.2	21.3
1	QPSK	1/2	2	216	12	1728	864	28.8	32.0	38.4	42.7
2	QPSK	3/4	2	216	12	1728	1296	43.2	48.0	57.6	64.0
3	16-QAM	1/2	4	216	12	3456	1728	57.6	64.0	76.8	85.3
4	16-QAM	3/4	4	216	12	3456	2592	86.4	96.0	115.2	128.0
5	64-QAM	2/3	6	216	12	5184	3456	115.2	128.0	153.6	170.7
6	64-QAM	3/4	6	216	12	5184	3888	129.6	144.0	172.8	192.0
7	64-QAM	5/6	6	216	12	5184	4320	144.0	160.0	192.0	213.3
8	256-QAM	3/4	8	216	12	6912	5184	172.8	192.0	230.4	256.0
9	256-QAM	5/6	8	216	12	6912	5760	192.0	213.3	256.0	284.4

Table 22-34—TVHT-MCSs for TVHT_MODE_4C and TVHT_MODE_4N, N_{SS} = 1

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) for 6 MHz or 7 MHz		Data rate (Mb/s) for 8 MHz	
								6.0 µs GI	3.0 µs GI	4.5 µs GI	2.25 µs GI
0	BPSK	1/2	1	432	24	432	216	7.2	8.0	9.6	10.7
1	QPSK	1/2	2	432	24	864	432	14.4	16.0	19.2	21.3
2	QPSK	3/4	2	432	24	864	648	21.6	24.0	28.8	32.0
3	16-QAM	1/2	4	432	24	1728	864	28.8	32.0	38.4	42.7
4	16-QAM	3/4	4	432	24	1728	1296	43.2	48.0	57.6	64.0
5	64-QAM	2/3	6	432	24	2592	1728	57.6	64.0	76.8	85.3
6	64-QAM	3/4	6	432	24	2592	1944	64.8	72.0	86.4	96.0
7	64-QAM	5/6	6	432	24	2592	2160	72.0	80.0	96.0	106.7
8	256-QAM	3/4	8	432	24	3456	2592	86.4	96.0	115.2	128.0
9	256-QAM	5/6	8	432	24	3456	2880	96.0	106.7	128.0	142.2

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Table 22-35—TVHT-MCSs for TVHT_MODE_4C and TVHT_MODE_4N, N_{SS} = 2

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) for 6 MHz or 7 MHz		Data rate (Mb/s) for 8 MHz	
								6.0 µs GI	3.0 µs GI	4.5 µs GI	2.25 µs GI
0	BPSK	1/2	1	432	24	864	432	14.4	16.0	19.2	21.3
1	QPSK	1/2	2	432	24	1728	864	28.8	32.0	38.4	42.7
2	QPSK	3/4	2	432	24	1728	1296	43.2	48.0	57.6	64.0
3	16-QAM	1/2	4	432	24	3456	1728	57.6	64.0	76.8	85.3
4	16-QAM	3/4	4	432	24	3456	2592	86.4	96.0	115.2	128.0
5	64-QAM	2/3	6	432	24	5184	3456	115.2	128.0	153.6	170.7
6	64-QAM	3/4	6	432	24	5184	3888	129.6	144.0	172.8	192.0
7	64-QAM	5/6	6	432	24	5184	4320	144.0	160.0	192.0	213.3
8	256-QAM	3/4	8	432	24	6912	5184	172.8	192.0	230.4	256.0
9	256-QAM	5/6	8	432	24	6912	5760	192.0	213.3	256.0	284.4

Table 22-36—TVHT-MCSs for TVHT_MODE_4C and TVHT_MODE_4N, N_{SS} = 3

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) for 6 MHz or 7 MHz		Data rate (Mb/s) for 8 MHz	
								6.0 µs GI	3.0 µs GI	4.5 µs GI	2.25 µs GI
0	BPSK	1/2	1	432	24	1296	648	21.6	24.0	28.8	32.0
1	QPSK	1/2	2	432	24	2592	1296	43.2	48.0	57.6	64.0
2	QPSK	3/4	2	432	24	2592	1944	64.8	72.0	86.4	96.0
3	16-QAM	1/2	4	432	24	5184	2592	86.4	96.0	115.2	128.0
4	16-QAM	3/4	4	432	24	5184	3888	129.6	144.0	172.8	192.0
5	64-QAM	2/3	6	432	24	7776	5184	172.8	192.0	230.4	256.0
6	64-QAM	3/4	6	432	24	7776	5832	194.4	216.0	259.2	288.0
7	64-QAM	5/6	6	432	24	7776	6480	216.0	240.0	288.0	320.0
8	256-QAM	3/4	8	432	24	10 368	7776	259.2	288.0	345.6	384.0
9	256-QAM	5/6	8	432	24	10 368	8640	288.0	320.0	384.0	426.7

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Table 22-37—TVHT-MCSs for TVHT_MODE_4C and TVHT_MODE_4N, N_{SS} = 4

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) for 6 MHz or 7 MHz		Data rate (Mb/s) for 8 MHz	
								6.0 µs GI	3.0 µs GI	4.5 µs GI	2.25 µs GI
0	BPSK	1/2	1	432	24	1728	864	28.8	32.0	38.4	42.7
1	QPSK	1/2	2	432	24	3456	1728	57.6	64.0	76.8	85.3
2	QPSK	3/4	2	432	24	3456	2592	86.4	96.0	115.2	128.0
3	16-QAM	1/2	4	432	24	6912	3456	115.2	128.0	153.6	170.7
4	16-QAM	3/4	4	432	24	6912	5184	172.8	192.0	230.4	256.0
5	64-QAM	2/3	6	432	24	10 368	6912	230.4	256.0	307.2	341.3
6	64-QAM	3/4	6	432	24	10 368	7776	259.2	288.0	345.6	384.0
7	64-QAM	5/6	6	432	24	10 368	8640	288.0	320.0	384.0	426.7
8	256-QAM	3/4	8	432	24	13 824	10 368	345.6	384.0	460.8	512.0
9	256-QAM	5/6	8	432	24	13 824	11 520	384.0	426.7	512.0	568.9

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23. Sub 1 GHz (S1G) PHY specification

23.1 Introduction

23.1.1 Introduction to the S1G PHY

Clause 23 specifies the PHY entity for an S1G orthogonal frequency division multiplexing (OFDM) system.

The S1G PHY is based on the VHT PHY defined in Clause 21, which in turn is based on HT PHY defined in Clause 19 and the OFDM PHY defined in Clause 17. The S1G PHY defines an OFDM PHY in the sub-1 GHz bands using narrower bandwidths than those in 2.4 GHz and 5 GHz bands, with maximum number of space-time streams supported being four, and with support for downlink multi-user (MU) transmissions. A downlink MU transmission supports up to four users with up to three space-time streams per user with the total number of space-time streams not exceeding four.

The S1G PHY provides support for 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz contiguous channel widths. A tone spacing of 31.25 kHz is used in all the bandwidths.

Transmissions of PPDUs with channel bandwidth 2 MHz, 4 MHz, 8 MHz, and 16 MHz are in general modulated the same way as 20 MHz, 40 MHz, 80 MHz and 160 MHz contiguous mode as specified in Clause 21, respectively, except with a 1/10 clock rate. For details refer to Table 23-4 (in 23.3.6). Transmissions of PPDUs with 1 MHz channel bandwidth are modulated as described in 23.3.4.4.

The S1G PHY data subcarriers are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), 64-QAM and 256-QAM. Forward error correction (FEC) coding (convolutional or LDPC coding) is used with coding rates of 1/2, 2/3, 3/4, and 5/6.

An S1G non-AP STA shall support the following Clause 23 features:

— 1 MHz and 2 MHz channel width
— S1G_1M, S1G_SHORT PPDU
— S1G_LONG PPDU, if ≥ 4 MHz channel width is supported
— Detect and decode SIG-A field of the S1G_LONG preamble.
— Single spatial stream MCSs 0 to 2, and MCS 10 (for 1 MHz PPDU only)
— BCC coding
— Normal Guard Interval T_{GI} as defined in Table 23-4 (in 23.3.6)
— Fixed Pilots

An S1G AP shall support the following Clause 23 features:

— 1 MHz and 2 MHz channel width
— S1G_1M, S1G_SHORT PPDU
— S1G_LONG PPDU, if ≥4 MHz channel width is supported
— Detect and decode SIG-A field of the S1G_LONG preamble.
— Single spatial stream MCSs 0 to 7, and MCS 10 (for 1 MHz PPDU only)
— BCC coding
— Normal Guard Interval T_{GI} as defined in Table 23-4 (in 23.3.6)
— Fixed Pilots

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An S1G STA may support the following Clause 23 features:

- 2 or more spatial streams (transmit and receive)
- S1G_LONG preamble when maximum channel width supported is less than 4 MHz
- Beamforming sounding (through S1G NDP) for an AP
- Beamforming sounding response (i.e., providing compressed beamforming feedback) for a non-AP STA
- STBC (transmit and receive)
- LDPC (transmit and receive)
- S1G MU PPDUs (transmit and receive)
- 4 MHz channel widths
- 8 MHz channel widths
- 16 MHz channel widths
- S1G-MCSs 8 and 9 (transmit and receive) for an AP, and S1G-MCSs 3-9 (transmit and receive) for a non-AP STA
- Short Guard Interval
- Traveling Pilots

23.1.2 Scope of S1G PHY services

The services provided to the MAC by the S1G PHY consist of the following protocol functions:

a) A function that defines a method of mapping the PSDUs into a framing format (PPDU) suitable for sending and receiving PSDUs between two or more STAs.

b) A function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs.

23.1.3 S1G PHY features

23.1.3.1 General

The S1G PHY contains two functional entities: the PHY function, and the physical layer management function (i.e., the PLME). Both of these functions are described in detail in 23.3 and 23.4.

The S1G PHY service is provided to the MAC through the PHY service primitives defined in Clause 8. The S1G PHY service interface is described in 23.2.

23.1.3.2 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.

23.1.3.3 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation; the actual method of implementation is left to the discretion of the developer.

The service of a layer is the set of capabilities that it offers to a user in the next higher layer. Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

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23.1.4 PPDU formats

The structure of the PPDU transmitted by an S1G STA is determined by the TXVECTOR parameters as defined in Table 23-1 (in 23.2.2).

The FORMAT parameter determines the overall structure of the PPDU, and the allowed values are:

— S1G, for S1G non-duplicate PPDUs
— S1G_DUP_2M, for S1G 2 MHz duplicate PPDUs
— S1G_DUP_1M, for S1G 1 MHz duplicate PPDUs

The PPDU bandwidth is determined by the CH_BANDWIDTH parameter, and the preamble type (i.e., S1G_1M preamble, S1G_SHORT preamble, and S1G_LONG preamble) is determined by the PREAMBLE_TYPE parameter.

— The 1 MHz format PPDU (S1G_1M) is used for non-duplicate S1G transmissions at 1 MHz bandwidth (i.e., CH_BANDWIDTH = CBW1), and for S1G_DUP_1M transmissions of any bandwidth (i.e., CH_BANDWIDTH = CBW1, CBW2, CBW4, CBW8, or CBW16). The S1G_1M preamble (see 23.3.8.3) is used. Support for the S1G_1M is mandatory.
— The greater than or equal to 2 MHz short format (S1G_SHORT) is used for non-duplicate S1G transmissions and for S1G_DUP_2M transmissions, at bandwidths of 2 MHz and higher (i.e., CH_BANDWIDTH = CBW2, CBW4, CBW8, or CBW16). The S1G_SHORT preamble (see 23.3.8.2.1) is used. This PPDU format is similar to the HT-greenfield format in Clause 19, which does not contain a legacy portion in the preamble. Support for S1G_SHORT is mandatory.
— The greater than or equal to 2 MHz long format (S1G_LONG) is used for non-duplicate S1G transmissions at bandwidths of 2 MHz and higher (i.e., CH_BANDWIDTH = CBW2, CBW4, CBW8, or CBW16). The S1G_LONG format is not used for S1G_DUP_2M transmissions. The S1G_LONG preamble (see 23.3.8.2.2) is used. This PPDU format is similar to the HT-mixed format in Clause 19. Support for S1G_LONG is optional if a STA supports only 1 MHz and 2 MHz PPDUs, and is mandatory if a STA supports wider than 2 MHz PPDUs. All S1G STAs shall support detecting and decoding up to the SIG-A field of S1G_LONG PPDUs.

An S1G_LONG PPDU can be further categorized as an S1G SU PPDU or an S1G MU PPDU. An S1G_LONG PPDU with MU_SU = MU is an S1G MU PPDU, otherwise it is an S1G SU PPDU. An S1G MU PPDU carries one or more PSDUs to one or more STAs and shall be an S1G_LONG PPDU.

23.2 S1G PHY service interface

23.2.1 Introduction

The PHY provides an interface to the MAC through an extension of the generic PHY service interface defined in 8.3.4. The interface includes TXVECTOR, RXVECTOR, and PHYCONFIG_VECTOR.

The TXVECTOR supplies the PHY with per-PPDU transmit parameters. Using the RXVECTOR, the PHY informs the MAC of the received PPDU parameters. Using the PHYCONFIG_VECTOR, the MAC configures the PHY for operation, independent of frame transmission or reception.

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23.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 23-1 are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive and/or as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive.

Table 23-1—TXVECTOR and RXVECTOR parameters

Parameter	Condition	Value	TXVECTOR	RXVECTOR
FORMAT		Determines the format of the PPDU. Enumerated type: S1G indicates S1G PPDU format. S1G_DUP_1M indicates S1G 1 MHz Duplicate PPDU format S1G_DUP_2M indicates S1G 2 MHz Duplicate PPDU format	Y	Y
PREAMBLE_TYPE	FORMAT is S1G and (CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16)	Determine the type of preamble of the S1G PPDU. Enumerated type: S1G_SHORT_PREAMBLE indicates the short preamble defined in 23.3.8.2.2. S1G_LONG_PREAMBLE indicates the long preamble defined in 23.3.8.2.3.	Y	Y
	FORMAT is S1G_DUP_2M	Set to S1G_SHORT_PREAMBLE.	Y	Y
	Otherwise	Not present	N	N
MU_SU	FORMAT is S1G and PREAMBLE_TYPE is S1G_LONG_PREAMBLE and (CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16)	Determine whether MU or SU of the S1G PPDU Enumerated type: Set to MU if NUM_USERS is 2 to 4. Set to SU if NUM_USERS is 1.	Y	Y
	Otherwise	Not present	N	N
NDP_INDICATION		Determine the type of S1G frame. Set to 1 if this packet is one of NDP CMAC PPDUs as defined in 23.3.12. Set to 0 otherwise.	Y	Y

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Table 23-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
NDP_CMAC_PPDU_BODY	NDP_INDICATION is 1	Set to concatenated bit fields, which describe the NDP CMAC PPDU body content in one of NDP CMAC PPDU types defined in Table 23-29. (See 23.3.12).	Y	Y
	Otherwise	Not present	N	N
SMOOTHING	FORMAT is S1G and (CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16) and PREAMBLE_TYPE is S1G_LONG_PREAMBLE and NUM_STS is larger than 1	Indicates whether frequency domain smoothing is recommended as part of channel estimation. Set to 1 if frequency domain smoothing is recommended. Set to 0 otherwise.	Y	Y
	FORMAT is S1G and (CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16) and PREAMBLE_TYPE is S1G_LONG_PREAMBLE and NUM_STS is 1	Not present	N	N
	Otherwise	Indicates whether frequency domain smoothing is recommended as part of channel estimation. Set to 1 if frequency domain smoothing is recommended. Set to 0 otherwise.	Y	Y
AGGREGATION		Indicates whether the PSDU contains an A-MPDU. Enumerated type: AGGREGATED indicates this packet has A-MPDU aggregation. NOT_AGGREGATED indicates this packet does not have A-MPDU aggregation.	Y	Y
SECTOR_ID	FORMAT is S1G and PREMABLE_TYPE is S1G_LONG_PREAMBLE	Indicates which sectorized beam of the available sectorized beams are used in the transmission. The length of the parameter is 8 bits. A 1 in bit position n, relative to the LSB, indicates that Sector n is used. This parameter is present only if sectorization is applied.	O	N
	Otherwise	Not present	N	N

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Table 23-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
N_TX		Indicates the number of transmit chains.	Y	N
EXPANSION_MAT	FORMAT is S1G and (CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16) and MU_SU is MU	Contains a vector in the number of selected subcarriers containing feedback matrices as defined in 23.3.10.2 based on the channel measured during the training symbols of a previous S1G NDP.	MU	N
	FORMAT is S1G and (CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16) and MU_SU is SU	Contains a vector in the number of selected subcarriers containing feedback matrices as defined in 23.3.10.2 based on the channel measured during the training symbols of a previous S1G NDP.	O	N
	Otherwise	Not present	N	N
CHAN_MAT	PSDU_LENGTH equals 0 and NDP_INDICATION is 0	Contains a set of compressed beamforming feedback matrices as defined in 23.3.10.2 based on the channel measured during the training symbols of the received S1G NDP.	N	Y
	Otherwise	Not present	N	N
DELTA_SNR	FORMAT is S1G and (CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16)	Contains an array of delta SNR values as defined in 9.4.1.51 based on the channel measured during the training symbols of the received S1G NDP. NOTE—In the RXVECTOR this parameter is present only for S1G NDPs for MU sounding.	MU	Y
	Otherwise	Not present	N	N
SNR		Contains an array of measures of the received SNR for each spatial stream. SNR indications of 8 bits are supported. SNR shall be the sum of the decibel values of SNR per tone divided by the number of tones represented in each stream as described in 9.4.1.49.	N	Y
FEC_CODING	FORMAT is S1G	Indicates which FEC encoding is used. Enumerated type: BCC_CODING indicates binary convolutional code. LDPC_CODING indicates low-density parity check code.	MU	Y
	FORMAT is S1G_DUP_2M or S1G_DUP_1M	Indicates which FEC encoding is used. Enumerated type: BCC_CODING indicates binary convolutional code. LDPC_CODING indicates low-density parity check code.	Y	Y

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Table 23-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
STBC		Indicates whether or not STBC is used. 0 indicates no STBC (N_{STS}=N_{SS} in the Data field). 1 indicates STBC is used (N_{STS}=$2N_{SS}$ in the Data field).	Y	Y
GI_TYPE		Indicates whether a short guard interval is used in the transmission of the Data field of the PPDU. Enumerated type: LONG_GI indicates short GI is not used in the Data field of the PPDU. SHORT_GI indicates short GI is used in the Data field of the PPDU.	Y	Y
TXPWR_LEVEL		The allowed values for the TXPWR_LEVEL parameter are in the range from 1 to N/2, where N is the number of octets in dot11TxPowerLevelExtended. This parameter is used to indicate which of the available transmit output power levels defined in dot11TxPowerLevelExtended shall be used for the current transmission.	Y	N
RSSI		The allowed values for the RSSI parameter are in the range 0 to 255. This parameter is a measure by the PHY of the power observed at the antenna connector used to receive the current PPDU measured during the reception of the LTF field. RSSI is intended to be used in a relative manner, and it is a monotonically increasing function of the received power.	N	Y
MCS	FORMAT is S1G and (CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16)	Indicates the modulation and coding scheme used in the transmission of the PPDU. Integer: range 0 to 9	M U	Y
	FORMAT is S1G_DUP_2M	Indicates the modulation and coding scheme used in the transmission of the PPDU. Integer: range 0 to 9	Y	Y
	Otherwise	Indicates the modulation and coding scheme used in the transmission of the PPDU. Integer: range 0 to 10	Y	Y
REC_MCS	FORMAT is [S1G with (CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16)] or S1G_DUP_2M	Indicates the MCS that the STA's receiver recommends. Integer: range 0 to 9	N	O
	Otherwise	Indicates the MCS that the STA's receiver recommends. Integer: range 0 to 10	N	O

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Table 23-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
CH_BANDWIDTH	FORMAT is S1G	Indicates the channel width of the transmitted PPDU: Enumerated type: CBW1 for 1 MHz CBW2 for 2 MHz CBW4 for 4 MHz CBW8 for 8 MHz CBW16 for 16 MHz	Y	Y
	FORMAT is S1G_DUP_2M	In TXVECTOR, indicates the channel width of the transmitted S1G 2 MHz Duplicate PPDU. In RXVECTOR, indicates the estimated channel width of the received S1G 2 MHz Duplicate PPDU. Enumerated type: CBW4 for 4 MHz CBW8 for 8 MHz CBW16 for 16 MHz	Y	Y
	FORMAT is S1G_DUP_1M	In TXVECTOR, indicates the channel width of the transmitted S1G 1 MHz Duplicate PPDU. In RXVECTOR, indicates the estimated channel width of the received S1G 1 MHz Duplicate PPDU. Enumerated type: CBW2 for 2 MHz CBW4 for 4 MHz CBW8 for 8 MHz CBW16 for 16 MHz	Y	Y
LENGTH	AGGREGATION is AGGREGATED	Indicates the packet duration in number of symbols in the PSDU	Y	Y
	AGGREGATION is NOT_AGGREGATED	Indicates the packet duration in number of octets in the PSDU	Y	Y
APEP_LENGTH	FORMAT is S1G and AGGREGATION is AGGREGATED	If equal to 0, indicates an S1G NDP for both RXVECTOR and TXVECTOR. If greater than 0 in the TXVECTOR, indicates the number of octets in the A-MPDU pre-EOF padding (see 10.12.2) carried in the PSDU. This parameter is used to determine the number of OFDM symbols in the Data field that do not appear after a subframe with 1 in the EOF subfield.	M U	O
	(FORMAT is S1G_DUP_2M or SIG_DUP_1M) and AGGREGATION is AGGREGATED	If equal to 0, indicates an S1G NDP for both RXVECTOR and TXVECTOR. If greater than 0 in the TXVECTOR, indicates the number of octets in the A-MPDU pre-EOF padding (see 10.12.2) carried in the PSDU. This parameter is used to determine the number of OFDM symbols in the Data field that do not appear after a subframe with 1 in the EOF subfield.	Y	O
	Otherwise	Not present	N	N

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Table 23-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
PSDU_LENGTH	FORMAT is S1G and (CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16) and MU_SU is MU	Indicates the value in the RXVECTOR obtained from 23.4.3.	N	Y
	Otherwise	If greater than 0 in the TXVECTOR and AGGREGATION is NOT_AGGREGATED, indicates the number of octets in the PSDU. If greater than 0 in the RXVECTOR, this parameter is the value obtained from 23.4.3. A value of 0 indicates an S1G NDP for both RXVECTOR and TXVECTOR.	Y	Y
USER_POSITION	FORMAT is S1G and (CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16) and MU_SU is MU	Index for user in MU transmission. Integer: range 0–3. NOTE—The entries in the USER_POSITION array are in ascending order.	Y	Y
	Otherwise	Not present	N	N
NUM_STS	FORMAT is S1G	Indicates the number of space-time streams. Integer: range 1–4 per user in the TXVECTOR and 0–4 in the RXVECTOR. NUM_STS summed over all users is in the range 1 to 4 for MU-MIMO.	M U	Y
	FORMAT is S1G_DUP_2M or S1G_DUP_1M	Indicates the number of space-time streams. Integer: range 1–4 per user in the TXVECTOR and 0–4 in the RXVECTOR.	Y	Y
GROUP_ID	FORMAT is S1G and (CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16) and MU_SU is MU	Indicates the group ID. Integer: range 1–62 (see Table 23-14 in 23.3.8.2.3.2.5).	Y	Y
	Otherwise	Not present	N	N
PARTIAL_AID	FORMAT is [S1G with (CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16) and (MU_SU is SU)] or S1G_DUP_2M	Provides an abbreviated indication of the intended recipient(s) of the PSDU (see 10.21). Integer: range 0–511 if UPLINK_INDICATION is 1, and range 0–63 if UPLINK_INDICATION is 0.	Y	Y
	Otherwise	Not present	N	N

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Table 23-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
NUM_USERS	FORMAT is S1G and (CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16) and MU_SU is MU	Indicates the number of users with nonzero space-time streams. Integer: range 1 to 4.	Y	N
	Otherwise	Set to 1	Y	N
BEAM_CHANGE	FORMAT is S1G and MU_SU is SU and (CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16) and PREAMBLE_TYPE is S1G_LONG_PREAMBLE and NUM_STS is 1	Set to 1 if the Q matrix is changed from the omnidirectional portion to the beam changeable portion of the long preamble, in at least one of the nonzero subcarrier of the omnidirectional portion as described in 23.3.8.2.3.2.5. Set to 0 if the Q matrix is unchanged in all the nonzero subcarriers of the omnidirectional portion. NOTE—If BEAM_CHANGE is 0 and PREAMBLE_TYPE is S1G_LONG_PREAMBLE, the receiver may do channel smoothing. Otherwise, smoothing is not recommended.	Y	Y
	Otherwise	Not present	N	N
RESPONSE_INDICATION		Set to 0 if No Response. Set to 1 if NDP Response. Set to 2 if Normal Response. Set to 3 if Long Response.	Y	Y
TRAVELING_PILOTS		Set to 1 if traveling pilots are used in the packet. Set to 0 otherwise.	Y	O
TIME_OF_DEPARTURE_REQUESTED		Boolean value: true indicates that the MAC entity requests that the PHY entity measures and reports time of departure parameters corresponding to the time when the first PPDU energy is sent by the transmitting port. false indicates that the MAC entity requests that the PHY entity neither measures nor reports time of departure parameters.	O	N
RX_START_OF_FRAME_OFFSET	dot11MgmtOptionTimingMsmtActivated is true	0 to 2^{32}– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble corresponding to the incoming frame arrived at the receive antenna port to the point in time at which this primitive is issued to the MAC.	N	Y
	Otherwise	Not present	N	N

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Table 23-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Condition	Value	TXVECTOR	RXVECTOR
UPLINK_INDICATION	NDP_INDICATION is 0 and FORMAT is S1G and CH_BANDWIDTH is not CBW1	Set to 1 if the S1G PPDU is addressed to AP Set to 0 otherwise (See 10.21).	Y	Y
	Otherwise	Not present	N	N
COLOR	UPLINK_INDICATION is 0 and NDP_INDICATION is 0 and (FORMAT is S1G or S1G_DUP_2M) and CH_BANDWIDTH is not CBW1 and MU_SU is SU	Set to a value of its choosing within the range 0 to 7 (See 10.21)	Y	Y
	Otherwise	Not present	N	N
SCRAMBLER_OR_CRC	NDP_INDICATION is 0	Indicates the Scrambler Initialization value in the Service field (as defined in 23.3.9.2) prior to descrambling. Bit sequence of 7 bits in length: [B0:B6] of the SERVICE field value prior to descrambling.	N	Y
	FORMAT is S1G and NDP_INDICATION is 1	Indicates the value of the calculated CRC in the SIG field. Bit sequence of 4 bits in length: Either [B26:B29] of the 1 MHz SIG field or [B38:B41] of the ≥ 2 MHz SIG field.	N	Y
	FORMAT is S1G_DUP_2M and NDP_INDICATION is 1	Indicates the value of the calculated CRC in the SIG field. Bit sequence of 4 bits in length: [B38:B41] of the ≥ 2 MHz SIG field.	N	Y
	FORMAT is S1G_DUP_1M and NDP_INDICATION is 1	Indicates the value of the calculated CRC in the SIG field. Bit sequence of 4 bits in length: [B26:B29] of the 1 MHz SIG field.	N	Y
	Otherwise	Not present	N	N

NOTE—In the TXVECTOR and RXVECTOR columns, the following apply:
Y = Present.
N = Not present.
O = Optionally present.
MU indicates that the parameter is present once for an S1G SU PPDU and present per user for an S1G MU PPDU. Parameters specified to be present per user are conceptually supplied as an array of values indexed by *u*, where *u* takes values 0 to NUM_USERS-1.

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23.2.3 Effect of CH_BANDWIDTH parameter on PPDU format

Table 23-2 shows the PPDU format as a function of the CH_BANDWIDTH parameter.

Table 23-2—PPDU format as a function of CH_BANDWIDTH parameter

FORMAT	CH_BANDWIDTH	PPDU format
S1G	CBW1	The STA transmits an S1G PPDU of 1 MHz bandwidth. If the operating channel width is wider than 1 MHz, then the transmission shall use the primary 1 MHz channel.
S1G	CBW2	The STA transmits an S1G PPDU of 2 MHz bandwidth. If the operating channel width is wider than 2 MHz, then the transmission shall use the primary 2 MHz channel.
S1G	CBW4	The STA transmits an S1G PPDU of 4 MHz bandwidth. If the operating channel width is wider than 4 MHz, then the transmission shall use the primary 4 MHz channel.
S1G	CBW8	The STA transmits an S1G PPDU of 8 MHz bandwidth. If the operating channel width is wider than 8 MHz, then the transmission shall use the primary 8 MHz channel.
S1G	CBW16	The STA transmits an S1G PPDU of 16 MHz bandwidth.
S1G_DUP_2M	CBW4	The STA transmits an S1G 2 MHz Duplicate PPDU using two adjacent 2 MHz channels as defined in 23.3.9.12.2. If the operating channel width is wider than 4 MHz, then the transmission shall use the primary 4 MHz channel. Phase rotation pattern for each 2 MHz channel is [1 j] from the lowest frequency as defined in Equation (23-7).
S1G_DUP_2M	CBW8	The STA transmits an S1G 2 MHz Duplicate PPDU using four adjacent 2 MHz channels as defined in 23.3.9.12.2. If the BSS operating channel width is 16 MHz, then the transmission shall use the primary 8 MHz channel. Phase rotation pattern for each 2 MHz channel is [1 -1 -1 -1] from the lowest frequency as defined in Equation (23-8).
S1G_DUP_2M	CBW16	The STA transmits an S1G 2 MHz Duplicate PPDU using eight adjacent 2 MHz channels as defined in 23.3.9.12.2. Phase rotation pattern for each 2 MHz channel is [1 -1 -1 -1 1 -1 -1 -1] from the lowest frequency as defined in Equation (23-9).
S1G_DUP_1M	CBW2	The STA transmits an S1G 1 MHz Duplicate PPDU using two adjacent 1 MHz channels as defined in 23.3.9.12.1. If the operating channel width is wider than 2 MHz, then the transmission shall use the primary 2 MHz channel. Phase rotation pattern for each Equation (23-10).
S1G_DUP_1M	CBW4	The STA transmits an S1G 1 MHz Duplicate PPDU using four adjacent 1 MHz channels as defined in 23.3.9.12.1. If the operating channel width is wider than 4 MHz, then the transmission shall use the primary 4 MHz channel. Phase rotation pattern for each 1 MHz channel is [1 j -j -1] from the lowest frequency as defined in Equation (23-11).

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Table 23-2—PPDU format as a function of CH_BANDWIDTH parameter *(continued)*

FORMAT	CH_BANDWIDTH	PPDU format
S1G_DUP_1M	CBW8	The STA transmits an S1G 1 MHz Duplicate PPDU using eight adjacent 1 MHz channels as defined in 23.3.9.12.1. If the BSS operating channel width is 16 MHz, then the transmission shall use the primary 8 MHz channel. Phase rotation pattern for each 1 MHz channel is [1 -1 1 1 1 1 -1 -1] from the lowest frequency as defined in Equation (23-12).
S1G_DUP_1M	CBW16	The STA transmits an S1G 1 MHz Duplicate PPDU using sixteen adjacent 1 MHz channels as defined in 23.3.9.12.1. Phase rotation pattern for each 1 MHz channel is [1 1 1 -1 1 1 1 -1 -1 -1 1 -1 1 1 -1 1] from the lowest frequency as defined in Equation (23-13).

23.3 S1G PHY sublayer

23.3.1 Introduction

This subclause provides the procedure by which PSDUs are converted to and from transmissions on the wireless medium.

During transmission, a PSDU (in the SU case) or one or more PSDUs (in the MU case) are processed (e.g., scrambled and coded) and appended to the PHY preamble to create the PPDU. At the receiver, the PHY preamble is processed to aid in the detection, demodulation and delivery of the PSDU.

23.3.2 S1G PPDU format

Three formats are defined for the S1G PHY: S1G_SHORT, S1G_LONG, and S1G_1M.

The general structure for S1G_SHORT is defined as in Figure 23-1. This format is used for SU transmission using 2 MHz, 4 MHz, 8 MHz, and 16 MHz PPDUs.

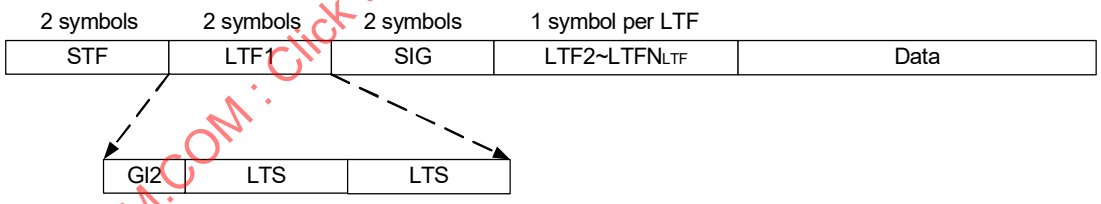

Figure 23-1—S1G_SHORT format

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The general structure for S1G_LONG is defined as in Figure 23-2. This frame format can be used for MU and SU beamformed transmissions using 2 MHz, 4 MHz, 8 MHz, and 16 MHz PPDUs.

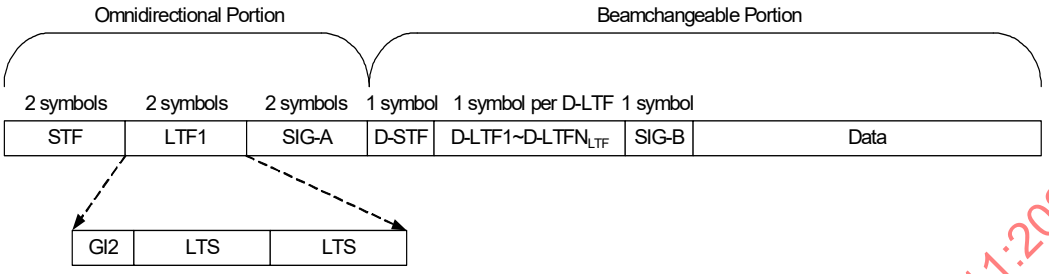

Figure 23-2—S1G_LONG format

The general structure for S1G_1M is defined as in Figure 23-3. This frame format is used for S1G_1M PPDU SU transmission.

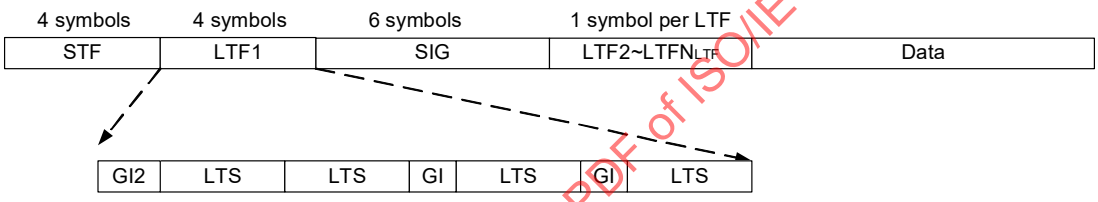

Figure 23-3—S1G_1M format

The fields of the S1G PPDU formats are summarized in Table 23-3.

Table 23-3—Fields of the S1G PPDU

Field	Description
STF	Short Training field
LTF	Long Training field
SIG	SIGNAL field
SIG-A	Signal A field
D-STF	Short Training field for the beam changeable portion
D-LTF	Long Training field for the beam changeable portion
SIG-B	Signal B field
Data	The Data field carries the PSDU(s)
GI	Guard interval
GI2	Double guard interval
LTS	Long training symbol

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The SIG-A, D-STF, D-LTF, and SIG-B fields exist only in S1G_LONG format. In an S1G NDP, the Data field is not present (see 23.3.11. The number of symbols in the LTF field of S1G_1M and S1G_SHORT, or in the D-LTF field of S1G_LONG, N_{VHTLTF}, can be either 1, 2, or 4 and is determined by the total number of space-time streams across all users being transmitted in the S1G PPDU (see Table 23-10 in 23.3.8.2.2).

23.3.3 Transmitter block diagram

Each field in an S1G PPDU can be generated using a subset of the following blocks (only select blocks are listed below):

a) PHY padding
b) Scrambler
c) BCC encoder parser
d) FEC (BCC or LDPC) encoders
e) Stream parser
f) Segment parser (for 16 MHz)
g) BCC Interleaver
h) Replicate the encoded bits (for 1 MHz MCS 10)
i) Constellation mapper
j) Pilot insertion
k) Replicate over multiple 1 MHz or 2 MHz widths
l) Multiply by first column of P_{HTLTF}
m) LDPC tone mapper
n) Segment deparser (for 16 MHz)
o) Space-time block code (STBC) encoder
p) Cyclic shift diversity (CSD) per STS insertion
q) Spatial mapper
r) Inverse discrete Fourier transform (IDFT)
s) Cyclic shift diversity (CSD) per chain insertion
t) Guard interval (GI) insertion
u) Windowing

The general transmission flow for S1G_1M MCS 0–9, and all the MCSs for S1G_SHORT and S1G_LONG formats are the same as the corresponding portions in 21.3.

Specifically, Figure 21-5, with “20 MHz” replaced by “2 MHz”, shows the transmit process for the SIG-A field of an S1G PPDU in S1G_LONG. These transmit blocks are also used to generate the omnidirectional portion of the S1G_LONG PPDU, except that the BCC encoder and interleaver are not used when generating the STF and LTF1 fields.

Figure 21-6 and Figure 21-7, with “20 MHz” replaced by “2 MHz”, show the transmit process for generating the SIG-B field of a 2 MHz, 4 MHz, and 8 MHz long format S1G PPDU for SU PPDU and MU PPDU, respectively. Figure 21-8, with “160 MHz” replaced by “16 MHz”, shows the transmit process for generating the SIG-B field of a 16 MHz long format S1G SU PPDU.

Figure 21-10 shows the transmitter blocks used to generate the BCC encoded Data field of a 2 MHz, 4 MHz, and 8 MHz SU PPDU in short or long format, and of an S1G_1M PPDU except MCS 10. It should be noted that the number of encoders is fixed to one for BCC (i.e., N_{ES}=1), in S1G operation. A subset of these transmitter blocks consisting of the constellation mapper and CSD blocks, as well as the blocks to the right

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of, and including, the spatial mapping block, are also used to generate the STF and LTF fields in S1G_1M and S1G_SHORT, or the D-STF and D-LTF fields in S1G_LONG. This is illustrated in Figure 23-6 in 23.3.8.2.2.4 for the mentioned LTF fields. A similar set of transmit blocks is used to generate the mentioned STF fields.

Figure 21-11 shows the transmitter blocks used to generate the LDPC encoded Data field of a 2 MHz, 4 MHz, and 8 MHz SU PPDU in short or long format, and of an S1G_1M PPDU except MCS 10.

Figure 21-12 shows the transmit process for generating the Data field of a 2 MHz, 4 MHz, and 8 MHz MU PPDU in long format with BCC and/or LDPC encoding. The number of encoders is fixed to one (i.e., N_{ES}=1) for BCC in S1G operation.

Figure 21-13 and Figure 21-14 show the transmit process for generating the Data field of a 16 MHz SU PPDU in short or long format, with BCC and LDPC encoding, respectively. The number of encoders is fixed to one (i.e., N_{ES}=1) for BCC in S1G operation.

Figure 23-4 below shows the transmit process for generating the Data field of an S1G_1M PPDU with MCS 10, either BCC or LDPC encoded.

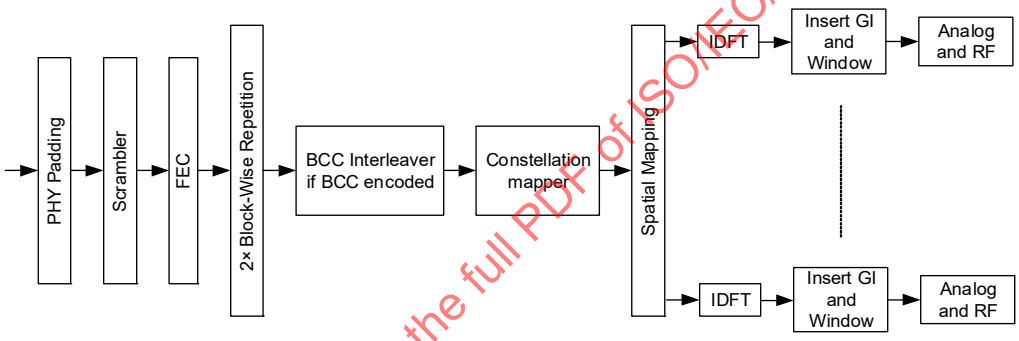

Figure 23-4—Transmitter block diagram for the Data field of an S1G_1M PPDU with BCC or LDPC encoding and MCS 10

23.3.4 Overview of the PPDU encoding process

23.3.4.1 General

This subclause provides an overview of the S1G PPDU encoding process.

23.3.4.2 Construction of the Preamble part in an S1G_LONG PPDU

23.3.4.2.1 Construction of STF

Construct the STF field as defined in 23.3.8.2.2.3 with the following highlights:

a) Determine the CH_BANDWIDTH from the TXVECTOR.

b) Sequence generation: Generate the STF field sequence over the CH_BANDWIDTH as described in 23.3.8.2.3.2.3.

c) Phase rotation: Apply appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11, 23.3.9.12, and 23.3.7.

d) IDFT: Compute the inverse discrete Fourier transform.

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e) CSD: Apply CSD for each transmit chain and frequency segment as described in 23.3.8.2.3.2.2.

f) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 23.3.7.

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

23.3.4.2.2 Construction of LTF1

Construct the LTF1 field as defined in 23.3.8.2.2.4 with the following highlights:

a) Determine the CH_BANDWIDTH from the TXVECTOR.

b) Sequence generation: Generate the LTF1 field sequence over the CH_BANDWIDTH as described in 23.3.8.2.2.4.

c) Phase rotation: Apply appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11, 23.3.9.12, and 23.3.7.

d) IDFT: Compute the inverse discrete Fourier transform.

e) CSD: Apply CSD for each transmit chain and frequency segment as described in 23.3.8.2.3.2.2.

f) Insert GI and apply windowing: Prepend a GI of 16 μs in duration and apply windowing as described in 23.3.7.

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

23.3.4.2.3 Construction of SIG-A

The SIG-A field consists of two symbols, SIG-A1 and SIG-A2, as defined in 23.3.8.2.3.2.5 and is constructed as follows:

a) Obtain the CH_BANDWIDTH, STBC, MU_SU, GROUP_ID (MU only), PARTIAL_AID (SU only), NUM_STS, GI_TYPE, FEC_CODING, MCS (SU only), NUM_USERS, LENGTH, AGGREGATION (SU only), RESPONSE_INDICATION, BEAM_CHANGE (SU only for single space-time stream), SMOOTHING and TRAVELING_PILOTS from the TXVECTOR. Add the reserved bits, append the calculated 4-bit CRC, then append the N_{tail} tail bits as shown in 23.3.8.2.3.2.5. This operation gives as a result 48 uncoded bits.

b) BCC encoder: Encode the data by a convolutional encoder at the rate of R=1/2 as described in 17.3.5.6.

c) BCC interleaver: Interleave as described in 17.3.5.7.

d) Constellation mapper: QBPSK modulate the first 48 interleaved bits by rotating by 90° counter-clockwise relative to the original BPSK as described in 23.3.8.2.3.2.5 to form the first symbol of SIG-A field. BPSK modulate the second 48 interleaved bits to form the second symbol of SIG-A field.

e) Pilot insertion: Insert pilots as described in 17.3.5.10.

f) Duplication and phase rotation: Duplicate SIG-A1 and SIG-A2 over each 2 MHz of the CH_BANDWIDTH. Apply the appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11, 23.3.9.12, and 23.3.7.

g) IDFT: Compute the inverse discrete Fourier transform.

h) CSD: Apply CSD for each transmit chain as described in 23.3.8.2.3.2.2.

i) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5.

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j) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

23.3.4.2.4 Construction of D-STF

The D-STF field is defined in 23.3.8.2.3.3.3 and constructed as follows:

a) Sequence generation: Generate the D-STF field in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 23.3.8.2.3.3.3.
b) Phase rotation: Apply appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11, 23.3.9.12, and 23.3.7.
c) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.3.2.2.
d) Spatial mapping: Apply the Q matrix as described in 23.3.10 and 23.3.9.11.
e) IDFT: Compute the inverse discrete Fourier transform.
f) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5.
g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

23.3.4.2.5 Construction of D-LTF

The D-LTF field is defined in 23.3.8.2.3.3.4 and constructed as follows:

a) Sequence generation: Generate the D-LTF field sequence in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 23.3.8.2.3.3.4.
b) Phase rotation: Apply appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11, 23.3.9.12, and 23.3.7.
c) A_{LTF} matrix mapping: Apply the P_{HTLTF} matrix to the D-LTF field sequence (the pilot tones are processed differently) as described in 23.3.8.2.3.3.4.
d) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.3.2.2.
e) Spatial mapping: Apply the Q matrix as described in 23.3.10 and 23.3.9.11.
f) IDFT: Compute the inverse discrete Fourier transform.
g) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5.
h) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

23.3.4.2.6 Construction of SIG-B

The SIG-B field is constructed per user as follows:

a) Obtain the MCS (for MU only) from the TXVECTOR.
b) SIG-B bits: Set the MCS (for MU only) as described in 23.3.8.2.3.3.5. Add the reserved bits and N_{tail} bits of tail.
c) SIG-B field Bit Repetition: Repeat the SIG-B field bits as a function of CH_BANDWIDTH as defined in 23.3.8.2.3.3.5.
d) BCC encoder: Encode the SIG-B field using BCC at rate R=1/2 as described in 17.3.5.6.

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e) Segment parser (if needed): For a 16 MHz transmission, divide the output bits of the BCC encoder into two frequency subblocks as described in 23.3.9.7. This block is bypassed for 2 MHz, 4 MHz, and 8 MHz S1G PPDU transmissions.

f) BCC interleaver: Interleave as described in 23.3.9.8.

g) Constellation mapper: Map to a BPSK constellation as defined in 17.3.5.8.

h) Segment deparser (if needed): For a 16 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 23.3.9.9.3. This block is bypassed for 2 MHz, 4 MHz, and 8 MHz S1G PPDU transmissions.

i) Pilot insertion: Insert pilots following the steps described in 21.3.10.10.

j) P_{HTLTF} matrix mapping: Apply the mapping of the first column of the P_{HTLTF} matrix to the data subcarriers as described in 23.3.8.2.3.3.5. The total number of data and pilot subcarriers is the same as in the Data field.

k) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.3.2.2.

l) Spatial mapping: Apply the Q matrix as described in 23.3.10 and 23.3.9.11.

m) Phase rotation: Apply the appropriate phase rotations for each 2 MHz subchannel as described in 23.3.9.11, 23.3.9.12, and 23.3.7.

n) IDFT: Compute the inverse discrete Fourier transform.

o) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5.

p) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

23.3.4.3 Construction of the Preamble part in an S1G_SHORT PPDU

23.3.4.3.1 Construction of STF

The STF field is defined in 23.3.8.2.2.3 and constructed as follows:

a) Determine the CH_BANDWIDTH from the TXVECTOR.

b) Sequence generation: Generate the STF field in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 23.3.8.2.2.3.

c) Phase rotation: Apply appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11, 23.3.9.12, and 23.3.7.

d) P_{HTLTF} matrix mapping: Apply the mapping of the first column of the P_{HTLTF} matrix to the STF field sequence as described in 23.3.8.2.2.4.

e) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.2.2.

f) Spatial mapping: Apply the Q matrix as described in 23.3.10 and 23.3.9.11.

g) IDFT: Compute the inverse discrete Fourier transform.

h) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5.

i) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

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23.3.4.3.2 Construction of LTF1

The LTF1 field is defined in 23.3.8.2.2.4 and constructed as follows:

a) Determine FORMAT from TXVECTOR.

b) Sequence generation: If FORMAT is S1G, generate the LTF1 field sequence in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 23.3.8.2.2.4. If format is S1G_DUP_2M, generate the LTF1 field sequence in the frequency domain over a 2 MHz bandwidth.

c) Phase rotation: Apply appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11, 23.3.9.12, and 23.3.7.

d) A_{LTF} matrix mapping: Apply the mapping of the first column of the P_{HTLTF} matrix to the LTF1 field sequence (the pilot tones are processed differently) as described in 23.3.8.2.2.4.

e) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.2.2.

f) Spatial mapping: Apply the Q matrix as described in 23.3.10 and 23.3.9.11.

g) IDFT: Compute the inverse discrete Fourier transform.

h) Insert GI and apply windowing: Prepend a GI of 16 μs in duration and apply windowing as described in 17.3.2.5.

i) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

23.3.4.3.3 Construction of SIG

The SIG field is constructed per-user as follows:

a) Obtain the CH_BANDWIDTH, STBC, PARTIAL_AID, NUM_STS, GI_TYPE, FEC_CODING, MCS, SMOOTHING, NUM_USERS, LENGTH, AGGREGATION, RESPONSE_INDICATION, NDP_INDICATION, TRAVELING_PILOTS, UPLINK_INDICATION, and COLOR, from the TXVECTOR. Add the reserved bits, append the calculated 4-bit CRC, then append the N_{tail} tail bits as shown in 23.3.8.2.2.5. This operation gives as a result 48 uncoded bits.

b) BCC encoder: Encode the data by a convolutional encoder at the rate of R=1/2 as described in 17.3.5.6.

c) BCC interleaver: Interleave as described in 17.3.5.7.

d) Constellation mapper: QBPSK modulate the first 48 interleaved bits as described in 17.3.5.8 to form the first symbol of SIG field. QBPSK modulate the second 48 interleaved bits to form the second symbol of SIG field.

e) Pilot insertion: Insert pilots as described in 17.3.5.10.

f) P_{HTLTF} matrix mapping: Apply the mapping of the first column of the P_{HTLTF} matrix to the data subcarriers as described in 23.3.8.2.2.5.

g) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.2.2.

h) Spatial mapping: Apply the Q matrix as described in 23.3.10 and 23.3.9.11.

i) Duplication and phase rotation: Duplicate two symbols of SIG field over each 2 MHz of the CH_BANDWIDTH. Apply the appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11, 23.3.9.12, and 23.3.7.

j) IDFT: Compute the inverse discrete Fourier transform.

k) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5.

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l) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

23.3.4.3.4 Construction of LTF2-LTFNLTF

The LTF2-LTFNLTF field is defined in 23.3.8.2.2.4 and constructed as follows:

a) Sequence generation: Generate the LTF2-LTFNLTF field sequence in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 23.3.8.2.2.4.

b) Phase rotation: Apply appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11, 23.3.9.12, and 23.3.7.

c) A_{LTF} matrix mapping: Apply the mapping of the P_{HTLTF} matrix (from the second column to the last column) to the LTF2-LTFNLTF field sequence (the pilot tones are processed differently) as described in 23.3.8.2.2.4.

d) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.2.2.

e) Spatial mapping: Apply the Q matrix as described in 23.3.10 and 23.3.9.11.

f) IDFT: Compute the inverse discrete Fourier transform.

g) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5.

h) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

23.3.4.4 Construction of the Preamble part in an S1G_1M PPDU

23.3.4.4.1 Construction of 1 MHz STF

The 1 MHz STF field is defined in 23.3.8.3.3 and constructed as follows:

a) Determine the CH_BANDWIDTH from the TXVECTOR if S1G 1 MHz Duplicate PPDU.

b) Sequence generation: Generate the 1 MHz STF field in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 23.3.8.3.3. Apply the 3 dB power boosting if the MCS from the TXVECTOR equals MCS 10 as described in 23.3.8.3.3.

c) Phase rotation: Apply appropriate phase rotation for each 1 MHz subchannel if S1G 1 MHz Duplicate PPDU as described in 23.3.9.12 and 23.3.7.

d) P_{HTLTF} matrix mapping: Apply the mapping of the first column of the P_{HTLTF} matrix to the 1 MHz STF field sequence as described in 23.3.8.3.4.

e) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.3.2.

f) Spatial mapping: Apply the Q matrix as described in 23.3.9.11.

g) IDFT: Compute the inverse discrete Fourier transform.

h) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5.

i) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

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23.3.4.4.2 Construction of 1 MHz LTF1

The 1 MHz LTF1 field is defined in 23.3.8.3.4 and constructed as follows:

a) Determine FORMAT from TXVECTOR.

b) Sequence generation: If FORMAT is S1G, generate the 1 MHz LTF1 field sequence in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 23.3.8.3.4. If FORMAT is S1G_DUP_1M, generate the LTF1 field sequence in the frequency domain over a 1 MHz bandwidth.

c) Phase rotation: Apply appropriate phase rotation for each 1 MHz subchannel if S1G 1 MHz Duplicate PPDU as described in 23.3.9.12 and 23.3.7.

d) A_{LTF} matrix mapping: Apply the mapping of the first column of the P_{HTLTF} matrix to the 1 MHz LTF1 field sequence (the pilot tones are processed differently) as described in 23.3.8.3.4.

e) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.3.2.

f) Spatial mapping: Apply the Q matrix as described in 23.3.9.11.

g) IDFT: Compute the inverse discrete Fourier transform.

h) Insert GI and apply windowing: Prepend a GI of 16 μs in duration for the first two symbols and insert a GI of 8 μs in duration per each subsequent symbol. Apply windowing as described in 17.3.2.5.

i) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

23.3.4.4.3 Construction of 1 MHz SIG

The SIG field is constructed per-user as follows:

a) Obtain the STBC, NUM_STS, GI_TYPE, FEC_CODING, MCS, SMOOTHING, LENGTH, AGGREGATION, RESPONSE_INDICATION, NDP_INDICATION and TRAVELING_PILOTS from the TXVECTOR. Add the reserved bits, append the calculated 4-bit CRC, then append the N_{tail} tail bits as shown in 23.3.8.3.5. This operation gives as a result 36 uncoded bits.

b) BCC encoder: Encode the data by a convolutional encoder at the rate of R=1/2 as described in 17.3.5.6 and apply the block-wise 2 times repetition on a per-OFDM symbol basis.

c) BCC interleaver: Interleave as described in 23.3.9.8.

d) Constellation mapper: BPSK modulate the interleaved bits as described in 17.3.5.8 to form the 6 symbols of SIG field.

e) Pilot insertion: Insert pilots as described in 17.3.5.10.

f) P_{HTLTF} matrix mapping: Apply the mapping of the first column of the P_{HTLTF} matrix to the data subcarriers as described in 23.3.8.3.5.

g) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.3.2.

h) Spatial mapping: Apply the Q matrix as described in 23.3.9.11.

i) Duplication and phase rotation: Duplicate 6 symbols of SIG field over each 1 MHz of the CH_BANDWIDTH if S1G 1 MHz Duplicate PPDU. Apply the appropriate phase rotation for each 1 MHz subchannel as described in 23.3.9.12 and 23.3.7.

j) IDFT: Compute the inverse discrete Fourier transform.

k) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5.

l) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

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23.3.4.4.4 Construction of 1 MHz LTF2-LTFNLTF

The 1 MHz LTF2-LTFNLTF field is defined in 23.3.8.3.4 and constructed as follows:

a) Sequence generation: Generate the 1 MHz LTF2-LTFNLTF field sequence in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 23.3.8.3.4.

b) Phase rotation: Apply appropriate phase rotation for each 1 MHz subchannel as described in 23.3.9.12 and 23.3.7 if S1G 1 MHz Duplicate PPDU.

c) A_{LTF} matrix mapping: Apply the mapping of the P_{HTLTF} matrix (from the second column to the last column) to the 1 MHz LTF2-LTFNLTF field sequence (the pilot tones are processed differently) as described in 23.3.8.3.4.

d) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.3.2.

e) Spatial mapping: Apply the Q matrix as described in 23.3.9.11.

f) IDFT: Compute the inverse discrete Fourier transform.

g) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5.

h) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

23.3.4.5 Construction of Preambles for S1G_DUP_2M and S1G_DUP_1M

For S1G_DUP_2M and S1G_DUP_1M, the preambles are initially constructed according to 23.3.4.3 and 23.3.4.4, respectively.

In the case of S1G_DUP_2M, the initial 2 MHz preamble is duplicated in frequency with phase rotation as defined in 23.3.4.3 to fill the final transmission bandwidth (i.e., 4 MHz, 8 MHz, or 16 MHz) indicated by the TXVECTOR parameter CH_BANDWIDTH.

In the case of S1G_DUP_1M, the initial 1 MHz preamble is duplicated in frequency with phase rotation as defined in 23.3.4.4 to fill the final transmission bandwidth (i.e., 2 MHz, 4 MHz, 8 MHz, or 16 MHz) indicated by the TXVECTOR parameter CH_BANDWIDTH.

23.3.4.6 Construction of Data field in S1G SU PPDUs for all cases except 1 MHz MCS 10

23.3.4.6.1 Using BCC

The construction of the Data field in an S1G SU PPDU with BCC encoding proceeds as follows:

a) SERVICE field: Generate the SERVICE field as described in 23.3.9.2 and append the PSDU to the SERVICE field.

b) PHY padding: Append the PHY pad bits to the PSDU as described in 23.3.9.4.3.2.

c) Scrambler: Scramble the PHY padded data as described in 23.3.9.3.

d) BCC encoder: Divide the scrambled bits between the encoders by sending bits to different encoders in a round robin manner. The number of encoders is determined by rate-dependent parameters described in 23.5. BCC encode as described in 23.3.9.4.2 and 23.3.9.4.3.

e) Stream parser: Rearrange the output of the BCC encoders into blocks as described in 23.3.9.6.

f) Segment parser (if needed): For a contiguous 16 MHz transmission, divide the output bits of each stream parser into two frequency subblocks as described in 23.3.9.7. This block is bypassed for 1 MHz, 2 MHz, 4 MHz, and 8 MHz S1G PPDU transmissions.

g) BCC interleaver: Interleave as described in 23.3.9.8.

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h) Constellation mapper: Map to BPSK, QPSK, 16-QAM, 64-QAM, or 256-QAM constellation points as described in 23.3.9.9.

i) Segment deparser (if needed): For a contiguous 16 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 23.3.9.9.3. This block is bypassed for 1 MHz, 2 MHz, 4 MHz, and 8 MHz S1G PPDU transmissions.

j) STBC: Apply STBC as described in 23.3.9.9.4.

k) Pilot insertion: Insert pilots following the steps described in 23.3.9.10.

l) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.2.2 if S1G_SHORT preamble is used, 23.3.8.2.3.3.2 if S1G_LONG preamble is used and 23.3.8.3.2 if S1G_1M preamble is used.

m) Spatial mapping: Apply the Q matrix as described in 23.3.10 and in 23.3.9.11.

n) Phase rotation: Apply the appropriate phase rotations for each 2 MHz subchannel if 2 MHz preamble is used or for each 1 MHz subchannel if S1G 1 MHz Duplicate PPDU as described in 23.3.9.11, 23.3.9.12, and 23.3.7.

o) IDFT: Compute the inverse discrete Fourier transform.

p) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 17.3.2.5. If the TXVECTOR parameter GI_TYPE equals LONG_GI, the GI duration shall be 8 μs. If the GI_TYPE parameter is SHORT_GI, the GI duration shall be 8 μs for the first OFDM symbol of the Data field, and 4 μs for all subsequent OFDM symbols.

q) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

23.3.4.6.2 Using LDPC

The construction of the Data field in an S1G SU PPDU with LDPC encoding proceeds as follows:

a) SERVICE field: Generate the SERVICE field as described in 23.3.9.2 and append the PSDU to the SERVICE field.

b) PHY padding: Append the PHY pad bits to the PSDU as described in 23.3.9.4.4.2.

c) Scrambler: Scramble the PHY-padded data as described in 23.3.9.3.

d) LDPC encoder: The scrambled bits are encoded using the LDPC code with the LENGTH from the TXVECTOR as described in 23.3.9.4.4.

e) Stream parser: The output of the LDPC encoder is rearranged into blocks as described in 23.3.9.6.

f) Segment parser (if needed): For a contiguous 16 MHz transmission, divide the output bits of each stream parser into two frequency subblocks as described in 23.3.9.7. This block is bypassed for 1 MHz, 2 MHz, 4 MHz, and 8 MHz S1G PPDU transmissions.

g) Constellation mapper: Map to BPSK, QPSK, 16-QAM, 64-QAM, or 256-QAM constellation points as described in 23.3.9.9.

h) LDPC tone mapper: The LDPC tone mapping shall be performed on all LDPC encoded streams as described in 23.3.9.9.2. LDPC tone mapper is bypassed for 1 MHz transmission.

i) Segment deparser (if needed): For a contiguous 16 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 23.3.9.9.3. This block is bypassed for 1 MHz, 2 MHz, 4 MHz, and 8 MHz S1G PPDU transmissions.

j) STBC: Apply STBC as described in 23.3.9.9.4.

k) Pilot insertion: Insert pilots following the steps described in 23.3.9.10.

l) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.2.2 if S1G_SHORT preamble is used, 23.3.8.2.3.3.2 if S1G_LONG preamble is used and 23.3.8.3.2 if S1G_1M preamble is used.

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m) Spatial mapping: Apply the *Q* matrix as described in 23.3.10 and in 23.3.9.11.

n) Phase rotation: Apply the appropriate phase rotations for each 2 MHz subchannel if 2 MHz preamble is used or for each 1 MHz subchannel if S1G 1 MHz Duplicate PPDU as described in 23.3.9.11, 23.3.9.12, and 23.3.7.

o) IDFT: Compute the inverse discrete Fourier transform.

p) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 17.3.2.5. If the TXVECTOR parameter GI_TYPE equals LONG_GI, the GI duration shall be 8 μs. If the GI_TYPE parameter is SHORT_GI, the GI duration shall be 8 μs for the first OFDM symbol of the Data field, and 4 μs for all subsequent OFDM symbols.

q) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

23.3.4.7 Construction of the Data field in an S1G SU PPDU (1 MHz MCS 10 mode)

23.3.4.7.1 Using BCC

The construction of the Data field in an S1G SU PPDU (1 MHz MCS 10 mode) with BCC encoding proceeds as follows:

a) SERVICE field: Generate the SERVICE field as described in 23.3.9.2 and append the PSDU to the SERVICE field.

b) PHY padding: Append the PHY pad bits to the PSDU as described in 23.3.9.4.3.2.

c) Scrambler: Scramble the PHY padded data as described in 23.3.9.3.

d) BCC encoder: BCC encode as described in 23.3.9.4.2 and 23.3.9.4.3.

e) Block repetition: Apply the block-wise 2 times repetition on a per-OFDM symbol basis as described in 23.3.9.5.

f) BCC interleaver: Interleave as described in 23.3.9.8.

g) Constellation mapper: Map to BPSK constellation points as described in 23.3.9.9.

h) Pilot insertion: Insert pilots following the steps described in 23.3.9.10.

i) Spatial mapping: Apply the *Q* matrix as described in 23.3.9.11.

j) Phase rotation: Apply appropriate phase rotation for each 1 MHz subchannel if S1G 1 MHz Duplicate PPDU as described in 23.3.9.12 and 23.3.7.

k) IDFT: Compute the inverse discrete Fourier transform.

l) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 17.3.2.5. If the TXVECTOR parameter GI_TYPE equals LONG_GI, the GI duration shall be 8 μs. If the GI_TYPE parameter is SHORT_GI, the GI duration shall be 8 μs for the first OFDM symbol of the Data field, and 4 μs for all subsequent OFDM symbols.

m) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

23.3.4.7.2 Using LDPC

The construction of the Data field in an S1G SU PPDU (1 MHz MCS 10 mode) with LDPC encoding proceeds as follows:

a) SERVICE field: Generate the SERVICE field as described in 23.3.9.2 and append the PSDU to the SERVICE field.

b) PHY padding: Append the PHY pad bits to the PSDU as described in 23.3.9.4.4.2.

c) Scrambler: Scramble the PHY padded data as described in 23.3.9.3.

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d) LDPC encoder: The scrambled bits are encoded using the LDPC code with the LENGTH from the TXVECTOR as described in 23.3.9.4.4.

e) Block repetition: Apply the block-wise 2 times repetition on a per-OFDM symbol basis as described in 23.3.9.5.

f) Constellation mapper: Map to BPSK constellation points as described in 23.3.9.9.

g) Pilot insertion: Insert pilots following the steps described in 23.3.9.10.

h) Spatial mapping: Apply the *Q* matrix as described in 23.3.9.11.

i) Phase rotation: Apply appropriate phase rotations for each 1 MHz subchannel if S1G 1 MHz Duplicate PPDU as described in 23.3.9.12 and 23.3.7.

j) IDFT: Compute the inverse discrete Fourier transform.

k) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 17.3.2.5. If the TXVECTOR parameter GI_TYPE equals LONG_GI, the GI duration shall be 8 μs. If the GI_TYPE parameter is SHORT_GI, the GI duration shall be 8 μs for the first OFDM symbol of the Data field, and 4 μs for all subsequent OFDM symbols.

l) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

23.3.4.8 Construction of the Data field in an S1G MU PPDU

23.3.4.8.1 General

For an MU transmission, the PPDU encoding process is performed on a per-user basis up to the input of the spatial mapping block except that the CSD is applied across users as described in 23.3.8.2.3.3.2 if an S1G_LONG preamble is used. All user data is combined and mapped to the transmit chains in the spatial mapping block. An S1G_1M PPDU, or an S1G_SHORT PPDU, or an 2 MHz S1G duplicate PPDU in S1G_LONG format shall not be used for an MU transmission.

23.3.4.8.2 Using BCC

A Data field with BCC encoding is constructed using the process described in 23.3.4.6.1 and 23.3.4.7.1 before the spatial mapping block and repeated for each user that uses BCC encoding.

23.3.4.8.3 Using LDPC

A Data field with LDPC encoding is constructed using the process described in 23.3.4.6.2 and 23.3.4.7.2 before the spatial mapping block and repeated for each user that uses LDPC encoding.

23.3.4.8.4 Combining to form an S1G MU PPDU

The per-user data is combined as follows:

a) Spatial Mapping: Apply the *Q* matrix as described in 23.3.10. The combining of all user data is done in this block.

b) Phase rotation: Apply the appropriate phase rotations for each 2 MHz subchannel as described in 23.3.9.11 and 23.3.7.

c) IDFT: Compute the inverse discrete Fourier transform.

d) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 17.3.2.5. If the TXVECTOR parameter GI_TYPE equals LONG_GI, the GI duration shall be 8 μs. If the GI_TYPE parameter is SHORT_GI, the GI duration shall be 8 μs for the first OFDM symbol of the Data field, and 4 μs for all subsequent OFDM symbols.

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e) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 and 23.3.8 for details.

23.3.5 Modulation and coding scheme

The S1G-MCS is a value that determines the modulation and coding used in the Data field of the PPDU. It is a compact representation that is carried in the SIG field or SIG-A field for S1G SU PPDUs and in the SIG-B field for S1G MU PPDUs using S1G_LONG. Rate-dependent parameters for the full set of S1G-MCSs are shown in Table 23-41 to Table 23-60 (in 23.5).

Table 23-41 to Table 23-60 give rate-dependent parameters for S1G-MCSs with indices 0 to 9 (and index 10 solely for 1 MHz, $N_{SS} = 1$), with number of spatial streams from 1 to 4 and bandwidth options of 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz. Equal modulation is applied to all streams for a particular user.

23.3.6 Timing-related parameters

Table 23-4 defines the timing-related parameters for all S1G PPDU formats, except the SIG field in S1G_SHORT, and the SIG-A field in S1G_LONG. Note that the timing-related parameters for the SIG field in S1G_1M PPDU and the SIG-B field in S1G_LONG are the same as those defined for the Data field as shown in Table 23-4.

Table 23-4—Timing-related constants

Parameter	CBW1	CBW2	CBW4	CBW8	CBW16	Description
N_{SD}	24	52	108	234	468	Number of data subcarriers per OFDM symbol
N_{SP}	2	4	6	8	16	Number of pilot subcarrier per OFDM symbol
N_{ST}	26	56	114	242	484	Total number of useful subcarriers per OFDM symbol
N_{SR}	13	28	58	122	250	Highest data subcarrier index per OFDM symbol
Δ_F	31.25 kHz					Subcarrier frequency spacing
T_{DFT}	32 μs = $1/\Delta_F$					IDFT/DFT period
T_{GI}	8 μs = $T_{DFT}/4$					Guard interval duration
T_{GI2}	16 μs					Double guard interval
T_{GIS}	4 μs = $T_{DFT}/8$					Short guard interval duration
T_{SYML}	40 μs = $T_{DFT} + T_{GI} = 1.25 \times T_{DFT}$					Duration of OFDM symbol with normal guard interval

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Table 23-4—Timing-related constants *(continued)*

Parameter	CBW1	CBW2	CBW4	CBW8	CBW16	Description
T_{SYMS}	36 µs = T_{DFT} + T_{GIS} = 1.125 × T_{DFT}					Duration of OFDM symbol with short guard interval
T_{SYM}	T_{SYML} or T_{SYMS} depending on the GI used					OFDM symbol duration
T_{STF}	160 µs = 4 × T_{SYML}	80 µs = 2 × T_{SYML}				STF field duration
T_{DSTF}	N/A	40 µs = T_{SYML}				S1G_LONG preamble D-STF field duration
T_{LTF1}	160 µs = 4 × T_{DFT} + 2 × T_{GI} + T_{GI2}	80 µs = 2 × T_{DFT} + T_{GI2}				First LTF field duration
T_{LTF}	40 µs = T_{SYML}					Second and subsequent LTF field duration
T_{DLTF}	N/A	40 µs = T_{SYML}				S1G_LONG preamble D-LTF field duration
T_{SIG}	240 µs = 6 × T_{SYML}	80 µs = 2 × T_{SYML}				SIG field duration
T_{SIG-A}	N/A	80 µs = 2 × T_{SYML}				S1G_LONG preamble SIG-A field duration
T_{SIG-B}	N/A	40 µs = T_{SYML}				S1G_LONG preamble SIG-B field duration
Nservice	8					Number of bits in the SERVICE field
N_{tail}	6					Number of tail bits per BCC encoder

NOTE— $N_{ST} = N_{SD} + N_{SP}$.

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Table 23-5 defines the timing-related parameters for the SIG field in S1G_SHORT, or the SIG-A field in S1G_LONG. Note that short/double guard interval is not used for SIG/SIG-A field in ≥ 2 MHz PPDUs.

Table 23-5—Timing-related constants for SIG/SIG-A field in ≥ 2 MHz PPDUs

Parameter	CBW1	CBW2	CBW4	CBW8	CBW16	Description
N_{SD}	N/A	48	48	48	48	Number of data subcarriers per OFDM symbol per 2 MHz subchannel
N_{SP}	N/A	4	4	4	4	Number of pilot subcarrier per OFDM symbol per 2 MHz subchannel
N_{ST}	N/A	52	52	52	52	Total number of useful subcarriers per OFDM symbol per 2 MHz subchannel
N_{SR}	N/A	26	56	120	248	Highest data subcarrier index per OFDM symbol
Δ_F	N/A	31.25 kHz				Subcarrier frequency spacing
T_{DFT}	N/A	32 μs = $1/\Delta_F$				IDFT/DFT period
T_{GI}	N/A	8 μs = $T_{DFT}/4$				Guard interval duration
T_{SYM}	N/A	40 μs = $T_{DFT} + T_{GI} = 1.25 \times T_{DFT}$				OFDM symbol duration
T_{SIG}	N/A	80 μs = $2 \times T_{SYM}$				SIG field duration
$T_{SIG\text{-}A}$	N/A	80 μs = $2 \times T_{SYM}$				S1G_LONG preamble SIG-A field duration

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Table 23-6 defines parameters used frequently in Clause 23.

Table 23-6—Frequently used parameters

Symbol	Explanation
N_{CBPS}, $N_{CBPS,u}$	Number of coded bits per symbol for user u, $u = 0, ..., N_u–1$. For an S1G SU PPDU, $N_{CBPS} = N_{CBPS,0}$. For an S1G MU PPDU, N_{CBPS} is undefined.
N_{CBPSS}, $N_{CBPSS,u}$	Number of coded bits per symbol per spatial stream. For the SIG-B field in S1G_LONG, $N_{CBPSS} = N_{SD}$ for all users. For the Data field, $N_{CBPSS,u}$ equals the number of coded bits per symbol per spatial stream for user u, $u = 0, ..., N_u–1$. For the Data field of an S1G SU PPDU, $N_{CBPSS} = N_{CBPSS,0}$. For the Data field of an S1G MU PPDU, N_{CBPSS} is undefined.
N_{CBPSSI}, $N_{CBPSSI,u}$	Number of coded bits per symbol per spatial stream per BCC interleaver block. For an S1G SU PPDU, $N_{CBPSSI} = \begin{cases} N_{CBPSS}, \text{ for 1 MHz, 2 MHz, 4 MHz, or 8 MHz} \\ \frac{N_{CBPSS}}{2}, \text{ for a 16 MHz PPDU} \end{cases}$ For an S1G MU PPDU for user u, $u = 0, ..., N_u–1$ $N_{CBPSSI,u} = \begin{cases} N_{CBPSS,u}, \text{ for 1 MHz, 2 MHz, 4 MHz, or 8 MHz} \\ \frac{N_{CBPSS,u}}{2}, \text{ for a 16 MHz PPDU} \end{cases}$
N_{DBPS}, $N_{DBPS,u}$	Number of data bits per symbol for user u, $u = 0, ..., N_u–1$. For an S1G SU PPDU, $N_{DBPS} = N_{DBPS,0}$. For an S1G MU PPDU, N_{DBPS} is undefined.
N_{BPSCS}, $N_{BPSCS,u}$	Number of coded bits per subcarrier per spatial stream for user u, $u = 0, ..., N_u–1$. For an S1G SU PPDU, $N_{BPSCS} = N_{BPSCS,0}$. For an S1G MU PPDU, N_{BPSCS} is undefined.
N_{RX}	Number of receive chains.
N_u	For S1G_LONG, the omnidirectional portion always has N_u=1, and in the beam changeable portion, N_u represents the number of users in the transmission (equal to the TXVECTOR parameter NUM_USERS). For S1G_1M and S1G_SHORT, N_u=1.
N_{STS}, $N_{STS,u}$	Number of space-time streams. For S1G_LONG, the omnidirectional portion always has $N_{STS,u}$=1 (see NOTE); and for the beam changeable portion $N_{STS,u}$ is the number of space-time streams for user u, $u = 0,…, N_u–1$. For S1G_1M and S1G_SHORT,$N_{STS} = N_{STS,0}$. For an S1G SU PPDU, $N_{STS} = N_{STS,0}$; for an S1G MU PPDU, N_{STS} is undefined.

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Table 23-6—Frequently used parameters *(continued)*

Symbol	Explanation
$N_{STS,total}$	For S1G_1M, S1G_SHORT, and the beam changeable portion of S1G_LONG, $N_{STS,total}$ is the total number of space-time streams in a PPDU. $N_{STS,total} = \sum_{u=0}^{N_u-1} N_{STS,u}$ For the omnidirectional portion of S1G_LONG, $N_{STS,total}$ is undefined. Note that $N_{STS,total} = N_{STS}$ for an S1G SU PPDU.
N_{SS}, $N_{SS,u}$	Number of spatial streams. For S1G_LONG, the omnidirectional portion always has $N_{SS,u}=1$ (see NOTE); and for the beam changeable portion $N_{SS,u}$ is the number of spatial streams for user u, $u = 0,\ldots, N_u-1$. For S1G_1M and S1G_SHORT, $N_{SS} = N_{SS,0}$. For an S1G SU PPDU, $N_{SS} = N_{SS,0}$; for an S1G MU PPDU, N_{SS} is undefined.
N_{TX}	Number of transmit chains.
N_{ES}, $N_{ES,u}$	The number of BCC encoders. For the SIG-B field of S1G_LONG, $N_{ES}=1$ for each user. For the beam changeable portion of S1G_LONG, $N_{ES,u}$ is the number of BCC encoders for the Data field for user u, $u = 0,\ldots N_u-1$. For the Data field of an S1G SU PPDU, $N_{ES} = N_{ES,0}$. For the Data field of an S1G MU PPDU, N_{ES} is undefined. For the Data field encoded using LDPC, $N_{ES}=1$ for an S1G SU PPDU and $N_{ES,u}=1$ for an S1G MU PPDU for user u, $u = 0, \ldots N_u-1$.
N_{LTF}	Number of long training fields in S1G_1M or S1G_SHORT; or the number of data long training fields in S1G_LONG (see 23.3.8.2.2.4, 23.3.8.2.3.3.3, and 23.3.8.3.4)
R, R_u	R_u is the coding rate for user u, $u = 0, \ldots, N_u-1$. For an S1G SU PPDU, $R = R_0$ For an S1G MU PPDU, R is undefined
M_u	For the omnidirectional portion of S1G_LONG, $M_u = 0$. Otherwise, $M_u = \sum_{u'=0}^{u-1} N_{STS,u'}$ with $M_0 = 0$.
NOTE—For the omnidirectional portion of S1G_LONG, u is 0 only since $N_u=1$.	

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23.3.7 Mathematical description of signals

For a description of the conventions used for the mathematical description of the signals, see 17.3.2.5.

For a 1 MHz S1G PPDU transmission, the 1 MHz is divided into 32 subcarriers. The signal is transmitted on subcarriers –13 to –1 and 1 to 13, with 0 being the center (DC) subcarrier.

For a 2 MHz S1G PPDU transmission, the 2 MHz is divided into 64 subcarriers. The signal is transmitted on subcarriers –28 to –1 and 1 to 28, with 0 being the center (DC) subcarrier.

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For a 4 MHz S1G PPDU transmission, the 4 MHz is divided into 128 subcarriers. The signal is transmitted on subcarriers –58 to –2 and 2 to 58.

For an 8 MHz S1G PPDU transmission, the 8 MHz is divided into 256 subcarriers. The signal is transmitted on subcarriers –122 to –2 and 2 to 122.

For a 16 MHz S1G PPDU transmission, the 16 MHz is divided into 512 subcarriers. The signal is transmitted on subcarriers –250 to –130, –126 to –6, 6 to 126, and 130 to 250.

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the relation shown in Equation (23-1).

$$r_{RF}(t) = \mathrm{Re}\{r(t)\exp(j2\pi f_c t)\} \quad (23\text{-}1)$$

where

f_c represents the center frequency of the carrier

The transmitted RF signal is derived by upconverting the complex baseband signal, which consists of several fields. The timing boundaries for the various fields of the different frame formats are shown in Figure 23-5, where N_{LTF} is the number of LTF or D-LTF field symbols and is defined in Table 23-10 (in 23.3.8.2.2.4), for up to $N_{STS,Total} = 4$.

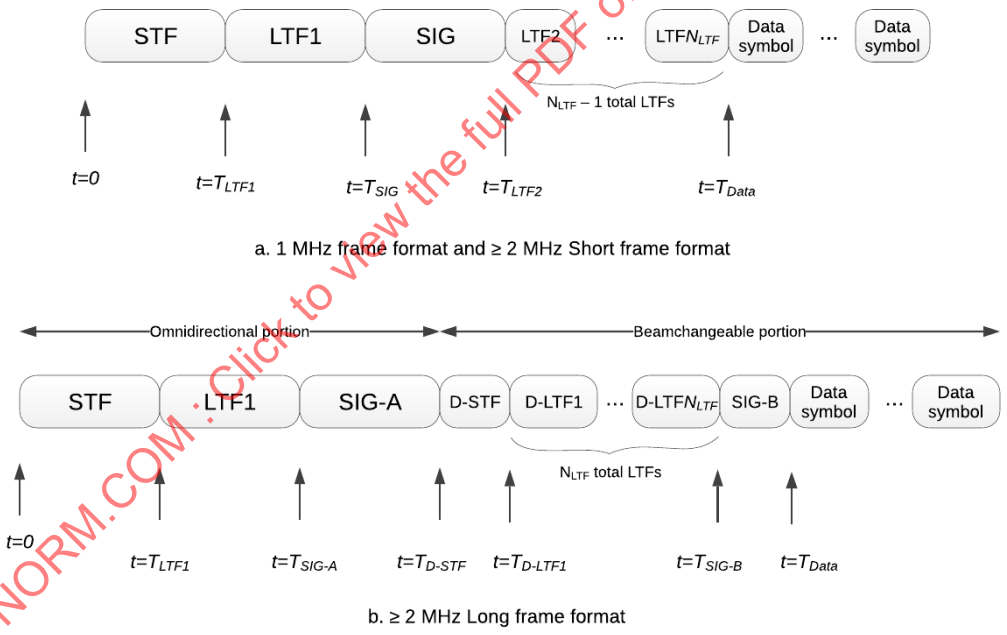

Figure 23-5—Timing boundaries for S1G PPDU fields

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The time offset, t_{Field}, determines the starting time of the corresponding field.

For the S1G_1M PPDU frame format and the S1G_SHORT PPDU frame format, the signal transmitted on transmitted on transmit chain i_{TX} shall be as shown in Equation (23-2).

$$r_{PPDU}^{i_{TX}}(t) = r_{STF}^{i_{TX}}(t) + r_{LTF1}^{i_{TX}}(t - t_{LTF1}) + r_{SIG}^{i_{TX}}(t - t_{SIG}) + \sum_{i_{LTF}=2}^{N_{LTF}} r_{LTF}^{(i_{TX}, i_{LTF})}(t - t_{LTF2} - (i_{LTF} - 2)T_{LTF}) + r_{Data}^{i_{TX}}(t - t_{Data}) \quad (23\text{-}2)$$

where

$$t_{LTF} = T_{STF}$$
$$t_{SIG} = t_{LTF1} + T_{LTF1}$$
$$t_{LTF2} = t_{SIG} + T_{SIG}$$
$$t_{Data} = t_{LTF2} + (N_{LTF} - 1)T_{LTF}$$

For the S1G_LONG PPDU format, the signal transmitted on transmit chain *iTX* shall be as shown in Equation (23-3).

$$r_{\mathrm{PPDU}}^{(i_{\mathrm{TX}})}(t) = r_{\mathrm{STF}}^{(i_{\mathrm{TX}})}(t) + r_{\mathrm{LTF1}}^{(i_{\mathrm{TX}})}(t - t_{\mathrm{LTF1}}) + r_{\mathrm{SIG\text{-}A}}^{(i_{\mathrm{TX}})}(t - t_{\mathrm{SIG}}) + r_{\mathrm{D\text{-}STF}}^{(i_{\mathrm{TX}})}(t - t_{D-STF}) + \sum_{i_{\mathrm{LTF}}=1}^{N_{\mathrm{LTF}}} r_{\mathrm{D\text{-}LTF}}^{(i_{\mathrm{TX}}, i_{\mathrm{LTF}})}(t - t_{\mathrm{D\text{-}LTF1}} - (i_{\mathrm{LTF}} - 1)T_{\mathrm{LTF}}) + r_{\mathrm{SIG\text{-}B}}^{(i_{\mathrm{TX}})}(t - t_{\mathrm{SIG\text{-}B}}) + r_{\mathrm{Data}}^{(i_{\mathrm{TX}})}(t - t_{\mathrm{Data}}) \quad (23\text{-}3)$$

where

$$t_{\mathrm{LTF1}} = T_{\mathrm{STF}}$$
$$t_{\mathrm{SIG\text{-}A}} = t_{\mathrm{LTF1}} + T_{\mathrm{LTF1}}$$
$$t_{\mathrm{D\text{-}STF}} = t_{\mathrm{SIG\text{-}A}} + T_{\mathrm{SIG\text{-}A}}$$
$$t_{\mathrm{D\text{-}LTF1}} = t_{\mathrm{D\text{-}STF}} + T_{\mathrm{D\text{-}STF}}$$
$$t_{\mathrm{SIG\text{-}B}} = t_{\mathrm{D\text{-}LTF1}} + N_{\mathrm{LTF1}} \cdot T_{\mathrm{LTF}}$$
$$t_{\mathrm{Data}} = t_{\mathrm{SIG\text{-}B}} + T_{\mathrm{SIG\text{-}B}}$$

Each field, $r_{Field}^{(i_{TX})}(t)$, is defined as the summation of one or more subfields, where each subfield is defined to be an inverse discrete Fourier transform as specified in Equation (23-4).

$$r_{\mathrm{Field}}^{(i_{\mathrm{TX}})}(t) = \frac{1}{\sqrt{N_{\mathrm{Field}}^{\mathrm{Tone}} N_{\mathrm{Norm}}}} w_{T_{\mathrm{Field}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_u - 1} \sum_{m=1}^{N_{STS,u}} \left[Q_k\right]_{i_{TX},(M_u+m)} \Upsilon_{k,\mathrm{BW}} X_{k,u}^{(m)} \exp\left(j2\pi k \Delta_F (t - T_{GI,Field} - T_{CS}(M_u + m))\right) \quad (23\text{-}4)$$

This general representation holds for all subfields. When the bandwidth is greater than or equal to 2 MHz and the S1G_LONG format is used, the total power of the time domain beam changeable portion field signals summed over all transmit chains should not exceed the total power of the time domain omnidirectional portion signals summed over all transmit chains. For notational simplicity, the parameter BW is omitted from some bandwidth dependent terms.

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Table 23-7 summarizes the various values of $N_{\text{Field}}^{\text{Tone}}$ as a function of bandwidth per frequency segment.

Table 23-7—Tone scaling factor and guard interval duration values for PHY fields

Field	$N_{\text{Field}}^{\text{Tone}}$ as a function of bandwidth per frequency segment					Guard interval duration
	1 MHz	2 MHz	4 MHz	8 MHz	16 MHz	
STF	6	12	24	48	96	N/A (See NOTE 2)
LTF1	26	56	114	242	484	For bandwidths ≥ 2 MHz, duration is T_{GI2}. For 1 MHz bandwidth, duration is T_{GI2} for first and second symbols, and T_{GI} for third and fourth symbols.
SIG	26	52	104	208	416	T_{GI}
SIG-A for long format	N/A	52	104	208	416	T_{GI}
D-STF for long format	N/A	12	24	48	96	N/A
LTF2~LTFN_{LTF}	26	56	114	242	484	T_{GI}
D-LTF for long format	N/A	56	114	242	484	T_{GI}
SIG-B for long format	N/A	56	114	242	484	T_{GI}
First Data Symbol	26	56	114	242	484	T_{GI} (see NOTE 3)
From second to the last Data Symbols	26	56	114	242	484	T_{GI} or T_{GIS} (see NOTE 3)
S1G_DUP_1M-Data (see NOTE 1)	N/A	52	104	208	416	T_{GI} or T_{GIS} (see NOTE 3)
S1G_DUP_2M-Data (see NOTE 1)	N/A	N/A	112	224	448	T_{GI} or T_{GIS} (see NOTE 3)

NOTE 1—For notational convenience, S1G_DUP_1M-Data and S1G_DUP_2M-Data is used as a label for the Data field of a duplicate PPDU with format type S1G_DUP_1M or S1G_DUP-2M, respectively.

NOTE 2—The OFDM symbols of the STF field do not have a guard interval, therefore its duration is not applicable.

NOTE 3—T_{GI} denotes guard interval duration when TXVECTOR parameter GI_TYPE equals LONG_GI, T_{GIS} denotes short guard interval duration when TXVECTOR parameter GI_TYPE equals SHORT_GI. Regardless of the GI_TYPE value in TXVECTOR, the first Data OFDM symbol always uses T_{GI} as its guard interval duration.

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N_{Norm} for the omnidirectional portion of the S1G_LONG, $N_{\text{Norm}} = N_{\text{TX}}$, for all other cases, $N_{\text{Norm}} = N_{STS,total}$, where $N_{STS,total}$ is given in Table 23-6.

$w_{\text{T}_{\text{Field}}}(t)$ is a windowing function. An example function, $w_{\text{T}_{\text{Field}}}(t)$, is given in 17.3.2.5.

T_{Subfield} is the duration of the subfield being referenced, and its usage is as follows:

- T_{STF} for the STF field, $T_{D\text{-}STF}$ for the D-STF field
- T_{LTF1} for the LTF1 field
- T_{SIG} for the SIG field, $T_{SIG\text{-}A}$ for the SIG-A field
- T_{LTF} for the LTF2~LTF$_{\text{NLTF}}$ fields for the S1G_1M, the S1G_SHORT format, and for the D-LTFs fields in the S1G_LONG format
- $T_{SIG\text{-}B}$ field for the SIG-B

N_u is defined in Table 23-6.

N_{SR} is the highest data subcarrier index per frequency segment and has values listed in Table 23-4 and in Table 23-5.

$N_{STS,u}$ is defined in Table 23-6.

M_u is defined in Table 23-6.

$[X]_{a,\,b}$ indicates the element in row a and column b of the matrix X, where $1 \le a \le N_{\text{row}}$, and $1 \le b \le N_{\text{col}}$. N_{row} and N_{col} are the number of rows and columns, respectively, of the matrix X.

Q_k is the spatial mapping matrix for the subcarrier k. For the omnidirectional portion of S1G_LONG, Q_k is a column vector, denoted as $Q_k^{(omni)}$, with N_{TX} elements with element i_{TX} being $\exp(-j2\pi k\Delta_F T_{CS}^{i_{TX}})$, where $T_{CS}^{i_{TX}}$ represents the cyclic shift for transmitter chain i_{TX} whose values are given in Table 23-12 (in 23.3.8.2.3.2.2). For other cases, Q_k is a matrix with N_{TX} rows and $N_{STS,total}$ columns.

Δ_F is the subcarrier frequency spacing given in Table 23-4.

$X_{k,\,u}^{(m)}$ is the frequency domain symbol in subcarrier k of user u for of space-time stream m. Some of the $X_{k,\,u}^{(m)}$ within $-N_{\text{SR}} \le k \le N_{\text{SR}}$ have a value of zero. Examples of such cases include the DC tones, guard tones on each side of the transmit spectrum, as well as the unmodulated tones of STF and D-STF fields.

$T_{GI,Field}$ is the guard interval duration used for each OFDM symbol in the field. The value for each field is defined in Table 23-7. T_{GI}, T_{GI2} and T_{GIS} are defined in Table 23-4.

$T_{CS}(l)$ for the omnidirectional portion of S1G_LONG, $T_{CS}(l) = 0$. For the other cases, $T_{CS}(l)$ represents the cyclic shift per space-time stream, whose value is defined in Table 23-9 (in 23.3.8.2.2.2) for ≥ 2 MHz, and Table 23-17 (in 23.3.8.3.2).

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The function $\Upsilon_{k,\mathrm{BW}}$ is used to represent a rotation of the tones. BW in $\Upsilon_{k,\mathrm{BW}}$ is determined by the TXVECTOR parameter CH_BANDWIDTH as defined in Table 23-8.

Table 23-8—CH_BANDWIDTH and Gamma sub$_{\mathrm{k,\,BW}}$

CH_BANDWIDTH	$\Upsilon_{k,\mathrm{BW}}$
CBW1	$\Upsilon_{k,1}$
CBW2	$\Upsilon_{k,2}$
CBW4	$\Upsilon_{k,4}$
CBW8	$\Upsilon_{k,8}$
CBW16	$\Upsilon_{k,16}$

For a 1 MHz PPDU transmission,

$$\Upsilon_{k,1} = 1 \tag{23-5}$$

For a 2 MHz PPDU transmission,

$$\Upsilon_{k,2} = 1 \tag{23-6}$$

For a 4 MHz PPDU transmissions of S1G or S1G_DUP_2M frames,

$$\Upsilon_{k,4} = \begin{cases} 1, & k < 0 \\ j, & k \geq 0 \end{cases} \tag{23-7}$$

For 8 MHz PPDU transmission of S1G or S1G_DUP_2M frames,

$$\Upsilon_{k,8} = \begin{cases} 1, k < -64 \\ -1, k \geq -64 \end{cases} \tag{23-8}$$

For 16 MHz PPDU transmissions of S1G or S1G_DUP_2M frames,

$$\Upsilon_{k,16} = \begin{cases} 1, & k < -192 \\ -1, & -192 \leq k < 0 \\ 1, & 0 \leq k < 64 \\ -1, & 64 \leq k \end{cases} \tag{23-9}$$

For 2 MHz PPDU transmissions of S1G_DUP_1M frames,

$$\Upsilon_{k,2} = \begin{cases} 1, k < 0 \\ -1, k \geq 0 \end{cases} \tag{23-10}$$

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For 4 MHz PPDU transmissions of S1G_DUP_1M frames,

$$\Upsilon_{k,4} = \begin{cases} 1, k < -32 \\ j, -32 \le k < 0 \\ -j, 0 \le k < 32 \\ -1, 32 \le k \end{cases} \quad (23\text{-}11)$$

For 8 MHz PPDU transmissions of S1G_DUP_1M frames,

$$\Upsilon_{k,8} = \begin{cases} 1, k < -96 \\ -1, -96 \le k < -64 \\ 1, -64 \le k < 64 \\ -1, 64 \le k \end{cases} \quad (23\text{-}12)$$

For 16 MHz PPDU transmissions of S1G_DUP_1M frames,

$$\Upsilon_{k,16} = \begin{cases} 1, k < -160 \\ -1, -160 \le k < -128 \\ 1, -128 \le k < -32 \\ -1, -32 \le k < 64 \\ 1, 64 \le k < 96 \\ -1, 96 \le k < 128 \\ 1, 128 \le k < 192 \\ -1, 192 \le k < 224 \\ 1, 224 \le k \end{cases} \quad (23\text{-}13)$$

23.3.8 S1G preamble

23.3.8.1 Introduction

Three preamble formats are defined that correspond to the three non-duplicate S1G PPDU formats: the S1G_1M preamble, the S1G_SHORT preamble, and the S1G_LONG preamble. The first two preamble formats are defined solely for single user, and the third preamble format may be used in either single user or multi-user PPDUs. The duplicate mode PPDU formats S1G_DUP_2M and S1G_DUP_1M use the S1G_SHORT and S1G_1M preambles, respectively.

All numeric fields are transmitted in unsigned format, LSB first.

23.3.8.2 Formats for greater than or equal to 2 MHz

23.3.8.2.1 Introduction

This subclause describes the preamble formats used for non-duplicate S1G PPDUs of 2 MHz and greater and duplicate S1G_DUP_2M PPDUs.

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23.3.8.2.2 S1G_SHORT preamble

23.3.8.2.2.1 General

The S1G_SHORT preamble is used for the S1G_SHORT and S1G_DUP_2M PPDU formats and is only used for SU transmissions. The S1G_SHORT preamble is structured similarly to the Greenfield format as defined in Clause 19.

23.3.8.2.2.2 Cyclic shift for S1G modulated fields

The cyclic shift values defined in this subclause apply to the STF, LTF, SIG and Data fields of the S1G_SHORT preamble PPDU, for ≥ 2 MHz transmit bandwidths. Throughout the S1G_SHORT preamble, cyclic shifts are applied to prevent beamforming when similar signals are transmitted in different space-time streams. The STF, LTF, and SIG fields start as single stream during generation but are replicated up to $N_{STS,total}$ streams. For the LTF, these replicated streams undergo P-matrix mapping prior to CSD application as shown in Figure 23-6 (in 23.3.8.2.2.4). For the STF and SIG the CSDs are applied per stream immediately after replication. The same cyclic shift is applied to the $N_{STS,total}$ streams during the transmission of the Data field of the S1G_SHORT preamble PPDU. The cyclic shift value $T_{CS}(n)$ for space-time stream n out of $N_{STS,total}$ total space-time streams is shown in Table 23-9.

Table 23-9—Cyclic shift values for the S1G_SHORT preamble PPDU

$T_{CS}(n)$ for ≥ 2 MHz, S1G_SHORT Preamble PPDU				
Total number of space-time streams ($N_{STS,total}$)	Cyclic shift for space-time stream n (μs)			
	1	2	3	4
1	0	—	—	—
2	0	−4	—	—
3	0	−4	−2	—
4	0	−4	−2	−6

23.3.8.2.2.3 STF definition

The STF field for a 2 MHz or 4 MHz transmission is defined by Equation (19-8) and Equation (19-9), respectively, in 19.3.9.3.3. For a 8 MHz or 16 MHz transmission, the STF field is defined by Equation (21-18) and Equation (21-19), respectively, in 21.3.8.2.2. Note that these equations do not include the phase rotation per 2 MHz subchannel.

The time domain representation of the STF field signal at transmit chain i_{TX} shall be as specified in Equation (23-14).

$$r_{\mathrm{STF}}^{(i_{\mathrm{TX}})}(t) = \frac{1}{\sqrt{N_{\mathrm{STF}}^{\mathrm{Tone}} N_{\mathrm{STS}}}} w_{T_{\mathrm{STF}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} \left[Q_k\right]_{i_{TX},m} \left[P_{HTLTF}\right]_{m,1} \Upsilon_{k,\mathrm{BW}} S_k \exp\left(j2\pi k \Delta_F (t - T_{CS}(m))\right) \quad (23\text{-}14)$$

where

N_{SR} is 26 for a 2 MHz transmission or defined in Table 23-4 for a 4 MHz, 8 MHz, or 16 MHz transmission

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S_k	is defined in Equation (19-8), Equation (19-9), Equation (21-8), or Equation (21-9) for a 2 MHz, 4 MHz, 8 MHz, or 16 MHz transmission, respectively.
$T_{CS}(m)$	represents the cyclic shift for space-time stream m with a value given in Table 23-9
$\Upsilon_{k,BW}$	is defined by Equation (23-6) to Equation (23-9)
Δ_F	is defined in Table 23-4
N_{STS}	is defined in Table 23-6
P_{HTLTF}	is defined in 19.3.9.4.6
N_{STF}^{Tone}	has the value given in Table 23-7
Q_k	is defined in 23.3.7

23.3.8.2.2.4 LTF definition

The LTF field provides means for the receiver to estimate the MIMO channel between the set of constellation mapper outputs (or, if STBC is applied, the STBC encoder outputs) and the receive chains. The transmitter provides training for N_{STS} space-time streams (spatial mapper inputs) used for the transmission of the PSDU. For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS}$ matrix. All S1G transmissions have a preamble that contains LTF symbols, where the data tones of each LTF symbol are multiplied by entries belonging to a matrix P_{HTLTF}, to enable channel estimation at the receiver.

The pilot tones of each LTF symbol are multiplied by the first column of the P_{HTLTF} matrix. The multiplication of the pilot tones in the LTF symbols by the first column of the P_{HTLTF} matrix instead of the whole P_{HTLTF} matrix is to allow receivers to track phase and frequency offset during MIMO channel estimation using the LTF. The number of LTF symbols, N_{LTF}, is a function of the total number of space-time streams N_{STS} as shown in Table 23-10. As a result, the LTF field consists of one, two, or four symbols that are necessary for the demodulation of the Data field in the PPDU or for channel estimation in an NDP.

Table 23-10—Number of LTFs required for different numbers of space-time streams

N_{STS}	N_{LTF}
1	1
2	2
3	4
4	4

The LTF field for a 2 MHz, 4 MHz, 8 MHz, or 16 MHz transmission is defined by Equation (21-36) Equation (21-37), Equation (21-38), and Equation (21-39), respectively, in 21.3.8.3.5. Note that these equations do not include the phase rotation per 2 MHz subchannel.

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The generation of the time domain LTF symbols is shown in Figure 23-6 where A^k_{LTF} is given in Equation (23-15).

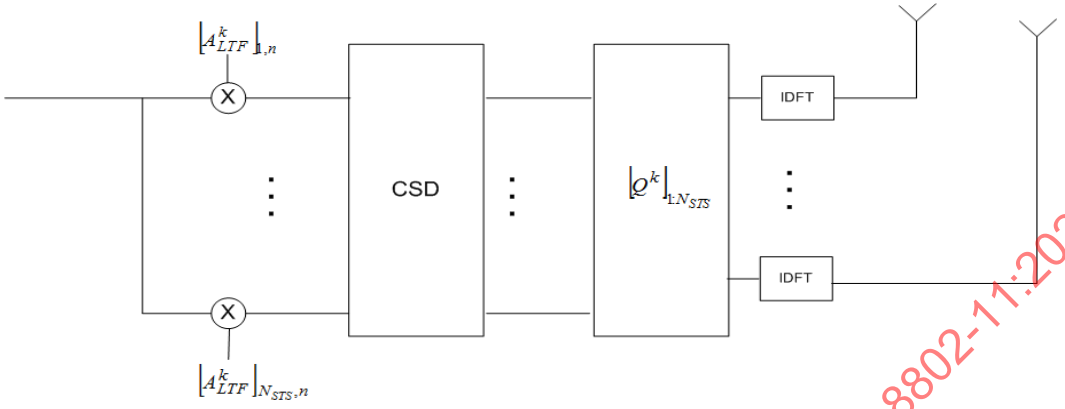

Figure 23-6—Generation of LTF symbols

$$A^k_{LTF} = \begin{cases} [P_{HTLTF}]_{*,1} \times [1\ 1\ 1\ 1], if\ k \in K_{Pilot_Fix} \\ P_{HTLTF}, \text{ otherwise} \end{cases} \quad (23\text{-}15)$$

where

K_{Pilot_Fix} is the subcarrier indices for the fixed pilot tones:

For a 2 MHz transmission, $K_{Pilot_Fix} = \{\pm 7, \pm 21\}$

For a 4 MHz transmission, $K_{Pilot_Fix} = \{\pm 11, \pm 25, \pm 53\}$

For an 8 MHz transmission, $K_{Pilot_Fix} = \{\pm 11, \pm 39, \pm 75, \pm 103\}$

For a 16 MHz transmission,

$K_{Pilot_Fix} = \{\pm 25, \pm 53, \pm 89, \pm 117, \pm 139, \pm 167, \pm 203, \pm 231\}$

$[P_{HTLTF}]_{*,1}$ is the first column of the P_{HTLTF} matrix

The time domain representation of the LTF1 field, and LTF2~LTF$_{N_{LTF}}$ fields signals at transmit chain i_{TX} shall be as specified in Equation (23-16) and Equation (23-17), respectively.

$$r^{(i_{TX})}_{LTF1}(t) = \frac{1}{\sqrt{N^{Tone}_{LTF} N_{STS}}} w_{T_{LTF1}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} \left(\begin{array}{l} [Q_k]_{i_{TX},m} \Upsilon_{k,BW} [A^k_{LTF}]_{m,1} LTF_k \\ \cdot \exp\left(j2\pi k \Delta_F (t - T_{GI2} - T_{CS}(m)) \right) \end{array} \right) \quad (23\text{-}16)$$

$$r^{(i_{TX})}_{LTF2\sim LTF_{N_{LTF}}}(t) = \frac{1}{\sqrt{N^{Tone}_{LTF} N_{STS}}} \sum_{n=1}^{N_{LTF}-1} w_{T_{LTF}}(t - (n-1)T_{LTF}) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} \left(\begin{array}{l} [Q_k]_{i_{TX},m} \Upsilon_{k,BW} [A^k_{LTF}]_{m,(n+1)} LTF_k \\ \cdot \exp\left(j2\pi k \Delta_F (t - (n-1)T_{LTF} - T_{GI} - T_{CS}(m)) \right) \end{array} \right) \quad (23\text{-}17)$$

where

LTF_k is defined in Equation (21-36), Equation (21-37), Equation (21-38), or Equation (21-39) for a 2 MHz, 4 MHz, 8 MHz, or 16 MHz transmission, respectively

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N_{SR} and T_{LTF}	are defined in Table 23-4
$T_{CS}(m)$	represents the cyclic shift for space-time stream m with a value given in Table 23-9
$\Upsilon_{k,BW}$	is defined by Equation (23-6) to Equation (23-9)
Δ_F	is defined in Table 23-4
N_{STS}	is defined in Table 23-6
A_{LTF}^{k}	is defined in Equation (23-15)
N_{LTF}^{Tone}	has the value given in Table 23-7
Q_k	is defined in 23.3.7

The first LTF (LTF1) field consists of two periods of the long training symbol, preceded by a double length (16 μs) cyclic prefix. The placement of the first and subsequent LTF fields in an S1G_SHORT PPDU is shown in Figure 23-1.

23.3.8.2.2.5 SIG definition

The SIG field carries information required to interpret S1G format PPDUs sent with a short preamble. The structure of the SIG field for the first symbol (SIG-1) is shown in Figure 23-7 and for the second symbol (SIG-2) is shown in Figure 23-8. The SIG field format of NDP CMAC PPDUs is described in Figure 23-21 (in 23.3.11).

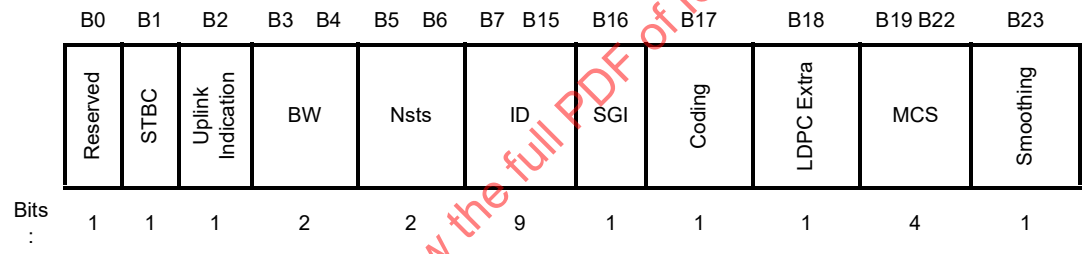

Figure 23-7—SIG-1 structure

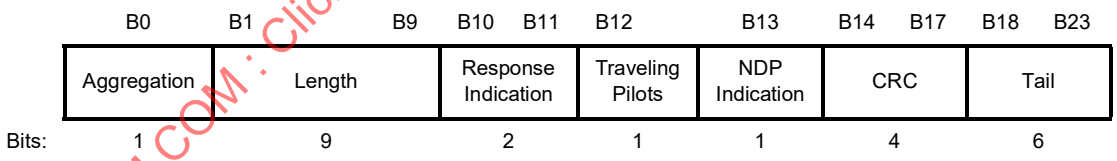

Figure 23-8—SIG-2 structure

The SIG field of S1G format PPDUs sent with a short preamble contains the fields listed in Table 23-11.

The SIG field is composed of two OFDM symbols, SIG-1 and SIG-2, each providing 24 data bits, as shown in Table 23-11. SIG-1 is transmitted before SIG-2. The SIG field symbols shall be BCC encoded at rate, R = 1/2, interleaved, mapped to a BPSK constellation, and have pilots inserted following the steps described in 17.3.5.6, 17.3.5.7, 17.3.5.8, and 17.3.5.9, respectively.

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Table 23-11—Fields in the SIG field of short preamble

Symbol	Bit	Field	Description
SIG-1	B0	Reserved	Reserved. Set to 1.
	B1	STBC	Set to 1 if all spatial streams have space-time block coding and set to 0 if no spatial streams has space-time block coding.
	B2	Uplink Indication	Set to 1 if the PPDU is addressed to an AP. Set to 0 otherwise. (See TXVECTOR parameter UPLINK_INDICATION.)
	B3–B4	BW	If FORMAT is S1G in TXVECTOR, set to 0 when CH_BANDWIDTH is CBW2 1 when CH_BANDWIDTH is CBW4 2 when CH_BANDWIDTH is CBW8 3 when CH_BANDWIDTH is CBW16 If FORMAT is S1G_DUP_2M in TXVECTOR, set to 0.
	B5–B6	Nsts	Set to 0 for 1 space-time stream Set to 1 for 2 space-time streams Set to 2 for 3 space-time streams Set to 3 for 4 space-time streams
	B7–B15	ID	If Uplink Indication field is not present or set to 1, B7–B15 are the partial AID to provide an abbreviated indication of the intended recipient(s) of the PSDU (see 10.21). If Uplink Indication field is set to 0, B7–B9 are an identifier of the BSS and B10–B15 are the partial AID. (See TXVECTOR parameter COLOR and TXVECTOR parameter PARTIAL_AID.)
	B16	Short GI	Set to 0 if short guard interval is not used in the Data field. Set to 1 if short guard interval is used in the Data field.
	B17	Coding	Set to 0 for BCC and 1 for LDPC
	B18	LDPC Extra	If Coding field is 1, set to 1 if the LDPC PPDU encoding process (of an SU PPDU), results in an extra OFDM symbol (or symbols) as described in 21.3.10.5.4, otherwise set to 0. If Coding field is 0, this field is set to 1.
	B19–B22	MCS	MCS Index
	B23	Smoothing	A value of 1 indicates that channel smoothing is recommended. A value of 0 indicates that channel smoothing is not recommended.

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Table 23-11—Fields in the SIG field of short preamble *(continued)*

Symbol	Bit	Field	Description
SIG-2	B0	Aggregation	Set to 1 when aggregation is ON (as indicated by AGGREGATION parameter of TXVECTOR), and 0 otherwise. NOTE— S1G PPDUs are transmitted with aggregation ON when PSDU to be carried is greater than 511 octets, as defined in 10.12.5.
	B1–B9	Length	When the Aggregation subfield is equal to 0, set to the number of octets in the PSDU. When the Aggregation subfield is equal to 1, set to N_{SYM_i} given in 23.4.3. (See TXVECTOR parameter PSDU_LENGTH.)
	B10–B11	Response Indication	Set to the value obtained from the TXVECTOR parameter RESPONSE_INDICATION. The Response Indication field indicates the presence and type of frame that is expected to follow SIFS after the current frame transmission (see 10.3.2.5).
	B12	Traveling Pilots	Set to 1 to indicate traveling pilots usage in packet. Otherwise 0 to indicate regular pilot tone locations.
	B13	NDP Indication	Differentiate the PPDU from an NDP CMAC PPDU: Set to 0 to indicate that the PPDU is not an NDP CMAC PPDU.
	B14–B17	CRC	CRC calculated as in 23.3.8.2.2.6.
	B18–B23	Tail	Used to terminate the trellis of the convolutional decoder. Set to 0.

The first and second half of the stream of 96 complex numbers generated by these steps (before pilot insertion) is divided into two groups of 48 complex numbers $d_{k,n}$, $k = 0, \ldots, 47$, where $n = 0, 1$, respectively. All the 96 complex numbers are rotated by 90° counter-clockwise relative to their original BPSK constellation points in order to accommodate differentiation of the S1G_SHORT PPDU from an S1G_1M PPDU, or from an S1G_LONG PPDU. The first rotated 48 complex numbers form the first symbol of SIG field; and the second rotated 48 complex numbers form the second symbol of SIG field, which follow the constellation diagram shown in Figure 23-9.

Figure 23-9—Data constellation in SIG field of S1G_SHORT

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The time domain waveform for the SIG field in an S1G_SHORT PPDU at transmit chain i_{TX} shall be as specified in Equation (23-18).

$$r_{\mathrm{SIG}}^{(i_{\mathrm{TX}})}(t) = \frac{1}{\sqrt{N_{\mathrm{SIG}}^{\mathrm{Tone}} N_{\mathrm{STS}}}} \sum_{n=0}^{1} w_{T_{\mathrm{SYML}}}(t - nT_{SYML}) \sum_{i_{BW}=0}^{N_{2MHz}-1} \left(\sum_{k=-26}^{26} \sum_{m=1}^{N_{STS}} \Upsilon_{(k-K_{shift}(i_{BW})),\mathrm{BW}} \left[Q_k \right]_{i_{TX},m} \left[P_{HTLTF} \right]_{m,1} \left(j.D_{k,n,2} + p_n P_k \right) \cdot \exp\left(j2\pi (k - K_{Shift}(i_{BW})) \Delta_F (t - nT_{SYML} - T_{GI} - T_{CS}(m)) \right) \right) \quad (23\text{-}18)$$

where

N_{2MHz} is the number of 2 MHz subchannels that are contained within the whole bandwidth of the current PPDU (e.g., $N_{2MHz} = 2$ for a 4 MHz PPDU)

$$K_{Shift}(i) = (N_{2MHz} - 1 - 2i).32 \quad (23\text{-}19)$$

$$D_{k,n,2} = \begin{cases} 0, & k = 0, \pm 7, \pm 21 \\ d_{M_2'(k),n}, & \text{otherwise} \end{cases} \quad (23\text{-}20)$$

where $M'_2(k)$ is defined in Equation (23-21)

$$M_2'(k) = \begin{cases} k + 26, & -26 \le k \le -22 \\ k + 25, & -20 \le k \le -8 \\ k + 24, & -6 \le k \le -1 \\ k + 23, & 1 \le k \le 6 \\ k + 22, & 8 \le k \le 20 \\ k + 21, & 22 \le k \le 26 \end{cases} \quad (23\text{-}21)$$

p_n and P_k are defined in 17.3.5.10
$T_{CS}(m)$ represents the cyclic shift for space-time stream m with a value given in Table 23-9
T_{SYML} is defined in Table 23-4
$\Upsilon_{k,BW}$ is defined by Equation (23-6) to Equation (23-9)
Δ_F is defined in Table 23-4
N_{STS} is defined in Table 23-6
P_{HTLTF} is defined in 19.3.9.4.6
N_{SIG}^{Tone} has the value given in Table 23-7
Q_k is defined in 23.3.7

NOTE—This definition results in a QBPSK modulation on the two symbols of SIG field, where the constellation of the data tones is rotated by 90º counter-clockwise relative to the third and fourth repetitions of LTF1 field in S1G_1M preamble, and relative to the second symbol of SIG-A field of the S1G_LONG preamble, respectively, as shown in Figure 23-1 to Figure 23-3, to facilitate the differentiation among the three preamble formats at the receiver.

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23.3.8.2.2.6 CRC calculation for S1G SIG-A fields

The CRC protects bits 0–25 of the 1 MHz SIG field and bits 0–37 of the ≥ 2 MHz SIG-A field. The value of the CRC field shall be the 1s complement of

$$crc(D) = (M(D) \oplus I(D))D^4 \bmod G(D) \quad (23\text{-}22)$$

where

$M(D) = m_0D^N + m_1D^{N-1} + \ldots + m_ND^0$ is the SIG field or SIG-A represented as a polynomial

where

N is 25 for the 1 MHz SIG field and 37 for the ≥ 2 MHz SIG-A field

m_i is the ith bit of the corresponding SIG/SIG-A field

$I(D) = \sum_{i=N-3}^{N} D^i$ are initialization values that are added modulo 2 to the first 4 bits of SIG/SIG-A field

$G(D) = D^4 + D^1 + 1$ is the CRC generating polynomial

$crc(D) = c_3D^3 + c_2D^2 + c_1D^1 + c_0D^0$

The CRC field is transmitted with c_3 first.

Figure 23-10 shows the operation of the CRC. First, the shift register is reset to all 1s. The bits are then passed through the XOR operation at the input. When the last bit has entered, the output is generated by shifting the bits out of the shift register, C3 first, through an inverter.

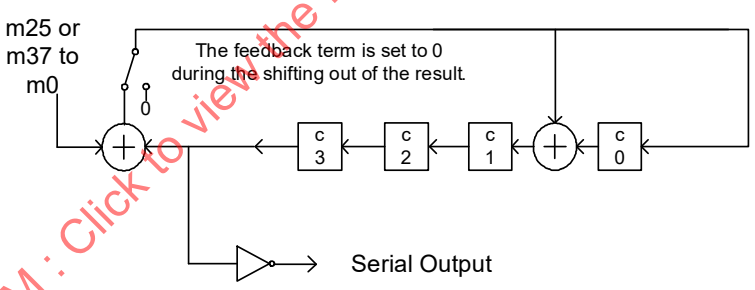

Figure 23-10—4-bit CRC calculation

As an example, if bits $\{m_0 \ldots m_{25}\}$ are given by {11 0110 0111 0110 1001 1110 1111}, the output bits $\{b_3 \ldots b_0\}$, where b_3 is output first, are {0101}.

23.3.8.2.3 S1G_LONG preamble

23.3.8.2.3.1 General

The S1G_LONG preamble is used for the S1G_LONG PPDU format. In contrast to the S1G_1M and S1G_SHORT preambles, the S1G_LONG preamble can be used for MU transmissions, in addition to SU transmissions. The S1G_LONG preamble is structured similarly to the Mixed mode format as defined in Clause 19 and Clause 21.

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23.3.8.2.3.2 Omnidirectional portion

23.3.8.2.3.2.1 General

The omnidirectional portion of the S1G_LONG preamble is single user and single-space-time stream modulated. By definition, to be omnidirectional, no spatial mapping (Q-matrix multiplication) is applied.

23.3.8.2.3.2.2 Cyclic shift for S1G modulated fields

This subclause describes the set of cyclic shift values (defined per-antenna) to be applied to the omnidirectional portion of the S1G_LONG preamble, namely the STF, LTF, and SIG-A fields. The STF, LTF, and SIG-A fields start as single-stream during generation but are replicated up to N_{TX} streams. These fields are mapped to the transmit antennas, at which point the cyclic shifts are applied. The cyclic shift values are defined in Table 23-12, which specifies the per-antenna cyclic shift value $T_{CS}^{i_{TX}}$ for antenna i_{TX} of the N_{TX} total transmit antennas.

Table 23-12—Per antenna cyclic shift values of S1G_LONG preamble PPDU

$T_{CS}^{i_{TX}}$ for ≥ 2 MHz, omnidirectional portion of S1G_LONG Preamble PPDU				
Total number of Tx antennas	**Cyclic shift (for Tx Antenna i_{TX}) (μs)**			
	1	**2**	**3**	**4**
1	0	N/A	N/A	N/A
2	0	–4	N/A	N/A
3	0	–4	–2	N/A
4	0	–4	–2	–6
NOTE—N/A = not applicable.				

23.3.8.2.3.2.3 STF definition

The STF field for 2 MHz, 4 MHz, 8 MHz, and 16 MHz are the same as the STF field in short preamble as specified in 23.3.8.2.2.3.

The time domain representation of the STF field signal at transmit chain i_{TX} shall be as specified in Equation (23-23).

$$r_{STF}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{STF}^{Tone} N_{TX}}} w_{T_{STF}}(t) \sum_{k=-N_{SR}}^{N_{SR}} [Q_k^{(\text{omni})}]_{i_{TX},1} \Upsilon_{k,\text{BW}} S_k \exp(j2\pi k \Delta_F t) \quad (23\text{-}23)$$

where

N_{SR} is 26 for a 2 MHz transmission or defined in Table 23-4 for a 4 MHz, 8 MHz or 16 MHz transmission.

S_k is defined in Equation (19-8), Equation (19-9), Equation (21-8), or Equation (21-9) for a 2 MHz, 4 MHz, 8 MHz, or 16 MHz transmission, respectively.

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$\Upsilon_{k,BW}$ is defined by Equation (23-6) to Equation (23-9)

Δ_F is defined in Table 23-4

N_{STF}^{Tone} has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-7

$Q_k^{(omni)}$ is defined in 23.3.7

23.3.8.2.3.2.4 LTF1 definition

The LTF1 field values for 2 MHz, 4 MHz, 8 MHz, and 16 MHz are the same as the LTF field in short preamble as specified in 23.3.8.2.2.4.

The time domain representation of the LTF1 field signal at transmit chain i_{TX} shall be as specified in Equation (23-24).

$$r_{\mathrm{LTF1}}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{LTF}^{Tone} N_{TX}}} w_{\mathrm{T}_{LTF1}}(t) \sum_{k=-N_{SR}}^{N_{SR}} [Q_k^{(\mathrm{omni})}]_{i_{TX},1} \Upsilon_{k,\mathrm{BW}} LTF_k \exp(j2\pi k \Delta_F (t - T_{GI2})) \quad (23\text{-}24)$$

where

LTF_k is defined in Equation (21-36), Equation (21-37), Equation (21-38), or Equation (21-39) for a 2 MHz, 4 MHz, 8 MHz, or 16 MHz transmission, respectively

N_{SR} is defined in Table 23-4

$\Upsilon_{k,BW}$ is defined by Equation (23-6) to Equation (23-9)

Δ_F is defined in Table 23-4

N_{STF}^{Tone} has the value given in Table 23-7

$Q_k^{(omni)}$ is defined in 23.3.7.

The LTF1 field consists of two periods of the long training symbol, preceded by a double length (16 μs) cyclic prefix. The placement of the first and subsequent LTF fields in an S1G_SHORT PPDU is shown in Figure 23-1.

23.3.8.2.3.2.5 SIG-A definition

The SIG-A field of the long preamble carries information required to interpret S1G format PPDUs sent using the long preamble. The structure of the SIG-A field is different for SU PPDUs and MU PPDUs. The structure of the SIG-A field for SU PPDUs for the first symbol (SIG-A1) is shown in Figure 23-11 and for the second symbol (SIG-A2) is shown in Figure 23-12. The structure of the SIG-A field for MU PPDUs for the first symbol (SIG-A1) is shown in Figure 23-13 and for the second symbol (SIG-A2) is shown in Figure 23-14.

The SIG-A field of S1G format PPDUs sent with an S1G_LONG preamble for SU contains the fields listed in Table 23-13 and for MU, the fields listed in Table 23-14.

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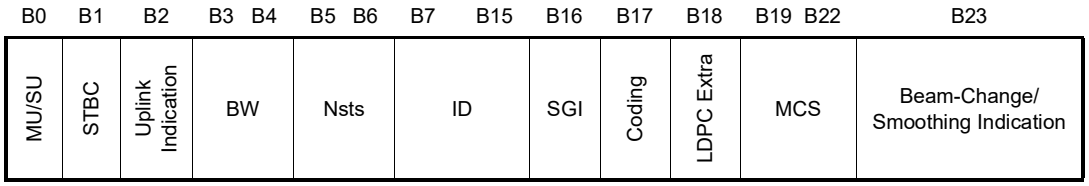

Figure 23-11—SIG-A1 structure for SU PPDU

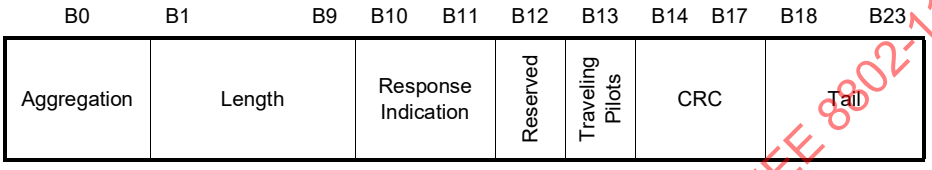

Figure 23-12—SIG-A2 structure for SU PPDU

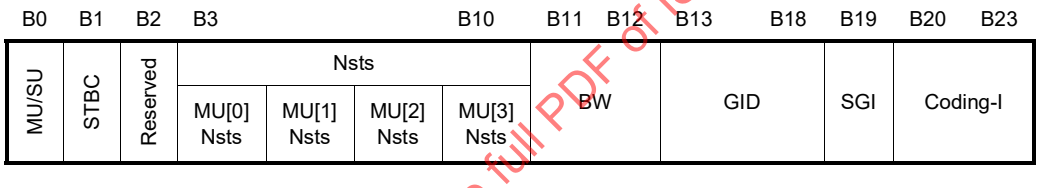

Figure 23-13—SIG-A1 structure for MU PPDU

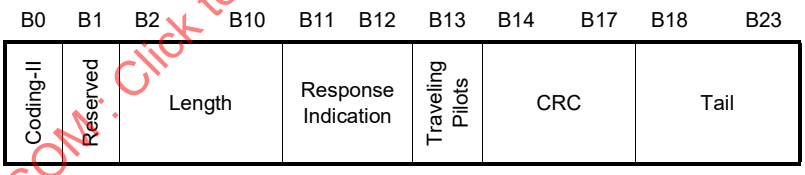

Figure 23-14—SIG-A2 structure for MU PPDU

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Table 23-13—Fields in the SIG-A field of S1G_LONG preamble SU PPDU

Symbol	Bit	Field	Description
SIG-A1	B0	MU/SU	Set to 0 for SU PPDUs.
	B1	STBC	Set to 1 if all spatial streams have space-time block coding and set to 0 if no spatial streams has space-time block coding.
	B2	Uplink Indication	Set to 1 if the PPDU is addressed to an AP. Set to 0 otherwise. (See TXVECTOR parameter UPLINK_INDICATION.)
	B3–B4	BW	Set to 0 for 2 MHz, 1 for 4 MHz, 2 for 8 MHz, 3 for 16 MHz
	B5–B6	Nsts	Set to 0 for 1 space-time stream Set to 1 for 2 space-time streams Set to 2 for 3 space-time streams Set to 3 for 4 space-time streams
	B7–B15	ID	If Uplink Indication field is not present or set to 1, B7–B15 are the partial AID to provide an abbreviated indication of the intended recipient(s) of the PSDU (see 10.21). If Uplink Indication field is set to 0, B7-B9 are an identifier of the BSS and B10–B15 are the partial AID. (See TXVECTOR parameter COLOR and TXVECTOR parameter PARTIAL_AID.)
	B16	Short GI	Set to 0 if short guard interval is not used in the Data field. Set to 1 if short guard interval is used in the Data field.
	B17	Coding	Set to 0 for BCC and 1 for LDPC
	B18	LDPC Extra	If Coding field is 1, set to 1 if the LDPC PPDU encoding process (of an SU PPDU), results in an extra OFDM symbol (or symbols) as described in 21.3.10.5.4, otherwise set to 0. If Coding field is 0, this field is set to 1.
	B19–B22	MCS	MCS Index
	B23	Beam Change/ Smoothing Indication	If Nsts subfield indicates 1 space-time stream, this field is a Beam Change Indication field: — A value of 1 indicates that the Q matrix is changed from the omnidirectional portion to the beam changeable portion of the preamble, in at least one of the nonzero subcarriers of the omnidirectional portion. — A value of 0 indicates that the Q matrix is unchanged in all the nonzero subcarriers of the omnidirectional portion. If Nsts subfield indicates more than 1 space-time stream, this field is a Smoothing Indication field: — A value of 1 indicates that channel smoothing is recommended, — A value of 0 indicates that channel smoothing is not recommended. See NOTE 1. See NOTE 2.

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Table 23-13—Fields in the SIG-A field of S1G_LONG preamble SU PPDU *(continued)*

Symbol	Bit	Field	Description
SIG-A2	B0	Aggregation	Set to 1 when aggregation is ON (as indicated by AGGREGATION parameter of TXVECTOR), and 0 otherwise. NOTE—S1G PPDUs are transmitted with aggregation ON when PSDU to be carried is greater than 511 octets, as defined in 10.12.5.
	B1–B9	Length	When the Aggregation subfield is equal to 0, set to the number of octets in the PSDU. When the Aggregation subfield is equal to 1, set to N_{SYM_i}, given in 23.4.3. (See TXVECTOR parameter PSDU_LENGTH.)
	B10–B11	Response Indication	Set to the value obtained from the TXVECTOR parameter RESPONSE_INDICATION. The Response Indication field indicates the presence and type of frame that is expected to follow SIFS after the current frame transmission (see 10.3.2.5).
	B12	Reserved	Reserved. Bit set to 1.
	B13	Traveling Pilots	Set to 1 to indicate traveling pilots usage in packet. Otherwise 0 to indicate regular pilot tone locations.
	B14–B17	CRC	CRC calculated as in 23.3.8.2.2.6.
	B18–B23	Tail	Used to terminate the trellis of the convolutional decoder. Set to 0.
NOTE 1—When the Nsts subfield indicates 1 space-time stream, if Beam Change/Smoothing Indication field is set to 0, the receiver may do channel smoothing. Otherwise, smoothing is not recommended. NOTE 2—The Q matrix for omnidirectional portion is $Q_k^{(\mathrm{omni})}$ as defined in 23.3.7.			

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Table 23-14—Fields in the SIG-A field of S1G_LONG preamble MU PPDU

Symbol	Bit	Field	Description
SIG-A1	B0	MU/SU	Set to 1 for MU PPDUs
	B1	STBC	Set to 0 in MU PPDUs.
	B2	Reserved	Reserved. Set to 1.
	B3–B10	NSTS	NSTS is divided into 4 user positions of 2 bits each, denoted by 4 subfields MU[0] Nsts …MU[3] Nsts. User position p, where $0 \le p \le 3$, uses bits $B(3+2p) - B(4+2p)$. The space-time streams of user u are indicated at user position $p = \text{USER_POSITION}[u]$ where $u = 0, 1, \ldots \text{NUM_USERS} - 1$ and the notation A[b] denotes the value of array A at index b. Zero space-time streams are indicated at positions not listed in the USER_POSITION array. Set to 0 for 0 space-time streams Set to 1 for 1 space-time stream Set to 2 for 2 space-time streams Set to 3 for 3 space-time streams
	B11–B12	BW	Set to 0 for 2 MHz, 1 for 4 MHz, 2 for 8 MHz, 3 for 16 MHz
	B13–B18	GID	In an MU PPDU the Group ID is set as defined in 23.3.10.4
	B19	Short GI	Set to 0 if short guard interval is not used in the Data field. Set to 1 if short guard interval is used in the Data field.
	B20–B23	Coding-I	If the MU[0] NSTS field is nonzero, then B20 indicates coding for user 0: set to 0 for BCC, 1 for LDPC. If the MU[0] NSTS field is 0, then B20 is reserved and set to 1. If the MU[1] NSTS field is nonzero, then B21 indicates coding for user 1: set to 0 for BCC, 1 for LDPC. If the MU[1] NSTS field is 0, then B21 is reserved and set to 1. If the MU[2] NSTS field is nonzero, then B22 indicates coding for user 2: set to 0 for BCC, 1 for LDPC. If the MU[2] NSTS field is 0, then B22 is reserved and set to 1. If the MU[3] NSTS field is nonzero, then B23 indicates coding for user 3: set to 0 for BCC, 1 for LDPC. If the MU[3] NSTS field is 0, then B23 is reserved and set to 1.
SIG-A2	B0	Coding-II	Set to 1 if at least one LDPC user's PPDU encoding process results in an extra OFDM symbol (or symbols) as described in 21.3.10.5.4 and 21.3.10.5.5. Set to 0 otherwise.
	B1	Reserved	Reserved. Set to 1.
	B2–B10	Length	Set to the N_{sym}, given in 23.4.3. NOTE— A-MPDU is always used for MU PPDUs.
	B11–B12	Response Indication	Set to the value obtained from the TXVECTOR parameter RESPONSE_INDICATION. The Response Indication field indicates the presence and type of frame that is expected to follow SIFS after the current frame transmission (see 10.3.2.5).
	B13	Traveling Pilots	Set to 1 to indicate traveling pilots usage in packet. Otherwise 0 to indicate regular pilot tone locations.
	B14–B17	CRC	CRC calculated as in 23.3.8.2.2.6.
	B18–B23	Tail	Used to terminate the trellis of the convolutional decoder. Set to 0.

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The SIG-A field is composed of two OFDM symbols, SIG-A1 and SIG-A2, each containing 24 data bits, as shown in Table 23-13. SIG-A1 is transmitted before SIG-A2. The SIG-A field symbols shall be BCC encoded at rate, R = 1/2, interleaved, mapped to a BPSK constellation, and have pilots inserted following the steps described in 17.3.5.6, 17.3.5.7, 17.3.5.8, and 17.3.5.9, respectively. The first and second half of the stream of 96 complex numbers generated by these steps (before pilot insertion) is divided into two groups of 48 complex numbers $d_{k,n}$, $k = 0, \ldots, 47$, where $n = 0, 1$, respectively. The first group of the 48 complex numbers are rotated by 90° counter-clockwise relative to their original BPSK constellation points in order to accommodate differentiation of the S1G_LONG PPDU from an S1G_1M PPDU. The second group of the 48 complex numbers without rotations may be used to accommodate differentiation of the S1G_LONG PPDU from an S1G_SHORT PPDU. The first rotated 48 complex numbers form the first symbol of SIG-A; and the second unrotated 48 complex numbers form the second symbol of SIG-A, which follow the constellation diagram shown in Figure 23-15.

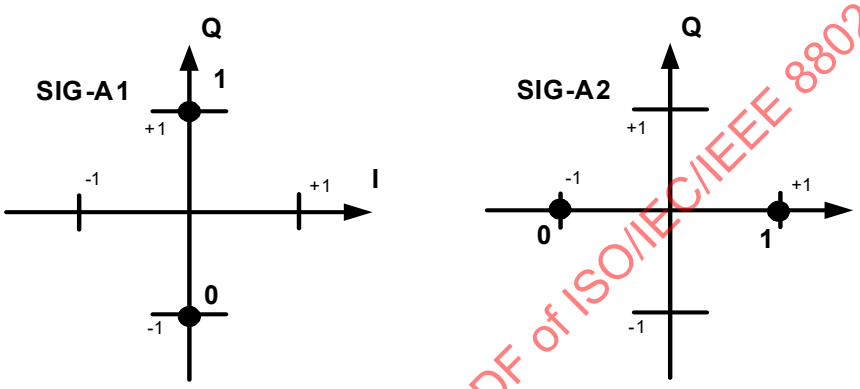

Figure 23-15—Data constellation in SIG-A field of S1G_LONG

The time domain waveform for the SIG-A field in an S1G_LONG PPDU at transmit chain i_{TX} shall be as specified in Equation (23-25).

$$r_{SIG-A}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{SIG-A}^{Tone} N_{TX}}} \sum_{n=0}^{1} w_{T_{SYML}}(t - nT_{SYML}) \sum_{i_{BW}=0}^{N_{2MHz}-1} \left(\sum_{k=-26}^{26} [Q_k^{(\text{omni})}]_{i_{TX},1} \Upsilon_{(k-K_{Shift}(i_{BW})),BW}((-1)^n j^{n+1} D_{k,n,2} + p_n P_k) \right.$$
$$\left. \exp(j2\pi(k - K_{Shift}(i_{BW}))\Delta_F(t - nT_{SYML} - T_{GI})) \right) \quad (23\text{-}25)$$

where

N_{2MHz}, $K_{Shift}(i)$, and $D_{k,n,2}$ are the same as those defined in 23.3.8.2.2.5

p_n and P_k are defined in 17.3.5.10

T_{SYML} is defined in Table 23-4

$\Upsilon_{k,BW}$ is defined by Equation (23-6) to Equation (23-9)

Δ_F is defined in Table 23-4

$N_{SIG\text{-}A}^{Tone}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-7

$Q_k^{(omni)}$ is defined in 23.3.7

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NOTE—As shown in Figure 23-1 to Figure 23-3, this definition results in a QBPSK modulation on the first symbol of SIG-A field, where the constellation of the data tones is rotated by 90º counter-clockwise relative to the third repetition of LTF1 field in S1G_1M preamble, facilitating its differentiation from S1G_1M; and the second symbol of SIG-A field is BPSK modulated, facilitating its differentiation from S1G_SHORT.

23.3.8.2.3.3 Beamchangeable portion

23.3.8.2.3.3.1 General

The beamchangeable portion of the S1G_LONG preamble can be either single-user or multi-user modulated with single or multiple space-time streams. Beamforming can be applied through spatial mapping (Q-matrix multiplication) starting with the beamchangeable portion of the preamble and continuing into the Data field.

Beamchangeable portion of the long preamble could be either single user or multi-user modulated.

23.3.8.2.3.3.2 Cyclic shift for S1G modulated fields

This subclause describes the set of cyclic shift values (defined per space-time stream) to be applied to the beamchangeable portion of the S1G_LONG preamble, namely the D-STF, D-LTF, and SIG-B fields. In a transmission, these fields start as single stream and are replicated up to $N_{STS,total}$ streams at which point the cyclic shifts are applied. The cyclic shift values are defined in Table 23-15, which specifies the per-stream cyclic shift value $T_{CS}(n)$ for space-time stream n out of $N_{STS,total}$ total space-time streams.

When the S1G_LONG preamble PPDU is used for an MU transmission, the cyclic shifts of the beamchangeable portion are applied sequentially, first per user and then per space-time stream up to the total number of users and space-time streams $N_{STS,total}$ as follows: the cyclic shift of the space-time stream number m for user u is given by $T_{CS}(M_u + m)$, of the row corresponding to $N_{STS,total}$ in Table 23-15. In this case, the index n takes into account the cyclic shifts already applied to space-time streams of prior users (M_u), and the space-time stream index (m) of the current user u in the sequence.

M_u is given by Table 23-6.

Table 23-15—Per space-time stream cyclic shift values of S1G_LONG preamble PPDU

$T^{long}_{CS,S1G}(n)$ for ≥2 MHz, beam changeable portion of S1G_LONG preamble PPDU				
Total number of space-time streams ($N_{STS,total}$)	Cyclic for space-time stream n (μs)			
	1	2	3	4
1	0	N/A	N/A	N/A
2	0	–4	N/A	N/A
3	0	–4	–2	N/A
4	0	–4	–2	–6
NOTE—N/A = not applicable.				

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23.3.8.2.3.3.3 D-STF definition

The main purpose of the D-STF field is to improve automatic gain control estimation in an SU or MU MIMO transmission. The duration of the D-STF field is 40 µs. The frequency domain sequence $\{S_k\}$ used to construct the D-STF field is the same as the STF field in short or long preamble as indicated in 23.3.8.2.2.3.

The time domain representation of the D-STF field signals at transmit chain i_{TX} shall be as specified in Equation (23-26).

$$r_{\text{D-STF}}^{(i_{\text{TX}})}(t) = \frac{1}{\sqrt{N_{\text{D-STF}}^{\text{Tone}} N_{\text{STS,total}}}} w_{T_{\text{D-STF}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_u-1} \sum_{m=1}^{N_{STS,u}} \left(\begin{array}{l} \left[Q_k\right]_{i_{TX},(M_u+m)} \Upsilon_{k,\text{BW}} . S_k \\ \cdot \exp\left(j2\pi k \Delta_F (t - T_{CS}(M_u + m))\right) \end{array} \right) \quad (23\text{-}26)$$

where

N_{SR} is defined in Table 23-4

$T_{CS(m)}$ represents the cyclic shift for space-time stream m with a value given in Table 23-15

$\Upsilon_{k,\text{BW}}$ is defined by Equation (23-6) to Equation (23-9)

Δ_F is defined in Table 23-4

$N_{STS,total}$, $N_{STS,u}$, N_u, and M_u are defined in Table 23-6.

$N_{\text{D-STF}}^{\text{Tone}}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-7

Q_k is defined in 23.3.7

The duration of the D-STF field is $T_{\text{D-STF}}$ regardless of the Short GI field setting in SIG-A.

23.3.8.2.3.3.4 D-LTF definition

The D-LTF field values for 2 MHz, 4 MHz, 8 MHz, and 16 MHz are the same as the LTF field in short preamble as specified in 23.3.8.2.2.4.

The generation of the time domain D-LTF field symbols per frequency segment is shown in Figure 23-6.

The time domain representation of the D-LTF field signals at transmit chain i_{TX} shall be as specified in Equation (23-27).

$$r_{\text{D-LTF}}^{(i_{\text{TX}})}(t) = \frac{1}{\sqrt{N_{\text{D-LTF}}^{\text{Tone}} N_{\text{STS,total}}}} \sum_{n=0}^{N_{LTF}-1} w_{T_{\text{D-LTF}}}(t - nT_{D-LTF}) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_u-1} \sum_{m=1}^{N_{STS,u}} \left(\begin{array}{l} \left[Q_k\right]_{i_{TX},(M_u+m)} \Upsilon_{k,\text{BW}} \cdot \left[A_{LTF}^k\right]_{(M_u+m),(n+1)} LTF_k \\ \cdot \exp\left(j2\pi k \Delta_F (t - nT_{D-LTF} - T_{GI} - T_{CS}(M_u + m))\right) \end{array} \right) \quad (23\text{-}27)$$

where

N_{SR} is defined in Table 23-4

$T_{CS(m)}$ represents the cyclic shift for space-time stream m with a value given in Table 23-15

$\Upsilon_{k,\text{BW}}$ is defined by Equation (23-6) to Equation (23-9)

Δ_F is defined in Table 23-4

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$N_{STS,total}$, $N_{STS,u}$, N_u, and M_u are defined in Table 23-6

A_{LTF}^{k} is defined in Equation (23-15)

$N_{\text{D-STF}}^{\text{Tone}}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-7

Q_k is defined in 23.3.7

As indicated by Equation (23-27), the duration of each symbol of the D-LTF field is $T_{\text{D-LTF}}$ regardless of the Short GI field setting in SIG-A.

The generation of the time domain D-LTF field symbols is the same as Figure 23-6, with N_{STS} replaced by $N_{STS,total}$.

23.3.8.2.3.3.5 SIG-B definition

If the SU/MU Indication subfield in SIG-A field is set to 0 (SU), then SIG-B field is one symbol that is identical to the first D-LTF field (D-LTF1). In this case, the time domain representation of the SIG-B field at transmit chain i_{TX} shall be as specified in Equation (23-27) with n=0.

If the SU/MU Indication subfield in SIG-A field is set to 1 (MU), then SIG-B field is one symbol and contains 26 bits in a 2 MHz PPDU, 27 bits in a 4 MHz PPDU and 29 bits in 8 MHz and 16 MHz PPDUs for each user. The fields in the SIG-B field are listed in Table 23-16.

Table 23-16—Fields in the SIG-B field for MU PPDU

Field	Bit Allocation				Description
	2 MHz	4 MHz	8 MHz	16 MHz	
MCS	B0–B3	B0–B3	B0–B3	B0–B3	Per-user MCS in MU-MIMO
Reserved	B4–B11	B4–B12	B4–B14	B4–B14	All 1s
CRC	B12–B19	B13–B20	B15–B22	B15–B22	
Tail	B20–B25	B21–B26	B23–B28	B23–B28	All 0s

The 8-bit CRC is calculated according to the procedure described in 23.3.8.2.3.3.6.

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In this case, the repetition, encoding, interleaving and modulation flow for the data subcarriers of SIG-B field in 2 MHz, 4 MHz, 8 MHz, and 16 MHz are identical to those specified for 20 MHz, 40 MHz, 80 MHz, and 160 MHz, respectively, as shown in 21.3.8.3.6. Different from the VHT-SIG-B field defined in Clause 21, the pilot subcarriers of SIG-B field are mapped by the first column of P_{HTLTF} matrix to N_{STS}, total space-time streams, and the pilot polarity of the SIG-B symbol is p_2 instead of p_3. The time domain representation for SIG-B field signal at transmit chain i_{TX} shall be as specified in Equation (23-28).

$$r_{\mathrm{SIG\text{-}B}}^{(i_{\mathrm{TX}})}(t)=\frac{1}{\sqrt{N_{\mathrm{SIG\text{-}B}}^{\mathrm{Tone}}N_{\mathrm{STS,total}}}}w_{T_{\mathrm{SIG\text{-}B}}}(t)$$
$$\sum_{k=-N_{SR}}^{N_{SR}}\sum_{u=0}^{N_u-1}\sum_{m=1}^{N_{STS,u}}\left(\begin{array}{l}\left[Q_k\right]_{i_{TX},(M_u+m)}\Upsilon_{k,\mathrm{BW}}\cdot\left[P_{HTLTF}\right]_{(M_u+m),1}\left(D_{k,BW}^{(u)}+p_2P_0^k\right)\\ \cdot\exp\left(j2\pi k\Delta_F(t-T_{GI}-T_{CS}(M_u+m))\right)\end{array}\right) \tag{23-28}$$

where

N_{SR} is defined in Table 23-4

$T_{CS(m)}$ represents the cyclic shift for space-time stream m with a value given in Table 23-15

$\Upsilon_{k,\mathrm{BW}}$ is defined by Equation (23-6) to Equation (23-9)

Δ_F is defined in Table 23-4

$N_{STS,total}$, $N_{STS,u}$, N_u, and M_u are defined in Table 23-6

P_{HTLTF} is defined in Equation (19-27) in 19.3.9.4.6

p_n is defined in 17.3.5.10

P_n^k is defined in 21.3.10.10

$N_{\mathrm{SIG\text{-}B}}^{\mathrm{Tone}}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-7

Q_k is defined in 23.3.7

For a 2 MHz transmission,

$$D_{k,2}^{(u)}=\begin{cases}0,k=0,\pm7,\pm21\\ d_{M_2'(k)}^{(u)},\text{otherwise}\end{cases} \tag{23-29}$$

$$M_2'(k)=\begin{cases}k+28, & -28\le k\le -22\\ k+27, & -20\le k\le -8\\ k+26, & -6\le k\le -1\\ k+25, & 1\le k\le 6\\ k+24, & 8\le k\le 20\\ k+23, & 22\le k\le 28\end{cases} \tag{23-30}$$

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For a 4 MHz transmission,

$$D_{k,4}^{(u)} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 25, \pm 53 \\ d_{M_4'(k)}^{(u)}, \text{otherwise} \end{cases} \quad (23\text{-}31)$$

$$M_4'(k) = \begin{cases} k+58, & -58 \le k \le -54 \\ k+57, & -52 \le k \le -26 \\ k+56, & -24 \le k \le -12 \\ k+55, & -10 \le k \le -2 \\ k+52, & 2 \le k \le 10 \\ k+51, & 12 \le k \le 24 \\ k+50, & 26 \le k \le 52 \\ k+49, & 54 \le k \le 58 \end{cases} \quad (23\text{-}32)$$

For an 8 MHz transmission,

$$D_{k,8}^{(u)} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 39, \pm 75, \pm 103 \\ d_{M_8'(k)}^{(u)}, \text{otherwise} \end{cases} \quad (23\text{-}33)$$

$$M_8'(k) = \begin{cases} k+122, & -122 \le k \le -104 \\ k+121, & -102 \le k \le -76 \\ k+120, & -74 \le k \le -40 \\ k+119, & -38 \le k \le -12 \\ k+118, & -10 \le k \le -2 \\ k+115, & 2 \le k \le 10 \\ k+114, & 12 \le k \le 38 \\ k+113, & 40 \le k \le 74 \\ k+112, & 76 \le k \le 102 \\ k+111, & 104 \le k \le 122 \end{cases} \quad (23\text{-}34)$$

For a 16 MHz transmission

$$D_{k,16}^{(u)} = \begin{cases} 0, k = 0, \pm 1, \pm 2, \pm 3, \pm 4, \pm 5, \pm 25, \pm 53, \pm 89, \pm 117, \pm 127, \pm 128, \pm 129, \pm 139, \pm 167, \pm 203, \pm 231 \\ d_{M_{16}'(k)}^{(u)}, \text{otherwise} \end{cases}$$

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$$M'_{16}(k) = \begin{cases} k+250, & -250 \le k \le -232 \\ k+249, & -230 \le k \le -204 \\ k+248, & -202 \le k \le -168 \\ k+247, & -166 \le k \le -140 \\ k+246, & -138 \le k \le -130 \\ k+243, & -126 \le k \le -118 \\ k+242, & -116 \le k \le -90 \\ k+241, & -88 \le k \le -54 \\ k+240, & -52 \le k \le -26 \\ k+239, & -24 \le k \le -6 \\ k+228, & 6 \le k \le 24 \\ k+227, & 26 \le k \le 52 \\ k+226, & 54 \le k \le 88 \\ k+225, & 90 \le k \le 116 \\ k+224, & 118 \le k \le 126 \\ k+221, & 130 \le k \le 138 \\ k+220, & 140 \le k \le 166 \\ k+219, & 168 \le k \le 202 \\ k+218, & 204 \le k \le 230 \\ k+217, & 232 \le k \le 250 \end{cases} \quad (23\text{-}35)$$

23.3.8.2.3.3.6 CRC calculation for SIG SIG-B field

The CRC protects the MCS and Reserved field bits of the SIG-B field. The value of the CRC field shall be the 1s complement of

$$crc(D) = (M(D) \oplus I(D))D^8 \bmod G(D) \quad (23\text{-}36)$$

where

$M(D) = m_0 D^N + m_1 D^{N-1} + \ldots + m_N D^0$ is the MCS and Reserved field appended (bits 0–N of SIG B) and represented as a polynomial

where

N is 11, 12, 14, and 14 for 2 MHz, 4 MHz, 8 MHz, and 16 MHz SIG-B fields, respectively

m_i is the ith bit of the corresponding SIG-B field

$I(D) = \sum_{i=N-7}^{N} D^i$ are the initialization values that are added to the first 8 bits of the SIG-B field

$G(D) = D^8 + D^2 + D^1 + 1$ is the CRC generating polynomial

$crc(D) = c_0 D^7 + c_1 D^6 + \ldots + c_6 D^1 + c_7$

The CRC field is transmitted with c_7 first.

Figure 19-8 in 19.3.9.4.4 shows the operation of the CRC using the same generator polynomial. For SIG-B CRC operation specifically, the bits will be input serially from m_N to m_0.

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23.3.8.3 Format for 1 MHz

23.3.8.3.1 Introduction

This subclause describes the preamble format used for non-duplicate S1G PPDUs of 1 MHz and duplicate S1G_DUP_1M PPDUs.

23.3.8.3.2 Cyclic shift for S1G modulated fields

The cyclic shift values defined in this subclause apply to the STF, LTF, SIG and Data fields of the S1G_1M PPDU. Throughout the S1G_1M preamble, cyclic shifts are applied to prevent beamforming when similar signals are transmitted in different space-time streams. The STF, LTF, and SIG fields start as single-stream during generation but are replicated up to $N_{STS,total}$ streams. For the LTF, these replicated streams undergo P-matrix mapping prior to CSD application as shown in Figure 23-6. For the STF and SIG, the CSDs are applied per stream immediately after replication. The same cyclic shift is applied to the $N_{STS,total}$ streams during the transmission of the Data field of the S1G_1M PPDU. The cyclic shift value $T_{CS}(n)$ for space-time stream n out of $N_{STS,total}$ total space-time streams is shown in Table 23-17.

Table 23-17—Cyclic shift values of S1G_1M PPDU

$T_{CS}(n)$ values for S1G_1M PPDU				
Total number of space-time streams ($N_{STS,total}$)	**Cyclic shift for space-time stream n (μs)**			
	1	**2**	**3**	**4**
1	0	—	—	—
2	0	–4	—	—
3	0	–4	–1	—
4	0	–4	–1	–5

23.3.8.3.3 STF definition

The STF field in S1G_1M preamble is repeated with 4 OFDM symbols, i.e., twice the duration of the STF fields in S1G_SHORT preamble and S1G_LONG preamble.

The time domain representation of the STF field signal at transmit chain i_{TX} shall be as specified in Equation (23-37).

$$r_{\mathrm{STF}}^{(i_{\mathrm{TX}})}(t) = \frac{\alpha(\mathrm{MCS})}{\sqrt{N_{\mathrm{STF}}^{\mathrm{Tone}} N_{\mathrm{STS}}}} w_{T_{\mathrm{STF}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} \left[Q_k\right]_{i_{TX},m} \left[P_{HTLTF}\right]_{m,1} \cdot S_k \exp\left(j2\pi k\Delta_F (t - T_{CS}(m))\right) \quad (23\text{-}37)$$

where

N_{SR} is defined in Table 23-4

$T_{CS}(m)$ represents the cyclic shift for space-time stream m with a value given in Table 23-17

Δ_F is defined in Table 23-4

N_{STS} is defined in Table 23-6

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P_{HTLTF} is defined in Equation (19-27) in 19.3.9.4.6

$N_{\text{STF}}^{\text{Tone}}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-7

S_k has nonzero values $[0.5, -1, 1, -1, -1, -0.5] \times (1+j) \times \sqrt{2/3}$ on tones $k = [-12,-8,-4,4,8,12]$, respectively

$\alpha(MCS)$ is an MCS dependent scaling factor, with the following value $\alpha(MCS) = \begin{cases} \sqrt{2}, & \text{MCS=10} \\ 1, & \text{otherwise} \end{cases}$

Q_k is defined in 23.3.7

23.3.8.3.4 LTF definition

The duration of the first LTF (LTF1) field in S1G_1M preamble is of 4 OFDM symbols with repetitions, i.e., twice the duration of the LTF1 fields in S1G_LONG preamble and S1G_SHORT preamble. The first two repetitions have the same structure as the LTF1 field in S1G_LONG preamble and S1G_SHORT preamble, i.e., they consist of two periods of the long training symbol, preceded by a double length (16 μs) cyclic prefix. Each of the last two repetitions of LTF1 field consists one period of the long training symbol preceded by a normal length (8 μs) cyclic prefix. The duration of the each of the remaining LTFs in S1G_1M preamble is of one OFDM symbol.

The placement of the first and subsequent LTFs in an S1G_1M PPDU is shown in Figure 23-3.

The generation of the time domain LTF symbols is the same as Table 23-6.

The time domain representation of the first two repetitions of the LTF1 field, and the last two repetitions of the LTF1 field shall be as specified in Equation (23-38) and Equation (23-39), respectively

$$r_{\text{LTF1_1,2}}^{(i_{\text{TX}})}(t) = \frac{1}{\sqrt{N_{\text{LTF}}^{\text{Tone}} N_{\text{STS}}}} w_{T_{\text{LTF1}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} \left(\begin{array}{l} \left[Q_k\right]_{i_{TX},m} \Upsilon_{k,\text{BW}} \left[A_{LTF}^{k}\right]_{m,1} LTF_k \\ \quad \cdot \exp\left(j2\pi k \Delta_F (t - T_{GI2} - T_{CS}(m))\right) \end{array} \right) \tag{23-38}$$

$$r_{\text{LTF1_3,4}}^{(i_{\text{TX}})}(t) = \frac{1}{\sqrt{N_{\text{LTF}}^{\text{Tone}} N_{\text{STS}}}} w_{T_{\text{LTF}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} \left(\begin{array}{l} \left[Q_k\right]_{i_{TX},m} \Upsilon_{k,\text{BW}} \left[A_{LTF}^{k}\right]_{m,1} LTF_k \\ \quad \cdot \exp\left(j2\pi k \Delta_F (t - T_{GI} - T_{CS}(m))\right) \end{array} \right) \tag{23-39}$$

where

N_{SR}, T_{LTF1}, and T_{LTF} are defined in Table 23-4

$T_{CS(m)}$ represents the cyclic shift for space-time stream m with a value given in Table 23-17

$\Upsilon_{k,\text{BW}}$ is defined by Equation (23-6) to Equation (23-9)

Δ_F is defined in Table 23-4

N_{STS} is defined in Table 23-6

$N_{\text{LTF}}^{\text{Tone}}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-7

A_{LTF}^{k} is defined in Equation (23-40)

Q_k is defined in 23.3.7

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$$A_{LTF}^{k} = \begin{cases} [P_{HTLTF}]_{*,1} \times [1 \quad 1 \quad 1 \quad 1], \text{ if } k \in K_{\text{Pilot_Fix}} \\ P_{HTLTF}, \text{ otherwise} \end{cases} \tag{23-40}$$

where

$K_{\text{Pilot_Fix}}$ is the subcarrier indices for the fixed pilot tones. For a 1 MHz transmission, $K_{\text{Pilot_Fix}} = \{\pm 7\}$.

$[P_{HTLTF}]_{*,1}$ is the first column of the P_{HTLTF} matrix.

$LTF_{-16:15} = \{0, 0, 0, 1, -1, 1, -1, -1, 1, -1, 1, 1, -1, 1, 1, 1, 0, -1, -1, -1, 1, -1, -1, -1, 1, -1, 1, 1, 1, -1, 0, 0\}$

NOTE 1—This LTF sequence is chosen to be orthogonal to both halves of the 2 MHz LTF sequence in order to facilitate the differentiation of S1G_1M preambles from S1G_SHORT and S1G_LONG preambles. The orthogonality metric used to select the sequences satisfied the criteria

$$\sum_{k} A(k)B(k)A(k+1)^{*}B(k+1)^{*} = 0$$

where {A} and {B} are the 1 MHz sequence and either of the halves of the 2 MHz sequence, and where k=1,2,3,...,16,18,19,...,31 skipping the 1 MHz DC location on k=17.

NOTE 2—This definition results in a BPSK modulation on the last two symbols of LTF1 field, to facilitate the differentiation of S1G_1M preambles from S1G_SHORT and S1G_LONG preamble.

The time domain representation of the LTF2~LTF_{NLTF} field signals at transmit chain i_{TX} shall be as specified in Equation (23-41).

$$r_{\text{LTF2~LTF}_{\text{NLTF}}}^{(i_{\text{TX}})}(t) = \frac{1}{\sqrt{N_{\text{LTF}}^{\text{Tone}} N_{\text{STS}}}} \sum_{n=1}^{N_{LTF}-1} w_{T_{\text{LTF}}}(t-(n-1)T_{LTF}) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} \left(\begin{array}{l} [Q_k]_{i_{TX},m} \cdot [A_{LTF}^{k}]_{m,(n+1)} LTF_k \\ \cdot \exp\left(j2\pi k \Delta_F (t-(n-1)T_{LTF} - T_{GI} - T_{CS}(m))\right) \end{array} \right) \tag{23-41}$$

where

N_{SR} and T_{LTF} are defined in Table 23-4

$T_{CS(m)}$ represents the cyclic shift for space-time stream m with a value given in Table 23-15

Δ_F is defined in Table 23-4

N_{STS} is defined in Table 23-6

A_{LTF}^{k} is defined in Equation (23-40)

$N_{\text{LTF}}^{\text{Tone}}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-7

Q_k is defined in 23.3.7

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23.3.8.3.5 SIG definition

The SIG field carries information required to interpret S1G_1M PPDUs. The structure of the 6 symbol SIG field (which carries 6 information bits per symbol) is shown in Figure 23-16. Note that unlike other SIG field structures the indexing of the bits incorporates all the SIG field symbols, i.e., B0–B5 denote the first symbol, B6–B11 the second, and so on. The SIG field format of NDP CMAC PPDUs is described in Figure 23-20 and Figure 23-21 (in 23.3.11).

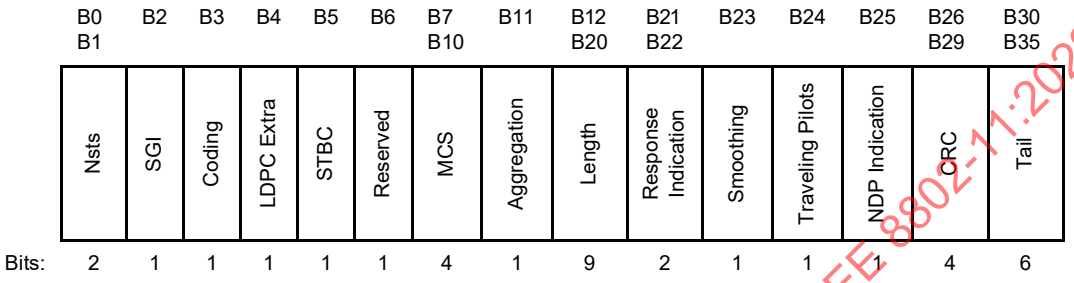

Figure 23-16—Structure of the 6 symbol SIG field of S1G_1M PPDU

The SIG field of S1G_1M PPDU contains the fields listed in Table 23-18.

Table 23-18—Fields in the SIG field of S1G_1M PPDU

Symbol	Bit	Field	Description
SIG-1	B0–B1	NSTS	Set to 0 for 1 space-time stream Set to 1 for 2 space-time streams Set to 2 for 3 space-time streams Set to 3 for 4 space-time streams
	B2	Short GI	Set to 0 if short guard interval is not used in the Data field. Set to 1 if short guard interval is used in the Data field.
	B3	Coding	Set to 0 for BCC and 1 for LDPC
	B4	LDPC Extra	If Coding field is 1, set to 1 if the LDPC PPDU encoding process (of an SU PPDU), results in an extra OFDM symbol (or symbols) as described in 21.3.10.5.4, otherwise set to 0. If Coding field is 0, this field is set to 1.
	B5	STBC	Set to 1 if all spatial streams have space-time block coding and set to 0 if no spatial streams has space-time block coding.
SIG-2	B6	Reserved	Reserved. Set to 1.
	B7–B10	MCS	MCS Index
	B11	Aggregation	Set to 1 when aggregation is ON (as indicated by AGGREGATION parameter of TXVECTOR), and 0 otherwise. NOTE— S1G PPDUs are transmitted with aggregation ON when PSDU to be carried is greater than 511 octets, as defined in 10.12.5.

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Table 23-18—Fields in the SIG field of S1G_1M PPDU *(continued)*

Symbol	Bit	Field	Description
SIG-3 and SIG-4	B12–B20	Length	When the Aggregation subfield is equal to 0, set to the number of octets in the PSDU. When the Aggregation subfield is equal to 1, set to N_{SYM_i}, given in 23.4.3. (See TXVECTOR parameter PSDU_LENGTH.)
	B21–B22	Response Indication	Set to the value obtained from the TXVECTOR parameter RESPONSE_INDICATION. The Response Indication field indicates the presence and type of frame that is expected to follow SIFS after the current frame transmission (see 10.3.2.5).
	B23	Smoothing	A value of 1 indicates that channel smoothing is recommended. A value of 0 indicates that channel smoothing is not recommended.
SIG-5	B24	Traveling Pilots	Set to 1 to indicate traveling pilots usage in packet. Otherwise 0 to indicate regular pilot tone locations.
	B25	NDP Indication	Differentiate the PPDU from an NDP CMAC PPDU: Set to 0 to indicate that the PPDU is not an NDP CMAC PPDU.
	B26–B29	CRC	CRC calculated as in 23.3.8.2.2.6.
SIG-6	B30–B35	Tail	Used to terminate the trellis of the convolutional decoder. Set to 0.

The SIG field of S1G_1M is composed of six OFDM symbols, SIG-1 ~ SIG-6, each containing 6 data bits, as shown in Table 23-18. SIG-1 is transmitted first and SIG-6 is the last. The SIG field symbols shall be BCC encoded at rate, R = 1/2, and repeated two times for the encoded bits within each OFDM symbol, interleaved, mapped to a BPSK constellation, and have pilots inserted, following the steps for MCS 10 transmission flow described in 23.3.9. The stream of 144 complex numbers generated by these steps (before pilot insertion) is divided into six groups of 24 complex numbers $d_{k,n}$, $k = 0, \ldots, 23$, where $n = 0, 1, \ldots, 5$, respectively. All the 144 complex numbers are BPSK modulated. The first 24 complex numbers form the first symbol of SIG field; and the second 24 complex numbers form the second symbol of SIG field, and so forth.

The time domain waveform for the SIG field in an S1G_1M PPDU at transmit chain i_{TX} shall be as specified in Equation (23-42).

$$r_{\mathrm{SIG}}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{\mathrm{SIG}}^{\mathrm{Tone}} N_{\mathrm{STS}}}} \sum_{n=0}^{5} w_{T_{\mathrm{SYML}}}(t - nT_{SYML}) \cdot \sum_{k=-13}^{13} \sum_{m=1}^{N_{STS}} \left[Q_k\right]_{i_{TX},m} \left[P_{HTLTF}\right]_{m,1} \left(D_{k,n,1} + p_n P_n^k\right) \cdot \exp\left(j2\pi k \Delta_F (t - nT_{SYML} - T_{GI} - T_{CS}(m))\right) \quad (23\text{-}42)$$

where

p_n is defined in 17.3.5.10, and P_n^k for S1G_1M is defined in 23.3.9.10

$T_{CS(m)}$ represents the cyclic shift for space-time stream *m* with a value given in Table 23-17

T_{SYML} is defined in Table 23-4

Δ_F is defined in Table 23-4

N_{STS} is defined in Table 23-6

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P_{HTLTF} is defined in Equation (19-27) in 19.3.9.4.6

$N_{\mathrm{SIG}}^{\mathrm{Tone}}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-7

Q_k is defined in 23.3.7

$$D_{k,n,1} = \begin{cases} 0, & k = 0, \pm 7 \\ d_{M_1'(k),n}, & \text{otherwise} \end{cases} \tag{23-43}$$

where

$M'_1(k)$ is defined in Equation (23-44)

$$M_1'(k) = \begin{cases} k+13, & -13 \le k \le -8 \\ k+12, & -6 \le k \le -1 \\ k+11, & 1 \le k \le 6 \\ k+10, & 8 \le k \le 13 \end{cases} \tag{23-44}$$

23.3.9 Data field

23.3.9.1 General

The number of OFDM symbols in the Data field is determined by the Length field in SIG field or SIG-A field of the three S1G PPDU formats, the preamble duration and the setting of the Short GI field in SIG field or SIG-A field, (see 23.3.8.2.2.5, 23.3.8.2.3.2.5, and 23.3.8.3.5). When BCC encoding is used, the Data field shall consist of the SERVICE field, the PSDU, the PHY pad bits and the tail bits (bits for SU and bits for each user u in MU). When LDPC encoding is used, the Data field shall consist of the SERVICE field, the PSDU and the PHY pad bits. No tail bits are present when LDPC encoding is used.

23.3.9.2 SERVICE field

In S1G PPDUs, the SERVICE field has 8 bits, which shall be denoted as bits 0–7. The bit 0 shall be transmitted first in time.

The SERVICE field is as shown in Table 23-19.

Table 23-19—SERVICE field

Bits	Field	Description
B0–B6	Scrambler Initialization	Set to 0
B7	Reserved	Set to 0

23.3.9.3 Scrambler

The SERVICE, PSDU and PHY pad parts of the Data field shall be scrambled by the scrambler defined in 17.3.5.5.

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23.3.9.4 Coding

23.3.9.4.1 General

The Data field shall be encoded using either the binary convolutional code (BCC) defined in 23.3.9.4.2 and 23.3.9.4.3, or the low-density parity check (LDPC) code defined in 23.3.9.4.4. The encoder is selected by the coding bit(s) in SIG field or SIG-A field of the three S1G PPDU formats, as defined in 23.3.8.2.2.5, 23.3.8.2.3.2.5, and 23.3.8.3.5. When BCC FEC encoding is used, the number of encoders is determined by rate-dependent parameters as defined in 23.5. The operation of the BCC FEC is described in 23.3.9.4.2 and 23.3.9.4.3. The operation of the LDPC coder is described in 23.3.9.4.4. Support for the reception of a BCC encoded Data field is mandatory.

23.3.9.4.2 BCC encoder parsing operation

The BCC encoder parsing operation for S1G PPDUs is the same as those specified in 21.3.10.5.2.

23.3.9.4.3 BCC coding and puncturing

23.3.9.4.3.1 General

The BCC coding and puncturing operation for S1G PPDUs is the same as those specified in 21.3.10.5.3.

23.3.9.4.3.2 Padding for BCC

For a BCC encoder, the number of PHY padding bits, $N_{PAD,u}$, is calculated as

$$N_{PAD,u} = N_{SYM} \times N_{DBPS,u} - 8 \times PSDU_LENGTH_u - N_{service} - N_{tail} \times N_{ES,u}$$

where

$PSDU_LENGTH_u$ is the value of the TXVECTOR parameter PSDU_LENGTH for user u

N_{SYM} is the number of symbols in the Data field and is given in 23.4.3 by Equation (23-79) for S1G SU PPDUs and Equation (23-82) for S1G MU PPDUs

For SU, $N_{PAD} = N_{PAD,0}$.

The padding flow for BCC encoded PPDUs is as follows:

For an S1G MU PPDU, or an S1G SU PPDU with the Aggregation subfield equal to 1 in its SIG field or SIG-A field, the MAC delivers a PSDU that fills the available octets in the Data field of the PPDU for each user u (i.e., append the maximum number of octets that is less than or equal to $N_{PAD,u}$). The PHY determines the number of PHY pad bits, which is $N_{PAD,u}$ modulo 8, and appends them to the PSDU, each of the PHY padding bits could be either 0 or 1. In this case, the Length subfield in SIG field or SIG-A field shall set the appropriate value indicating N_{SYM} data symbols.

For an S1G SU PPDU with the Aggregation subfield equal to 0 in its SIG field or SIG-A field, MAC padding is not conducted and the PHY directly appends N_{PAD} padding bits to the PSDU, each of the PHY padding bits could be either 0 or 1. In this case, the Length field shall set the appropriate value indicating PSDU_LENGTH in number of octets.

Both the PSDU and the PHY padding bits are scrambled and finally the $6.N_{ES}$ zero tail bits are appended after the scrambled PSDU and PHY padding bits.

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23.3.9.4.4 LDPC coding

23.3.9.4.4.1 General

For an S1G SU PPDU using LDPC coding to encode the Data field, the LDPC code and encoding process described in 19.3.11.7 shall be used with the following modifications. First, all bits in the Data field including the scrambled SERVICE, PSDU, and pad bits are encoded. Thus, N_{pld} for S1G SU PPDUs shall be computed using Equation (23-45) instead of Equation (19-35).

$$N_{pld} = N_{SYM,init} \times N_{DBPS} \tag{23-45}$$

where

$N_{SYM,init}$ is given by Equation (23-46) if the Aggregation subfield in its SIG field or SIG-A field is set to 1 or Equation (23-47) otherwise.

$$N_{SYM,init} = m_{STBC} \times \left\lceil \frac{8 \cdot APEP_LENGTH + N_{service}}{m_{STBC} \cdot N_{DBPS}} \right\rceil \tag{23-46}$$

$$N_{SYM,init} = m_{STBC} \times \left\lceil \frac{8 \cdot PSDU_LENGTH + N_{service}}{m_{STBC} \cdot N_{DBPS}} \right\rceil \tag{23-47}$$

where

m_{STBC}	is equal to 2 when STBC is used, and 1 otherwise
$APEP_LENGTH$	is the value of TXVECTOR parameter APEP_LENGTH
$PSDU_LENGTH$	is the value of TXVECTOR parameter PSDU_LENGTH

Following the calculation of N_{pld}, N_{avbits} shall be computed using Equation (23-48) instead of Equation (19-36).

$$N_{avbits} = N_{SYM,init} \times N_{CBPS} \tag{23-48}$$

In addition, if N_{SYM} computed in Equation (19-41) in step d) of 19.3.11.7.5 is greater than $N_{SYM,init}$, then the LDPC Extra field of its SIG field or SIG-A field shall be set to 1. Otherwise, the LDPC Extra field of its SIG field or SIG-A field shall be set to 0.

LDPC codes used in S1G MU PPDUs shall follow the definitions in 19.3.11.7. Refer to 23.3.9.4.5 for a description of the LDPC encoding process for S1G MU PPDUs.

23.3.9.4.4.2 Padding for LDPC

For LDPC encoding, the number of PHY padding bits for user u, $N_{PAD,u}$ is calculated as

$$N_{PAD,u} = N_{SYM,init} \times N_{DBPS,u} - 8 \times PSDU_LENGTH_u - N_{service}$$

where

$PSDU_LENGTH_u$ is the value of the TXVECTOR parameter PSDU_LENGTH for user u

$N_{SYM,init}$ is the initial number of symbols for the Data field when using LDPC given in 23.4.3 by Equation (23-82) for S1G SU PPDUs and Equation (23-83) for S1G MU PPDUs.

For SU, there is only one user, hence $N_{PAD} = N_{PAD,0}$.

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The padding flow for LDPC encoded PPDUs is as follows:

The initial parameter computation $N_{SYM,init}$, N_{pld} and N_{avbits} are identical to those defined in 21.3.10.5.4.

For an S1G MU PPDU, or an S1G SU PPDU with the Aggregation subfield equal to 1 in its SIG field or SIG-A field, the MAC delivers a PSDU that fills the available octets in the Data field of the PPDU for each user *u* (i.e., append the maximum number of octets that is less than or equal to N_{PAD} or $N_{PAD,u}$). The PHY determines the number of pad bits, which is N_{PAD} mod 8 or $N_{PAD,u}$ mod 8, and appends them to the PSDU, each of the PHY padding bits could be either 0 or 1. In this case, the Length subfield in SIG field or SIG-A field shall set the appropriate value indicating N_{SYM} data symbols.

For an S1G SU PPDU with the Aggregation subfield equal to 0 in its SIG field or SIG-A field, MAC padding is not conducted and the PHY directly appends N_{PAD} padding bits to the PSDU, each of the PHY padding bits could be either 0 or 1. In this case, the Length field shall set the appropriate value indicating PSDU_LENGTH in number of octets

Both the PSDU and the PHY padding bits are scrambled, and then finally the scrambled PSDU and PHY padding bits are LDPC encoded according to 21.3.10.5.4.

In both cases, if $N_{SYM} > N_{SYM,\ init}$, the LDPC Extra subfield of SIG field or SIG-A field shall be set to 1 (see 23.3.8.2.2.5, 23.3.8.2.3.2.5, and 23.3.8.3.5).

23.3.9.4.5 Encoding process for S1G MU PPDUs

The encoding process for S1G MU PPDUs using S1G_LONG is the same as those specified in 21.3.10.5.5.

23.3.9.5 Repetition for 1 MHz MCS 10

In an 1 MHz PPDU that is modulated by MCS 10, the 6 information bits of each OFDM symbol are encoded with R=1/2, then the 12 encoded bits in each OFDM symbol is block-wise repeated by the following steps.

Assume that the sequence $[C_1 \ldots C_{12}]$ represents the 12 encoded bits in each OFDM symbol, the output bit stream after the repetition is:

$$C_{out}=[[C_1 \ldots C_{12}], [C_1 \ldots C_{12}] \text{ XOR } s], \quad (23\text{-}49)$$

where

s = [1 0 0 0 0 1 0 1 0 1 1 1]

The 24 output bits of the repetition are then sent to BCC interleaver (if BCC encoded) or the constellation mapper (if LDPC encoded).

23.3.9.6 Stream parser

The stream parser for S1G PPDUs is the same as those specified in 21.3.10.6 with up to 4 spatial streams.

For S1G_1M PPDU modulated using MCS 10, more than one spatial stream shall not be applied.

23.3.9.7 Segment parser

The segment parser for S1G 16 MHz PPDUs is the same as those specified for 160 MHz PPDUs in 21.3.10.7.

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23.3.9.8 BCC interleaver

The BCC interleavers for S1G 2 MHz, 4 MHz, 8 MHz, and 16 MHz PPDUs are the same as those defined for 20 MHz, 40 MHz, 80 MHz, and 160 MHz PPDUs, respectively, as specified in 21.3.10.8.

For S1G_1M PPDU, the interleaver parameters are defined by Table 23-20.

Table 23-20—Number of rows and columns in the interleaver for 1 MHz

Parameter	1 MHz
N_{COL}	8
N_{ROW}	$3 \times N_{BPSCS}$
N_{ROT} ($N_{SS} \leq 4$)	2

The interleaver parameters for 1 MHz MCS 10 is identical to the parameters used for 1 MHz MCS 0.

23.3.9.9 Constellation mapping

23.3.9.9.1 General

The constellation mappings for S1G PPDUs modulated using MCS 0 to MCS 9 are the same as those specified in 21.3.10.9.1 with the same MCS indices.

The constellation mapping for 1 MHz MCS 10 is identical to the BPSK constellation mapping that is applied in MCS 0.

23.3.9.9.2 LDPC tone mapping

The LDPC tone mappings for S1G 2 MHz, 4 MHz, 8 MHz, and 16 MHz PPDUs are the same as those defined for 20 MHz, 40 MHz, 80 MHz, and 160 MHz PPDUs, respectively, as specified in 21.3.10.9.2.

For LDPC encoded S1G_1M PPDU, LDPC tone mapping is not applied.

23.3.9.9.3 Segment deparser

The segment deparser for S1G 16 MHz PPDUs is the same as those specified for 160 MHz PPDUs in 21.3.10.9.3.

23.3.9.9.4 Space-time block coding

The STBC for S1G PPDUs is the same as those specified in 21.3.10.9.4.

For S1G_1M PPDU modulated using MCS 10, STBC shall not be applied.

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23.3.9.10 Pilot subcarriers

For an S1G_1M SIG field and Data field, two pilot tones shall be inserted in subcarriers. For fixed pilots, the pilot mapping for subcarrier k for symbol n shall be as specified in Equation (23-50).

$$P_n^{\{-7,7\}} = \{\psi_{(n \bmod 2)+2}, \psi_{((n+1) \bmod 2)+2}\} \quad (23\text{-}50)$$

$$P_n^{k \notin \{-7,7\}} = 0$$

where

ψ_m is given in Table 21-21 in 21.3.10.10

For S1G_SHORT PPDU and S1G_LONG PPDU, with fixed pilots, P_n^k with same FFT sizes is identical to what is defined in 21.3.10.10.

For traveling pilots, at symbol n, P_n^k is defined as follows:

$$P_n^k = \begin{cases} 1.5 \times P_{n,\,\text{fix}}^{k_{\text{Pilot_Fix}}^{(l)}}, & k \in K_{\text{Pilot_Travel}}(n) \text{ and } k = K_{\text{Pilot_Travel}}^{(l)}(n) \\ 0, & \text{otherwise} \end{cases} \quad (23\text{-}51)$$

where

$K_{\text{Pilot_Travel}}(n)$ is the set of traveling pilot subcarrier positions corresponding to data symbol n ($n = 0,1,2,\ldots N_{SYM}-1$)

$K_{\text{Pilot_Travel}}^{(l)}(n)$ is the pilot tone position in the pilot subcarrier set $K_{\text{Pilot_Travel}}(n)$ corresponding to pilot index l, as shown in Table 23-21 to Table 23-28

$P_{n,\,\text{fix}}^k$ is identical to P_n^k for fixed pilots

$k_{\text{Pilot_Fix}}^{(l)}$ is the pilot tone position corresponding to pilot index l in the case of fixed pilots, specifically:

For 1 MHz, $\{k_{\text{Pilot_Fix}}^{(0)}, k_{\text{Pilot_Fix}}^{(1)}\} = \{-7, 7\}$

For 2 MHz, $\{k_{\text{Pilot_Fix}}^{(0)}, \ldots, k_{\text{Pilot_Fix}}^{(3)}\} = \{-21, -7, 7, 21\}$

For 4 MHz, $\{k_{\text{Pilot_Fix}}^{(0)}, \ldots, k_{\text{Pilot_Fix}}^{(5)}\} = \{-53, -25, -11, 11, 25, 53\}$

For 8 MHz, $\{k_{\text{Pilot_Fix}}^{(0)}, \ldots, k_{\text{Pilot_Fix}}^{(7)}\} = \{-103, -75, -39, -11, 11, 39, 75, 103\}$

For 16 MHz,

$\{k_{\text{Pilot_Fix}}^{(0)}, \ldots, k_{\text{Pilot_Fix}}^{(15)}\} = \{-231, -203, -167, -139, -117, -89, -53, -25, 25, 53, 89, 117, 139, 167, 203, 231\}$

The traveling pilot positions for symbol n, $K_{\text{Pilot_Travel}}(n)$, are derived by the following paragraphs.

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For an S1G SU PPDU where in its SIG field or SIG-A field the NSTS subfield indicates one space-time stream and the Traveling Pilots subfield is set to 1, the traveling pilots positions $K_{\text{Pilot_Travel}}(n)$ varies from symbol to symbol according to Table 23-21 to Table 23-24 for bandwidth 1 MHz, 2 MHz, 4 MHz, and 8 MHz. In this case, for data symbol n (n = 0,1,2,….N_{SYM}-1), the pilot positions $K_{\text{Pilot_Travel}}(n)$ equal to those in the column corresponding to the pattern index.:

$$m(n) = n \bmod N_{TP,BW} \tag{23-52}$$

where

$N_{TP,BW}$ is the traveling pilot pattern period with the following values:

$N_{TP,1\text{MHz}} = 13$

$N_{TP,2\text{MHz}} = 14$

$N_{TP,4\text{MHz}} = 19$

$N_{TP,8\text{MHz}} = 32$

$N_{TP,16\text{MHz}} = 32$

Table 23-21—Traveling pilot positions for NSTS=1, 1 MHz S1G PPDU

Pilot Index *l*	Pattern Index *m*												
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
0	–2	–10	–5	–13	–8	–3	–11	–6	–1	–9	–4	–12	–7
1	12	4	9	1	6	11	3	8	13	5	10	2	7

Table 23-22—Traveling pilot positions for NSTS=1, 2 MHz S1G PPDU

Pilot Index *l*	Pattern Index *m*													
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
0	–28	–24	–20	–16	–26	–22	–18	–27	–23	–19	–15	–25	–21	–17
1	–12	–8	–4	–2	–14	–10	–6	–11	–7	–3	1	–13	–9	–5
2	4	8	12	16	2	6	10	5	9	13	17	–1	3	7
3	20	24	28	26	14	18	22	21	25	23	27	11	15	19

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Table 23-23—Traveling pilot positions for NSTS=1, 4 MHz S1G PPDU

Pilot Index *l*	Pattern Index *m*																		
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
0	–49	–41	–33	–25	–17	–9	–58	–50	–42	–34	–26	–18	–10	–2	–51	–43	–35	–27	–19
1	–30	–22	–14	–6	–55	–47	–39	–31	–23	–15	–7	–56	–48	–40	–32	–24	–16	–8	–57
2	–11	–3	–52	–44	–36	–28	–20	–12	–4	–53	–45	–37	–29	–21	–13	–5	–54	–46	–38
3	11	19	27	35	43	51	2	10	18	26	34	42	50	58	9	17	25	33	41
4	30	38	46	54	5	13	21	29	37	45	53	4	12	20	28	36	44	52	3
5	49	57	8	16	24	32	40	48	56	7	15	23	31	39	47	55	6	14	22

Table 23-24—Traveling pilot positions for NSTS=1, 8 MHz S1G PPDU

Pilot Index *l*	Pattern Index *m*															
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
0	–122	–118	–114	–110	–106	–102	–98	–94	–120	–116	–112	–108	–104	–100	–96	–92
1	–90	–86	–82	–78	–74	–70	–66	–62	–88	–84	–80	–76	–72	–68	–64	–60
2	–58	–54	–50	–46	–42	–38	–34	–30	–56	–52	–48	–44	–40	–36	–32	–28
3	–26	–22	–18	–14	–10	–6	–2	2	–24	–20	–16	–12	–8	–4	2	4
4	6	10	14	18	22	26	30	34	8	12	16	20	24	28	32	36
5	38	42	46	50	54	58	62	66	40	44	48	52	56	60	64	68
6	70	74	78	82	86	90	94	98	72	76	80	84	88	92	96	100
7	102	106	110	114	118	122	120	–120	104	108	112	116	120	122	–2	–122

Pilot Index *l*	Pattern Index *m*															
	16	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
0	–121	–117	–113	–109	–105	–101	–97	–93	–119	–115	–111	–107	–103	–99	–95	–91
1	–89	–85	–81	–77	–73	–69	–65	–61	–87	–83	–79	–75	–71	–67	–63	–59
2	–57	–53	–49	–45	–41	–37	–33	–29	–55	–51	–47	–43	–39	–35	–31	–27
3	–25	–21	–17	–13	–9	–5	–2	3	–23	–19	–15	–11	–7	–3	2	5
4	7	11	15	19	23	27	31	35	9	13	17	21	25	29	33	37
5	39	43	47	51	55	59	63	67	41	45	49	53	57	61	65	69
6	71	75	79	83	87	91	95	99	73	77	81	85	89	93	97	101
7	103	107	111	115	119	121	2	–121	105	109	113	117	121	121	–2	–121

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For an S1G SU PPDU where in its SIG field or SIG-A field the NSTS subfield indicates two space-time streams, STBC subfield is set to 1 and the Traveling Pilots subfield is set to 1, the traveling pilots positions $K_{\text{Pilot_Travel}}(n)$ varies every other symbol according to Table 23-25 to Table 23-28 for bandwidth 1 MHz, 2 MHz, 4 MHz, and 8 MHz. In this case, for data symbol n (n = 0,1,2,….N_{SYM}–1), the pilot positions $K_{\text{Pilot_Travel}}(n)$ equal to those in the column corresponding to the pattern index.

$$m(n) = \left\lfloor \frac{n}{2} \right\rfloor \bmod N_{TP,BW} \tag{23-53}$$

where

$N_{TP,BW}$ is the traveling pilot pattern period with the following values:

$N_{TP,1\text{MHz}} = 7$

$N_{TP,2\text{MHz}} = 7$

$N_{TP,4\text{MHz}} = 10$

$N_{TP,8\text{MHz}} = 16$

$N_{TP,16\text{MHz}} = 16$

Table 23-25—Traveling pilot positions for NSTS=2 and STBC=1, 1 MHz S1G PPDU

Pilot Index *l*	Pattern Index *m*						
	0	**1**	**2**	**3**	**4**	**5**	**6**
0	–3	–13	–9	–5	–1	–11	–7
1	11	1	5	9	13	3	7

Table 23-26—Traveling pilot positions for NSTS=2 and STBC=1, 2 MHz S1G PPDU

Pilot Index *l*	Pattern Index *m*						
	0	**1**	**2**	**3**	**4**	**5**	**6**
0	–28	–24	–20	–16	–26	–22	–18
1	–12	–8	–4	–2	–14	–10	–6
2	4	8	12	16	2	6	10
3	20	24	28	26	14	18	22

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Table 23-27—Traveling pilot positions for NSTS=2 and STBC=1, 4 MHz S1G PPDU

Pilot Index *l*	Pattern Index *m*									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	–50	–44	–38	–32	–26	–20	–14	–8	–2	–56
1	–30	–24	–18	–12	–6	–58	–54	–48	–42	–36
2	–10	–4	–58	–52	–46	–40	–34	–28	–22	–16
3	10	16	22	28	34	40	46	52	58	4
4	30	36	42	48	54	58	6	12	18	24
5	50	56	2	8	14	20	26	32	38	44

Table 23-28—Traveling pilot positions for NSTS=2 and STBC=1, 8 MHz S1G PPDU

Pilot Index *l*	Pattern Index *m*															
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
0	–122	–118	–114	–110	–106	–102	–98	–94	–120	–116	–112	–108	–104	–100	–96	–92
1	–90	–86	–82	–78	–74	–70	–66	–62	–88	–84	–80	–76	–72	–68	–64	–60
2	–58	–54	–50	–46	–42	–38	–34	–30	–56	–52	–48	–44	–40	–36	–32	–28
3	–26	–22	–18	–14	–10	–6	–2	2	–24	–20	–16	–12	–8	–4	2	4
4	6	10	14	18	22	26	30	34	8	12	16	20	24	28	32	36
5	38	42	46	50	54	58	62	66	40	44	48	52	56	60	64	68
6	70	74	78	82	86	90	94	98	72	76	80	84	88	92	96	100
7	102	106	110	114	118	122	120	–120	104	108	112	116	120	122	–2	–122

For a 16 MHz S1G PPDU with traveling pilots, in the data symbol n (n = 0,1,2,…N_{SYM}–1), there are a total of 16 pilot subcarriers, whose positions $K_{\text{Pilot_Travel}}(n)$ are expressed as

$$K_{\text{Pilot_Travel}}(n) = \begin{cases} K_{\text{Pilot_Travel,8MHz}}(n) - 128, \text{ for pilot indices } 0 \le l \le 7 \\ K_{\text{Pilot_Travel,8MHz}}(n) + 128, \text{ for pilot indices } 8 \le l \le 15 \end{cases} \quad (23\text{-}54)$$

where $K_{\text{Pilot_Travel,8MHz}}(n)$ is the traveling pilot positions of the 8 pilot subcarriers for symbol index n and 8 MHz, calculated based on Table 23-24 for a single space-time stream, or based on Table 23-28 for STBC with two space-time streams.

For S1G MU PPDUs, or S1G SU PPDUs with more than two space-time streams, or S1G SU PPDUs with two space-time streams without STBC, traveling pilots are not defined.

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23.3.9.11 OFDM modulation

For S1G transmissions using S1G_SHORT, the Data field signal from transmit chain i_{TX}, $1 \le i_{TX} \le N_{TX}$, shall be as specified in Equation (23-55).

$$r_{Data}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{Data}}^{\text{Tone}} N_{\text{STS}}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - T_{Accum}(n)) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} ([Q_k]_{i_{TX},m} \gamma_{k,BW} (\tilde{D}_{k,m,n,BW} + [P_{HTLTF}]_{m,g(n)} \cdot p_{n+2} P_n^k) \exp(j2\pi k \Delta_F (t - T_{Accum}(n) - T_{GI,Data}(n) - T_{CS}(m)))) \quad (23\text{-}55)$$

where

$$g(n) = \begin{cases} (n \bmod 2) + 1, & \text{if the STBC bit and Traveling Pilots bit in SIG field are both set to 1} \\ 1, & \text{otherwise} \end{cases}$$

For S1G transmissions using S1G_LONG, the Data field signal from transmit chain i_{TX}, $1 \le i_{TX} \le N_{TX}$, shall be as specified in Equation (23-56).

$$r_{Data}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{Data}}^{\text{Tone}} N_{\text{STS,total}}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - T_{Accum}(n)) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_u - 1} \sum_{m=1}^{N_{STS,u}} ([Q_k]_{i_{TX},(M_u+m)} \gamma_{k,BW} (\tilde{D}_{k,m,n,BW} + [P_{HTLTF}]_{m,g(n)} \cdot p_{z(n)} P_{(z(n)-2)}^k) \exp(j2\pi k \Delta_F (t - T_{Accum}(n) - T_{GI,Data}(n) - T_{CS}(m)))) \quad (23\text{-}56)$$

where

$$g(n) = \begin{cases} (n \bmod 2) + 1, & \text{if the STBC bit and Traveling Pilots bit in SIG-A field are both set to 1} \\ 1, & \text{otherwise} \end{cases}$$

For S1G transmissions using S1G_1M, the Data field signal from transmit chain i_{TX}, $1 \le i_{TX} \le N_{TX}$, shall be as specified in Equation (23-57).

$$r_{Data}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{Data}}^{\text{Tone}} N_{\text{STS}}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - T_{Accum}(n)) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} ([Q_k]_{i_{TX},m} \gamma_{k,BW} (\tilde{D}_{k,m,mn,BW} + [P_{HTLTF}]_{m,1} \cdot p_{n+6} P_n^k) \exp(j2\pi k \Delta_F (t - T_{Accum}(n) - T_{GI,Data}(n) - T_{CS}(m)))) \quad (23\text{-}57)$$

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where

N_{SR} is defined in Table 23-4

p_n is defined in 17.3.5.10

P_n^k is defined in 23.3.9.10

$T_{CS(m)}$ represents the cyclic shift for space-time stream m with a value given in Table 23-9 in the case of ≥ 2 MHz formats, and in Table 23-17 in the case of S1G_1M

$\Upsilon_{k,\mathrm{BW}}$ is defined by Equation (23-6) to Equation (23-9)

Δ_F is defined in Table 23-4

N_{STS}, $N_{STS,total}$, and $N_{STS,u}$ are defined in Table 23-6

P_{HTLTF} is defined in Equation (19-27) in 19.3.9.4.6

$N_{\mathrm{Data}}^{\mathrm{Tone}}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-7

N_u, and M_u are defined in Table 23-6

$z(n)$ in Equation (23-56) is defined as follows:

$$z(n) = \begin{cases} n+2, \text{ if the MU/SU bit in SIG-A field is set to 0} \\ n+3, \text{ if the MU/SU bit in SIG-A field is set to 1} \end{cases}$$

$T_{GI,Data}(n)$ is the guard interval duration with the value as follows:

$$T_{GI,Data}(n) = \begin{cases} T_{GI}, \text{ if } n = 0 \\ T_{GI}, \text{ if } n > 0 \text{ and Short GI subfield of SIG or SIG-A field is 0} \\ T_{SGI}, \text{ if } n > 0 \text{ and Short GI subfield of SIG or SIG-A field is 1} \end{cases} \quad (23\text{-}58)$$

$\tilde{D}_{k,m,n,BW}$ is defined by Equation (23-59).

$$\tilde{D}_{k,m,n,BW} = \begin{cases} 0, & \text{if } k \in K_{\mathrm{Pilot}}(n) \\ d_{M'_{BW}(k),\,m,\,n,} & \text{otherwise} \end{cases} \quad (23\text{-}59)$$

where

$$K_{Pilot}(n) = \begin{cases} K_{Pilot_\mathrm{Fix}}, & \text{if the Traveling Pilot bit in SIG or SIG-A field is set to 0} \\ K_{Pilot_\mathrm{Travel}}(n), & \text{if the Traveling Pilot bit in SIG or SIG-A field is set to 1} \end{cases} \quad (23\text{-}60)$$

in which $K_{\mathrm{Pilot_Fix}}$ is defined in 23.3.8.2.2.4 for ≥ 2 MHz and 23.3.8.3.4 for 1 MHz, and $K_{\mathrm{Pilot_Travel}}(n)$ is defined in 23.3.9.10; and $M'_{BW}(k)$ is defined in Equation (23-30) to Equation (23-35) in 23.3.8.2.3.5 for 2 MHz, 4 MHz, 8 MHz, and 16 MHz, as well as Equation (23-44) in 23.3.8.3.5 for 1 MHz.

$T_{Accum}(n)$ is the accumulated duration from data symbol 0 to data symbol (*n-1*).

$$T_{Accum}(n) = \begin{cases} 0, & \text{if } n = 0 \\ T_{SYML} + (n-1)T_{SYM}, & \text{if } n > 0 \end{cases} \quad (23\text{-}61)$$

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where

T_{SYML} and T_{SYM} are defined in Table 23-4

Q_k is a spatial mapping/steering matrix with N_{TX} rows and N_{STS} or $N_{STS,total}$ columns for subcarrier k. Q_k may be frequency dependent. Refer to the examples of listed in 19.3.11.11.2 for examples of that could be used for S1G SU PPDUs. Note that implementations are not restricted to the spatial mapping matrix examples listed in 19.3.11.11.2 and the number of transmit chains N_{TX} could be up to 4. For SU PPDUs to which beamforming is applied, Q_k is a beamforming steering matrix and is derived from the TXVECTOR parameter EXPANSION_MAT. For S1G MU PPDUs, Q_k is the DL-MU-MIMO steering matrix and is derived from the TXVECTOR parameter EXPANSION_MAT. The beamforming steering matrices and DL-MU-MIMO steering matrices are implementation specific.

The autodetection between 1 MHz and 2 MHz preambles assumes channel smoothness. It is recommended that the spatial mapping matrix Q_k applied to LTF1 field is chosen such that it preserves the smoothness of the physical channel. This can, for example, be achieved by minimizing the amplitude and phase variation of each element of Q_k in successive tones.

Examples:

a) The following may be used Q_k: Q_k as defined for cyclic shift diversity using the values specified in the corresponding tables.

b) The following Q_k should not be used:
   — Antenna hopping as described in 19.3.11.11.2 c) 2)
   — The values of Q_k on successive tones flip between 1 and 0

23.3.9.12 S1G 1 MHz and 2 MHz duplicate transmission

23.3.9.12.1 S1G 1 MHz duplicate transmission

An S1G 1 MHz duplicate transmission is used to transmit to S1G STAs that may be present in a part of a 2 MHz, 4 MHz, 8 MHz, or 16 MHz channel.

In an S1G 1 MHz duplicate PPDU, both the S1G_1M preamble and Data field are duplicated in each 1 MHz subchannel of the 2 MHz, 4 MHz, 8 MHz, or 16 MHz channel. Both an 1 MHz data PPDU and an 1 MHz NDP may be duplicated.

For S1G 1 MHz duplicate transmission, the Data field signal from transmit chain i_{TX}, $1 \le i_{TX} \le N_{TX}$, shall be as specified in Equation (23-62).

$$r_{Data}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{1\text{MHz_DUP_Data}}^{\text{Tone}} N_{STS}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - T_{Accum}(n)) \sum_{i_{BW}=0}^{N_{1MHz}-1} \left(\sum_{k=-13}^{13} \sum_{m=1}^{N_{STS}} [Q_k]_{i_{TX}, m} \gamma_{1MHz,\, k-(K_{Shift,\,1MHz}(i_{BW})),\, BW} (\tilde{D}_{k,m,n,1MHz} + [P_{HTLTF}]_{m,\, g(n)} \cdot p_{n+6} P_n^k) \right.$$
$$\left. \exp(j2\pi(k - K_{Shift,\,1MHz}(i_{BW}))\Delta_F \cdot (t - T_{Accum}(n) - T_{GI,\,Data}(n) - T_{CS}(m))) \right) \quad (23\text{-}62)$$

where

p_n is defined in 17.3.5.10

P_n^k is defined in 23.3.9.10

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$T_{CS(m)}$ represents the cyclic shift for space-time stream m with a value given in Table 23-17

$\Upsilon_{1MHz,k,\mathrm{BW}}$ is defined by Equation (23-10) to Equation (23-13)

Δ_F is defined in Table 23-4

N_{STS} is defined in Table 23-6

P_{HTLTF} is defined in Equation (19-27) in 19.3.9.4.6

$N^{\mathrm{Tone}}_{1\mathrm{MHz_DUP_Data}}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-7

$T_{GI,Data}(n)$ is defined in Equation (23-58)

$\tilde{D}_{k,n,n,BW}$ is defined in Equation (23-59)

$T_{Accum}(n)$ is defined in Equation (23-61)

N_{1MHz} is the number of 1 MHz subchannels that are contained within the whole bandwidth of the current PPDU (e.g., $N_{1MHz} = 4$ for a 4 MHz PPDU)

$$g(n) = \begin{cases} (n \bmod 2) + 1, & \text{if the STBC bit and Traveling Pilots bit in SIG-A field are both set to 1} \\ 1, & \text{otherwise} \end{cases}$$

$$K_{Shift,1MHz}(i) = (N_{1MHz} - 1 - 2i).16 \tag{23-63}$$

23.3.9.12.2 S1G 2 MHz duplicate transmission

An S1G 2 MHz duplicate transmission is used to transmit to S1G STAs that may be present in a part of a 4 MHz, 8 MHz, or 16 MHz channel.

In an S1G 2 MHz duplicate PPDU, the S1G_SHORT preamble and Data field are duplicated in each 2 MHz subchannel of the 4 MHz, 8 MHz, or 16 MHz channel.

A 2 MHz NDP sounding shall not be duplicated. Instead, a 4 MHz, 8 MHz, or 16 MHz NDP shall be transmitted whenever needed. NDP CMAC PPDUs transmitted over a 4 MHz, 8 MHz, or 16 MHz channel shall be carried in an S1G 2 MHz duplicate frame.

For an S1G 2 MHz duplicate PPDU, the Data field signal from transmit chain i_{TX}, $1 \le i_{TX} \le N_{TX}$, shall be as specified in Equation (23-64).

$$r^{(i_{TX})}_{Data}(t) = \frac{1}{\sqrt{N^{\mathrm{Tone}}_{2\mathrm{MHz_DUP_Data}} N_{STS}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - T_{Accum}(n)) \sum_{i_{BW}=0}^{N_{2MHz}-1} \left(\sum_{k=-28}^{28} \sum_{m=1}^{N_{STS}} \right.$$

$$\left([Q_k]_{i_{TX},m} \gamma_{(k - K_{Shift}(i_{BW})),BW} (\tilde{D}_{k,m,n,2MHz} + [P_{HTLTF}]_{m,g(n)} \cdot p_{n+2} P^k_n) \right.$$

$$\left. \left. \exp(j2\pi(k - K_{Shift}(i_{BW}))\Delta_F \cdot (t - T_{Accum}(n) - T_{GI,Data}(n) - T_{CS}(m))) \right) \right) \tag{23-64}$$

where

p_n is defined in 17.3.5.10

P^k_n is defined in 23.3.9.10

$T_{CS(m)}$ represents the cyclic shift for space-time stream m with a value given in Table 23-9

$\Upsilon_{k,\mathrm{BW}}$ is defined by Equation (23-6) to Equation (23-9)

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Δ_F	is defined in Table 23-4
N_{STS}	is defined in Table 23-6
P_{HTLTF}	is defined in Equation (19-27) in 19.3.9.4.6
$N^{\text{Tone}}_{\text{2MHz_DUP_Data}}$	has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-7
$T_{GI,Data}(n)$	is defined in Equation (23-58)
$\tilde{D}_{k,n,n,BW}$	is defined in Equation (23-59)
$T_{Accum}(n)$	is defined in Equation (23-61)
N_{2MHz}	is the number of 2 MHz subchannels that are contained within the whole bandwidth of the current PPDU (e.g., $N_{2MHz} = 2$ for a 4 MHz PPDU)

$$g(n) = \begin{cases} (n \bmod 2) + 1, & \text{if the STBC bit and Traveling Pilots bit in SIG-A field are both set to 1} \\ 1, & \text{otherwise} \end{cases}$$

$K_{Shift}(i)$ is defined in Equation (23-19)

23.3.10 SU-MIMO and DL-MU-MIMO Beamforming

23.3.10.1 General

S1G SU-MIMO and DL-MU-MIMO beamforming are techniques used by a STA with multiple antennas (the beamformer) to steer signals using knowledge of the channel to improve throughput. The general description of SU-MIMO and DL-MU-MIMO beamforming is identical to its VHT counterparts as described in 21.3.11.1 with VHT replaced by S1G.

In S1G operation, the SU-MIMO allows beamforming up to 4 space-time streams, and DL-MU-MIMO beamforming allows up to 4 total number of space-time streams for all users each with up to 3 space-time streams.

S1G beamforming exchange is defined only for 2 MHz, 4 MHz, 8 MHz, and 16 MHz.

23.3.10.2 Beamforming Feedback Matrix V

The description of beamforming feedback matrix V in an S1G band is identical to its VHT counterpart as described in 21.3.11.2 with VHT replaced by S1G.

Compressed beamforming feedback using 19.3.12.3.6 is the only beamforming feedback format defined for S1G operation. In certain cases when the ψ angle is not included in the feedback frame (e.g., for SU feedback with $N_c = 1$), the ψ angles not included in the feedback report are given the values below, which will correspond to a single column V matrix having elements with equal magnitude:

If $N_r \times N_c = 4 \times 1$, $\Psi_{21} = 0.25\pi$, $\Psi_{31} = 0.196\pi$, $\Psi_{41} = 0.167\pi$
If $N_r \times N_c = 3 \times 1$, $\Psi_{21} = 0.25\pi$, $\Psi_{31} = 0.196\pi$
If $N_r \times N_c = 2 \times 1$, $\Psi_{21} = 0.25\pi$

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23.3.10.3 Maximum Number of Total Spatial Streams in S1G MU PPDUs

An MU capable STA shall support reception of S1G MU PPDUs with the total number of space-time streams across the NUM_USERS users being less than or equal to its Compressed Steering Number of Beamformer Antennas Supported in the S1G Capabilities Information field. The upper limit is 4 spatial streams.

23.3.10.4 Group ID

The description of Group ID in an S1G band is identical to its VHT counterpart as described in 21.3.11.4 with VHT replaced by S1G.

23.3.11 S1G preamble format for NDPs

An NDP may be used for sounding or for NDP CMAC PPDUs. In the case of NDP sounding, the SIG field in an NDP shall indicate multiple space-time streams and more than one LTF fields; NDP CMAC PPDUs only contain single space-time stream with one LTF field.

NDP is the only S1G sounding format.

NDP for sounding is defined only using the S1G_SHORT, and NDP for sounding is not allowed for 1 MHz transmissions. NDP CMAC PPDUs may either use an S1G_SHORT, or an S1G_1M.

The format of an S1G NDP for sounding is shown in Figure 23-17.

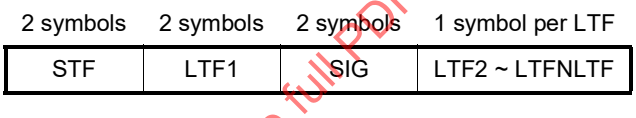

Figure 23-17—S1G NDP for sounding format

NOTE—The number of LTF symbols in the NDP is determined by the NSTS subfield in SIG field.

Transmission of an S1G NDP for sounding shall comply with the following rules:

- Shall use the S1G PPDU format but without the Data field.
- Shall use the S1G_SHORT.
- Shall use the following settings in SIG field:
  - MCS field is set to 0.
  - Length field is set to 0.
  - Bandwidth field is set to the same value as the TXVECTOR parameter CH_BANDWIDTH in the preceding VHT NDP Announcement frame carried in an S1G PPDU.
  - NSTS field indicates two or more space-time streams.
  - Partial AID field is set as described in 10.21.
  - The NDP indication bit is set to 0.
  - Response Indication field is set to Long Response (see TXVECTOR parameter RESPONSE_INDICATION).

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The format of an NDP CMAC PPDU in 2 MHz, 4 MHz, 8 MHz, or 16 MHz is shown in Figure 23-18. The > 2 MHz NDP CMAC PPDUs are 2 MHz NDP CMAC PPDUs duplicated up to the transmission bandwidth according to CH_BANDWIDTH in TXVECTOR.

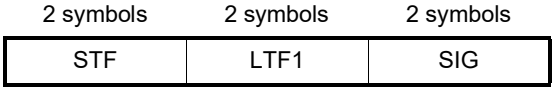

Figure 23-18—NDP CMAC PPDU for ≥ 2 MHz

The format of an S1G NDP CMAC PPDU in 1 MHz is shown in Figure 23-19. S1G NDP CMAC PPDUs for 1 MHz are duplicated up to their transmission bandwidth according to CH_BANDWIDTH in TXVECTOR.

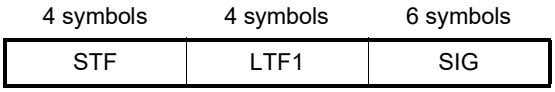

Figure 23-19—NDP CMAC PPDU for 1 MHz

Transmission of an NDP CMAC PPDU shall comply with the following rules:

- Shall use the S1G PPDU format but without the Data field.
- Shall use either the S1G_SHORT or the S1G_1M.
- Shall use the following settings in SIG field:
  - The NDP indication bit is set to 1.
- Shall contain only one LTF field.

The SIG field formats of NDP CMAC PPDUs are shown in Figure 23-20 and Figure 23-21.

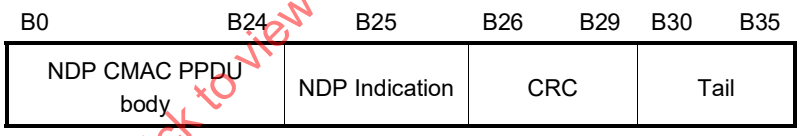

Figure 23-20—SIG field format for 1 MHz NDP CMAC PPDU

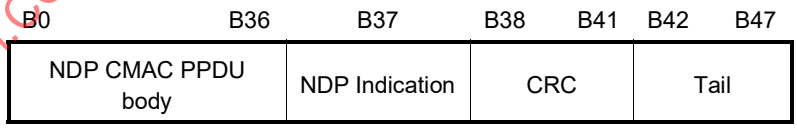

Figure 23-21—SIG field format for ≥ 2 MHz NDP CMAC PPDU

The NDP CMAC PPDU body field is described in 23.3.12.

The NDP Indication field is set to 1.

The CRC field is described in 23.3.8.2.2.6. Tail field is set to 0.

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23.3.12 NDP CMAC PPDUs

23.3.12.1 General

The format of NDP CMAC PPDUs that use the S1G_1M format is shown in Figure 23-19. Figure 23-20 shows the SIG field format that contains the NDP CMAC PPDU body field. B25 of the SIG field (the second bit of the fifth symbol) is set to 1 to indicate an NDP CMAC PPDU. The NDP CMAC PPDU body field is 25 bits for NDP CMAC PPDUs that are transmitted using the S1G_1M format (NDP_1M).

The format of NDP CMAC PPDUs that use the S1G_SHORT format is shown in Figure 23-18. Figure 23-21 shows the SIG field format that contains the NDP CMAC PPDU body field. B37 of the SIG field (the fourteenth bit of the second symbol) is set to 1 to indicate an NDP CMAC PPDU. The NDP CMAC PPDU body field is 37 bits for NDP CMAC PPDUs that are transmitted using the S1G_SHORT format (NDP_2M).

An NDP CMAC PPDU is indicated by setting the TXVECTOR parameter NDP_INDICATION to 1. The TXVECTOR parameter NDP_CMAC_PPDU_BODY is set to the concatenated bits of the NDP CMAC PPDU body field.

An RXVECTOR parameter NDP_INDICATION equal to 1 indicates reception of an NDP CMAC PPDU, and the NDP CMAC PPDU body field of the frame is obtained from the RXVECTOR parameter NDP_CMAC_PPDU_BODY.

The PHY preamble format for transmission of NDP CMAC PPDUs is defined in 23.3.11.

This subclause describes the NDP CMAC PPDU body field content for each of the NDP CMAC PPDU types. The type of the NDP CMAC PPDU is indicated in the NDP CMAC PPDU Type field and its values are defined in Table 23-29.

NDP CMAC frames are not MPDUs but NDPs, but they obey the rules for equivalent MPDUs, as shown in Table 23-29.

Table 23-29—NDP CMAC PPDU Type field values

Value	Meaning	Equivalent MPDU	See subclause
0	NDP CTS or NDP CF-End	CTS or CF-End	23.3.12.2.1, 23.3.12.2.2
1	NDP PS-Poll	PS-Poll	23.3.12.2.3
2	NDP Ack	Ack	23.3.12.2.4
3	NDP PS-Poll-Ack	Ack to PS-Poll	23.3.12.2.5
4	NDP BlockAck	BlockAck	23.3.12.2.6
5	NDP Beamforming Report Poll	Beamforming Report Poll	23.3.12.2.7
6	NDP Paging	Action	23.3.12.2.8
7	NDP Probe Request	Probe Request	23.3.12.2.9

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23.3.12.2 NDP CMAC PPDU details

23.3.12.2.1 NDP CTS

23.3.12.2.1.1 NDP_1M CTS

The format of the NDP CMAC PPDU body field of the NDP_1M CTS frame is shown in Figure 23-22.

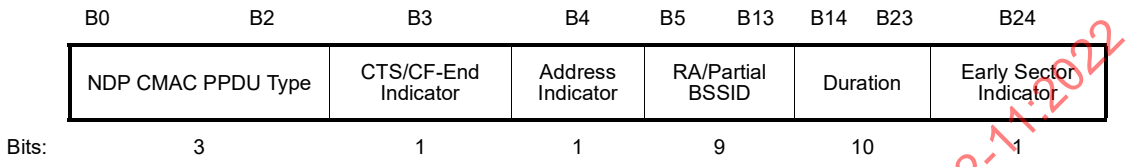

Figure 23-22—NDP CMAC PPDU body field of the NDP_1M CTS frame

The NDP CMAC PPDU Type field is set to 0.

The CTS/CF-End Indicator field is set to 0.

The Address Indicator field is set to 0 to indicate that the RA/Partial BSSID field contains the partial identifier of the receiving STA. It is set to 1 to indicate that the RA/Partial BSSID field contains the partial BSSID of the BSS of the AP transmitting the frame and is interpreted as a broadcast address (see 10.3.2.9 for the receiving STA's behavior). When the NDP CTS frame is used in the sector training it is set to 1.

The RA/Partial BSSID (PBSSID) field indicates:

— RA: the partial AID of the receiving non-AP STA or the partial BSSID of the receiving AP's BSS as described in 10.21

— Partial BSSID: the partial BSSID of the BSS of the transmitting AP as described in 10.21

The Duration field is expressed in units of OFDM symbol duration (40 μs) (Table 23-4) and follows the definitions in 9.3.1.3.

The Early Sector Indicator field is set to 1 to indicate that the NDP CTS frame is followed by the sectorized beam frame exchange. It is set to 0 to indicate that the NDP CTS frame is not followed by the sectorized beam frame exchange.

23.3.12.2.1.2 NDP_2M CTS

The format of the NDP CMAC PPDU body field of the NDP_2M CTS frame is shown in Figure 23-23.

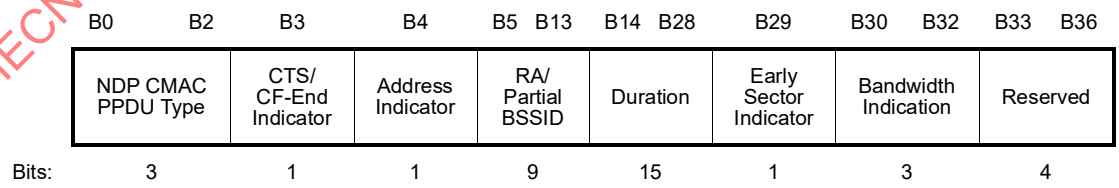

Figure 23-23—NDP CMAC PPDU body field of the NDP_2M CTS frame

The NDP CMAC PPDU Type field is set to 0.

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The CTS/CF-End Indicator field is set to 0.

The Address Indicator field is set to 0 to indicate that the RA/Partial BSSID field contains the partial identifier of the receiving STA. It is set to 1 to indicate that the RA/Partial BSSID field contains the partial BSSID of the BSS of the AP transmitting the frame and is interpreted as a broadcast address (see 10.3.2.9 for the receiving STA's behavior). When the NDP CTS frame is used in the sector training it is set to 1.

The RA/Partial BSSID (PBSSID) field indicates

— RA: the partial AID of the receiving non-AP STA or the partial BSSID of the receiving AP's BSS as described in 10.21
— Partial BSSID: the partial BSSID of the BSS of the transmitting AP as described in 10.21

The Duration field is expressed in units of microseconds and follows the definitions in 9.3.1.3.

The Early Sector Indicator field is set to 1 to indicate that the NDP CTS frame is followed by the sectorized beam frame exchange. It is set to 0 to indicate that the NDP CTS frame is not followed by the sectorized beam frame exchange.

The Bandwidth Indication field is described in 9.2.4.1.11.

23.3.12.2.2 NDP CF-End

23.3.12.2.2.1 NDP_1M CF-End

The format of the NDP CMAC PPDU body field of the NDP_1M CF-End frame is shown in Figure 23-24.

	B0 B2	B3	B4 B12	B13 B22	B23 B24
	NDP CMAC PPDU Type	CTS/CF-End Indicator	Partial BSSID (TA)	Duration	Reserved
Bits:	3	1	9	10	2

Figure 23-24—NDP CMAC PPDU body field of the NDP_1M CF-End frame

The NDP CMAC PPDU Type field is set to 0.

The CTS/CF-End Indicator field is set to 1.

The Partial BSSID field indicates the PARTIAL_AID of the address of the STA contained in the AP.

The Duration field is expressed in units of OFDM symbol time (40 μs) and follows the definitions in 9.3.1.6.

23.3.12.2.2.2 NDP_2M CF-End

The format of the NDP CMAC PPDU body field of the NDP_2M CF-End frame is shown in Figure 23-25.

	B0 B2	B3	B4 B12	B13 B27	B28 B36
	NDP CMAC PPDU Type	CTS/CF-End Indicator	Partial BSSID (TA)	Duration	Reserved
Bits:	3	1	9	15	9

Figure 23-25—NDP CMAC PPDU body field of the NDP_2M CF-End frame

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The NDP CMAC PPDU Type field is set to 0.

The CTS/CF-End Indicator field is set to 1.

The Partial BSSID field indicates the PARTIAL_AID of the address of the STA contained in the AP.

The Duration field is expressed in units of microseconds and follows the definitions in 9.3.1.6.

23.3.12.2.3 NDP PS-Poll

23.3.12.2.3.1 NDP_1M PS-Poll

The format of the NDP CMAC PPDU body field of the NDP_1M PS-Poll frame is shown in Figure 23-26.

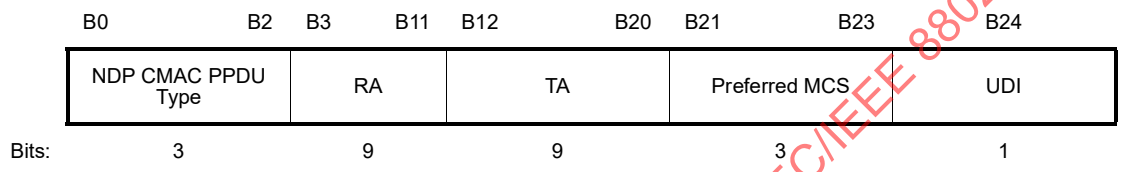

Figure 23-26—NDP CMAC PPDU body field of the NDP_1M PS-Poll frame

The NDP CMAC PPDU Type field is set to 1.

The RA field indicates the partial AID of the STA contained in the AP as described in 10.21.

The TA field indicates the partial AID of the STA transmitting the frame as described in 10.21.

The Preferred MCS field indicates the preferred MCS level for an 1 MHz channel width of the STA for downlink transmission. Mapping between Preferred MCS value and corresponding MCS index is shown in Table 23-30.

Table 23-30—Preferred MCS subfield values for NDP_1M PS-Poll frame

Preferred MCS value	MCS Index	Description
0	0	BPSK 1/2
1	1 or 2	QPSK 1/2 or QPSK 3/4
2	3 or 4	16-QAM 1/2 or 16-QAM 3/4
3	5 or 6	64-QAM 2/3 or 64-QAM 3/4
4	7 or 8	64-QAM 5/6 or 256-QAM 3/4
5	9	64-QAM 5/6
6	10	BPSK 1/4
7	No Preference	

The Uplink Data Indicator (UDI) subfield indicates if the STA has uplink data to transmit:

— Set to 0 to indicate that there is no uplink data present
— Set to 1 to indicate that there is uplink data present

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23.3.12.2.3.2 NDP_2M PS-Poll

The format of the NDP CMAC PPDU body field of the NDP_2M PS-Poll frame is shown in Figure 23-27.

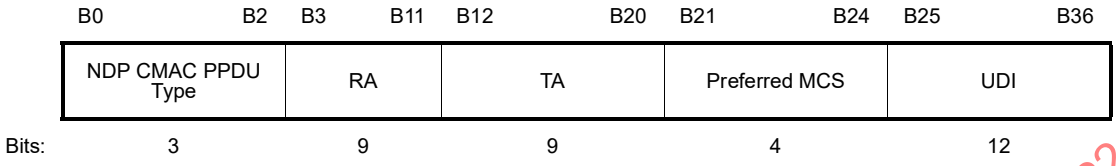

Figure 23-27—NDP CMAC PPDU body field of the NDP_2M PS-Poll frame

The NDP CMAC PPDU Type field is set to 1.

The RA field indicates the partial AID of the address of the STA contained in the AP as described in 10.21.

The TA field indicates the partial AID of the address of the STA transmitting the frame as described in 10.21.

The Preferred MCS field indicates the preferred MCS level for a 2 MHz channel width of the STA for downlink transmission. Mapping between Preferred MCS value and corresponding MCS index is shown in Table 23-31.

Table 23-31—Preferred MCS subfield values for NDP_2M PS-Poll frame

Preferred MCS value	MCS Index	Description
0–9	0–9	The value represents MCS index for the STA's preferred MCS level.
10	No Preference	
11–15	Reserved	

The Uplink Data Indicator (UDI) subfield indicates if the STA has uplink data to transmit and is used by an SST STA to indicate its selected SST channel:

— Set to 0 to indicate that there is no uplink data present
— Set to 1 to indicate that there is uplink data present but the estimated time for the transmission of the uplink Data frames that are present at the STA is not determined.
— Set to a value between 2 and 9 to indicate the relative position of the selected SST channel with respect to the lowest numbered channel in the SST Enabled Channel Bitmap field of a received SST Operation element. For example, setting the UDI to 2 indicates that the selected SST channel is the first channel in the SST Enabled Channel Bitmap field, while setting the UDI to 3 indicates that the selected SST channel is the second channel in the SST Enabled Channel Bitmap field, etc.
— Set to a value greater than 9 to indicate the estimated time, in units of 40 μs, required for the transmission of the uplink Data frames that are present at the STA, excluding the duration of their response and applicable IFS durations.

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23.3.12.2.4 NDP Ack

23.3.12.2.4.1 General

The NDP Ack frame, used to respond to an S1G frame, other than an NDP PS-Poll frame, is described in this subclause.

23.3.12.2.4.2 NDP_1M Ack

The format of the NDP CMAC PPDU body field of the NDP_1M Ack frame is shown in Figure 23-28.

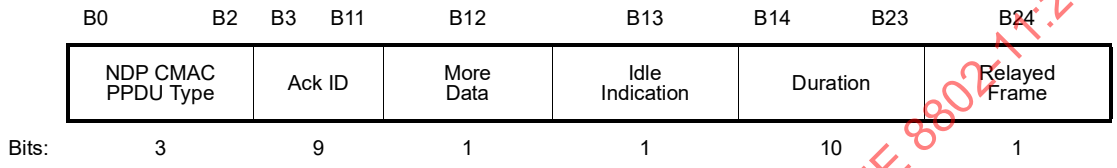

Figure 23-28—NDP CMAC PPDU body field of the NDP_1M Ack frame

The NDP CMAC PPDU Type field is set to 2.

The Ack ID field is set to the bit sequence Scrambler Initialization[0:6] || FCS[30:31] obtained from the scrambler initialization value in the Service field (as defined in 23.3.9.2) prior to descrambling, and the FCS field of the PSDU that carries the soliciting frame. The scrambler initialization value is obtained from the RXVECTOR parameter SCRAMBLER_OR_CRC.

The More Data field is described in 9.2.4.1.8.

The Idle Indication field is set to 0 if the value of the Duration field sets the NAV as described in 9.2.5.7. Otherwise, it is set to 1 if the value of the Duration field indicates an idle period.

If the Idle Indication field is 0, the Duration field is set as described in 9.2.5.7 where the value is expressed in units of 40 μs. If the Idle Indication field is 1, the Duration field is set to the duration of time, in milliseconds, during which an idle period (during which there is no frame transmission) is expected from the STA that elicited the response, starting from the end of the NDP Ack frame response.

The Relayed Frame field is set as described in 10.54.5 and 10.61.

23.3.12.2.4.3 NDP_2M Ack

The format of the NDP CMAC PPDU body field of the NDP_2M Ack frame is shown in Figure 23-29.

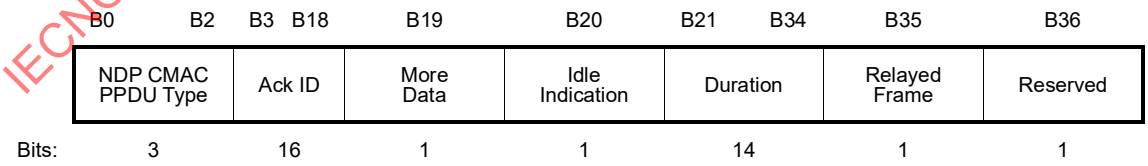

Figure 23-29—NDP CMAC PPDU body field of the NDP_2M Ack frame

The NDP CMAC PPDU Type field is set to 2.

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The Ack ID field is set to the bit sequence Scrambler Initialization [0:6] || FCS[23:31] obtained from the scrambler initialization value in the Service field (as defined in 23.3.9.2) prior to descrambling, and the FCS field of the PSDU that carries the soliciting frame. The scrambler initialization value is obtained from the RXVECTOR parameter SCRAMBLER_OR_CRC.

The More Data field is described in 9.2.4.1.8.

The Idle Indication field is set to 0 if the value of the Duration field sets the NAV as described in 9.2.5.7. Otherwise, it is set to 1 if the value of the Duration field indicates an idle period.

If the Idle Indication field is 0, the Duration field is set as described in 9.2.5.7 where the value is expressed in units of 1 microsecond. If the Idle Indication field is 1, the Duration field is set to the duration of time, in milliseconds, during which an idle period (during which there is no frame transmission) is expected from the STA that elicited the response, starting from the end of the NDP Ack frame response.

The Relayed Frame field is set as described in 10.54.5 and 10.61.

23.3.12.2.5 NDP PS-Poll-Ack

23.3.12.2.5.1 General

The NDP PS-Poll-Ack frame, used to respond to an NDP PS-Poll frame, is described in this subclause.

23.3.12.2.5.2 NDP_1M PS-Poll-Ack

The format of the NDP CMAC PPDU body field of the NDP_1M PS-Poll-Ack frame is shown in Figure 23-30.

	B0 B2	B3 B11	B12	B13	B14 B23	B24
	NDP CMAC PPDU Type	Ack ID	More Data	Idle Indication	Duration	Reserved
Bits:	3	9	1	1	10	1

Figure 23-30—NDP CMAC PPDU body field of the NDP_1M PS-Poll-Ack frame

The NDP CMAC PPDU Type field is set to 3.

The Ack ID field is set to the bit sequence CRC[0:3] || TA[4:8] obtained from the CRC and TA field of the NDP PS-Poll frame that elicited the response. The CRC value is obtained from the RXVECTOR parameter SCRAMBLER_OR_CRC.

The More Data field is described in 9.2.4.1.8.

The Idle Indication field is set to 0 if the value of the Duration field is an extension of the Ack ID. Otherwise, it is set to 1 if the value of the Duration field indicates an idle period.

If the Idle Indication field is 0, the Duration field is set to the bit sequence TA[3] || RA[0:8] obtained from the RA and TA fields of the NDP PS-Poll frame that elicited the response. If the Idle Indication is 1, the Duration field is set to the duration of time, in milliseconds, during which an idle period (during which there is no frame transmission) is expected from the STA that elicited the response, starting from the end of the NDP PS-Poll-Ack frame response.

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23.3.12.2.5.3 NDP_2M PS-Poll-Ack

The format of the NDP CMAC PPDU body field of the NDP_2M PS-Poll-Ack frame is shown in Figure 23-31.

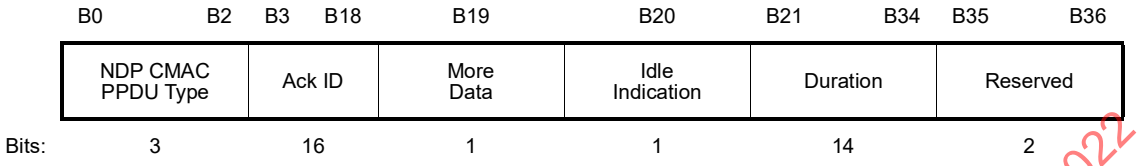

Figure 23-31—NDP CMAC PPDU body field of the NDP_2M PS-Poll-Ack frame

The NDP CMAC PPDU Type field is set to 3.

The Ack ID field is set to the bit sequence CRC[0:3] || TA[0:8] || RA[6:8]] obtained from the CRC, TA, and RA field of the NDP PS-Poll frame that elicited the response. The CRC value is obtained from the RXVECTOR parameter SCRAMBLER_OR_CRC.

The More Data field is described in 9.2.4.1.8.

The Idle Indication field is set to 0 if the value of the Duration field sets the NAV as described in 10.3.2.15. Otherwise, it is set to 1 if the value of the Duration field indicates an idle period.

If the Idle Indication field is 0, the Duration field is set as described in 10.3.2.15, where the value is expressed in units of 1 microsecond.

If the Idle Indication field is 1, the Duration field is set to the duration of time, in milliseconds, during which an idle period (during which there is no frame transmission) is expected from the STA that elicited the response, starting from the end of the NDP PS-Poll-Ack frame response.

23.3.12.2.6 NDP BlockAck

23.3.12.2.6.1 NDP_1M BlockAck

The format of the NDP CMAC PPDU body field of the NDP_1M BlockAck frame is shown in Figure 23-32.

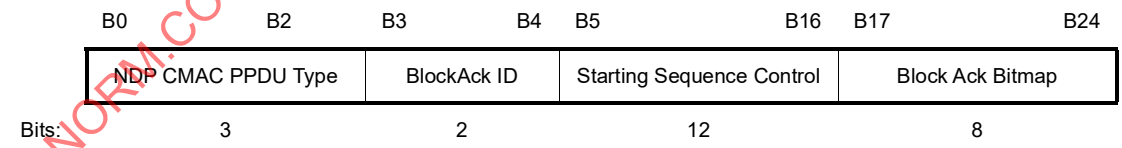

Figure 23-32—NDP CMAC PPDU body field of the NDP_1M BlockAck frame

The NDP CMAC PPDU Type field is set to 4.

The BlockAck ID field contains the identifier of the NDP BlockAck frame. It is set to the 2 LSBs of the bit sequence of the scrambler initialization value in the SERVICE field (as defined in 23.3.9.2), prior to descrambling, of the PSDU that carries the soliciting frame. The scrambler initialization value is obtained from the RXVECTOR parameter SCRAMBLER_OR_CRC.

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The Starting Sequence Control field contains the sequence number of the first MSDU or A-MSDU for which the NDP BlockAck frame is sent. This field is defined in 10.25.6.5 when the NDP BlockAck is used during a block ack agreement and is defined in 10.3.2.12 when it is used in a fragment BA procedure.

The Block Ack Bitmap field of the NDP BlockAck frame is used to indicate the received status of:

— Up to 8 MSDUs and A-MSDUs when the NDP BlockAck is used during a block ack agreement. Each bit that is equal to 1 in the NDP BlockAck bitmap acknowledges the reception of a single MSDU or A-MSDU in the order of sequence number, with the first bit of the NDP BlockAck bitmap corresponding to the MSDU or A-MSDU with the sequence number that matches the value of the Starting Sequence Control field.

— Up to 8 fragments of an MSDU when the NDP BlockAck is used in a fragment BA procedure (see 10.3.2.12). Each bit that is equal to 1 in the BlockAck Bitmap acknowledges the reception of a single fragment of an MSDU, in the order of the fragment number, with the first bit of the BlockAck Bitmap corresponding to the MPDU with fragment number equal to 0 or 8.

The transmitting (receiving) STA encodes (decodes) the BlockAck ID field and the Starting Sequence Control field of the NDP BlockAck frames applying the protection mechanism described in 10.57.

23.3.12.2.6.2 NDP_2M BlockAck

The format of the NDP CMAC PPDU body field of the NDP_2M BlockAck frame is shown in Figure 23-33.

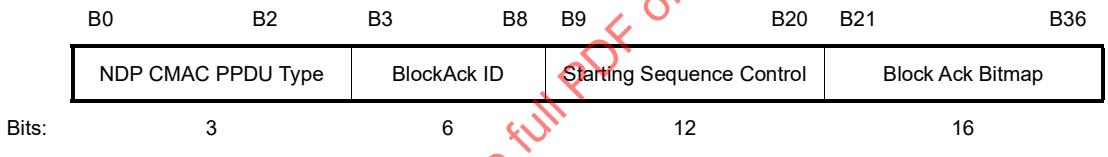

Figure 23-33—NDP CMAC PPDU body field of the NDP_2M BlockAck frame

The NDP CMAC PPDU Type field is set to 4.

The BlockAck ID field contains the identifier of the NDP BlockAck frame. It is set to the 6 LSBs of the bit sequence of the scrambler initialization value in the SERVICE field (as defined in 23.3.9.2), prior to descrambling, of the PSDU that carries the soliciting frame. The scrambler initialization value is obtained from the RXVECTOR parameter SCRAMBLER_OR_CRC.

The Starting Sequence Control field contains the sequence number of the first MSDU or A-MSDU for which the NDP BlockAck frame is sent. This field is defined in when the NDP BlockAck is used during a block ack agreement and is defined in 10.3.2.12 when it is used in a fragment BA procedure.

The Block Ack Bitmap field of the NDP BlockAck frame is used to indicate the received status of:

— Up to 16 MSDUs and A-MSDUs when the NDP BlockAck is used during a block ack agreement. Each bit that is equal to 1 in the NDP BlockAck bitmap acknowledges the reception of a single MSDU or A-MSDU in the order of sequence number, with the first bit of the NDP BlockAck bitmap corresponding to the MSDU or A-MSDU with the sequence number that matches the value of the Starting Sequence Control field.

— Up to 16 fragments of an MSDU when the NDP BlockAck is used in a fragment BA procedure (see 10.3.2.12). Each bit that is equal to 1 in the BlockAck Bitmap acknowledges the reception of a single fragment of an MSDU, in the order of the fragment number, with the first bit of the BlockAck Bitmap corresponding to the MPDU with fragment number equal to 0.

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The transmitting (receiving) STA encodes (decodes) the BlockAck ID field and the Starting Sequence Control field of the NDP BlockAck frames applying the protection mechanism described in 10.57.

23.3.12.2.7 NDP Beamforming Report Poll

23.3.12.2.7.1 NDP_2M Beamforming Report Poll

The format of the NDP CMAC PPDU body field of the NDP_2M Beamforming Report Poll frame is shown in Figure 23-34.

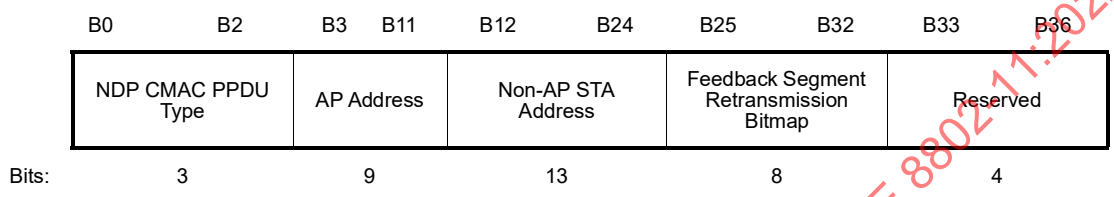

Figure 23-34—NDP CMAC PPDU body field of the NDP_2M Beamforming Report Poll frame

The NDP CMAC PPDU Type field is set to 5.

The AP Address field indicates the partial BSSID of the AP's BSS as described in 10.21.

The Non-AP STA Address field indicates the AID of the non-AP STA.

The Feedback Segment Retransmission Bitmap field indicates the feedback segments to be polled in a VHT Compressed Beamforming report, which is contained in one or more VHT Compressed Beamforming frames.

23.3.12.2.8 NDP Paging

23.3.12.2.8.1 NDP_1M Paging

The format of the NDP CMAC PPDU body field of the NDP_1M Paging frame is shown in Figure 23-35.

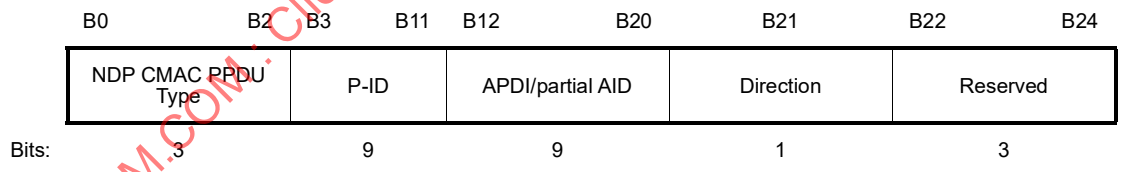

Figure 23-35—NDP CMAC PPDU body field of the NDP_1M Paging frame

The NDP CMAC PPDU Type field is set to 6.

The P-ID field is the identifier of the NDP paging requester, as described in 10.47.6.

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If the Direction field is 1 the APDI/partial AID field indicates the AP direction information (APDI), where

— The 8 MSBs of the APDI, depending on the value of the Action subfield of the NDP Paging Response, contain
  — The PTSF subfield if the Action subfield is not equal to 4. The PTSF subfield is set to the value of the partial TSF of the transmitting STA as defined in 10.47.6.
  — The ASD subfield if the Action subfield is equal to 4. The ASD subfield is the additional sleep duration and is set to the time, in units of SIFS, after which the receiver STA is in awake state as described in 10.47.6.
— The LSB of the APDI is the Check Beacon Flag subfield and is an indicator of critical changes in the Beacon frame as described in 10.47.6.

If the Direction field is 0, the APDI/partial AID field indicates the partial AID of the NDP paging responder STA.

The Direction field is set to 1, if the NDP paging responder is an AP, otherwise it is set to 0.

23.3.12.2.8.2 NDP_2M Paging

The format of the NDP CMAC PPDU body field of the NDP_2M Paging frame is shown in Figure 23-36.

Figure 23-36—NDP CMAC PPDU body field of the NDP_2M Paging frame

The NDP CMAC PPDU Type field is set to 6.

The P-ID field is the identifier of the NDP paging requester, as described in 10.47.6.

If the Direction field is 1, the APDI/partial AID field indicates the APDI (AP Direction Information) where:

— The 8 MSBs of the APDI, depending on the value of the Action subfield of the NDP Paging Response, contain
  — The PTSF subfield if the Action subfield is not equal to 4. The PTSF subfield is set to the value of the partial TSF of the transmitting STA as defined in 10.47.6.
  — The ASD subfield if the Action subfield is equal to 4. The ASD subfield is the additional sleep duration and is set to the time, in units of SIFS, after which the receiver STA is in awake state as described in 10.47.6.
— The LSB of the APDI is the Check Beacon Flag subfield and is an indicator of critical changes in the Beacon frame as described in 10.47.6.

If the Direction field is 0, the APDI/partial AID field indicates the partial AID of the NDP paging responder STA.

The Direction field is set to 1, if the NDP paging responder is an AP, otherwise it is set to 0.

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23.3.12.2.9 NDP Probe Request

23.3.12.2.9.1 General

NDP Probe Request frames are used in the procedures described in 11.1.4.3.6.

23.3.12.2.9.2 NDP_1M Probe Request

The format of the NDP CMAC PPDU body field of the NDP_1M Probe Request frame is shown in Figure 23-37.

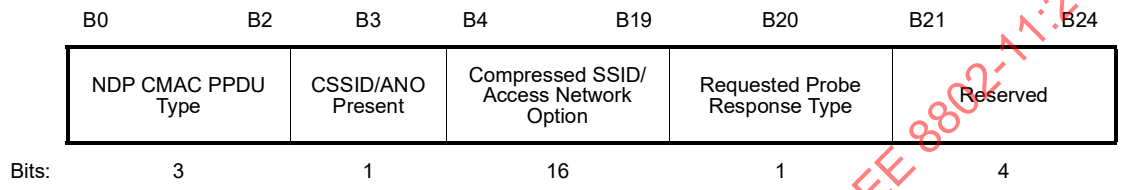

Figure 23-37—NDP CMAC PPDU body field of the NDP_1M Probe Request frame

The NDP CMAC PPDU Type field is set to 7.

The CSSID/ANO Present field indicates if the NDP Probe Request frame contains a Compressed SSID field or an Access Network Option field:

— Set to 0 if the NDP Probe Request frame contains the Compressed SSID field.
— Set to 1 if the NDP Probe Request frame contains the Access Network Option field.

When the CSSID/ANO Present field is 0, the Compressed SSID/Access Network Option field bits [0:15] are set to Compressed SSID, which is the 2 least significant octets of a 32-bit CRC calculated as defined 9.2.4.8, wherein the calculated fields is the Full SSID.

When the CSSID/ANO Present field is 1, the Compressed SSID/Access Network Option field bits [0:7] are set to Access Network Option, which is defined in 9.4.2.91 (see Figure 9-483). The Compressed SSID/Access Network Option field bits [8:15] are reserved.

The Requested Probe Response Type field indicates the Probe Response type:

— Set to 0 if the STA requests a PV1 Probe Response frame.
— Set to 1 if the STA requests a Probe Response frame.

23.3.12.2.9.3 NDP_2M Probe Request

The format of the NDP CMAC PPDU body field of the NDP_2M Probe Request frame is shown in Figure 23-38.

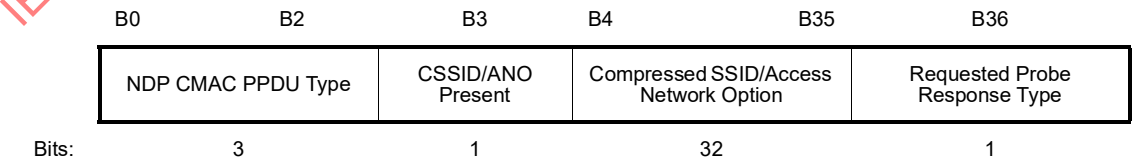

Figure 23-38—NDP CMAC PPDU body field of the NDP_2M Probe Request frame

The NDP CMAC PPDU Type field is set to 7.

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The CSSID/ANO Present field indicates if the NDP Probe Request frame contains a Compressed SSID field or an Access Network Option field:

— Set to 0 if the NDP Probe Request contains the Compressed SSID field.
— Set to 1 if the NDP Probe Request contains the Access Network Option field.

When the CSSID/ANO Present field is 0, the Compressed SSID/Access Network Option field bits [0:31] are set to Compressed SSID, which is a 32-bit CRC calculated as defined in 9.2.4.8, wherein the calculated fields is the Full SSID.

When the CSSID/ANO Present field is 1, the Compressed SSID/Access Network Option field bits [0:7] are set to Access Network Option, which is defined in 9.4.2.91 (see Figure 9-483). The Compressed SSID/Access Network Option field bits [8:31] are reserved.

The Requested Probe Response Type field indicates the Probe Response type:

— Set to 0 if the STA requests a PV1 Probe Response frame.
— Set to 1 if the STA requests a Probe Response frame.

23.3.13 Regulatory requirements

WLANs implemented in accordance with this standard are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The PHY specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regulations are subject to revision, or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PHY specification. Regulatory requirements that do not affect interoperability are not addressed in this standard. Implementers are referred to the regulatory sources in Annex D for further information. Operation in countries within defined regulatory domains may be subject to additional or alternative national regulations.

23.3.14 Channelization

STAs compliant with the physical layer defined in Clause 23 operate in the channels (700 MHz – 1 GHz) defined in Annex E.

The channel center frequency, f_c, is defined as

$$f_c\,[\text{MHz}] = \mathit{ChannelStartingFrequency} + f_{\text{separation}} \times \mathit{ChannelCenterFrequencyIndex}$$

where

$f_{\text{separation}}$ is the frequency separation between channels, and has the value of 0.5 MHz

ChannelStartingFrequency and *ChannelCenterFrequencyIndex* are region and operating class specific and given in Annex E. The Channel spacing column in Annex E denotes the corresponding bandwidth for S1G operation.

The center frequency of the primary 1 MHz or primary 2 MHz channel, $f_{c,\,\text{primary}}$, is defined as:

$$f_{c,\,\text{primary}}\,[\text{MHz}] = \mathit{ChannelStartingFrequency} + f_{\text{separation}} \times \mathit{PrimaryChannelNumber}$$

where

$f_{\text{separation}}$ is the frequency separation between channels, and has the value of 0.5 MHz

PrimaryChannelNumber is the subchannel index of the primary 1 or 2 MHz channel within the overall bandwidth for S1G operation

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23.3.15 Slot time

The slot time for the S1G PHY shall be 52 µs.

23.3.16 Transmit and receive port impedance

Transmit and receive antenna port impedance for each transmit and receive antenna is defined in 17.3.8.7.

23.3.17 S1G transmit specification

23.3.17.1 Transmit spectrum mask

NOTE 1—In the presence of additional regulatory restrictions, the device has to meet both the regulatory requirements and the mask defined in this subclause.

NOTE 2—Transmit spectral mask figures in this subclause are not drawn to scale.

NOTE 3—For rules regarding TX center frequency leakage levels see 23.3.17.4.2. Transmit modulation accuracy specifications are described in 23.3.17.4.2 and 23.3.17.4.3. The test method is described in 23.3.17.4.4. The spectral mask requirements in this subclause do not apply to the RF LO leakage.

For a 1 MHz mask PPDU, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 0.9 MHz, –20 dBr at 0.6 MHz frequency offset, –28 dBr at 1 MHz frequency offset and –40 dBr at 1.5 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 0.45 and 0.6 MHz, 0.6 and 1 MHz, and 1 and 1.5 MHz shall be linearly interpolated in dB domain from the requirements for 0.45, 0.6, 1 and 1.5 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –40 dBm/MHz at any frequency offset. Figure 23-39 shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –40 dBm/MHz.

Measurements shall be made using a 10 kHz resolution bandwidth and a 100 Hz video bandwidth.

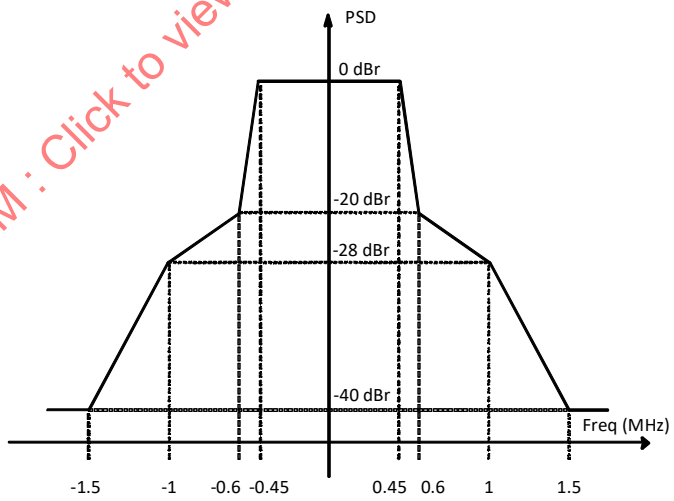

Figure 23-39—Transmit spectral mask for 1 MHz channel

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For a 2 MHz mask PPDU, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 1.8 MHz, –20 dBr at 1.1 MHz frequency offset, –28 dBr at 2 MHz frequency offset and –40 dBr at 3 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 0.9 and 1.1 MHz, 1.1 and 2 MHz, and 2 and 3 MHz shall be linearly interpolated in dB domain from the requirements for 0.9, 1.1, 2 and 3 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –43 dBm/MHz at any frequency offset. Figure 23-40 shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –43 dBm/MHz.

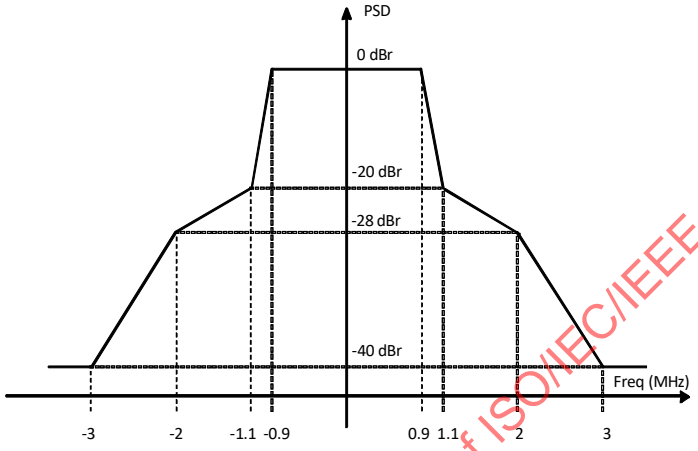

Figure 23-40—Transmit spectral mask for 2 MHz channel

For a 4 MHz mask PPDU, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 3.8 MHz, –20 dBr at 2.1 MHz frequency offset, –28 dBr at 4 MHz frequency offset and –40 dBr at 6 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 1.9 and 2.1 MHz, 2.1 and 4 MHz, and 4 and 6 MHz shall be linearly interpolated in dB domain from the requirements for 1.9, 2.1, 4 and 6 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –46 dBm/MHz at any frequency offset. Figure 23-41 shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –46 dBm/MHz.

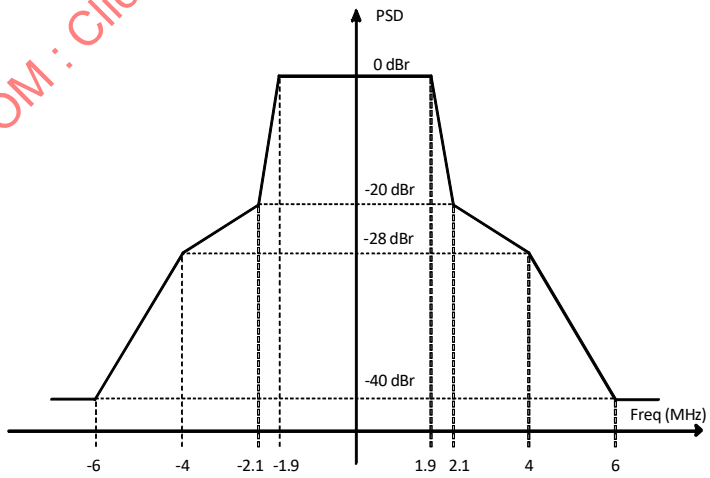

Figure 23-41—Transmit spectral mask for 4 MHz channel

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For a 8 MHz mask PPDU, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 7.8 MHz, –20 dBr at 4.1 MHz frequency offset, –28 dBr at 8 MHz frequency offset and –40 dBr at 12 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 3.9 and 4.1 MHz, 4.1 and 8 MHz, and 8 and 12 MHz shall be linearly interpolated in dB domain from the requirements for 3.9, 4.1, 8 and 12 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –49 dBm/MHz at any frequency offset. Figure 23-42 shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –49 dBm/MHz.

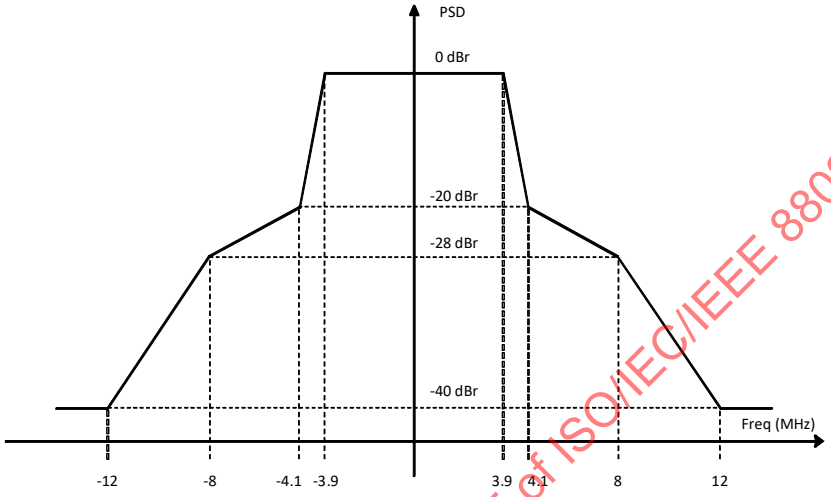

Figure 23-42—Transmit spectral mask for 8 MHz channel

For a 16 MHz mask PPDU, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 15.8 MHz, –20 dBr at 8.1 MHz frequency offset, –28 dBr at 16 MHz frequency offset and –40 dBr at 24 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 7.9 and 8.1 MHz, 8.1 and 16 MHz, and 16 and 24 MHz shall be linearly interpolated in dB domain from the requirements for 7.9, 8.1, 16 and 24 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –49 dBm/MHz at any frequency offset. Figure 23-43 shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –49 dBm/MHz.

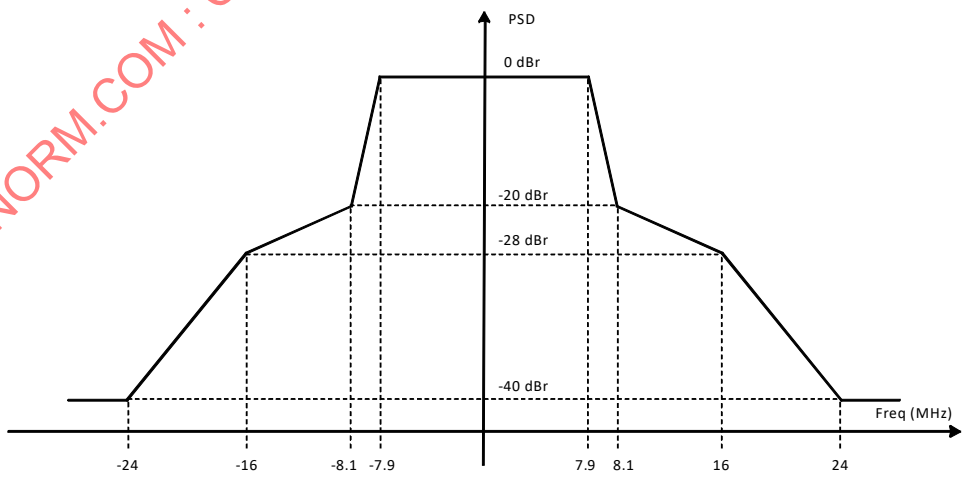

Figure 23-43—Transmit spectral mask for 16 MHz channel

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23.3.17.2 Spectral flatness

Spectral flatness measurements shall be conducted using BPSK modulated PPDUs.

Let $E_{i,\,avg}$ denote the average constellation energy of a BPSK modulated subcarrier i in an S1G data symbol.

In a normal mode S1G transmission or contiguous S1G 1 MHz or 2 MHz Duplicate mode transmission having a bandwidth listed in Table 23-32, $E_{i,\,avg}$ of each of the subcarriers with indices listed as tested subcarrier indices shall not deviate by more than the specified maximum deviation in Table 23-32 from the average of $E_{i,\,avg}$ over subcarrier indices listed as averaging subcarrier indices. Averaging of $E_{i,\,avg}$ is done in the linear domain.

For the spectral flatness test, the transmitting STA shall be configured to use a spatial mapping matrix Q_k with flat frequency response. Each output port under test of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The requirements apply to 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz normal mode transmissions and transmissions based on 1 and 2 MHz duplicated segments.

Table 23-32—Maximum spectral flatness deviations

Format	BW of transmission (MHz)	Averaging subcarrier indices	Tested subcarrier indices	Maximum deviation (dB)
Normal Mode S1G	1	–8 to –1 and +1 to +8	–8 to –1 and +1 to +8	± 4
			–13 to –9 and +9 to +13	+4/–6
	2	–16 to –1 and +1 to +16	–16 to –1 and +1 to +16	± 4
			–28 to –17 and +17 to +28	+4/–6
	4	–42 to –2 and +2 to +42	–42 to –2 and +2 to +42	± 4
			–58 to –43 and +43 to +58	+4/–6
	8	–84 to –2 and +2 to +84	–84 to –2 and +2 to +84	± 4
			–122 to –85 and +85 to +122	+4/–6
	16	–172 to –130, –126 to –44, +44 to +126, and +130 to +172	–172 to –130, –126 to –44, +44 to +126, and +130 to +172	± 4
			–250 to –173, –43 to –6, +6 to +43, and +173 to +250	+4/–6

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Table 23-32—Maximum spectral flatness deviations *(continued)*

Format	BW of transmission (MHz)	Averaging subcarrier indices	Tested subcarrier indices	Maximum deviation (dB)
S1G 1 MHz Duplicate Mode	2	–15 to –3 and +3 to +15	–15 to –3 and +3 to +15	± 4
			–29 to –17 and +17 to +29	
	4	–42 to –35, –29 to –17, –15 to –3, +3 to +15, +17 to +29, and +35 to +42	–42 to –35, –29 to –17, –15 to –3, +3 to +15, +17 to +29, and +35 to +42	± 4
			–61 to –49, –47 to –43, +43 to +47, and +49 to +61	+4/–6
	8	–84 to –81, –79 to –67, –61 to –49, –47 to –35, –29 to –17, –15 to –3, +3 to +15, +17 to +29, +35 to +47, +49 to +61, +67 to +79, and +81 to +84	–84 to –81, –79 to –67, –61 to –49, –47 to –35, –29 to –17, –15 to –3, +3 to +15, +17 to +29, +35 to +47, +49 to +61, +67 to +79, and +81 to +84	± 4
			–125 to –113, –111 to –99, –93 to –85, +85 to +93, +99 to +111, and +113 to +125	+4/–6
	16	–172 to –163, –157 to –145, –143 to –131, –125 to –113, –111 to –99, –93 to –81, –79 to –67, –61 to –49, –47 to –44, +44 to +47, +49 to +61, +67 to +79, +81 to +93, +99 to +111, +113 to +125, +131 to +143, +145 to +157, and +163 to +172	–172 to –163, –157 to –145, –143 to –131, –125 to –113, –111 to –99, –93 to –81, –79 to –67, –61 to –49, –47 to –44, +44 to +47, +49 to +61, +67 to +79, +81 to +93, +99 to +111, +113 to +125, +131 to +143, +145 to +157, and +163 to +172	± 4
			–253 to –241, –239 to –227, –221 to –209, –207 to –195, –189 to –177, –175 to –173, –43 to –35, –29 to –17, –15 to –3, +3 to +15, +17 to +29, +35 to +43,+173 to +175, +177 to +189, +195 to +207, +209 to +221, +227 to +239, and +241 to +253	+4/–6

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Table 23-32—Maximum spectral flatness deviations *(continued)*

Format	BW of transmission (MHz)	Averaging subcarrier indices	Tested subcarrier indices	Maximum deviation (dB)
S1G 2 MHz Duplicate Mode	4	–42 to –33, –31 to –6, +6 to +31, and +33 to +42	–42 to –33, –31 to –6, +6 to +31, and +33 to +42	± 4
			–58 to –43 and +43 to +58	+4/–6
	8	–84 to –70, –58 to –33, +33 to +58, +70 to +84	–84 to –70, –58 to –33, –31 to –6, +6 to +31, +33 to +58, and +70 to +84	± 4
			–122 to –97, –95 to –85, +85 to +95, and+97 to +122	+4/–6
	16	–172 to –161, –159 to –134, –122 to –97, –95 to –70, –58 to –44, +44 to +58, +70 to +95, +97 to +122, +134 to +159, +161 to +172	–172 to –161, –159 to –134, –122 to –97, –95 to –70, –58 to –44, +44 to +58, +70 to +95, +97 to +122, +134 to 159, and +161 to +172	± 4
			–250 to –225, –223 to –198, –186 to –173, –43 to –33, –31 to –6, +6 to +31, +33 to +43, +173 to +186, +198 to 223, and +225 to +250	+4/–6

23.3.17.3 Transmit center frequency and symbol clock frequency tolerance

The symbol clock frequency and transmit center frequency tolerance shall be ± 20 ppm. The transmit center frequency and the symbol clock frequency for all transmit antennas and frequency segments shall be derived from the same reference oscillator.

23.3.17.4 Modulation accuracy

23.3.17.4.1 Introduction to modulation accuracy tests

Transmit modulation accuracy specifications are described in 23.3.17.4.2 and 23.3.17.4.3. The test method is described in 23.3.17.4.4.

23.3.17.4.2 Transmitter center frequency leakage

TX LO leakage is a consequence of the RF local oscillator (LO) and is the DC power emitted at its tuned center frequency. This TX LO leakage shall meet the following requirements for all formats and bandwidths:

— When the RF LO is in the center of the transmitted PPDU BW, the power measured at the center of transmission BW using resolution BW 31.25 kHz shall not exceed the average power per-subcarrier of the transmitted PPDU, or equivalently,($P - 10\log_{10}(N_{ST})$), where P is the transmit power per antenna in dBm, and N_{ST} is defined in Table 23-4.

— When the RF LO is not at the center of the transmitted PPDU BW, the power measured at the location of the RF LO using resolution BW 31.25 kHz shall fall within that resolution BW of a 2 MHz channelization boundary and shall not exceed the maximum of –27 dB relative to the total transmit power and –15 dBm, or equivalently max(P–27,–15), where P is the transmit power per

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antenna in dBm. If 2 MHz channelization is not allowed in the regulatory region of operation, the TX LO leakage shall fall within the resolution BW of a 1 MHz channelization boundary and shall not exceed the maximum of –27 dB relative to the total transmit power and –15 dBm, or equivalently max(P–27,–15), where P is the transmit power per antenna in dBm.

The transmit center frequency leakage is specified per antenna.

23.3.17.4.3 Transmitter constellation error

The relative constellation RMS error, calculated by first averaging over subcarriers, OFDM PPDUs and spatial streams [see Equation (19-89)] shall not exceed a data-rate dependent value according to Table 23-33. The number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized testing instrumentation input ports. In the test, N_{SS}=N_{STS} (no STBC) shall be used. Each output port of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The requirements apply to 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz transmissions.

Table 23-33—Allowed relative constellation error versus constellation size and coding rate

Modulation	Coding rate	Relative constellation error (dB)
BPSK	1/2 with 2× repetition	–4
BPSK	1/2	–5
QPSK	1/2	–10
QPSK	3/4	–13
16-QAM	1/2	–16
16-QAM	3/4	–19
64-QAM	2/3	–22
64-QAM	3/4	–25
64-QAM	5/6	–27
256-QAM	3/4	–30
256-QAM	5/6	–32

23.3.17.4.4 Transmitter modulation accuracy (EVM) test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signals into a stream of complex samples at sampling rate greater than or equal to the bandwidth of the signal being transmitted; except that for duplicate transmissions, each 1 MHz or 2 MHz subchannel may be tested independently while all subchannels are being transmitted.

The instrument shall have sufficient accuracy in terms of I/Q arm amplitude and phase balance, DC offsets, phase noise, and analog to digital quantization noise. A possible embodiment of such a setup is converting the signals to a low IF frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components. The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or equivalent procedure:

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a) Start of PPDU shall be detected.
b) Transition from STF field to LTF1 field shall be detected and fine timing shall be established.
c) Coarse and fine frequency offsets shall be estimated.
d) Symbols in a PPDU shall be derotated according to estimated frequency offset.
e) For each LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and derotate the subcarrier values according to the estimated phase.
f) Estimate the complex channel response coefficient for each of the subcarriers and each of the transmit streams.
g) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, derotate the subcarrier values according to the estimated phase, group the results from all the receiver chains in each subcarrier to a vector, and multiply the vector by a zero-forcing equalization matrix generated from the estimated channel.
h) For each data-carrying subcarrier in each spatial stream, find the closest constellation point and compute the Euclidean distance from it.
i) Compute the average across PPDUs of the RMS of all errors per PPDU as given by Equation (19-89).

The test shall be performed over at least 20 PPDUs [as defined in Equation (19-89)]. The PPDUs under test shall be at least 16 data OFDM symbols long. Random data shall be used for the symbols.

23.3.17.5 Time of Departure accuracy

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex T with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is

$1 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{1\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW1

$2 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{2\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW2

$4 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{4\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW4

$8 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{8\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW8

$16 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{16\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW16

where

f_H is the nominal center frequency in Hz of the highest channel in the channel set
f_L is the nominal center frequency in Hz of the lowest channel in the channel set, the channel set is the set of channels upon which frames providing measurements are transmitted.

— FIRST_TRANSITION_FIELD is the STF field.
— SECOND_TRANSITION_FIELD is the LTF1 field.
— TRAINING_FIELD is the LTF1 field windowed in a manner that should approximate the windowing described in 17.3.2.5 with TTR = 1000 ns.
— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns for a CH_BANDWIDTH parameter equal to CBW16, and unspecified otherwise.

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

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23.3.18 S1G receiver specification

23.3.18.1 Receiver minimum input sensitivity

The packet error ratio (PER) shall be less than 10% for a PSDU length of 256 octets with the rate-dependent input levels listed in Table 23-34. The test in this subclause and the minimum sensitivity levels specified in Table 23-34 apply only to non-STBC modes, 8 μs GI, BCC, and S1G PPDU.

Table 23-34—Receiver minimum input level sensitivity

Modulation	Rate (R)	Minimum sensitivity (1 MHz PPDU) (dBm)	Minimum sensitivity (2 MHz PPDU) (dBm)	Minimum sensitivity (4 MHz PPDU) (dBm)	Minimum sensitivity (8 MHz PPDU) (dBm)	Minimum sensitivity (16 MHz PPDU) (dBm)
BPSK	1/2 with 2× repetition	–98	N/A	N/A	N/A	N/A
BPSK	1/2	–95	–92	–89	–86	–83
QPSK	1/2	–92	–89	–86	–83	–80
QPSK	3/4	–90	–87	–84	–81	–78
16-QAM	1/2	–87	–84	–81	–78	–75
16-QAM	3/4	–83	–80	–77	–74	–71
64-QAM	2/3	–79	–76	–73	–70	–67
64-QAM	3/4	–78	–75	–72	–69	–66
64-QAM	5/6	–77	–74	–71	–68	–65
256-QAM	3/4	–72	–69	–66	–63	–60
256-QAM	5/6	–70	–67	–64	–61	–58

23.3.18.2 Adjacent channel rejection

Adjacent channel rejection for *W* MHz channels (where *W* is 1, 2, 4, 8, or 16) shall be measured by setting the requested signal's strength 3 dB above the rate dependent sensitivity specified in 23.3.18.1 and raising the power of the interfering signal of *W* MHz bandwidth until 10% PER is caused for a PSDU length of 256 octets. The power difference between the interfering and requested channel is the corresponding adjacent channel rejection. The center frequency of the adjacent channel shall be placed *W* MHz away from the center frequency of the requested signal.

The interfering signal in the adjacent channel shall be a conformant S1G signal, unsynchronized with the signal in the channel under test, and shall have a minimum duty cycle of 50%. For a conforming S1G PHY, the corresponding rejection shall be no less than specified in Table 23-35.

The test in this subclause and the adjacent sensitivity levels specified in Table 23-35 only apply to non-STBC modes with 8 μs GI and BCC.

The measurement of adjacent channel rejection for 2/4/8/16 MHz operation in a regulatory domain is only required if such a frequency band plan is permitted in that regulatory domain.

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Table 23-35—Minimum required adjacent and nonadjacent channel rejection levels

Modulation	Rate, R	Adjacent Channel Rejection (dB)		Nonadjacent Channel Rejection (dB)	
		1 MHz Channel	2/4/8/16 MHz Channel	1 MHz Channel	2/4/8/16 MHz Channel
BPSK	1/2 with 2× repetition	19	N/A	35	N/A
BPSK	1/2	16	16	32	32
QPSK	1/2	13	13	29	29
QPSK	3/4	11	11	27	27
16-QAM	1/2	8	8	24	24
16-QAM	3/4	4	4	20	20
64-QAM	2/3	0	0	16	16
64-QAM	3/4	–1	–1	15	15
64-QAM	5/6	–2	–2	14	14
256-QAM	3/4	–7	–7	9	9
256-QAM	5/6	–9	–9	7	7

23.3.18.3 Nonadjacent channel rejection

Nonadjacent channel rejection for *W* MHz channels (where *W* is 1, 2, 4, 8, or 16) shall be measured by setting the requested signal's strength 3 dB above the rate-dependent sensitivity specified in Table 23-35, and raising the power of the interfering signal of W MHz bandwidth until a 10% PER occurs for a PSDU length of 256 octets. The power difference between the interfering and requested channel is the corresponding nonadjacent channel rejection. The center frequency of the nonadjacent channel shall be placed 2×*W* MHz or more away from the center frequency of the requested signal.

The interfering signal in the nonadjacent channel shall be a conformant S1G signal, unsynchronized with the signal in the channel under test, and shall have a minimum duty cycle of 50%. For a conforming OFDM PHY, the corresponding rejection shall be no less than specified in Table 23-35.

The test in this subclause and the nonadjacent sensitivity levels specified in Table 23-35 only apply to non-STBC modes with 8 μs GI and BCC.

The measurement of nonadjacent channel rejection for 2/4/8/16 MHz operation in a regulatory domain is only required if such a frequency band plan is permitted in that regulatory domain.

23.3.18.4 Receiver maximum input level

The receiver shall provide a maximum PER of 10% at a PSDU length of 256 octets, for a maximum input level of –30 dBm, measured at each antenna for any baseband S1G modulation.

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23.3.18.5 CCA sensitivity

23.3.18.5.1 General

The thresholds in this subclause are compared with the signal level at each receiving antenna.

23.3.18.5.2 Type 1 and type 2 channelization for CCA levels

In S1G operation, the CCA sensitivity levels are defined such that they are dependent and specific to country channelization and channel location within the frequency band. For S1G channelizations in all regions of the world, there are to be two available classifications for channels and CCA levels, defined as type 1 and type 2.

For BSSs set up on channels classified as using type 1, STAs are to use what are referred to in this subclause as type 1 CCA levels when performing their CCA procedures. Likewise, if the BSS is set up on channels classified as type 2, STAs are required to use type 2 specific CCA levels. For SST BSS setups (see 10.52) where the SST BSS can include both type 1 and type 2 channels, the device in the SST BSS shall use the CCA level (type 1 or type 2) that corresponds to the current channel that is being accessed when performing their CCA procedures. The type 1 and type 2 channel classification for different operating classes in different regions of the world are denoted by "CCA Level Classification" in Table E-4 to Table E-5 in Annex E.

In general, type 1 channels have CCA levels set to favor protection of ongoing transmissions and range of devices, relative to type 2 channels. Type 2 channels have CCA levels set to favor higher bandwidth and data rate transmissions, and to allow for higher reuse within the total network across different BSSs (relative to type 1 channels). To achieve this, type 2 channel CCA levels (i.e., thresholds) are defined to be higher than type 1 channel CCA levels.

CCA levels will impact system behavior and performance increasingly with loading, therefore it is generally advantageous for BSSs primarily serving devices requiring more channel and transmission protection to set up on type 1 channels, and for BSSs expected to service devices with higher bandwidth and data rate transmissions to set up on type 2 channels if the region/country has both type 1 and type 2 channels available.

An S1G STA configures its active CCA conditions by generating a PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive with the CCA_SENSITIVITY_TYPE parameter. For operating in type 1 channels, the MAC sublayer generates a PHY-CONFIG.request primitive with a PHYCONFIG_VECTOR parameter CCA_SENSITIVITY_TYPE set to CCA_SENSITIVITY_TYPE_1. For operating in type 2 channels, the MAC sublayer generates a PHY-CONFIG.request primitive with a PHYCONFIG_VECTOR parameter CCA_SENSITIVITY_TYPE set to CCA_SENSITIVITY_TYPE_2. For operating the 8/16 MHz intended channel width in type 2 channels, the MAC sublayer generates a PHY-CONFIG.request primitive with a PHYCONFIG_VECTOR parameter CCA_SENSITIVITY_TYPE set to CCA_SENSITIVITY_TYPE_2_WIDEBAND.

23.3.18.5.3 CCA sensitivity for operating classes requiring CCA-ED

For the operating classes requiring CCA-Energy Detect (CCA-ED), CCA shall also detect a medium busy condition when CCA-ED detects a channel busy condition.

For improved spectrum sharing, CCA-ED is required in some bands. The behavior class indicating CCA-ED is given in Table E-1 to Table E-4. The operating classes requiring the corresponding CCA-ED behavior class are given in Annex E. A STA that is operating within an operating class that requires CCA-ED shall operate with CCA-ED.

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There is no distinction between type 1 and type 2 channel CCA levels for CCA-Energy Detect threshold levels, and all channels will use the same set of values: CCA-ED shall indicate a channel busy condition when the received signal strength exceeds the CCA-ED threshold of –75 dBm for the primary 1 MHz, –72 dBm for the primary 2 MHz channel and the secondary 2 MHz channels, –69 dBm for the secondary 4 MHz channel, and –66 dBm for the secondary 8 MHz channel.

23.3.18.5.4 CCA sensitivity for signals occupying the primary 2 MHz and/or primary 1 MHz channel

23.3.18.5.4.1 General

In S1G operation, the CCA sensitivity levels a device shall use when detecting the start of S1G PPDUs are based on whether the occupied primary channel in question is classified as type 1 or type 2.

For devices operating in type 1 channels, the PHY shall issue a PHY-CCA.indication(BUSY, {primary1}) if one of the following conditions is present in an otherwise idle primary 1 MHz channel:

— The start of an S1G_1M PPDU or duplicate S1G_1M PPDU detected in the primary 1 MHz channel at or above –98 dBm within the primary 1 MHz channel with > 90% probability within a period aCCATime (see 23.4.4).

— Any S1G PPDU detected at or above –89 dBm within the primary 1 MHz channel with > 90% probability within a period of aCCAMidTime (see 23.4.4).

For devices operating in type 2 channels, the PHY shall issue a PHY-CCA.indication(BUSY, {primary1}) if one of the following conditions is present in an otherwise idle primary 1 MHz channel:

— The start of an S1G_1M PPDU or duplicate S1G_1M PPDU detected in the primary 1 MHz channel at or above –89 dBm within the primary 1 MHz channel with > 90% probability within a period aCCATime (see 23.4.4).

— Any S1G PPDU detected at or above –86 dBm within the primary 1 MHz channel with > 90% probability within a period of aCCAMidTime (see 23.4.4).

The device shall not issue a PHY-CCA.indication(BUSY, {primary2}), PHY-CCA.indication(BUSY, {secondary2}), PHY-CCA.indication(BUSY, {secondary4}), or PHY-CCA.indication(BUSY, {secondary8}) until the end of the duration indicated by the packet or until all conditions above are no longer satisfied. Additionally, for both type 1 and type 2 channels, the device shall issue a PHY-CCA.indication(BUSY, {primary1}) if any received signal in the primary 1 MHz channel exceeds the CCA-ED threshold of –75 dBm within a period aCCATime.

For devices operating in type 1 channels, the PHY shall issue a PHY-CCA.indication(BUSY, {primary2}) if the conditions for issuing PHY-CCA.indication(BUSY, {primary1}) are not present and one of the following conditions is met in an otherwise idle 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width:

— An S1G_1M PPDU detected in the nonprimary 1 MHz portion of the primary 2 MHz channel at or above –89 dBm within the nonprimary 1 MHz with > 90% probability within a period of aCCAMidTime (see 23.4.4).

— A ≥ 2 MHz S1G PPDU at or above –89 dBm within the primary 2 MHz channel with > 90% probability within a period of aCCAMidTime (see 23.4.4).

— Any of the applicable conditions listed in Table 23-36. An applicable condition shall be met (i.e., triggered) if the PHY detects the start of the described PPDU(s) in Table 23-36 with > 90% probability within a period of aCCATime (see 23.4.4).

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Table 23-36—Additional conditions for CCA BUSY on the primary 2 MHz in type 1 channelization

Operating Channel Width	Conditions
2 MHz, 4 MHz, 8 MHz, 16 MHz	The start of a 2 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –92 dBm in the primary 2 MHz channel.
4 MHz, 8 MHz, 16 MHz	The start of a 4 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –89 dBm in the primary 4 MHz channel.
8 MHz, 16 MHz	The start of an 8 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –86 dBm in the primary 8 MHz channel.
16 MHz	The start of a 16 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –83 dBm.

For devices operating in type 2 channels, the PHY shall issue a PHY-CCA.indication(BUSY, {primary2}) if the conditions for issuing PHY-CCA.indication(BUSY, {primary1}) are not present and one of the following conditions is met in an otherwise idle 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width:

— An S1G_1M PPDU is detected in the nonprimary 1 MHz portion of the primary 2 MHz channel at or above –86 dBm within the nonprimary 1 MHz with > 90% probability within a period of aCCAMidTime (see 23.4.4).

— A ≥ 2 MHz S1G PPDU at or above –86 dBm within the primary 2 MHz channel with > 90% probability within a period of aCCAMidTime (see 23.4.4).

— Any of the applicable conditions listed in Table 23-37. An applicable condition shall be met (i.e., triggered) if the PHY detects the start of the described PPDU(s) in Table 23-37 with > 90% probability within a period of aCCATime (see 23.4.4).

Table 23-37—Additional conditions for CCA BUSY on the primary 2 MHz in type 2 channelization

Operating Channel Width	Conditions
2 MHz, 4 MHz, 8 MHz, 16 MHz	The start of a 2 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –89 dBm in the primary 2 MHz channel.
4 MHz, 8 MHz, 16 MHz	The start of a 4 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –86 dBm in the primary 4 MHz channel.
8 MHz, 16 MHz	The start of an 8 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –83 dBm in the primary 8 MHz channel.
16 MHz	The start of a 16 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –80 dBm.

The device shall not issue a PHY-CCA.indication(BUSY, {secondary2}), PHY-CCA.indication(BUSY, {secondary4}), or PHY-CCA.indication(BUSY, {secondary8}) until the end of the duration indicated by the

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packet or until all conditions above are no longer satisfied. Additionally, for both type 1 and type 2 channels, the device shall issue a PHY-CCA.indication(BUSY, {primary2}) if any received signal in the primary 2 MHz channel exceeds the CCA-ED threshold of –72 dBm within a period aCCATime.

Additionally, when a STA detects an S1G_SHORT or S1G_LONG PPDU with a Partial AID field of its SIG field indicating a partial AID or COLOR value that matches its own partial AID or BSSID, the PHY shall issue a PHY-CCA.indication(BUSY, {primary2}) for the remaining duration of the PPDU as indicated in its preamble.

23.3.18.5.4.2 CCA sensitivity for devices in type 2 channels implementing intended 8 or 16 MHz transmit channel width channel access procedure

For devices operating in type 2 channels, if the device intends to transmit an 8 or 16 MHz channel width PPDU and the device implements the procedure and rules for high intended BW transmission channel access described in 10.23.2.6, the PHY shall issue a PHY-CCA.indication(BUSY, {primary}) if one of the following conditions is present in an otherwise idle primary 1 MHz channel:

— The start of an S1G_1M PPDU or duplicate S1G_1M PPDU detected in the primary 1 MHz channel at or above –86 dBm within the primary 1 MHz channel with > 90% probability within a period aCCATime (see 23.4.4).

— Any S1G PPDU detected at or above –86 dBm with > 90% probability within a period of aCCAMidTime (see 23.4.4).

The device shall not issue a PHY-CCA.indication(BUSY, {primary2}), PHY-CCA.indication(BUSY, {secondary2}), PHY-CCA.indication(BUSY, {secondary4}), or PHY-CCA.indication(BUSY, {secondary8}) until the end of the duration indicated by the packet or until all conditions above are no longer satisfied. Additionally, the device shall issue a PHY-CCA.indication(BUSY, {primary1}) if any received signal in the primary 1 MHz channel exceeds the CCA-ED threshold of –75 dBm within a period aCCATime.

The PHY shall issue a PHY-CCA.indication(BUSY, {primary2}) if the conditions for issuing PHY-CCA.indication(BUSY, {primary1}) are not present and one of the following conditions is met in an otherwise idle 8 MHz or 16 MHz operating channel width:

— An S1G_1M PPDU is detected in the nonprimary 1 MHz portion of the primary 2 MHz channel at or above –86 dBm within the nonprimary 1 MHz with > 90% probability within a period of aCCAMidTime (see 23.4.4).

— A ≥ 2 MHz S1G PPDU at or above –86 dBm within the primary 2 MHz channel with > 90% probability within a period of aCCAMidTime (see 23.4.4).

— Any of the applicable conditions listed in Table 23-38. An applicable condition shall be met (i.e., triggered) if the PHY detects the start of the described PPDU(s) in Table 23-38 with > 90% probability within a period of aCCATime (see 23.4.4).

The device shall not issue a PHY-CCA.indication(BUSY, {secondary2}), PHY-CCA.indication(BUSY, {secondary4}), or PHY-CCA.indication(BUSY, {secondary8}) until the end of the duration indicated by the packet or until all conditions above are no longer satisfied. Additionally, for both type 1 and type 2 channels, the device shall issue a PHY-CCA.indication(BUSY, {primary2}) if any received signal in the primary 2 MHz channel exceeds the CCA-ED threshold of –72 dBm within a period of aCCATime.

Additionally, when a STA detects an S1G_SHORT or S1G_LONG PPDU with a Partial AID field of its SIG field indicating a partial AID or COLOR value that matches its own partial AID or BSSID, the PHY shall issue a PHY-CCA.indication(BUSY, {primary2}) for the remaining duration of the PPDU as indicated in its preamble.

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Table 23-38—Additional conditions for CCA BUSY on the primary 2 MHz in type 2 channelization for 8/16 MHz intended channel width

Operating Channel Width	Conditions
8 MHz, 16 MHz	The start of a 2 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –86 dBm in the primary 2 MHz channel.
8 MHz, 16 MHz	The start of a 4 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –83 dBm in the primary 4 MHz channel.
8 MHz, 16 MHz	The start of an 8 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –80 dBm in the primary 8 MHz channel.
16 MHz	The start of a 16 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –77 dBm.

23.3.18.5.5 CCA sensitivity for signals not occupying the primary 2 MHz channel

In S1G operation, the CCA sensitivity levels for detecting signals in the secondary channels may be classified separately for type 1 or type 2 channels.

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary2}) if the conditions for issuing PHY-CCA.indication(BUSY, {primary2}) are not present and one of the following conditions are present in an otherwise idle 4 MHz, 8 MHz, 16 MHz operating channel width:

— For both type 1 and type 2 channels, any signal within the secondary 2 MHz channel at or above a threshold of –72 dBm within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the PHY shall not issue a PHY-CCA.indication(BUSY,{secondary4}), PHY-CCA.indication(BUSY,{secondary8}) or PHY-CCA.indication(IDLE) while the threshold continues to be exceeded.

— For type 1 channels, a 2 MHz S1G PPDU detected in the secondary 2 MHz channel at or above –86 dBm with > 90% probability within a period of aCCAMidTime (see 23.4.4).

— For type 2 channels, a 2 MHz S1G PPDU detected in the secondary 2 MHz channel at or above –82 dBm with > 90% probability within a period of aCCAMidTime (see 23.4.4).

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary4}) if the conditions for issuing PHY-CCA.indication(BUSY, {primary2}) and PHY-CCA.indication(BUSY, {secondary2}) are not present and one of the following conditions are present in an otherwise idle 8 MHz, 16 MHz operating channel width:

— For both type 1 and type 2 channels, any signal within the secondary 4 MHz channel at or above a threshold of –69 dBm within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the PHY shall not issue a PHY-CCA.indication(BUSY, {secondary8}) or PHY-CCA.indication(IDLE) while the threshold continues to be exceeded.

— For type 1 channels:

  — A 4 MHz S1G PPDU detected in the secondary 4 MHz channel at or above –86 dBm with > 90% probability within a period of aCCAMidTime (see 23.4.4).

  — A 2 MHz S1G PPDU detected in any 2 MHz subchannel of the secondary 4 MHz channel at or above –86 dBm with > 90% probability within a period of aCCAMidTime.

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— For type 2 channels:
  — A 4 MHz S1G PPDU detected in the secondary 4 MHz channel at or above –82 dBm with > 90% probability within a period of aCCAMidTime (see 23.4.4).
  — A 2 MHz S1G PPDU detected in any 2 MHz subchannel of the secondary 4 MHz channel at or above –82 dBm with > 90% probability within a period of aCCAMidTime.

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary8}) if the conditions for PHY-CCA.indication(BUSY, {primary2}), PHY-CCA.indication(BUSY, {secondary2}) and PHY-CCA.indication(BUSY,{secondary4}) are not present and one of the following conditions are present in an otherwise idle 16 MHz operating channel width:

— For both type 1 and type 2 channels, any signal within the secondary 8 MHz channel at or above –66 dBm.
— For type 1 channels:
  — An 8 MHz S1G PPDU detected in the secondary 8 MHz channel at or above –83 dBm with > 90% probability within a period of aCCAMidTime (see 23.4.4).
  — A 4 MHz S1G PPDU detected in any 4 MHz subchannel of the secondary 8 MHz channel at or above –86 dBm with > 90% probability within a period of aCCAMidTime.
  — A 2 MHz S1G PPDU detected in any 2 MHz subchannel of the secondary 8 MHz channel at or above –86 dBm with > 90% probability within a period of aCCAMidTime.
— For type 2 channels:
  — An 8 MHz S1G PPDU detected in the secondary 8 MHz channel at or above –79 dBm with > 90% probability within a period aCCAMidTime (see 23.4.4).
  — A 4 MHz S1G PPDU detected in any 4 MHz subchannel of the secondary 8 MHz channel at or above –82 dBm with > 90% probability within a period of aCCAMidTime.
  — A 2 MHz S1G PPDU detected in any 2 MHz subchannel of the secondary 8 MHz channel at or above –82 dBm with > 90% probability within a period of aCCAMidTime.

23.3.18.6 RSSI

The RSSI parameter returned in the RXVECTOR shall be calculated during the reception of the (D-)LTFs and shall be a monotonically increasing function of the received power.

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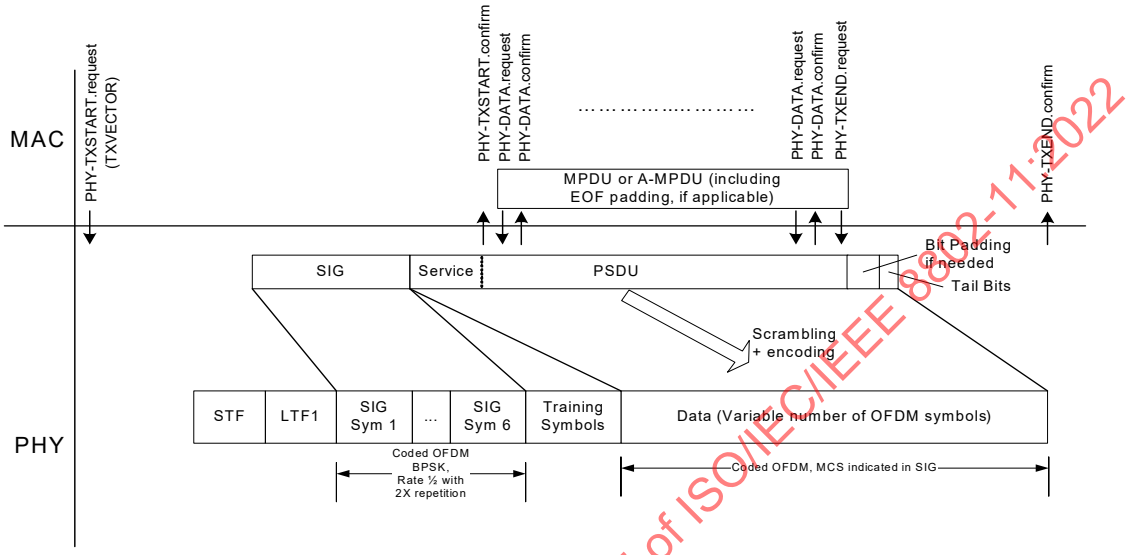
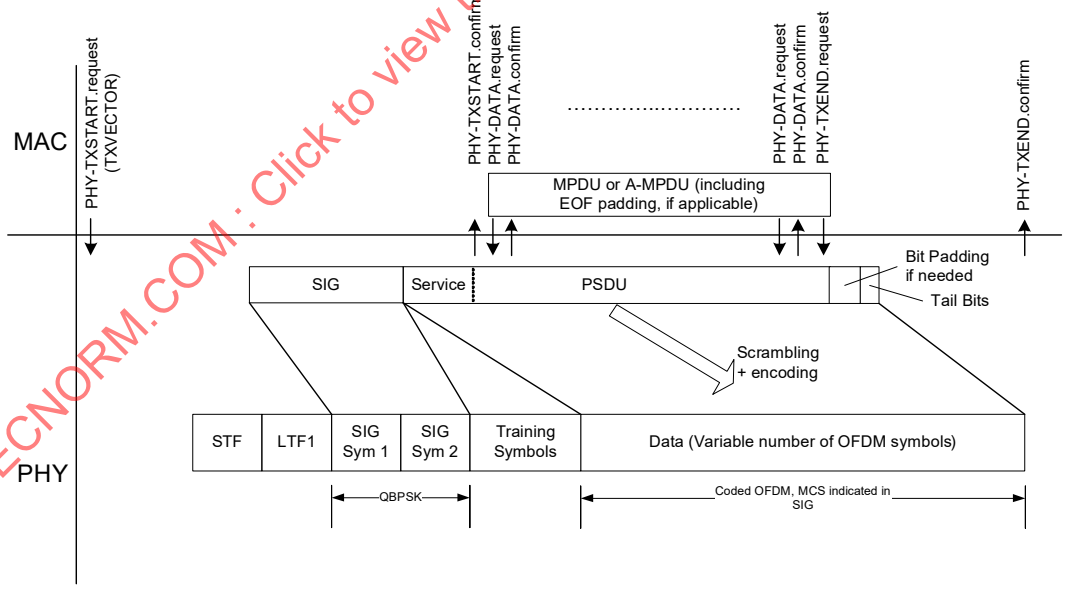
23.3.19 PHY transmit procedure

The typical transmit procedure is shown in Figure 23-44, Figure 23-45, and Figure 23-46. For this transmit procedure, the FORMAT parameter of the PHY-TXSTART.request(TXVECTOR) primitive is S1G. These transmit procedures do not describe the operation of optional features, such as LDPC, STBC, or MU.



NOTE—This procedure does not describe the operation of optional features such as MU-MIMO, LDPC or STBC.

Figure 23-44—PHY transmit procedure for an SU transmission using S1G_1M procedure



NOTE—This procedure does not describe the operation of optional features such as MU-MIMO, LDPC or STBC.

Figure 23-45—PHY transmit procedure for an SU transmission using S1G_SHORT procedure

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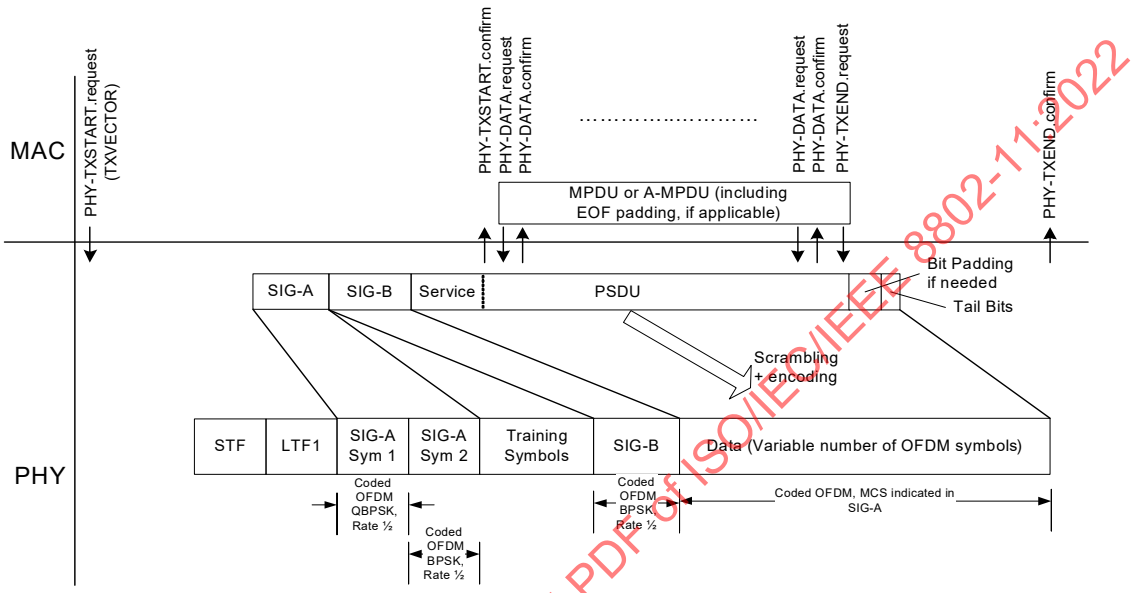
NOTE—For an MU PPDU the A-MPDU is per user in the MAC sublayer and the S1G training symbols, SIG-B, and Data are per user in the PHY layer in Figure 23-46, with the number S1G training symbols depending on the total number of space-time streams across all users.

In order to transmit data, the MAC generates a PHY-TXSTART.request primitive, which causes the PHY entity to enter the transmit state. Further, the PHY is set to operate at the appropriate frequency through station management via the PLME, as specified in 23.4.



NOTE—This procedure does not describe the operation of optional features, such as MU-MIMO, LDPC or STBC.

Figure 23-46—PHY transmit procedure for an SU transmission using S1G_LONG procedure

Other transmit parameters, such as S1G-MCS coding types and transmit power, are set via the PHY SAP using the PHY-TXSTART.request(TXVECTOR) primitive, as described in 23.2.2.

The PHY indicates the state of the primary channel and other channels (if any) via the PHY-CCA.indication primitive (see 23.3.18.5 and 8.3.5.12). Note that under some circumstances, the MAC uses the value of the PHY-CCA.indication primitive before (and if) issuing the PHY-TXSTART.request primitive. Transmission of the PPDU shall be initiated by the PHY after receiving the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request primitive are specified in Table 23-1.

Transmission of the PHY preamble shall start immediately, using the parameters passed in the PHY-TXSTART.request primitive and the PHY shall issue a PHY-TXSTART.confirm primitive to the MAC.

After the PHY preamble transmission is started, the PHY entity immediately initiates data scrambling and data encoding. The encoding method for the Data field is based on the FEC_CODING, CH_BANDWIDTH, NUM_STS, STBC, MCS, and NUM_USERS parameter of the TXVECTOR, as described in 23.3.2.

The SERVICE field and PSDU are encoded as described in 23.3.3. The data shall be exchanged between the MAC and the PHY through a series of PHY-DATA.request(DATA) primitives issued by the MAC, and PHY-DATA.confirm primitives issued by the PHY. Zero to seven PHY padding bits are appended to the PSDU to make the number of bits in the coded PSDU an integer multiple of the number of coded bits per OFDM symbol.

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Transmission can be prematurely terminated by the MAC through the primitive PHY-TXEND.request primitive. PSDU transmission is terminated by receiving a PHY-TXEND.request primitive. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY. In an SU transmission, normal termination occurs after the transmission of the final bit of the last PSDU octet, according to the number of OFDM symbols indicated by NSYM (see 23.4.3).

In the PHY, the GI or short GI is inserted in every data OFDM symbol as a countermeasure against delay spread.

A NDP CMAC transmit procedure is shown in Figure 23-47 and Figure 23-48.

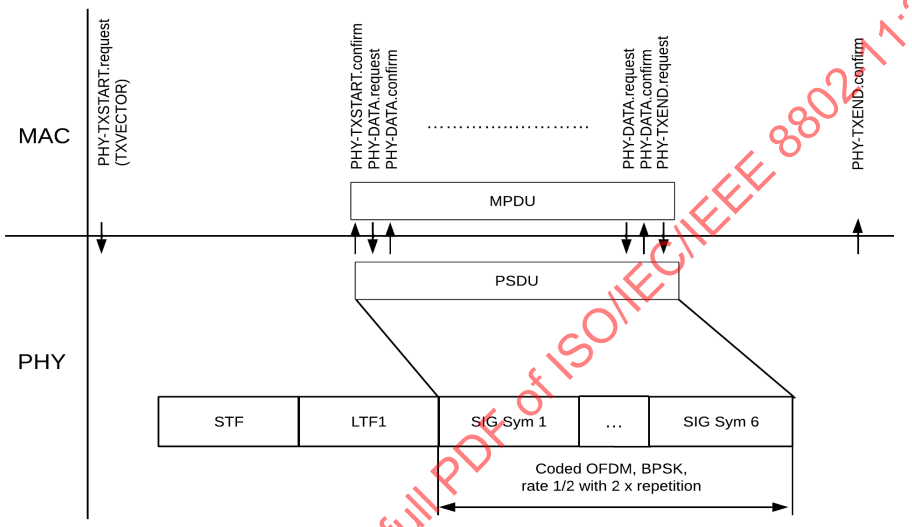

Figure 23-47—PHY transmit procedure for an NDP CMAC PPDU transmission using S1G_1M format

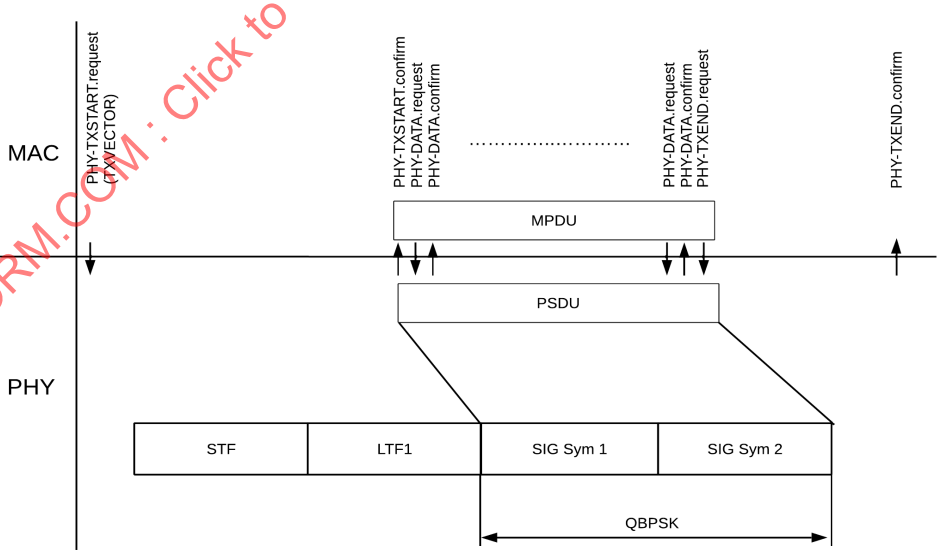

Figure 23-48—PHY transmit procedure for an NDP CMAC PPDU transmission using S1G_SHORT format

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In case of transmission of the NDP CMAC PPDU, the PHY performs the same procedure like the typical transmit procedure as described in this subclause except as follows

— No service field appended
— No PHY padding bits appended to the PSDU
— No scrambling applied to PSDU
— PSDU is mapping to the SIG field

When the PPDU transmission is completed the PHY entity enters the receive state.

A typical state machine implementation of the transmit PHY for an S1G PPDU transmission is provided in Figure 23-49. Request (.request) and confirmation (.confirm) primitives are issued once per state as shown. This state machine does not describe the operation of optional features, such as multi-user, LDPC, or STBC.

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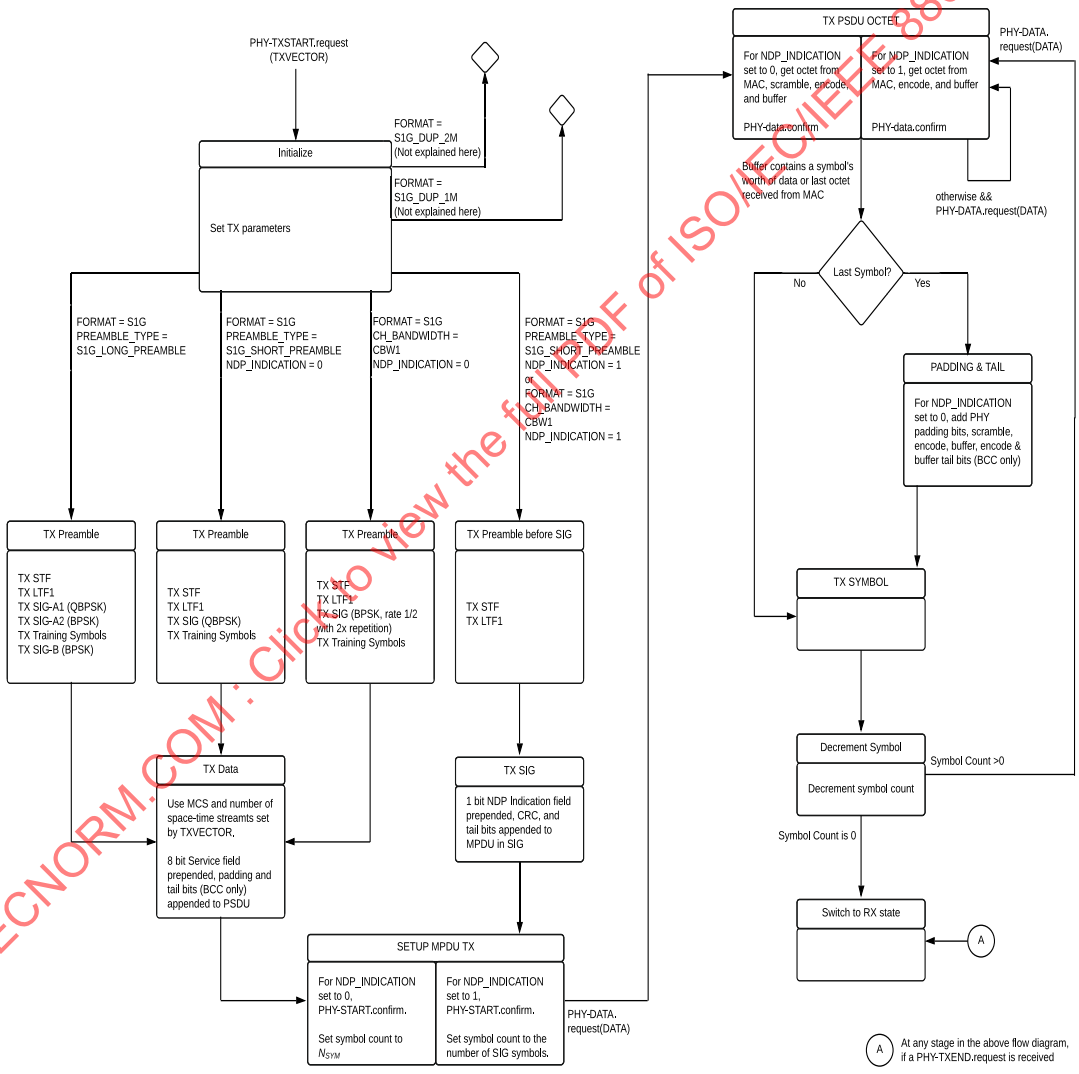

Figure 23-49—PHY transmit state machine for an S1G PPDU transmission

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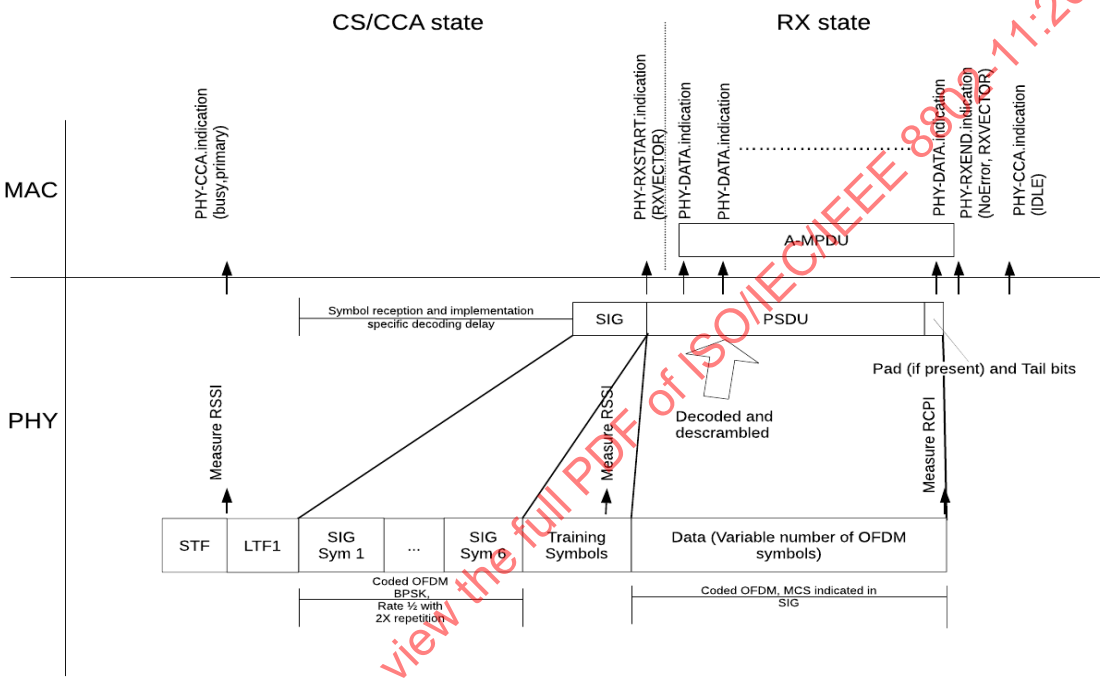
23.3.20 PHY receive procedure

Typical PHY receive procedures are shown in Figure 23-50, Figure 23-51, and Figure 23-52, corresponding to S1G_1M preamble format, S1G_SHORT preamble format, and S1G_LONG preamble format, respectively. A typical state machine implementation of the receive PHY is given in Figure 23-53. This receive procedure and state machine do not describe the operation of optional features, such as LDPC or STBC. Through station management (via the PLME) the PHY is set to the appropriate frequency, as specified in 23.4. The PHY has also been configured with group information (i.e., group membership and position in group) so that it can receive data intended for the STA. Other receive parameters, such as RSSI and indicated DATARATE, may be accessed via the PHY SAP.



NOTE—This procedure does not describe the operation of optional features, such as LDPC or STBC.

Figure 23-50—PHY receive procedure for an SU transmission, S1G_1M procedure

Upon receiving the transmitted PHY preamble overlapping the primary 2 MHz channel in a greater than or equal to 2 MHz BSS, or primary 1 MHz channel in a 1 MHz BSS, the PHY measures a receive signal strength. This activity is indicated by the PHY to the MAC via a PHY-CCA.indication primitive. A PHY-CCA.indication(BUSY, channel-list) primitive is also issued as an initial indication of reception of a signal as specified in 23.3.18.5. The CH_BANDWIDTH parameter indicates one of the 1 MHz, 2 MHz, 4 MHz, 8 MHz and 16 MHz channel widths.

The PHY shall not issue a PHY-RXSTART.indication primitive in response to a PPDU that does not overlap the primary channel.

The PHY includes the most recently measured RSSI value in the PHY-RXSTART.indication(RXVECTOR) primitive issued to the MAC.

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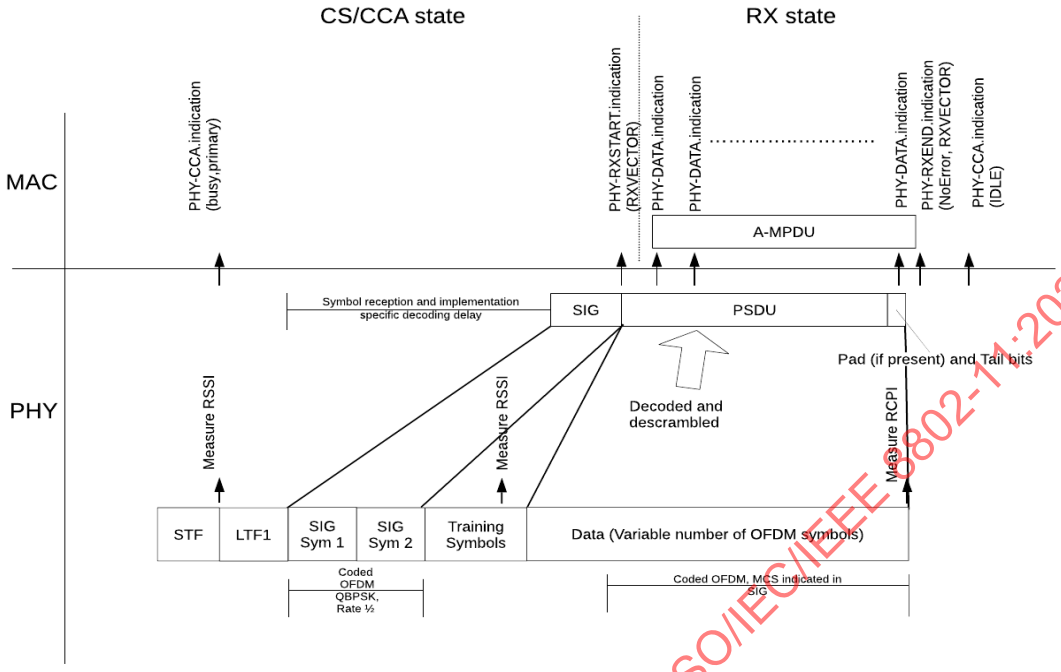
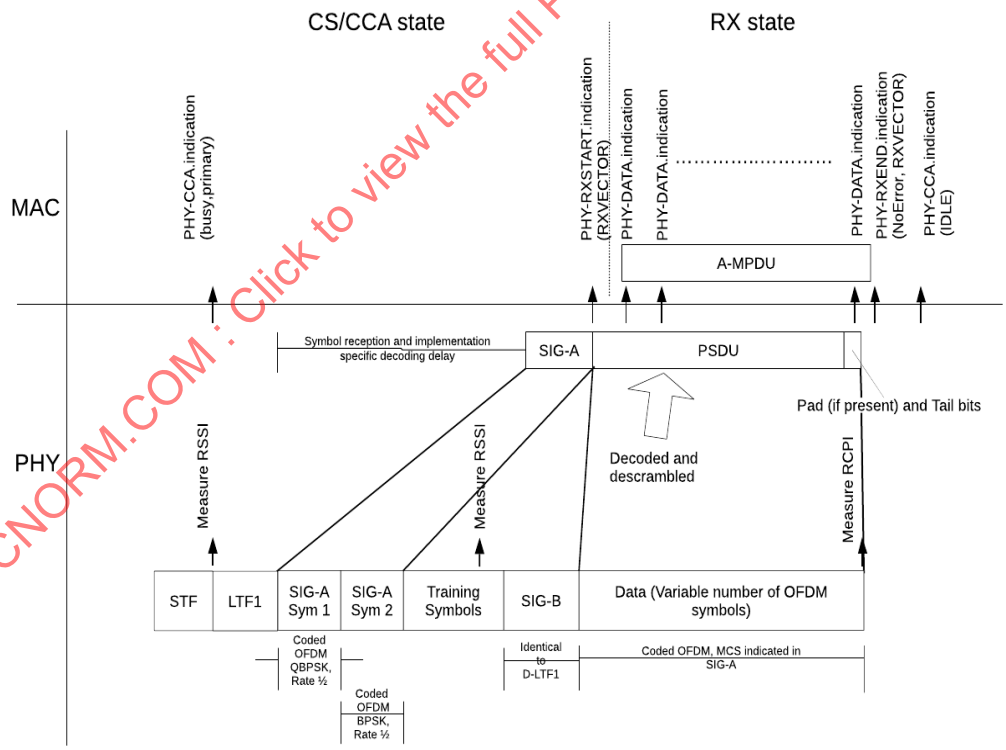


NOTE—This procedure does not describe the operation of optional features, such as LDPC or STBC.

Figure 23-51—PHY receive procedure for an SU transmission, S1G_SHORT procedure



NOTE—This procedure does not describe the operation of optional features, such as LDPC or STBC. This procedure describes the case where SIG-A indicates a mode not requiring decoding of SIG-B.

Figure 23-52—PHY receive procedure for an SU transmission, S1G_LONG procedure

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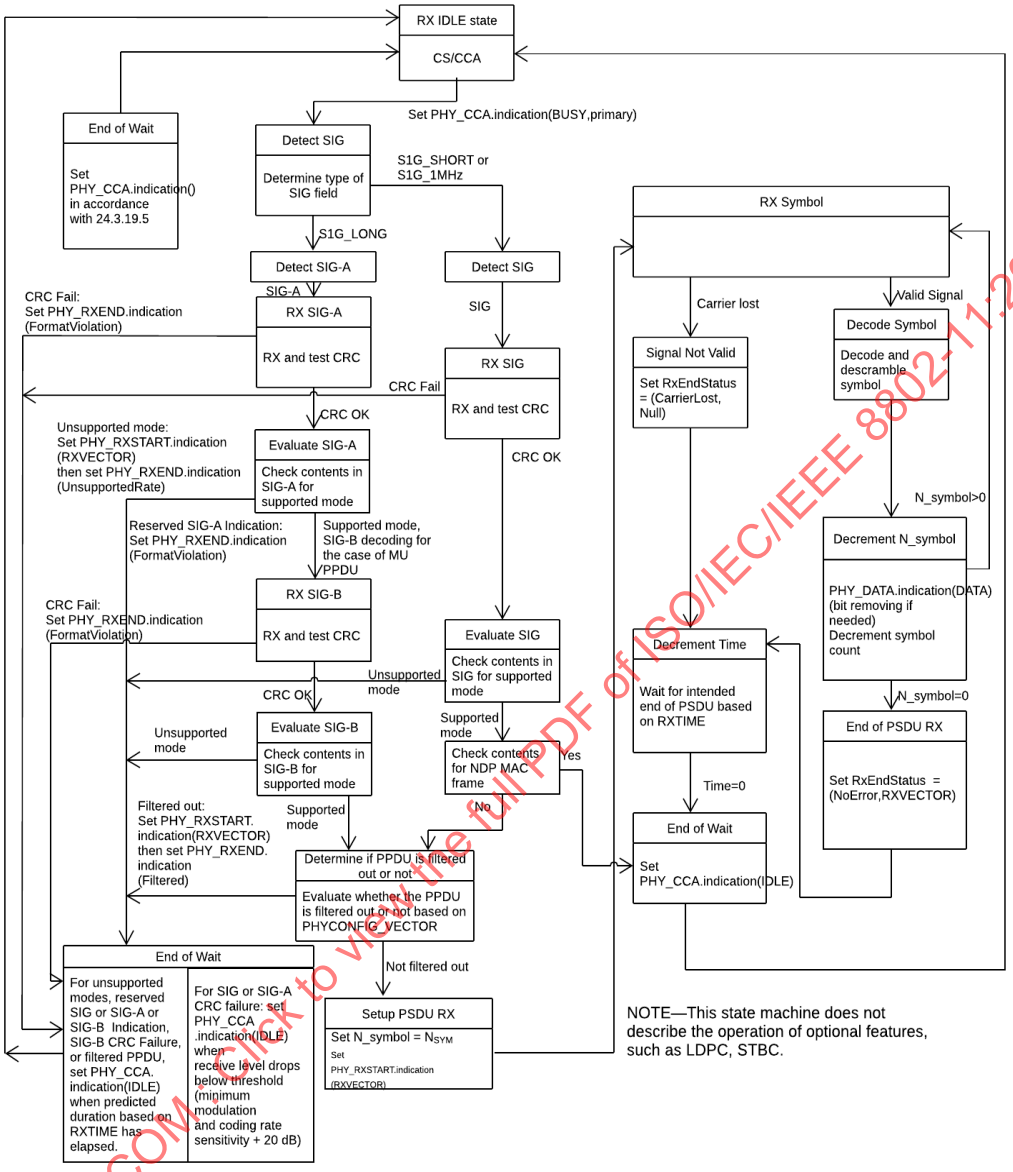

Figure 23-53—PHY receive state machine

After the PHY-CCA.indication(BUSY, channel-list) is issued, the PHY entity shall begin receiving the training symbols and searching for SIG or SIG-A in order to set the maximum duration of the data stream and get other PHY parameters such as the demodulation type, code type, and the decoding rate. If the check of the SIG or SIG-A CRC is not valid, a PHY-RXSTART.indication primitive is not issued, and instead the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive, and set PHY_CCA.indication(IDLE) when receive level drops below threshold (minimum modulation and coding rate sensitivity + 20 dB). If a valid SIG or SIG-A CRC is indicated, and the Uplink Indication bit is 1 and the ID field value matches the PBSSID of the BSS of which the STA is a member or the Uplink Indication bit is 0 and the COLOR field value matches the COLOR indicated by the AP to which the STA is associated, then the S1G PHY shall maintain PHY-CCA.indication(BUSY, channel-list) for the predicted duration of

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the transmitted PPDU, as defined by RXTIME in Equation (23-69) or Equation (23-70), for all supported modes, unsupported modes, and Reserved SIG or SIG-A Indication. If a valid SIG or SIG-A CRC is indicated, and the Uplink Indication bit is 1 and the ID field value does not match the PBSSID of the BSS of which the STA is a member or the Uplink Indication bit is 0 and the COLOR field value does not match the COLOR indicated by the AP to which the STA is associated, then the S1G PHY shall maintain PHY-CCA.indication(BUSY, channel-list) for the predicted duration of the transmitted PPDU, as defined by RXTIME in Equation (23-69) or Equation (23-70), for all supported modes, unsupported modes, and Reserved SIG-A Indication if the reception meets the minimum CCA sensitivity level specified in 23.3.18.5.4. Reserved SIG or SIG-A Indication is defined as an SIG or SIG-A with Reserved bits equal to 0 or a combination not valid as defined in 23.3.8.2.2.5, 23.3.8.2.3.2.5, or 23.3.8.3.5, or a combination of S1G-MCS and NSTS not included in 23.5 or any other SIG or SIG-A field bit combinations that do not correspond to modes of PHY operation defined in Clause 23.

Subsequently, if dot11TimingMsmtActivated is true, a PHY-RXSTART.indication (RXVECTOR) shall be issued and RX_START_OF_FRAME_OFFSET parameter within the RXVECTOR shall be forwarded (see 23.2.2).

NOTE—The RX_START_OF_FRAME_OFFSET value is used as described in 6.3.55 in order to estimate when the start of the preamble for the incoming frame was detected on the medium at the receive antenna connector.

If the SIG or SIG-A indicates an unsupported mode, the PHY shall issue PHY-RXEND.indication(UnsupportedRate). If the SIG or SIG-A indicates an invalid CRC or Reserved SIG or SIG-A Indication, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation).

If the PHY preamble reception is successful and a valid SIG or SIG-A CRC is indicated:

— Upon reception of an S1G_LONG format preamble, after receiving a valid SIG-A indicating a supported mode, the PHY entity shall begin receiving the rest of S1G training symbols and SIG-B. If the received MU/SU subfield in SIG-A has a value indicating SU PPDU (see 23.3.8.2.3.2.5), the PHY entity does not need to decode SIG-B since in this case SIG-B does not carry any information bit (see 23.3.8.2.3.3.5). If the SIG-B is not decoded, subsequent to an indication of a valid SIG-A, a PHY-RXSTART.indication (RXVECTOR) primitive shall be issued.

  If the received MU/SU subfield in SIG-A has a value indicating MU PPDU (see 23.3.8.2.3.2.5), SIG-B shall be decoded. If the check of the SIG-B CRC is not valid, a PHY-RXSTART.indication primitive is not issued, and instead the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive, and the S1G PHY shall maintain PHYCCA.indication(BUSY, channel-list) for the predicted duration of the transmitted PPDU, as defined by RXTIME in Equation (23-69) or Equation (23-70), for all supported modes, unsupported modes, and Reserved SIG-B Indication. Reserved SIG-B Indication is defined as a SIG-B with the bits of the Reserved field not all 1s or MCS not included in 23.5. If the SIG-B indicates an unsupported mode, the PHY shall issue the error condition PHY-RXEND.indication(UnsupportedRate) primitive, and a PHY-RXSTART.indication primitive shall not be issued. If the check of the SIG-B CRC is valid and it indicates a supported mode, a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. The RXVECTOR associated with this primitive includes the parameters specified in Table 23-1.

— Upon reception of an S1G_SHORT or S1G_1M format preamble, after receiving a valid SIG indicating a supported mode, the PHY entity shall begin receiving the rest of S1G training symbols, and then a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. The RXVECTOR associated with this primitive includes the parameters specified in Table 23-1.

  In this case, if the NDP Indication subfield in SIG field has a value indicating an NDP CMAC PPDU, the PHY shall generate a PHYCCA.indication(IDLE) primitive and return to RX IDLE state, and it shall not issue the PHY-RXSTART.indication(RXVECTOR) primitive.

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The PHY optionally filters out the PPDU based on the GID, MU[0-3] NSTS, UPLINK_INDICATION and ID fields of SIG or SIG-A and the contents of the PHYCONFIG_VECTOR as follows:

- The PHY shall not filter out the PPDU if one of the following is true:
  - ($g = 0$) and (l_{00} is true) and (*partialaid* is included in PARTIAL_AID_LIST_GID00)
  - ($g = 63$) and (l_{63} is true) and (*partialaid* is included in PARTIAL_AID_LIST_GID63)
  - ($1 \leq g \leq 62$) and (MembershipStatusInGroupID[g] = 1) and (n_{STS}[UserPositionInGroupID[g]] > 0)
- where
  - l_{NN} is the one of the LISTEN_TO_GID*NN* parameters of the PHYCONFIG_VECTOR
  - MembershipStatusInGroupID[g] is the Membership Status Array field of the GROUP_ID_MANAGEMENT parameter of the PHYCONFIG_VECTOR for group g
  - g is defined to be
    - The value of the GroupID field of the SIG-A for an S1G MU PPDU
    - 0 for an S1G SU PPDU when UPLINK_INDICATION is equal to 1
    - 63, in all other cases
  - $n_{STS}[u]$ is the value of the MU[u] NSTS field of SIG or SIG-A
  - UserPositionInGroupID[g] is the User Position Array field of the GROUP_ID_MANAGEMENT parameter of the PHYCONFIG_VECTOR for group g
  - *partialaid* is the value of the ID field of SIG or SIG-A
- Otherwise, the PHY may filter out the PPDU.

If the PPDU is filtered out, the PHY shall issue a PHY-RXEND.indication(Filtered) primitive.

The Data field follows the training and signal fields. When the Coding subfield in SIG or SIG-A field indicates BCC, the number of symbols in the Data field is determined by Equation (23-65).

$$N_{SYM} = \begin{cases} \text{LENGTH}, & \text{if Aggregation} = 1 \\ m_{STBC} \times \left\lceil \dfrac{8 \times LENGTH + N_{service} + N_{tail} \times N_{ES}}{m_{STBC} \times N_{DBPS}} \right\rceil, & \text{if Aggregation} = 0 \end{cases} \quad (23\text{-}65)$$

where

N_{ES} and N_{DBPS}	are defined in Table 23-6
$N_{service}$ and N_{tail}	are defined in Table 23-4
m_{STBC}	is equal to 2 when STBC is used, and 1 otherwise
LENGTH and Aggregation	are the values indicated by the LENGTH and Aggregation subfields of SIG or SIG-A field, respectively

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When the Coding subfield in SIG or SIG-A indicates LDPC and Aggregation subfield in SIG or SIG-A field is 1, the number of symbols in the Data field is determined by Equation (23-66).

$$N_{SYM} = LENGTH \tag{23-66}$$

where
LENGTH is the value indicated by the LENGTH subfield of SIG or SIG-A field

When the Coding subfield in SIG or SIG-A indicates LDPC and Aggregation subfield in SIG or SIG-A field is 0, the parameter $N_{SYM,\,init}$ is determined by Equation (23-67).

$$N_{SYM,\,init} = m_{STBC} \times \left\lceil \frac{8 \times LENGTH + N_{service}}{m_{STBC} \times N_{DBPS}} \right\rceil \tag{23-67}$$

where
N_{DBPS} is defined in Table 23-6
$N_{service}$ is defined in Table 23-4
m_{STBC} is equal to 2 when STBC is used, and 1 otherwise
LENGTH is the value indicated by the LENGTH subfield of SIG or SIG-A field

In this case, the number of symbols in the Data field N_{SYM} is determined by Equation (23-68).

$$N_{SYM} = \begin{cases} N_{SYM,\,init}, & \text{if LDPC Extra OFDM Symbol = 0} \\ N_{SYM,\,init} + 1, & \text{if LDPC Extra OFDM Symbol = 1 and STBC = 0} \\ N_{SYM,\,init} + 2, & \text{if LDPC Extra OFDM Symbol = 1 and STBC = 1} \end{cases} \tag{23-68}$$

where
LENGTH is the value indicated by the LENGTH subfield of SIG or SIG-A field
LDPC Extra OFDM Symbol is the value indicated by LDPC Extra subfield in SIG or SIG-A field
STBC is the value indicated by the STBC subfield in SIG or SIG-A field

The PHY parameter RXTIME for the case of S1G_SHORT or S1G_1M format is determined by Equation (23-69).

$$RXTIME(\mu s) = \begin{cases} T_{DSTF} + T_{LTF}(N_{LTF} - 1) + N_{SYM} T_{SYML}, & \text{if Short GI = 0} \\ T_{DSTF} + T_{LTF}(N_{LTF} - 1) + T_{SYML} + (N_{SYM} - 1).T_{SYMS}, & \text{if Short GI = 1} \end{cases} \tag{23-69}$$

where
T_{LTF}, T_{SYML} and T_{SYMS} are defined in Table 23-4
N_{LTF} is defined in Table 23-10

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The PHY parameter RXTIME for the case of S1G_LONG format is determined by Equation (23-70).

$$RXTIME(\mu s) = \begin{cases} T_{DSTF} + N_{LTF}T_{DLTF} + T_{SIG-B} + N_{SYM}T_{SYML}, & \text{if Short GI} = 0 \\ T_{DSTF} + N_{LTF}T_{DLTF} + T_{SIG-B} + T_{SYML} + (N_{SYM} - 1).T_{SYMS}, & \text{if Short GI} = 1 \end{cases} \quad (23\text{-}70)$$

where

T_{DLTF}, T_{SIG-B}, T_{SYML} and T_{SYMS} are defined in Table 23-4

N_{LTF} is defined in Table 23-10

When the Aggregation subfield in the SIG or SIG-A field is equal to 0, the value of the PSDU_LENGTH parameter returned in the RXVECTOR using is set to the LENGTH field of the SIG/SIG-A.

When the Aggregation subfield in the SIG or SIG-A field is equal to 1, the value of the PSDU_LENGTH parameter returned in the RXVECTOR using BCC encoding is calculated using Equation (23-71).

$$\text{PSDU_LENGTH} = \left\lfloor \frac{N_{SYM}N_{DBPS} - N_{service} - N_{tail} \cdot N_{ES}}{8} \right\rfloor \quad (23\text{-}71)$$

where

N_{ES} is defined in Table 23-6

N_{DBPS} is defined in Table 23-6

$N_{service}$ and N_{tail} are defined in Table 23-4

The value of the PSDU_LENGTH parameter returned in the RXVECTOR using LDPC encoding is calculated using Equation (23-72).

$$PSDU_LENGTH = \left\lfloor \frac{N_{SYM}.N_{DBPS} - N_{service}}{8} \right\rfloor \quad (23\text{-}72)$$

where

N_{DBPS} is defined in Table 23-6

$N_{service}$ is defined in Table 23-4

When the Aggregation subfield in the SIG or SIG-A field is equal to 1, the value of the PSDU_LENGTH parameter returned in the RXVECTOR for an NDP sounding or an NDP CMAC PPDU is 0.

If signal loss occurs during reception prior to completion of the PSDU reception, the error condition PHY-RXEND.indication(CarrierLost) shall be reported to the MAC. After waiting for the end of the PSDU as determined by Equation (23-69) or Equation (23-70), the PHY shall set the PHY-CCA.indication(IDLE) primitive and return to the RX IDLE state.

The received PSDU bits are assembled into octets, decoded, and presented to the MAC using a series of PHY-DATA.indication(DATA) primitive exchanges. Any final bits that cannot be assembled into a complete octet are considered pad bits and discarded. After the reception of the final bit of the last PSDU octet, and possible padding and tail bits, the receiver shall be returned to the RX IDLE state, as shown in Figure 23-53.

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23.4 S1G PMLE

23.4.1 PLME_SAP sublayer management primitives

Table 23-39 lists the MIB attributes that may be accessed by the PHY entities and the intra-layer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.5.

Table 23-39—S1G PHY MIB attributes

Managed object	Default value/range	Operational semantics
dot11PHYOperationTable		
dot11PHYType	s1g	Static
dot11PHYTxPowerTable		
dot11NumberSupportedPowerLevels	Implementation dependent	Static
dot11TxPowerLevel1	Implementation dependent	Static
dot11TxPowerLevel2	Implementation dependent	Static
dot11TxPowerLevel3	Implementation dependent	Static
dot11TxPowerLevel4	Implementation dependent	Static
dot11TxPowerLevel5	Implementation dependent	Static
dot11TxPowerLevel6	Implementation dependent	Static
dot11TxPowerLevel7	Implementation dependent	Static
dot11TxPowerLevel8	Implementation dependent	Static
dot11CurrentTxPowerLevel	Implementation dependent	Static
dot11TxPowerLevelExtended	Implementation dependent	Static
dot11CurrentTxPowerLevelExtended	Implementation dependent	Static
dot11PHYS1GTable		
dot11CurrentPrimaryChannel	Implementation dependent	Dynamic
dot11CurrentChannelWidth	Implementation dependent	Dynamic
dot11CurrentChannelCenterFrequencyIndex	Implementation dependent	Dynamic
dot11S1GChannelWidthOptionImplemented	Implementation dependent	Static
dot11ShortGIOptionIn1MImplemented	false/Boolean	Static
dot11ShortGIOptionIn1MActivated	false/Boolean	Dynamic
dot11ShortGIOptionIn2MImplemented	false/Boolean	Static
dot11ShortGIOptionIn2MActivated	false/Boolean	Dynamic
dot11ShortGIOptionIn4MImplemented	false/Boolean	Static
dot11ShortGIOptionIn4MActivated	false/Boolean	Dynamic

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Table 23-39—S1G PHY MIB attributes *(continued)*

Managed object	Default value/range	Operational semantics
dot11ShortGIOptionIn8MImplemented	false/Boolean	Static
dot11ShortGIOptionIn8MActivated	false/Boolean	Dynamic
dot11ShortGIOptionIn16MImplemented	false/Boolean	Static
dot11ShortGIOptionIn16MActivated	false/Boolean	Dynamic
dot11S1GLDPCCodingOptionImplemented	false/Boolean	Static
dot11S1GLDPCCodingOptionActivated	false/Boolean	Dynamic
dot11S1GTxSTBCOptionImplemented	false/Boolean	Static
dot11S1GTxSTBCOptionActivated	false/Boolean	Dynamic
dot11S1GRxSTBCOptionImplemented	false/Boolean	Static
dot11S1GRxSTBCOptionActivated	false/Boolean	Dynamic
dot11S1GMaxNTxChainsImplemented	Implementation dependent	Static
dot11S1GMaxNTxChainsActivated	Implementation dependent	Dynamic
dot11S1GTravelingPilotOptionImplemented	Implementation dependent	Static
dot11S1GTravelingPilotOptionActivated	Implementation dependent	Dynamic
dot11S1GTransmitBeamformingConfigTable		
dot11ReceiveStaggerSoundingOptionImplemented	false/Boolean	Static
dot11TransmitStaggerSoundingOptionImplemented	false/Boolean	Static
dot11ReceiveNDPOptionImplemented	false/Boolean	Static
dot11TransmitNDPOptionImplemented	false/Boolean	Static
dot11ImplicitTransmitBeamformingOptionImplemented	false/Boolean	Static
dot11CalibrationOptionImplemented	Implementation dependent	Static
dot11ExplicitCSITransmitBeamformingOptionImplemented	false/Boolean	Static
dot11ExplicitNonCompressedBeamformingMatrixOptionImplemented	false/Boolean	Static
dot11ExplicitTransmitBeamformingCSIFeedbackOptionImplemented	Implementation dependent	Static
dot11ExplicitNoncompressedBeamformingFeedbackOptionImplemented	Implementation dependent	Static
dot11ExplicitCompressedBeamformingFeedbackOptionImplemented	Implementation dependent	Static
dot11NumberBeamformingCSISupportAntenna	Implementation dependent	Static
dot11NumberNonCompressedBeamformingMatrixSupportAntenna	Implementation dependent	Static
dot11NumberCompressedBeamformingMatrixSupportAntenna	Implementation dependent	Static
dot11S1GSUBeamformerOptionImplemented	false/Boolean	Static

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Table 23-39—S1G PHY MIB attributes *(continued)*

Managed object	Default value/range	Operational semantics
dot11S1GSUBeamformeeOptionImplemented	false/Boolean	Static
dot11S1GMUBeamformerOptionImplemented	false/Boolean	Static
dot11S1GMUBeamformeeOptionImplemented	false/Boolean	Static
dot11S1GNumberSoundingDimensions	Implementation dependent	Static
dot11S1GBeamformeeNTxSupport	Implementation dependent	Static

23.4.2 PHY MIB

S1G PHY MIB attributes are defined in Annex C with specific values defined in Table 23-39. The "Operational semantics" column in Table 23-39 contains two types: static and dynamic.

— Static MIB attributes are fixed and cannot be modified for a given PHY implementation.

— Dynamic MIB attributes are interpreted according to the MAX-ACCESS field of the MIB attribute.

When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.

23.4.3 TXTIME and PSDU_LENGTH calculation

For S1G_SHORT preamble, the value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated for an S1G PPDU using Equation (23-73) for short GI and Equation (23-74) for long GI.

$$\text{TXTIME} = \begin{cases} T_{PREAMBLE} + T_{SIG} + T_{LTF} \cdot (N_{LTF} - 1), \text{ if } N_{SYM} = 0 \\ T_{PREAMBLE} + T_{SIG} + T_{LTF} \cdot (N_{LTF} - 1) + T_{SYML} + T_{SYMS} \cdot (N_{SYM} - 1), \text{ if} N_{SYM} > 0 \end{cases} \quad (23\text{-}73)$$

$$\text{TXTIME} = T_{PREAMBLE} + T_{SIG} + T_{LTF} \cdot (N_{LTF} - 1) + T_{SYML} \cdot N_{SYM} \quad (23\text{-}74)$$

where

$T_{PREAMBLE} = T_{STF} + T_{LTF1}$

T_{STF}, T_{LTF1}, T_{LTF}, T_{SYML} and T_{SYMS} are defined in Table 23-4

T_{SIG} is defined in Table 23-5

N_{LTF} is defined in Table 23-10

For S1G_LONG preamble, the value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated for an S1G PPDU using Equation (23-75) for short GI and Equation (23-76) for long GI.

$$\text{TXTIME} = \begin{cases} T_{PREAMBLE} + T_{SIG-A} + T_{D_PREAMBLE} + T_{SIG-B}, \text{ if } N_{SYM} = 0 \\ T_{PREAMBLE} + T_{SIG-A} + T_{D_PREAMBLE} + T_{SIG-B} + T_{SYML} + T_{SYMS} \cdot (N_{SYM} - 1), \text{ if } N_{SYM} > 0 \end{cases} \quad (23\text{-}75)$$

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$$\text{TXTIME} = T_{PREAMBLE} + T_{SIG-A} + T_{D_PREAMBLE} + T_{SIG-B} + T_{SYML} N_{SYM} \quad (23\text{-}76)$$

where

$T_{PREAMBLE} = T_{STF} + T_{LTF1}$

$T_{D_PREAMBLE} = T_{DSTF} + T_{DLTF} \cdot N_{LTF}$

T_{STF}, T_{LTF1}, T_{DSTF}, T_{DLTF}, T_{SIG-B}, T_{SYML} and T_{SYMS} are defined in Table 23-4

T_{SIG-A} is defined in Table 23-5.

N_{LTF} is defined in Table 23-10.

For S1G_1M preamble, the value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated for an S1G PPDU using Equation (23-77) for short GI and Equation (23-78) for long GI.

$$\text{TXTIME} = \begin{cases} T_{PREAMBLE} + T_{SIG} + T_{LTF} \cdot (N_{LTF} - 1), \text{ if } N_{SYM} = 0 \\ T_{PREAMBLE} + T_{SIG} + T_{LTF} \cdot (N_{LTF} - 1) + T_{SYML} + T_{SYMS}(N_{SYM} - 1), \text{ if } N_{SYM} > 0 \end{cases} \quad (23\text{-}77)$$

$$\text{TXTIME} = T_{PREAMBLE} + T_{SIG} + T_{LTF} \cdot (N_{LTF} - 1) + T_{SYML} N_{SYM} \quad (23\text{-}78)$$

where

$T_{PREAMBLE} = T_{STF} + T_{LTF1}$

T_{STF}, T_{LTF1}, T_{LTF}, T_{SIG}, T_{SYML} and T_{SYMS} are defined in Table 23-4

N_{LTF} is defined in Table 23-10

For an NDP, there is no Data field and $N_{SYM} = 0$.

For an S1G SU PPDU using BCC encoding, the total number of data symbols in the Data field, $N_{SYM,}$ is given by Equation (23-79) if the Aggregation subfield in its SIG field or SIG-A field is set to 1 or Equation (23-80) otherwise.

$$N_{SYM} = m_{STBC} \times \left\lceil \frac{8 \cdot APEP_LENGTH + N_{service} + N_{tail} \cdot N_{ES}}{m_{STBC} \cdot N_{DBPS}} \right\rceil \quad (23\text{-}79)$$

$$N_{SYM} = m_{STBC} \times \left\lceil \frac{8 \cdot PSDU_LENGTH + N_{service} + N_{tail} \cdot N_{ES}}{m_{STBC} \cdot N_{DBPS}} \right\rceil \quad (23\text{-}80)$$

where

m_{STBC} is equal to 2 when STBC is used, and 1 otherwise

N_{ES} and N_{DBPS} are defined in Table 23-6

$N_{service}$ and N_{tail} are defined in Table 23-4

PSDU_LENGTH is the value of TXVECTOR parameter PSDU_LENGTH

For an S1G SU PPDU using LDPC encoding, the total number of data symbols in the Data field, N_{SYM}, is given in 23.3.9.4.4.

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For an S1G MU PPDU, the total number of data symbols in the Data field, N_{SYM}, is given by

$$N_{SYM} = \max\{N_{SYM,u}\}_{u=0}^{N_{user}-1}$$

where

$N_{SYM,u}$ is defined in Equation (23-79) replacing N_{SYM}, $APEP_LENGTH$, N_{ES}, and N_{DBPS} with $N_{SYM,u}$, $APEP_LENGTH_u$, $N_{ES,u}$, and $N_{DBPS,u}$ for BCC and in 23.3.9.4.4 for LDPC

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for an S1G SU PPDU using BCC encoding is calculated using Equation (23-81)

$$PSDU_LENGTH = \left\lfloor \frac{N_{SYM} \cdot N_{DBPS} - N_{service} - N_{tail} N_{ES}}{8} \right\rfloor \quad (23\text{-}81)$$

where

N_{SYM} is given by Equation (23-79) or Equation (23-80)

N_{ES} and N_{DBPS} are defined in Table 23-6

$N_{service}$ and N_{tail} are defined in Table 23-4

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for an S1G SU PPDU using LDPC encoding is calculated using Equation (23-82)

$$PSDU_LENGTH = \left\lfloor \frac{N_{SYM,init} \cdot N_{DBPS} - N_{service}}{8} \right\rfloor \quad (23\text{-}82)$$

where

$N_{SYM,init}$ is given by Equation (23-46) or Equation (23-47)

N_{DBPS} is defined in Table 23-6

$N_{service}$ is defined in Table 23-4

The value of the PSDU_LENGTH parameter for user u returned in the PLME-TXTIME.confirm primitive and in the RXVECTOR for an S1G MU PPDU is calculated using Equation (23-83)

$$PSDU_LENGTH_u = \begin{cases} \left\lfloor \frac{N_{SYM} \cdot N_{DBPS,u} - N_{service} - N_{tail} N_{ES,u}}{8} \right\rfloor & \text{when BCC is used for user } u \\ \left\lfloor \frac{N_{SYM_max_init} \cdot N_{DBPS,u} - N_{service}}{8} \right\rfloor & \text{when LDPC is used for user } u \end{cases} \quad (23\text{-}83)$$

where

$N_{SYM_max_init}$ is given by Equation (21-65)

$N_{ES,u}$ is N_{ES} for user u, where N_{ES} is defined in Table 23-6

$N_{DBPS,u}$ is N_{DBPS} for user u, where N_{DBPS} is defined in Table 23-6

$N_{service}$ and N_{tail} are defined in Table 23-4

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for an NDP is 0.

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23.4.4 PHY characteristics

The static S1G PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, shall be as shown in Table 23-40. The definitions for these characteristics are given in 6.5.4.

Table 23-40—S1G PHY characteristics

Characteristics	Value
aSlotTime	52 μs
aSIFSTime	160 μs
aCCATime	< 40 μs
aRxPHYStartDelay	600 μs for S1G_1M preamble; 280 μs for S1G_SHORT preamble and S1G_LONG preamble.
aRxTxTurnaroundTime	Implementation dependent, see 10.3.7.
aTxPHYDelay	Implementation dependent, see 10.3.7.
aRxPHYDelay	Implementation dependent, see 10.3.7.
aRxTxSwitchTime	Implementation dependent, see 10.3.7.
aTxRampOnTime	Implementation dependent, see 10.3.7.
aAirPropagationTime	6 μs
aMACProcessingDelay	Implementation dependent, see 10.3.7.
aDTT2UTTTime	320 μs
aCCAMidTime	212 μs
aPPDUMaxTime	27 920 μs (see NOTE 1)
aPSDUMaxLengthWithNoAggregation	511 octets (see NOTE 2)
aPSDUMaxLength	797 159 octets (see NOTE 3)

NOTE 1—This is the maximum PPDU duration in μs for an S1G_1M PPDU with a bandwidth of 1 MHz, S1G-MCS 10 and 1 spatial stream, limited by PSDU length of 511 octets.

NOTE 2—This is the maximum PSDU length in octets for an S1G PPDU supported by the Length field in the S1G SIG field when the Aggregation field is 0.

NOTE 3—This is the maximum length in octets for an S1G SU PPDU with a bandwidth of 16 MHz, S1G-MCS 9 and 4 spatial streams, limited by 511 data symbols supported by the Length field in the S1G SIG field, excluding the SERVICE field and tail bits.

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23.5 Parameters for S1G-MCSs

The rate-dependent parameters for 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz, N_{SS} = 1,...,4 are given in Table 23-41 to Table 23-60. Support for 4 μs GI is optional in all cases. Support for MCS 8 and 9 (when valid) is optional in all cases. An S1G AP-STA shall support single spatial stream MCSs within the range MCS 0 to MCS 7 for all channel widths for which it has indicated support regardless of the Tx or Rx Highest Supported Data Rate subfield values in the VHT Supported MCS Set field. An S1G non-AP STA shall support single spatial stream MCSs within the range MCS 0 to MCS 2 for 1 and 2 MHz channel widths.

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When more than one spatial stream is supported, the Tx or Rx Highest Supported Data Rate subfield values in the VHT Supported MCS Set field may result in a reduced MCS range (cut-off) for greater than one spatial stream. Support for 1 MHz and 2 MHz with N_{ss} = 1 is mandatory. Support for 1 and 2 MHz with N_{ss} = 2,3,4 is optional. Support for 4 MHz, 8 MHz, and 16 MHz with N_{ss} = 1,...,4 is optional.

NOTE—When LDPC is used with MCS 10, the resulting N_{CBPS} is 12 because the 2× repetition is applied after the LDPC encoding procedure.

Table 23-41—S1G-MCSs for 1 MHz, N_{ss} = 1

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	24	2	24	12	1	300.0	333.3
1	QPSK	1/2	2	24	2	48	24	1	600.0	666.7
2	QPSK	3/4	2	24	2	48	36	1	900.0	1000.0
3	16-QAM	1/2	4	24	2	96	48	1	1200.0	1333.3
4	16-QAM	3/4	4	24	2	96	72	1	1800.0	2000.0
5	64-QAM	2/3	6	24	2	144	96	1	2400.0	2666.7
6	64-QAM	3/4	6	24	2	144	108	1	2700.0	3000.0
7	64-QAM	5/6	6	24	2	144	120	1	3000.0	3333.3
8	256-QAM	3/4	8	24	2	192	144	1	3600.0	4000.0
9	256-QAM	5/6	8	24	2	192	160	1	4000.0	4444.4
10	BPSK	1/2 with 2× repetition	1	24	2	24	6	1	150.0	166.7

Table 23-42—S1G-MCSs for 1 MHz, N_{ss} = 2

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	24	2	48	24	1	600.0	666.7
1	QPSK	1/2	2	24	2	96	48	1	1200.0	1333.3
2	QPSK	3/4	2	24	2	96	72	1	1800.0	2000.0
3	16-QAM	1/2	4	24	2	192	96	1	2400.0	2666.7
4	16-QAM	3/4	4	24	2	192	144	1	3600.0	4000.0
5	64-QAM	2/3	6	24	2	288	192	1	4800.0	5333.3
6	64-QAM	3/4	6	24	2	288	216	1	5400.0	6000.0
7	64-QAM	5/6	6	24	2	288	240	1	6000.0	6666.7
8	256-QAM	3/4	8	24	2	384	288	1	7200.0	8000.0
9	256-QAM	5/6	8	24	2	384	320	1	8000.0	8888.9

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Table 23-43—S1G-MCSs for 1 MHz, N_{SS} = 3

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	24	2	72	36	1	900.0	1000.0
1	QPSK	1/2	2	24	2	144	72	1	1800.0	2000.0
2	QPSK	3/4	2	24	2	144	108	1	2700.0	3000.0
3	16-QAM	1/2	4	24	2	288	144	1	3600.0	4000.0
4	16-QAM	3/4	4	24	2	288	216	1	5400.0	6000.0
5	64-QAM	2/3	6	24	2	432	288	1	7200.0	8000.0
6	64-QAM	3/4	6	24	2	432	324	1	8100.0	9000.0
7	64-QAM	5/6	6	24	2	432	360	1	9000.0	10 000.0
8	256-QAM	3/4	8	24	2	576	432	1	10800.0	12000.0
9	256-QAM	5/6	8	24	2	576	480	1	12000.0	13333.3

Table 23-44—S1G-MCSs for 1 MHz, N_{SS} = 4

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	24	2	96	48	1	1200.0	1333.3
1	QPSK	1/2	2	24	2	192	96	1	2400.0	2666.7
2	QPSK	3/4	2	24	2	192	144	1	3600.0	4000.0
3	16-QAM	1/2	4	24	2	384	192	1	4800.0	5333.3
4	16-QAM	3/4	4	24	2	384	288	1	7200.0	8000.0
5	64-QAM	2/3	6	24	2	576	384	1	9600.0	10 666.7
6	64-QAM	3/4	6	24	2	576	432	1	10 800.0	12 000.0
7	64-QAM	5/6	6	24	2	576	480	1	12 000.0	13 333.3
8	256-QAM	3/4	8	24	2	768	576	1	14 400.0	16 000.0
9	256-QAM	5/6	8	24	2	768	640	1	16 000.0	17 777.8

Table 23-45—S1G-MCSs for 2 MHz, N_{SS} = 1

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	52	4	52	26	1	650.0	722.2
1	QPSK	1/2	2	52	4	104	52	1	1300.0	1444.4
2	QPSK	3/4	2	52	4	104	78	1	1950.0	2166.7
3	16-QAM	1/2	4	52	4	208	104	1	2600.0	2888.9
4	16-QAM	3/4	4	52	4	208	156	1	3900.0	4333.3
5	64-QAM	2/3	6	52	4	312	208	1	5200.0	5777.8
6	64-QAM	3/4	6	52	4	312	234	1	5850.0	6500.0
7	64-QAM	5/6	6	52	4	312	260	1	6500.0	7222.2
8	256-QAM	3/4	8	52	4	416	312	1	7800.0	8666.7
9	Not valid									

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Table 23-46—S1G-MCSs for 2 MHz, N_{SS} = 2

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	52	4	104	52	1	1300.0	1444.4
1	QPSK	1/2	2	52	4	208	104	1	2600.0	2888.9
2	QPSK	3/4	2	52	4	208	156	1	3900.0	4333.3
3	16-QAM	1/2	4	52	4	416	208	1	5200.0	5777.8
4	16-QAM	3/4	4	52	4	416	312	1	7800.0	8666.7
5	64-QAM	2/3	6	52	4	624	416	1	10 400.0	11 555.6
6	64-QAM	3/4	6	52	4	624	468	1	11 700.0	13 000.0
7	64-QAM	5/6	6	52	4	624	520	1	13 000.0	14 444.4
8	256-QAM	3/4	8	52	4	832	624	1	15 600.0	17 333.3
9	Not valid									

Table 23-47—S1G-MCSs for 2 MHz, N_{SS} = 3

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	52	4	156	78	1	1950.0	2166.7
1	QPSK	1/2	2	52	4	312	156	1	3900.0	4333.3
2	QPSK	3/4	2	52	4	312	234	1	5850.0	6500.0
3	16-QAM	1/2	4	52	4	624	312	1	7800.0	8666.7
4	16-QAM	3/4	4	52	4	624	468	1	11 700.0	13 000.0
5	64-QAM	2/3	6	52	4	936	624	1	15 600.0	17 333.3
6	64-QAM	3/4	6	52	4	936	702	1	17 550.0	19 500.0
7	64-QAM	5/6	6	52	4	936	780	1	19 500.0	21 666.7
8	256-QAM	3/4	8	52	4	1248	936	1	23 400.0	26 000.0
9	256-QAM	5/6	8	52	4	1248	1040	1	26 000.0	28 888.9

Table 23-48—S1G-MCSs for 2 MHz, N_{SS} = 4

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	52	4	208	104	1	2600.0	2888.9
1	QPSK	1/2	2	52	4	416	208	1	5200.0	5777.8
2	QPSK	3/4	2	52	4	416	312	1	7800.0	8666.7
3	16-QAM	1/2	4	52	4	832	416	1	10 400.0	11 555.6
4	16-QAM	3/4	4	52	4	832	624	1	15 600.0	17 333.3
5	64-QAM	2/3	6	52	4	1248	832	1	20 800.0	23 111.1
6	64-QAM	3/4	6	52	4	1248	936	1	23 400.0	26 000.0
7	64-QAM	5/6	6	52	4	1248	1040	1	26 000.0	28 888.9
8	256-QAM	3/4	8	52	4	1664	1248	1	31 200.0	34 666.7
9	Not valid									

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Table 23-49—S1G-MCSs for 4 MHz, N_{SS} = 1

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	108	6	108	54	1	1350.0	1500.0
1	QPSK	1/2	2	108	6	216	108	1	2700.0	3000.0
2	QPSK	3/4	2	108	6	216	162	1	4050.0	4500.0
3	16-QAM	1/2	4	108	6	432	216	1	5400.0	6000.0
4	16-QAM	3/4	4	108	6	432	324	1	8100.0	9000.0
5	64-QAM	2/3	6	108	6	648	432	1	10 800.0	12 000.0
6	64-QAM	3/4	6	108	6	648	486	1	12 150.0	13 500.0
7	64-QAM	5/6	6	108	6	648	540	1	13 500.0	15 000.0
8	256-QAM	3/4	8	108	6	864	648	1	16 200.0	18 000.0
9	256-QAM	5/6	8	108	6	864	720	1	18 000.0	20 000.0

Table 23-50—S1G-MCSs for 4 MHz, N_{SS} = 2

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	108	6	216	108	1	2700.0	3000.0
1	QPSK	1/2	2	108	6	432	216	1	5400.0	6000.0
2	QPSK	3/4	2	108	6	432	324	1	8100.0	9000.0
3	16-QAM	1/2	4	108	6	864	432	1	10 800.0	12 000.0
4	16-QAM	3/4	4	108	6	864	648	1	16 200.0	18 000.0
5	64-QAM	2/3	6	108	6	1296	864	1	21 600.0	24 000.0
6	64-QAM	3/4	6	108	6	1296	972	1	24 300.0	27 000.0
7	64-QAM	5/6	6	108	6	1296	1080	1	27 000.0	30 000.0
8	256-QAM	3/4	8	108	6	1728	1296	1	32 400.0	36 000.0
9	256-QAM	5/6	8	108	6	1728	1440	1	36 000.0	40 000.0

Table 23-51—S1G-MCSs for 4 MHz, N_{SS} = 3

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	108	6	324	162	1	4050.0	4500.0
1	QPSK	1/2	2	108	6	648	324	1	8100.0	9000.0
2	QPSK	3/4	2	108	6	648	486	1	12 150.0	13 500.0
3	16-QAM	1/2	4	108	6	1296	648	1	16 200.0	18 000.0
4	16-QAM	3/4	4	108	6	1296	972	1	24 300.0	27 000.0
5	64-QAM	2/3	6	108	6	1944	1296	1	32 400.0	36 000.0
6	64-QAM	3/4	6	108	6	1944	1458	1	36 450.0	40 500.0
7	64-QAM	5/6	6	108	6	1944	1620	1	40 500.0	45 000.0
8	256-QAM	3/4	8	108	6	2592	1944	1	48 600.0	54 000.0
9	256-QAM	5/6	8	108	6	2592	2160	1	54 000.0	60 000.0

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Table 23-52—S1G-MCSs for 4 MHz, N_{SS} = 4

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	108	6	432	216	1	5400.0	6000.0
1	QPSK	1/2	2	108	6	864	432	1	10 800.0	12 000.0
2	QPSK	3/4	2	108	6	864	648	1	16 200.0	18 000.0
3	16-QAM	1/2	4	108	6	1728	864	1	21 600.0	24 000.0
4	16-QAM	3/4	4	108	6	1728	1296	1	32 400.0	36 000.0
5	64-QAM	2/3	6	108	6	2592	1728	1	43 200.0	48 000.0
6	64-QAM	3/4	6	108	6	2592	1944	1	48 600.0	54 000.0
7	64-QAM	5/6	6	108	6	2592	2160	1	54 000.0	60 000.0
8	256-QAM	3/4	8	108	6	3456	2592	1	64 800.0	72 000.0
9	256-QAM	5/6	8	108	6	3456	2880	1	72 000.0	80 000.0

Table 23-53—S1G-MCSs for 8 MHz, N_{SS} = 1

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	234	8	234	117	1	2925.0	3250.0
1	QPSK	1/2	2	234	8	468	234	1	5850.0	6500.0
2	QPSK	3/4	2	234	8	468	351	1	8775.0	9750.0
3	16-QAM	1/2	4	234	8	936	468	1	11 700.0	13 000.0
4	16-QAM	3/4	4	234	8	936	702	1	17 550.0	19 500.0
5	64-QAM	2/3	6	234	8	1404	936	1	23 400.0	26 000.0
6	64-QAM	3/4	6	234	8	1404	1053	1	26 325.0	29 250.0
7	64-QAM	5/6	6	234	8	1404	1170	1	29 250.0	32 500.0
8	256-QAM	3/4	8	234	8	1872	1404	1	35 100.0	39 000.0
9	256-QAM	5/6	8	234	8	1872	1560	1	39 000.0	43 333.3

Table 23-54—S1G-MCSs for 8 MHz, N_{SS} = 2

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	234	8	468	234	1	5850.0	6500.0
1	QPSK	1/2	2	234	8	936	468	1	11 700.0	13 000.0
2	QPSK	3/4	2	234	8	936	702	1	17 550.0	19 500.0
3	16-QAM	1/2	4	234	8	1872	936	1	23 400.0	26 000.0
4	16-QAM	3/4	4	234	8	1872	1404	1	35 100.0	39 000.0
5	64-QAM	2/3	6	234	8	2808	1872	1	46 800.0	52 000.0
6	64-QAM	3/4	6	234	8	2808	2106	1	52 650.0	58 500.0
7	64-QAM	5/6	6	234	8	2808	2340	1	58 500.0	65 000.0
8	256-QAM	3/4	8	234	8	3744	2808	1	70 200.0	78 000.0
9	256-QAM	5/6	8	234	8	3744	3120	1	78 000.0	86 666.7

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Table 23-55—S1G-MCSs for 8 MHz, N_{SS} = 3

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	234	8	702	351	1	8775.0	9750.0
1	QPSK	1/2	2	234	8	1404	702	1	17 550.0	19 500.0
2	QPSK	3/4	2	234	8	1404	1053	1	26 325.0	29 250.0
3	16-QAM	1/2	4	234	8	2808	1404	1	35 100.0	39 000.0
4	16-QAM	3/4	4	234	8	2808	2106	1	52 650.0	58 500.0
5	64-QAM	2/3	6	234	8	4212	2808	1	70 200.0	78 000.0
6	64-QAM	3/4	6	234	8	4212	3159	1	78 975.0	87 750.0
7	64-QAM	5/6	6	234	8	4212	3510	1	87 750.0	97 500.0
8	256-QAM	3/4	8	234	8	5616	4212	1	105 300.0	117 000.0
9	256-QAM	5/6	8	234	8	5616	4680	1	117 000.0	130 000.0

Table 23-56—S1G-MCSs for 8 MHz, N_{SS} = 4

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	234	8	936	468	1	11 700.0	13 000.0
1	QPSK	1/2	2	234	8	1872	936	1	23 400.0	26 000.0
2	QPSK	3/4	2	234	8	1872	1404	1	35 100.0	39 000.0
3	16-QAM	1/2	4	234	8	3744	1872	1	46 800.0	52 000.0
4	16-QAM	3/4	4	234	8	3744	2808	1	70 200.0	78 000.0
5	64-QAM	2/3	6	234	8	5616	3744	1	93 600.0	104 000.0
6	64-QAM	3/4	6	234	8	5616	4212	1	105 300.0	117 000.0
7	64-QAM	5/6	6	234	8	5616	4680	1	117 000.0	130 000.0
8	256-QAM	3/4	8	234	8	7488	5616	1	140 400.0	156 000.0
9	256-QAM	5/6	8	234	8	7488	6240	1	156 000.0	173 333.3

Table 23-57—S1G-MCSs for 16 MHz, N_{SS} = 1

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	468	16	468	234	1	5850.0	6500.0
1	QPSK	1/2	2	468	16	936	468	1	11 700.0	13 000.0
2	QPSK	3/4	2	468	16	936	702	1	17 550.0	19 500.0
3	16-QAM	1/2	4	468	16	1872	936	1	23 400.0	26 000.0
4	16-QAM	3/4	4	468	16	1872	1404	1	35 100.0	39 000.0
5	64-QAM	2/3	6	468	16	2808	1872	1	46 800.0	52 000.0
6	64-QAM	3/4	6	468	16	2808	2106	1	52 650.0	58 500.0
7	64-QAM	5/6	6	468	16	2808	2340	1	58 500.0	65 000.0
8	256-QAM	3/4	8	468	16	3744	2808	1	70 200.0	78 000.0
9	256-QAM	5/6	8	468	16	3744	3120	1	78 000.0	86 666.7

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Table 23-58—S1G-MCSs for 16 MHz, N_{SS} = 2

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	468	16	936	468	1	11 700.0	13 000.0
1	QPSK	1/2	2	468	16	1872	936	1	23 400.0	26 000.0
2	QPSK	3/4	2	468	16	1872	1404	1	35 100.0	39 000.0
3	16-QAM	1/2	4	468	16	3744	1872	1	46 800.0	52 000.0
4	16-QAM	3/4	4	468	16	3744	2808	1	70 200.0	78 000.0
5	64-QAM	2/3	6	468	16	5616	3744	1	93 600.0	104 000.0
6	64-QAM	3/4	6	468	16	5616	4212	1	105 300.0	117 000.0
7	64-QAM	5/6	6	468	16	5616	4680	1	117 000.0	130 000.0
8	256-QAM	3/4	8	468	16	7488	5616	1	140 400.0	156 000.0
9	256-QAM	5/6	8	468	16	7488	6240	1	156 000.0	173 333.3

Table 23-59—S1G-MCSs for 16 MHz, N_{SS} = 3

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	468	16	1404	702	1	17 550.0	19 500.0
1	QPSK	1/2	2	468	16	2808	1404	1	35 100.0	39 000.0
2	QPSK	3/4	2	468	16	2808	2106	1	52 650.0	58 500.0
3	16-QAM	1/2	4	468	16	5616	2808	1	70 200.0	78 000.0
4	16-QAM	3/4	4	468	16	5616	4212	1	105 300.0	117 000.0
5	64-QAM	2/3	6	468	16	8424	5616	1	140 400.0	156 000.0
6	64-QAM	3/4	6	468	16	8424	6318	1	157 950.0	175 500.0
7	64-QAM	5/6	6	468	16	8424	7020	1	175 500.0	195 000.0
8	256-QAM	3/4	8	468	16	11 232	8424	1	210 600.0	234 000.0
9	256-QAM	5/6	8	468	16	11 232	9360	1	234 000.0	260 000.0

Table 23-60—S1G-MCSs for 16 MHz, N_{SS} = 4

MCS Idx	Mod	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data_rate (kb/s)	
									8 μs GI	4 μs GI
0	BPSK	1/2	1	468	16	1872	936	1	23400.0	26000.0
1	QPSK	1/2	2	468	16	3744	1872	1	46800.0	52000.0
2	QPSK	3/4	2	468	16	3744	2808	1	70200.0	78000.0
3	16-QAM	1/2	4	468	16	7488	3744	1	93600.0	104000.0
4	16-QAM	3/4	4	468	16	7488	5616	1	140400.0	156000.0
5	64-QAM	2/3	6	468	16	11 232	7488	1	187200.0	208000.0
6	64-QAM	3/4	6	468	16	11 232	8424	1	210600.0	234000.0
7	64-QAM	5/6	6	468	16	11 232	9360	1	234000.0	260000.0
8	256-QAM	3/4	8	468	16	14 976	11 232	1	280800.0	312000.0
9	256-QAM	5/6	8	468	16	14 976	12 480	1	312000.0	346666.7

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24. China directional multi-gigabit (CDMG) PHY specification

24.1 CDMG PHY introduction

24.1.1 Scope

The CDMG PHY supports a 1.08 GHz channel width in comparison with the DMG PHY in Clause 20, which supports a 2.16 GHz channel width. As many aspects of CDMG PHY are the same as DMG PHY, this clause mainly lists the new features corresponding to Clause 20.

The CDMG PHY supports two modulation methods:

— A control modulation using MCS 0 of the CDMG Control mode defined in 24.4

— A single carrier (SC) modulation using MCS 1 to MCS 16 of the CDMG SC mode defined in 24.5 and MCS 17 to MCS 23 of the CDMG low-power SC mode defined in 24.6

All CDMG modulation methods share a similar preamble (see 24.3.6).

The services provided to the MAC by the CDMG PHY consist of the following protocol functions, defined as follows:

a) A function that defines a method of mapping the PHY service data units (PSDU) into a framing format (PPDU) suitable for sending and receiving PSDUs between two or more STAs.

b) A function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. Depending on the MCSs, these STAs support a mixture of CDMG SC mode, CDMG low-power SC mode, and CDMG control mode.

24.1.2 CDMG PHY functions

24.1.2.1 General

The CDMG PHY contains two functional entities: the PHY and the layer management function (PLME). Each of these functions is described in detail in 24.3 to 24.9. The CDMG PHY service is provided to the MAC through the PHY service primitives defined in Clause 8.

24.1.2.2 PHY management entity

The PLME performs management of the local PHY functions in conjunction with the MLME.

24.1.2.3 Service specification method

The description for service specification method is the same as that contained in 20.1.2.2.

24.2 CDMG PHY service interface

24.2.1 Introduction

The introduction for CDMG PHY service interface is the same as that contained in 20.2.1.

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24.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 24-1 are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive and/or as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive.

Table 24-1—TXVECTOR and RXVECTOR parameters

Parameter	Value	TXVECTOR	RXVECTOR
MCS	The MCS parameter is an enumerated type that indicates the modulation and coding scheme used in the transmission of the packet. Values are integers in the range 0–23. — A MCS value of 0 indicates the use of CDMG control mode or CDMG robust PHY mode. — MCS values of 1 to 16 indicate use of Single Carrier modulations. The value is an index to Table 24-4. — MCS values of 17–23 indicate use of CDMG low-power SC mode. The value is an index toTable 24-6. The CDMG low-power SC mode is obsolete. Support for this mechanism might be removed in a later revision of the standard.	Y	Y
LENGTH	Indicates the number of octets in the PSDU in the range 1–262 143.	Y	Y
ADD_PPDU	Enumerated type: — ADD-PPDU indicates that this PPDU is immediately followed by another PPDU with no IFS or preamble on the subsequent PPDU. — NO-ADD-PPDU indicates no additional PPDU follows this PPDU.	Y	Y
PPDU_TYPE	Enumerated type: — TRN-R indicates either a PPDU whose Data field is followed by one or more TRN subfields, or a PPDU that is requesting TRN subfields to be appended to a future response PPDU. — TRN-T indicates a PPDU whose Data field is followed by one or more TRN subfields. The transmitter may change AWV configuration at the beginning of each TRN subfield. This parameter is reserved if TRN_LEN is 0.	Y	Y
TRN_LEN	TRN_LEN indicates the length of the training field. Values are in the range 0–16 (see 24.9.2.2.3).	Y	Y
AGGREGATION	Indicates whether the PSDU contains an A-MPDU. Enumerated type: — AGGREGATED indicates this is a PSDU with A-MPDU aggregation. — NOT_AGGREGATED indicates this is a PSDU without A-MPDU aggregation.	Y	Y
RSSI	The allowed values for the RSSI parameter are in the range from 0 to 255. This parameter is a measure by the PHY of the power observed at the input of the antennas plus the antenna gain, or equivalent antenna gain for a phase-array antenna, used to receive the current PPDU. RSSI shall be measured during the reception of the PHY preamble. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power.	N	Y
SNR	This parameter indicates the SNR measured during the reception of a CDMG control mode packet. Values are –10 dB to 53.75 dB in 0.25 dB steps.	N	Y

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Table 24-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Value	TXVECTOR	RXVECTOR
ANT_CONFIG	Indicates which antenna configuration(s) is to be used throughout the transmission of the packet and when to switch between configurations. Values are implementation dependent.	Y	N
CHAN_MEASUREMENT	Channel as measured during the reception of the TRN subfields. Each measurement includes 63 complex numbers.	N	Y
TIME_OF_DEPARTURE_REQUESTED	Enumerated type: — true indicates that the MAC entity requests that the PHY entity measure and report time of departure parameters corresponding to the time when the first frame energy is sent by the transmitting port. — false indicates that the MAC entity requests that the PHY entity neither measure nor report time of departure parameters.	O	N
RX_START_OF_FRAME_OFFSET	0 to 2^{32}–1. An estimate of the offset (in 10 nanosecond units) from the point in time at which the start of the preamble corresponding to the incoming frame arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC.	N	See NOTE
BEAM_TRACKING_REQUEST	This parameter indicates whether beam tracking is requested. Enumerated type: — BEAM-TRACKING-REQUESTED or BEAM-TRACKING-NOT-REQUESTED.	Y	Y
LAST_RSSI	In the TXVECTOR, LAST_RSSI indicates the received power level of the last packet with a valid PHY header that was received a SIFS before transmission of the current packet; otherwise, it is 0 (10.3.2.3.3). In the RXVECTOR, LAST_RSSI indicates the value of the LAST_RSSI field from the PCLP header of the received packet.Valid values are integers in the range 0 to 15: — Values of 2 to 14 represent power levels (–74+value×2) dBm. — A value of 15 represents power greater than or equal to –45 dBm. — A value of 1 represents power less than or equal to –71 dBm. — A value of 0 indicates that the previous packet was not received a SIFS before the current transmission.	Y	Y
Turnaround	Set to 1 or 0 as specified in 10.3.2.3.3.	Y	Y
ENHANCED_BEAM_TRACKING_REQUEST	This parameter indicates whether enhanced beam tracking is requested. Enumerated type: — ENHANCED-BEAM-TRACKING-REQUESTED or ENHANCED-BEAM-TRACKING-NOT-REQUESTED.	Y	Y
ROBUST_MODE	This parameter incorporating with the MCS parameter is an enumerated type that indicates CDMG control mode or CDMG robust PHY mode used in the transmission of the packet. It is present if MCS index is 0. Values are integers in the range 0–2. — A CDMG ROBUST_MODE value of 0 indicates the use of CDMG control mode. — A CDMG ROBUST_MODE value of 1 indicates the use of CDMG robust PHY mode 0. — A CDMG ROBUST_MODE value of 2 indicates the use of CDMG robust PHY mode 1. This parameter is not present if MCS index is not 0.	Y	Y

NOTE—"Y" if dot11TimingMsmtActivated is true; otherwise, "N".

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24.2.3 TXSTATUS parameters

The parameters listed in Table 24-2 are defined as part of the TXSTATUS parameter list in the PHY-TXSTART.confirm primitive.

Table 24-2—TXSTATUS parameters

Parameter	Value
TIME_OF_DEPARTURE	When the first frame energy is sent by the transmitting port, in units equal to 1/TIME_OF_DEPARTURE_ClockRate. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request.
TIME_OF_DEPARTURE_ClockRate	0 to 2^{16}–1. The clock rate, in units of MHz, is used to generate the TIME_OF_DEPARTURE value. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request.
TX_START_OF_FRAME_OFFSET	0 to 2^{32}–1. An estimate of the offset (in 10 nanosecond units) from the point in time at which the start of the preamble corresponding to the frame was transmitted at the transmit antenna connector to the point in time at which this primitive is issued to the MAC.

24.3 Common parameters

24.3.1 Channelization

The CDMG PHY operates in the channels defined in Annex E and shall support at least channel numbers 2, 35, and 36.

The channel center frequency is defined as:

Channel center frequency = Channel starting frequency + Channel spacing × (Channel number mod 32)

where the channel starting frequency is equal to 56.16 GHz, and the channel spacing is defined in Table E-6 in Annex E.

24.3.2 Transmit mask

The transmitted spectrum shall adhere to the transmit spectrum mask shown in Figure 24-1. The transmit spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 0.94 GHz, –17 dBr at a 0.6 GHz offset, –22 dBr at a 1.35 GHz offset, and –30 dBr at a 1.53 GHz offset and above, inside the channels allowed for the regulatory domain in which the STA is transmitting. The measurement shall be made using a 1 MHz resolution bandwidth and a 300 kHz video bandwidth.

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The transmitted spectrum shall be measured on data packets longer than 10 µs without the training fields.

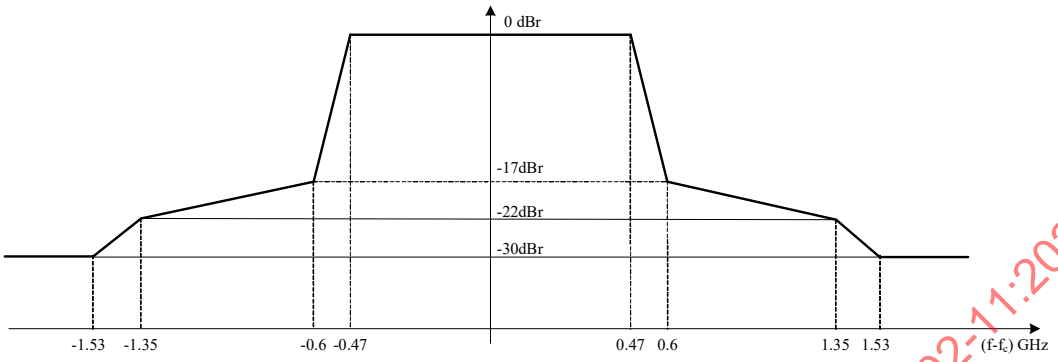

Figure 24-1—Transmit mask

24.3.3 Common requirements

24.3.3.1 Introduction

This subclause describes the common requirement from all three CDMG modes: control, SC, and low-power SC.

In all of the modes, all defined fields are transmitted bit 0 first in time.

24.3.3.2 Center frequency tolerance

24.3.3.2.1 General

The transmitter center frequency tolerance shall be ± 20 ppm.

24.3.3.2.2 Center frequency convergence

The transmitter center frequency shall converge to within 1 ppm of its final value within 0.9 µs from the start of the packet.

24.3.3.3 Symbol clock tolerance

The symbol clock frequency tolerance shall be ± 20 ppm.

The transmit center frequency and the symbol clock frequency shall be derived from the same reference oscillator.

24.3.3.4 Transmit center frequency leakage

The transmitter center frequency leakage shall not exceed –23 dB relative to the overall transmitted power.

24.3.3.5 Transmit rampup and rampdown

The description for transmit rampup and rampdown for CDMG PHY is the same as that contained in 20.3.3.5.

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24.3.3.6 Antenna setting

Antenna setting shall remain constant for the transmission of the entire packet except for the case of transmission of BRP-TX PPDU (see 24.9.2.2). During the transmission of BRP-TX PPDUs it shall remain constant for the transmission of the STF, CE field, and Data field.

24.3.3.7 Maximum input requirement

The receiver maximum input level is the maximum power level at the receive antenna(s) of the incoming signal, in dBm, present at the input of the receiver for which the error rate criterion (defined in 24.3.3.8) is met. A receiver shall have a receiver maximum input level at the receive antenna(s) of at least 10 $\mu W/cm^2$ for each of the modulation formats that the receiver supports.

24.3.3.8 Receiver minimum input sensitivity

For MCS 0, the PER shall be less than 5% for a PSDU length of 256 octets with the MCS dependent input levels listed in Table 24-3 defined at the antenna connector. For the other MCSs, the PER shall be less than 1% for a PSDU length of 4096 octets with the MCS dependent input levels listed in Table 24-3 defined at the antenna connector.

NOTE—For RF power measurements performed over the air, the input level is corrected to compensate for the antenna gain in the implementation. The gain of the antenna is the maximum estimated gain by the manufacturer. In the case of the phased-array antenna, the gain of the phased-array antenna is the maximum sum of estimated element gain minus 3 dB implementation loss.

Table 24-3 assumes 5 dB implementation loss and 10 dB noise factor (noise figure).

Table 24-3—Receiver minimum input level sensitivity

MCS	Receive sensitivity (dBm)
0	–81
1	–71
2	–69
3	–68
4	–67
5	–65
6	–66
7	–65
8	–64
9	–62
10	–58
11	–57
12	–56
13	–54

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Table 24-3—Receiver minimum input level sensitivity *(continued)*

MCS	Receive sensitivity (dBm)
14	–49
15	–48
16	–46
17	–67
18	–63
19	–60
20	–60
21	–60
22	–60
23	–60

24.3.4 Timing-related parameters

Table 24-4 defines timing-related parameters.

Table 24-4—Timing-related parameters

Parameter	Value
N_{GI}	64
N_{SPB}	448
F_c: chip rate	880 MHz
T_c: chip time	1 / F_c (~1.14 ns)
T_{seq}	128 × T_c (~146 ns)
T_{STF}: Detection sequence duration	18 × T_{seq} (~2618.2 ns)
T_{CE}: Channel estimation sequence duration	9 × T_{seq} (~1309.1 ns)
T_{HEADER}: header duration	3 × 512 × T_c (~1.75 µs)
$T_{STF\text{-}CP}$: Control mode short training field duration	50 × T_{seq} (~7.2727 µs)
$T_{CE\text{-}CP}$: Control mode channel estimation field duration	T_{CE} (~1309.1 ns)
T_{Data}	(N_{BLKS} × aSCBlockSize + aSCGILength) × T_c NOTE—N_{BLKS} is defined in 20.5.3.2.3.3 and aSCBlockSize and aSCGILength are defined in Table 20-30.

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24.3.5 Mathematical conventions in the signal description

The description for CDMG PHY packet structure and related equations is the same as that contained in 20.3.5.1.

24.3.6 Common preamble

24.3.6.1 General

The preamble is the part of the PPDU that is used for packet detection, AGC, frequency offset estimation, synchronization, I/Q imbalance estimation, indication of modulation (SC), and channel estimation. The SFS field in the preamble enables the receiver to perform estimation and compensation for the packet in a time domain and frequency domain according to the STF. The format of the preamble consists of a Short Training field followed by a Channel Estimation field. Figure 24-2 illustrates the SC packet preamble.

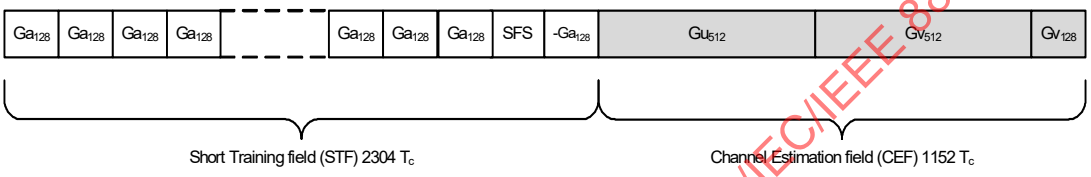

Figure 24-2—CDMG SC mode preamble

All numeric fields are transmitted in unsigned format, LSB first.

24.3.6.2 Short training field

The Short Training field is composed of 16 repetitions of sequences $Ga_{128}(n)$ of length 128 defined in 20.10, a single frequency sequence (SFS) of length 256 that used for I/Q imbalance estimation, followed by a single sequence $-Ga_{128}(n)$. The SFS is defined as

$$SFS(n) = \exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots$$

The waveform for the Short Training field is

$$r_{STF}(nT_c) = \begin{cases} (Ga_{128}(n \bmod 128))\exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots, 16 \times 128 - 1 \\ \exp\left(j\pi\frac{n}{2}\right), n = 16 \times 128, \ldots, 17 \times 128 - 1 \\ (-Ga_{128}(n \bmod 128))\exp\left(j\pi\frac{n}{2}\right), n = 17 \times 128, \ldots, 18 \times 128 - 1 \end{cases}$$

24.3.6.3 Channel estimation field

The Channel Estimation field is used for channel estimation, as well as indication of which modulation is going to be used for the packet, and enables the receiver to suppress nonlinear impact generated in a power amplification process according to the CE field. The Channel Estimation field is composed of a concatenation of two sequences $Gu_{512}(n)$ and $Gv_{512}(n)$ where the last 128 samples of $Gu_{512}(n)$ are equal to the last 128 samples used in the Short Training field. They are followed by a 128 samples sequence $Gv_{128}(n)$ equal to the first 128 samples of both $Gu_{512}(n)$ and $Gv_{512}(n)$.

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The Gu_{512} and Gv_{512} sequences are defined as

$$Gu_{512} = \left[-Gb_{128}\ -Ga_{128}\ Gb_{128}\ -Ga_{128}\right]$$

$$Gv_{512} = \left[-Gb_{128}\ Ga_{128}\ -Gb_{128}\ -Ga_{128}\right]$$

When the data field of the packet is modulated using single carrier, the Gu_{512} and Gv_{512} fields are concatenated in the order illustrated in Figure 24-3.

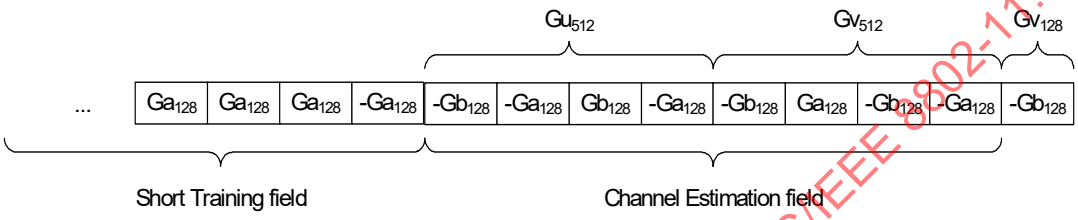

Figure 24-3—Channel Estimation field for SC packets

The waveform for the channel estimation sequence is

$$r_{CE_{SC}}(nT_c) = (Gu_{512}(n) + Gv_{512}(n-512) + Gv_{128}(n-1024))\exp\left(j\pi\frac{n}{2}\right),\ n = 0, 1, \ldots, 1151$$

Note that sequences $Gu_{512}(n)$ and $Gv_{512}(n)$ are defined for $0 \le n \le 511$. For other values of n, $Gu_{512}(n)$ and $Gv_{512}(n)$ are set to 0.

24.3.7 HCS calculation for headers of CDMG control mode and CDMG SC mode

The description for HCS calculation for headers of CDMG control mode and CDMG SC mode is the same as that contained in 20.3.7.

24.3.8 Common LDPC parity matrices

The description for common LDPC parity matrices for CDMG PHY is the same as that contained in 20.3.8.

24.3.9 Scrambler

The description for CDMG PHY scrambler is the same as that contained in 20.3.9.

24.3.10 Received channel power indicator (RCPI) measurement

The description for received channel power indicator (RCPI) measurement for CDMG PHY is the same as that contained in 20.3.10.

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24.4 CDMG control mode

24.4.1 Introduction

Transmission and reception of control mode PPDUs are mandatory. CDMG control mode uses the same chip rate as the CDMG SC mode. CDMG control mode is transmitted when the TXVECTOR indicates MCS 0.

The modulation and coding scheme for the CDMG control mode is shown in Table 24-5.

Table 24-5—CDMG control mode modulation and coding scheme

MCS index	Modulation	Code rate	Data rate
0	DBPSK	1/2[a]	13.75 Mb/s[a]

[a] Code rate and data rate might be lower due to codeword shortening.

24.4.2 PPDU format

The CDMG control mode PPDU is composed of the Preamble, Header, Data field, and possibly AGC and TRN subfields. This is shown in Figure 24-4.

Figure 24-4—CDMG control mode PPDU format

24.4.3 Transmission

24.4.3.1 Preamble

24.4.3.1.1 General

The preamble is the part of the CDMG control mode PPDU that is used for packet detection, AGC, frequency offset estimation, synchronization, indication of frame type, and channel estimation.

The preamble is composed of two parts as shown in Figure 24-5: the Short Training field and the Channel Estimation field.

Figure 24-5—CDMG control mode preamble

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24.4.3.1.2 Short Training field

The Short Training field is composed of 48 repetitions of sequences $Gb_{128}(n)$ of length 128, followed by a single $-Gb_{128}(n)$ sequence (for synchronization) and then a single $-Ga_{128}(n)$ sequence. The sequences $Ga_{128}(n)$ and $Gb_{128}(n)$ are defined in 20.10.

The waveform for the Short Training field is

$$r_{STF}(nT_c) = \begin{cases} Gb_{128}(n \bmod 128)\exp\left(j\pi\frac{n}{2}\right), & n = 0, 1, \ldots, 48 \times 128 - 1 \\ -Gb_{128}(n \bmod 128)\exp\left(j\pi\frac{n}{2}\right), & n = 48 \times 128, \ldots, 49 \times 128 - 1 \\ -Ga_{128}(n \bmod 128)\exp\left(j\pi\frac{n}{2}\right), & n = 49 \times 128, \ldots, 50 \times 128 - 1 \end{cases}$$

Note that sequences $Ga_{128}(n)$ and $Gb_{128}(n)$ are defined for $0 \le n \le 127$. For other values of n, they are set to 0.

24.4.3.1.3 Channel Estimation field

The Channel Estimation field is the same as the Channel Estimation field of the CDMG SC mode, as defined in Figure 24-3 of 24.3.6.3.

24.4.3.2 Header

24.4.3.2.1 General

In the CDMG control mode, the preamble is followed by the header block. The header consists of several fields that define the details of the PPDU to be transmitted.

The header fields are described in Table 24-1.

Table 24-1—CDMG control mode header fields

Field name	Bit	Description
Differential Encoder Initialization	B0	Used to initialize the differential encoding *c(0)* in 20.4.3.3.4. May be set to any value.
Scrambler Initialization	B1–B4	Bits X1–X4 of the initial scrambler state (see 20.4.3.3.2).
Length	B5–B14	Number of data octets in the PSDU. Range 14–1023.
PPDU Type	B15	As defined in Table 24-3.
Training Length	B16–B20	Length of the training field. The use of this field is defined in 24.9.2.2.3.
Turnaround	B21	Contains a copy of the parameter TURNAROUND from the TXVECTOR.

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Table 24-1—CDMG control mode header fields *(continued)*

Field name	Bit	Description
Robust PHY Mode Indication/Reserved bits	B22–B23	— Set to 00: control mode. — Set to 01: robust PHY mode 0. — Set to 10: robust PHY mode 1. — Set to 11: reserved.
HCS	B24–B39	Header check sequence. Calculation of the header check sequence is defined in 24.3.7.

Reserved bits are set to 0 by the transmitter and shall be ignored by the receiver.

24.4.3.2.2 Generation of HCS bits

The header check sequence (HCS) is calculated over bits 0–23 and uses CRC 16-CCITT as described in 24.3.7.

24.4.3.2.3 Header encoding and modulation

The header bits followed by the HCS bits are prepended to the data field bits and passed into the data field encoder per 24.4.3.3. The minimal payload length is 14 octets

24.4.3.3 Data field

The description for Data field for CDMG control mode is the same as that contained in 20.4.3.3.

24.4.4 Performance requirements

24.4.4.1 Transmit requirements

24.4.4.1.1 Introduction

Transmitter performance requirements of the CDMG control mode are defined in 24.4.4.1.2.

24.4.4.1.2 Transmit EVM

The description for transmit EVM for CDMG control mode is the same as that contained in 20.4.4.1.2.

24.4.4.2 Receive requirements

24.4.4.2.1 Introduction

This subclause describes the performance requirement from the CDMG control mode receiver.

24.4.4.2.2 CCA

The start of a CDMG control mode transmission at a receive level greater than –71 dBm shall cause CCA to indicate busy with a probability > 90% within 3 μs.

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24.5 CDMG SC mode

24.5.1 Introduction

Transmission and reception of CDMG SC mode PPDUs are mandatory for selected MCSs.

24.5.2 PPDU format

A SC frame is composed of the Short Training field (STF), the Channel Estimation (CE) field, the Header, SC blocks and optional training fields, as shown in Figure 24-6.

Figure 24-6—SC frame format

The robust PHY modes use the CDMG control mode with short spreading sequences for the data. (See Table 24-2.) The following Golay complementary sequences Ga(8) and Ga(4) are used as spreading sequences for robust PHY mode 0 and 1, respectively.

Ga(8)=(+1, +1, +1, −1, +1, +1, −1, +1)

Ga(4)=(+1, +1, +1, −1)

Table 24-2—CDMG robust PHY modes

CDMG-Robust mode	Modulation	Code rate	Spreading sequence	Data rate (Mb/s)
0	DBPSK	1/2	Ga(8)	55
1	DBPSK	1/2	Ga(4)	110

24.5.3 Transmission

24.5.3.1 Header

24.5.3.1.1 General

In the CDMG SC mode, the preamble is followed by the header. The header consists of several fields that define the details of the PPDU to be transmitted. The encoding and modulation of the header are described in 24.5.3.1.4.

The header fields are described in Table 24-3.

Reserved bits are set to 0 by the transmitter and shall be ignored by the receiver.

If the Additional PPDU field is equal to 1, the Training Length field shall be set to 0.

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Table 24-3—CDMG SC mode header fields

Field name	Number of bits	Start bit	Description
Scrambler Initialization	7	0	Bits X1–X7 of the initial scrambler state (see 20.3.9).
MCS	6	7	Modulation and coding scheme (see Table 24-4).
Length	18	13	Number of data octets in the PSDU. Range 1–262 143.
Additional PPDU	1	31	Contains a copy of the parameter ADD_PPDU from the TXVECTOR. A value of 1 indicates that this PPDU is immediately followed by another PPDU with no IFS or preamble on the subsequent PPDU. A value of 0 indicates that no additional PPDU follows this PPDU.
PPDU Type	1	32	Corresponds to the TXVECTOR parameter PPDU_TYPE. — PPDU Type = 0 (BRP-RX PPDU, see 20.9.2.2.3), indicates either a packet whose Data field is followed by one or more TRN subfields (when the Beam Tracking Request field is 0 or in CDMG control mode), or a PPDU that contains TRN subfields to be appended to a future response PPDU (when the Beam Tracking Request field is 1). — PPDU Type = 1 (BRP-RX PPDU, see 20.9.2.2.3), indicates a PPDU whose Data field is followed by one or more TRN subfields. The transmitter may change AWV at the beginning of each TRN subfield. The field is reserved when the Training Length field is 0.
Training Length	5	33	Corresponds to the TXVECTOR parameter TRN_LEN. If the Beam Tracking Request field is 0, the Training Length field indicates the length of the training field. The use of this field is defined in 24.9.2.2.3. A value of 0 indicates that no training field is present in this PPDU. If the Beam Tracking Request field is 1 and the PPDU Type field is 1, the Training Length field indicates the length of the training field appended to this PPDU. If the PPDU Type field is 0, the Training Length field indicates the length of the training field requested for receive training.
Aggregation	1	38	Set to 1 to indicate that the PPDU in the data portion of the packet contains an A-MPDU; otherwise, set to 0.
Beam Tracking Request	1	39	Corresponds to the TXVECTOR parameter BEAM_TRACKING_REQUEST. Set to 1 to indicate the need for beam tracking (10.42.7); otherwise, set to 0. The Beam Tracking Request field is reserved when the Training Length field is 0.
Last RSSI	4	40	Contains a copy of the parameter LAST_RSSI from the TXVECTOR. The value is an unsigned integer: Values of 2 to 14 represent power levels (–74+value×2) dBm. A value of 15 represents a power greater than or equal to –45 dBm. A value of 1 represents a power less than or equal to –71 dBm. A value of 0 indicates that the previous packet was not received a SIFS period before the current transmission.
Turnaround	1	44	As defined in Table 24-1.

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Table 24-3—CDMG SC mode header fields *(continued)*

Field name	Number of bits	Start bit	Description
Enhanced Beam Tracking Request	1	45	Corresponds to the TXVECTOR parameter ENHANCED_BEAM_TRACKING_REQUEST. Set to 1 to indicate that one STF and CE field are appended to the Data and TRN fields. Otherwise, set to 0.
Reserved	2	46	
HCS	16	48	Header check sequence. Definition of this field calculation is in 24.5.3.1.3.

24.5.3.1.2 Modulation and coding scheme

The modulation and coding scheme (MCS) field specifies the modulation and code rate that is used in the PPDU. The modulation and coding schemes for the SC mode are defined in Table 24-4.

Table 24-4—CDMG SC mode modulation and coding schemes

MCS index	Modulation	N_{CBPS}	Repetition	Code rate	Data rate (Mb/s)
1	π/2-BPSK	1	2	1/2	192.5
2	π/2-BPSK	1	1	1/2	385
3	π/2-BPSK	1	1	5/8	481.25
4	π/2-BPSK	1	1	3/4	577.5
5	π/2-BPSK	1	1	13/16	625.625
6	π/2-QPSK	2	1	1/2	770
7	π/2-QPSK	2	1	5/8	962.5
8	π/2-QPSK	2	1	3/4	1155
9	π/2-QPSK	2	1	13/16	1251.25
10	π/2-16-QAM	4	1	1/2	1540
11	π/2-16-QAM	4	1	5/8	1925
12	π/2-16-QAM	4	1	3/4	2310
13	π/2-16-QAM	4	1	13/16	2502.5
14	π/2-64-QAM	6	1	5/8	2887.5
15	π/2-64-QAM	6	1	3/4	3465
16	π/2-64-QAM	6	1	13/16	3453.75

Transmit and receive support for MCS 9 and below is mandatory. Other MCSs are optional.

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24.5.3.1.3 Generation of the HCS bits

Calculation of the HCS for bits 0–47 of the header is defined in 24.3.7.

24.5.3.1.4 Header encoding and modulation

The description for header encoding and modulation for CDMG SC mode is the same as that contained in 20.5.3.1.4.

24.5.3.2 The Data field

24.5.3.2.1 General

The data field consists of the payload data of the PSDU and possible padding. The data are padded with zeros, scrambled, encoded, and modulated as described in the following subclauses. The amount of padding is defined in 24.5.3.2.3.

24.5.3.2.2 Scrambler

The description for CDMG SC mode scrambler is the same as that contained in 20.5.3.2.2.

24.5.3.2.3 Encoding

The description for CDMG SC mode encoding is the same as that contained in 20.5.3.2.3.

24.5.3.2.4 Modulation mapping

24.5.3.2.4.1 General

The coded and padded bit stream is converted into a stream of complex constellation points according to the modulation specified in the MCS table.

24.5.3.2.4.2 π/2-BPSK modulation

The description for CDMG SC mode π/2-BPSK modulation is the same as that contained in 20.5.3.2.4.2.

24.5.3.2.4.3 π/2-QPSK modulation

The description for CDMG SC mode π/2-QPSK modulation is the same as that contained in 20.5.3.2.4.3.

24.5.3.2.4.4 π/2-16-QAM modulation

The description for CDMG SC mode π/2-16-QAM modulation is the same as that contained in 20.5.3.2.4.5.

24.5.3.2.4.5 π/2-64-QAM modulation

In π/2-64-QAM modulation, the input bit stream is grouped into sets of 6 bits and mapped according to the following equation:

$$\tilde{s}(k) = \frac{1}{\sqrt{42}}((8c_{6k}-4)-(2c_{6k}-1)(4c_{6k+1}-2)+(2c_{6k}-1)(2c_{6k+1}-1)(2c_{6k+2}-1)) + j\frac{1}{\sqrt{42}}((8c_{6k+3}-4)-(2c_{6k+3}-1)(4c_{6k+4}-2)+(2c_{6k+3}-1)(2c_{6+4}-1)(2c_{6k+5}-1))$$

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where k is the output symbol index, k = 0, 1, …. Each output symbol is then rotated according to the following equation:

$$s_k = s_k \cdot e^{j \cdot \pi \cdot k/2}$$

The constellation bit encoding for 64-QAM is shown in Figure 24-7.

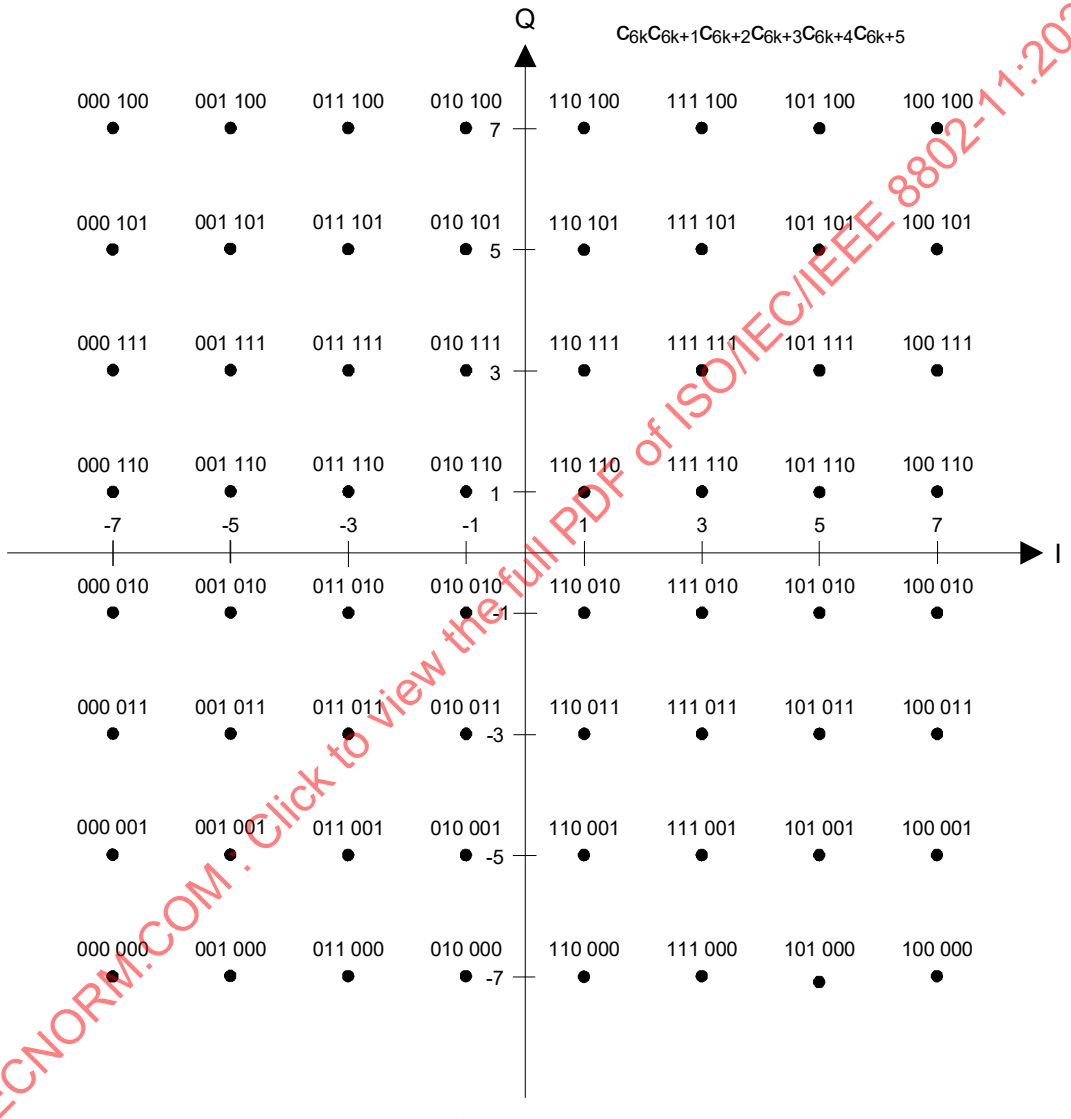

Figure 24-7—64-QAM constellation bit encoding

24.5.3.2.5 Symbol blocking and guard insertion

The description for CDMG SC mode symbol blocking and guard insertion is the same as that contained in 20.5.3.2.5.

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24.5.4 Performance requirements

24.5.4.1 Transmit requirements

24.5.4.1.1 Transmit EVM

The transmit EVM accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc.

The instrumentation shall perform carrier lock, symbol timing recovery, and amplitude adjustment while making the measurements. The equalizer shall be trained using information in the SC preamble (STF and/or CE field). For the CDMG SC mode EVM, measuring N_s samples at the sample rate, the measured symbols should not contain the first and the last hundred symbols of a given packet (ramp up/down). The EVM is calculated according to the formula below:

$$EVM = 20\log_{10}\left(\sqrt{\left(\frac{1}{N_s P_{avg}}\sum_{i=1}^{N_S}[(I_i - I_i^* - I_0)^2 + (Q_i - Q_i^* - Q_0)^2]\right)}\right)$$

where

N_s is the number of samples to be measured and N_s should be 1000

P_{avg} is the average power of the constellation

(I_i, Q_i) is the complex coordinates of the measured symbol i

(I_i^*, Q_i^*) is the complex coordinates of the ideal constellation point for the measured symbol i

(I_0, Q_0) is the complex DC term chosen to reduce EVM

The test equipment should use a root-raised cosine filter with roll-off factor of 0.25 for the pulse shaping filter when conducting EVM measurement.

The transmit pulse shaping used is left to the implementer.

The relative constellation error (EVM) shall not exceed a MCS dependent value according to Table 24-5.

Table 24-5—CDMG SC mode EVM requirements

MCS index	Modulation	Coding rate	EVM value (dB)
1	π/2-BPSK	1/2 with repetition	–6
2	π/2-BPSK	1/2	–7
3	π/2-BPSK	5/8	–9
4	π/2-BPSK	3/4	–10
5	π/2-BPSK	13/16	–12
6	π/2-QPSK	1/2	–11
7	π/2-QPSK	5/8	–12

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Table 24-5—CDMG SC mode EVM requirements *(continued)*

MCS index	Modulation	Coding rate	EVM value (dB)
8	π/2-QPSK	3/4	–13
9	π/2-QPSK	13/16	–15
10	π/2-16-QAM	1/2	–19
11	π/2-16-QAM	5/8	–20
12	π/2-16-QAM	3/4	–21
13	π/2-16-QAM	13/16	–23
14	π/2-64-QAM	5/8	–25
15	π/2-64-QAM	3/4	–26
16	π/2-64-QAM	13/16	–28

24.5.4.1.2 Time of departure accuracy

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is 880×10^6 sample/s.
— FIRST_TRANSITION_FIELD is Short Training field.
— SECOND_TRANSITION_FIELD is Channel Estimation field.
— TRAINING_FIELD is Channel Estimation field.
— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns.

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

24.5.4.2 Receive requirements

24.5.4.2.1 Introduction

This subclause describes the receiver requirements of the CDMG SC mode.

24.5.4.2.2 CCA sensitivity

The start of a CDMG SC mode transmission at a receive level greater than the minimum sensitivity for MCS 1 (–71 dBm) shall cause CCA to indicate busy with a probability > 90% within 1 μs. The receiver shall hold the carrier sense signal busy for any signal 20 dB above the minimum sensitivity for MCS 1.

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24.6 CDMG low-power SC mode

24.6.1 Introduction

The CDMG low-power SC mode is obsolete. Support for this mechanism might be removed in a later revision of the standard.

The CDMG low-power SC mode is an optional SC mode. This mode can provide lower processing power requirements for CDMG transceivers.

24.6.2 Transmission

24.6.2.1 Preamble

The CDMG low-power SC mode uses the same preamble as the CDMG SC mode.

24.6.2.2 Header

24.6.2.2.1 General

The CDMG low-power SC mode header fields are the same fields as in the CDMG SC mode (see Table 24-3 in 24.5.3.1).

The CDMG low-power SC mode modulation and coding schemes are listed in Table 24-6.

Table 24-6—CDMG low-power SC mode modulation and coding schemes

MCS	Modulation	Effective code rate	Coding scheme	N_{CPB}	Rate (Mb/s)
17	π/2-BPSK	13/28	RS(224,208)+Block-Code(16,8)	392	313
18	π/2-BPSK	13/21	RS(224,208)+Block-Code(12,8)	392	417
19	π/2-BPSK	52/63	RS(224,208)+SPC(9,8)	392	556
20	π/2-QPSK	13/28	RS(224,208)+Block-Code(16,8)	392	625.5
21	π/2-QPSK	13/21	RS(224,208)+Block-Code(12,8)	392	834
22	π/2-QPSK	52/63	RS(224,208)+SPC(9,8)	392	1112
23	π/2-QPSK	13/14	RS(224,208)+Block-Code(8,8)	392	1251.5

24.6.2.2.2 Header encoding and modulation

The description for header encoding and modulation for CDMG low-power SC mode is the same as that contained in 20.6.2.2.2.

24.6.2.3 Data field

The description for CDMG SC mode Data field is the same as that contained in 20.6.2.3.

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24.7 PHY transmit procedure

The PHY transmit procedure is shown in Figure 24-8. In order to transmit data, a PHY-TXSTART.request primitive shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate frequency through station management via the PLME, as specified in 24.10. Other transmit parameters, such as MCS and transmit power, are set via the PHY SAP with the PHY-TXSTART.request(TXVECTOR) primitive, as described in 24.2.2.

Transmission of the PHY preamble may start if TIME_OF_DEPARTURE_REQUESTED is false and shall start immediately if TIME_OFDEPARTURE_REQUESTED is true, based on the parameters passed in the PHY-TXSTART.request primitive.

The preamble format (control or SC mode) depends on the MCS in the PHY-TXSTART.request primitive. The PHY shall calculate the length of the packet according the MCS and the length specified in the PHY-TXSTART.request primitive, adding padding bits if necessary.

The PHY continues with the encoding and transmission of the header according to the parameters of the PHY-TXSTART.request(TXVECTOR) primitive. The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. The data are encoded as described in 20.4.3.3.3, 20.5.3.2.3, and 20.6.2.3.3. The encoded data are then modulated as described in 24.4, 24.5, and 24.6, depending on the MCS requested in the PHY-TXSTART.request primitive. Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. PHY-TXSTART shall be disabled by receiving a PHY-TXEND.request primitive.

Transmission of the PSDU is completed with the transmission of the last bits of the (encoded) PSDU. If no TRN units are specified in the PHY-TXSTART.request primitive, the PHY shall issue a PHY-TXEND primitive after the transmission of the last bits. If TRN units are requested in the PHY-TXSTART.request primitive, the transmission continues with the transmission of the AGC subfields and TRN units. The PHY issues the PHY-TXEND.confirm primitive to the MAC after the transmission of the last TRN unit. The packet transmission shall be completed, and the PHY entity shall enter the receive state (i.e., PHY-TXSTART shall be disabled). Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

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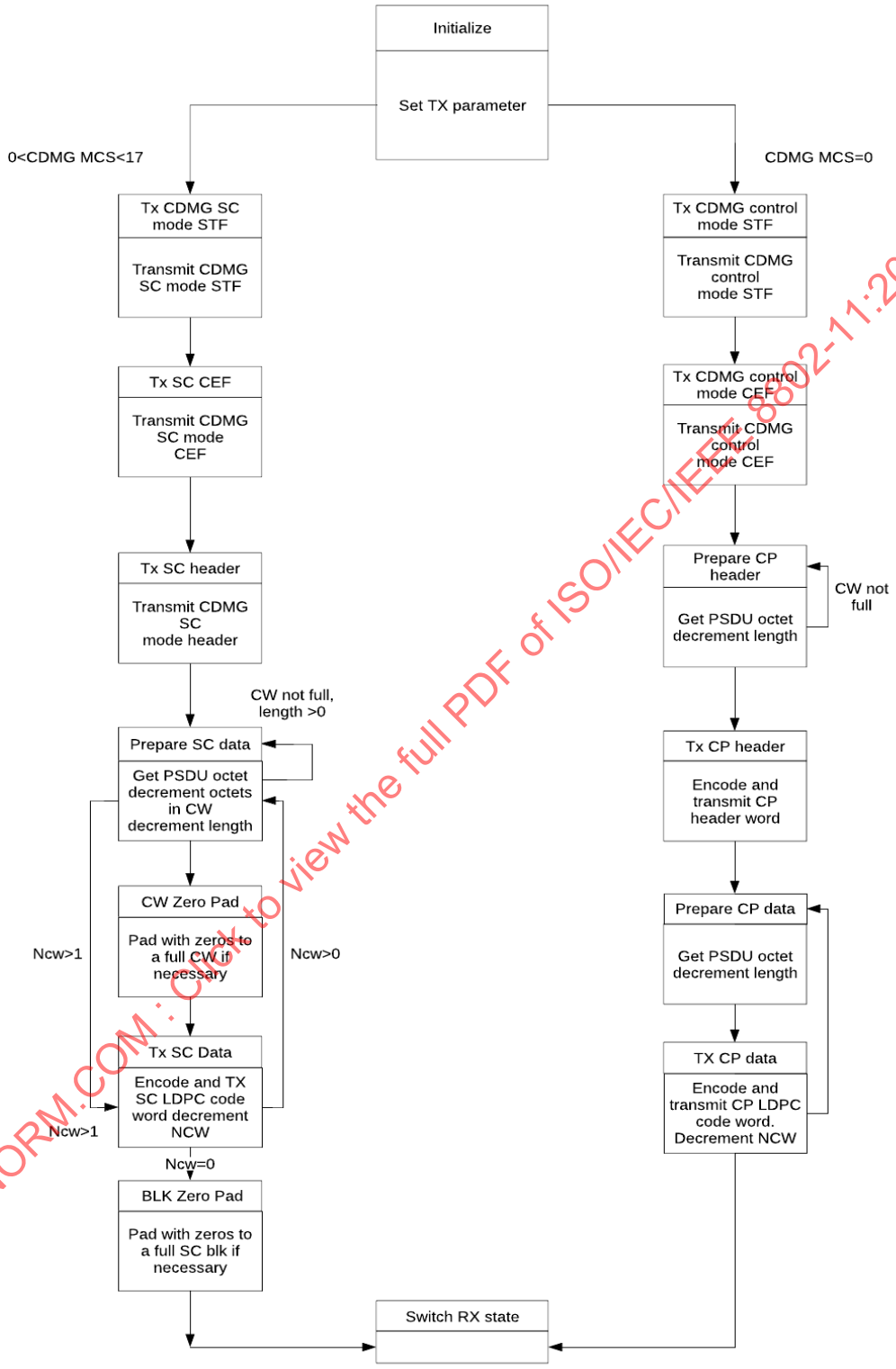

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Figure 24-8—Typical Tx state machine (Training Length=0 is assumed; some optional features such as CDMG SC low-power mode are not shown)

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24.8 PHY receive procedure

A CDMG STA shall follow the DMG receive procedure defined in 20.8 when a DMG PPDU is detected on a 2.16 GHz channel.

The CDMG PHY receive procedure follows similar rules as descrived in 20.8.

24.9 Beamforming

24.9.1 Beamforming concept

The beamforming concept is the same as that contained in 20.9.1.

24.9.2 Beamforming frame format

24.9.2.1 Sector-level sweep

PPDUs transmitted during transmit sector sweep are CDMG control mode PPDUs. PPDUs transmitted during receive sector sweep are CDMG control mode or CDMG SC mode PPDUs.

24.9.2.2 Beam refinement

24.9.2.2.1 General

See 20.9.2.2.1 for the general description of beam refinement.

In addition to DMG beam refinement features, enhanced beam tracking is a process that the CDMG STAs can use to improve their antenna configurations (or antenna weight vectors) both for transmission and reception and measure the backup channel performance of an alternative link via beam tracking. Once the current link has poor quality due to blockage or antenna rotation, the CDMG STAs can switch to an alternative link. Only if the alternative link has been set and enhanced beam tracking is enabled, can CDMG STAs perform enhanced beam tracking. The procedure of enhanced beam tracking is described in 10.42.9.

In addition to TRN training sequences appended, CDMG enhanced beam tracking uses BRP-RX or BRP-TX PPDUs that have an STF and a CE field appended to them.

— BRP-RX PPDUs are PPDUs that have e-TRN-R/TRN-R training sequences following the Data field. These PPDUs with TRN-R sequences enable receiver antenna weight vector training, and these PPDUs with e-TRN-R sequences enable receiver antenna weight vector training and measuring one alternative link.

— BRP-TX PPDUs are PPDUs that have e-TRN-T/TRN-T training sequences following the Data field. The transmitting STA may change antenna configuration at the beginning of each sequence. The receiving STA performs measurements on these sequences and sends feedback to the STA that transmits the BRP-TX PPDU, including the measurement results of alternative link.

24.9.2.2.2 BRP PPDU structure

If the Enhanced Beam Tracking Request field in the PHY header is 0, each beam refinement packet is composed of an STF, a CE field, and a Data field followed by a training field containing an AGC field and a receiver training field, as shown in Figure 20-20.

If the Enhanced Beam Tracking Request field in the PHY header is equal to 1, each BRP PPDU is composed of an STF, a CE field, and a data field followed by a training field containing an AGC field, a receiver training field (TRN-R/T), an STF, and a CE field. The STF and CE fields at the end of the BRP PPDU have

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the same structure as those at the beginning of the PPDU as defined in 24.3.6. The collection of the AGC field, TRN field, STF, and CE field at the end of BRP PPDU is termed an *e-TRN field*. The AGC fields and TRN fields are used to train the current link and the adjacent links of the current link during beam tracking process. The alternative link is a beam link with different propagation characteristic that cannot be measured accurately by the AGC field and the training field (TRN-R/T) that are used for measuring the adjacent beam links. The STF and the CE field at the end of BRP PPDU are used for measuring and training the alternative link of CDMG STAs during enhanced beam tracking (see 10.42.9). The BRP PPDU structure for CDMG STAs that perform enhanced beam tracking is shown in Figure 24-9.

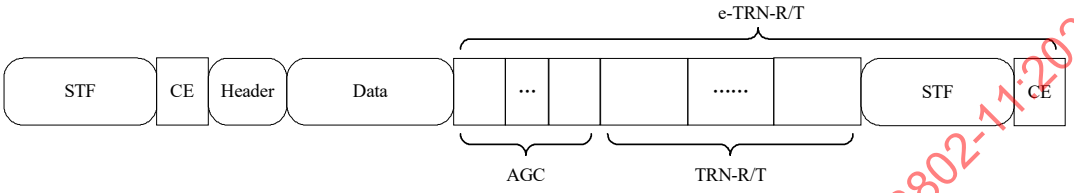

Figure 24-9—BRP PPDU structure (CDMA STAs)

24.9.2.2.3 BRP PPDU header fields

The description for BRP PPDU header fields is the same as that contained in 20.9.2.2.3.

24.9.2.2.4 BRP PPDU duration

The minimum duration of the data field of a BRP PPDU when sent in an SC mode is aBRPminSCblocks SC blocks (see 24.5.3.2.5), and, if needed, the data field of the packet shall be extended by extra 0 padding to generate the required number of SC blocks. Table 24-7 contains the values of N_{CWmin} for MCSs 1 to 9 necessary to compute the padding described in 20.5.3.2.3.3.

Table 24-7—Zero filling for SC BRP PPDUs with MCSs 1 to 9

MCS index	Modulation	N_{CBPS}	Repetition	Code rate	Data rate (Mb/s)	N_{CWmin}
1	π/2-BPSK	1	2	1/2	192.5	12
2	π/2-BPSK	1	1	1/2	385	12
3	π/2-BPSK	1	1	5/8	481.25	12
4	π/2-BPSK	1	1	3/4	577.5	12
5	π/2-BPSK	1	1	13/16	625.625	12
6	π/2-QPSK	2	1	1/2	770	23
7	π/2-QPSK	2	1	5/8	962.5	23
8	π/2-QPSK	2	1	3/4	1155	23
9	π/2-QPSK	2	1	13/16	1251.25	23

The minimum duration of the data field of a BRP PPDU when sent with the low-power SC mode is N_{BLK_MIN} low-power SC blocks (see 20.6.2.3.3).

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24.9.2.2.5 AGC field

The beam refinement AGC fields are composed of 4*N* repetitions of the sequence [Ga_{64} Ga_{64} Ga_{64} Ga_{64} Ga_{64}] when the packet is transmitted using the SC mode and [Gb_{64} Gb_{64} Gb_{64} Gb_{64} Gb_{64}] when the packet is transmitted using the control mode. The sequences Ga64 and Gb64 are defined in 20.10. The sequences are transmitted using rotated π/2-BPSK modulation.

In a BRP-TX PPDU, the transmitter may change the TX AWV configuration at the beginning of each AGC field. Any transmit signal transients that occur due to this TX AWV configuration change shall completely settle by the end of the first Ga64 or Gb64 subsequence. The set of AWVs used for the AGC subfields should be the same as that used for the TRN-T fields. In a BRP-RX PPDU, the transmitter shall use the same TX AWV as in the preamble and data fields of the packet.

24.9.2.2.6 TRN field

The description for TRN field is the same as that contained in 20.9.2.2.6.

24.9.2.2.7 Channel measurement

The description for channel measurement is the same as that contained in 20.9.2.2.7.

24.10 CDMG PLME

24.10.1 PLME SAP sublayer management primitives

Table 24-1 lists the MIB attributes that may be accessed by the PHY entities and the intra-layer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.5.

24.10.2 CDMG PHY MIB

All CDMG PHY MIB attributes are defined in Annex C, with specific values defined in Table 24-1. The column titled “Operational semantics” in Table 24-1 contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. Dynamic MIB attributes can be modified by some management entity.

Table 24-1—CDMG PHY MIB attribute default values

Managed object	Default value/range	Operational semantics
dot11PHYOperationTable		
dot11PHYType	cdmg(12)	Static
dot11PHYCDMGTable		
dot11LowPowerSCPHYImplemented	Boolean	Static
dot11LowPowerSCPHYActivated	Boolean	Dynamic

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When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.

24.10.3 TXTIME calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated according to the following equations.

For the CDMG SC PHY (N_{TRN} is Training Length field defined in the header; see, for example, Table 24-3):

$$TXTIME = \begin{cases} T_{STF} + T_{CE} + T_{header} + T_{Data} & N_{TRN} = 0 \\ T_{STF} + T_{CE} + T_{header} + \max\{T_{Data}, (\alpha \times \beta + \gamma) \times T_C\} + N_{TRN} \times T_{TRN-Unit} & N_{TRN} > 0 \text{ and SC} \end{cases}$$

where

α = aBRPminSCblocks
β = aSCBlockSize
γ = aSCGILength
$T_{TRN-Unit}$ = aBRPTRNBlock $\times$ T_C

For the CDMG control PHY:

$$TXTIME = T_{STF-CP} + T_{CE-CP} + (11 \times 8 + (Length - 6) \times 8 + N_{CW} \times 168) \times T_C \times 32 + N_{TRN} \times T_{TRN-Unit}$$

where N_{CW} calculation is defined in 20.4.3.3.3.

24.10.4 PHY characteristics

The static CDMG PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, shall be as shown in Table 24-1. The definitions for these characteristics are given in 6.5.4.

Table 24-1—CDMG PHY characteristics

PHY parameter	Value
aPPDUMaxTime	4 ms
aPSDUMaxLength	262 143 octets

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25. China millimeter-wave multi-gigabit (CMMG) PHY specification

25.1 Introduction

25.1.1 Introduction to CMMG PHY

Clause 25 specifies the PHY entities for China millimeter-wave multi-gigabit (CMMG) single carrier (SC) and orthogonal frequency division multiplexing (OFDM) systems.

The maximum number of space-time streams supported in CMMG SC and OFDM system is four.

The CMMG PHY provides support for 540 MHz and 1080 MHz channel widths.

The CMMG PHY data are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), and 64-QAM. Forward error correction (FEC) coding (LDPC coding) is used with coding rates of 1/2, 3/4, 5/8, and 13/16.

A CMMG STA shall support the following features:

- 540 MHz channel width
- Control mode and SC mode (directional transmit and receive)
- Single spatial stream MCS 0 (control mode transmit and receive) in all supported channel widths
- Single spatial stream MCSs 1 to 3 (SC mode transmit and receive) in all supported channel widths
- LDPC coding with length 672
- Normal guard interval as defined in Table 25-3

A CMMG STA may support the following features:

- Support for 1080 MHz channel width
- CMMG-MCSs 4 to 8 (SC mode transmit and receive)
- CMMG-MCSs 9 to 16 (OFDM mode transmit and receive)
- Two or more spatial streams (transmit and receive)
- Short guard interval (transmit and receive)
- LDPC coding with length 2016
- Support MIMO transmission (SC mode and OFDM mode with omnidirectional antenna pattern or quasi-omni antenna pattern transceiver)
- STBC (transmit and receive)
- Transmit beamforming sounding (by sending a CMMG NDP)
- Responding to transmit beamforming sounding

NOTE—MIMO transmission only applies in the case where the antenna pattern is the omnidirectional antenna pattern or quasi-omni antenna pattern.

25.1.2 Scope of CMMG PHY services

The CMMG PHY supports three modulation methods:

- A control modulation using MCS 0 (the CMMG control mode; see 25.4)
- A single carrier (SC) modulation using MCS 1 to MCS 8 (the CMMG SC mode; see 25.5)
- An OFDM modulation using MCS 9 to MCS 16 (the CMMG OFDM mode; see 25.6)

All these modulation methods share a common preamble (see 25.3.5).

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The services provided to the MAC by the CMMG PHY consist of the following protocol functions:

a) A function that defines a method of mapping the PSDUs into a framing format (PPDU) suitable for sending and receiving PSDUs between two or more STAs.

b) A function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. Depending on the PPDU format, these STAs support a mixture of CMMG Control mode, CMMG SC mode, and CMMG OFDM mode.

25.1.3 CMMG PHY functions

25.1.3.1 General

The CMMG PHY contains two functional entities: the PHY function and the physical layer management function (PLME). Each of these functions is described in detail in 25.4 (for CMMG control mode), 25.5 (for CMMG SC mode), 25.6 (for CMMG OFDM mode), and 25.14 (for CMMG PLME). The CMMG PHY service is provided to the MAC through the PHY service primitives defined in Clause 6.

25.1.3.2 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.

25.1.3.3 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation; the actual method of implementation is left to the discretion of the CMMG PHY compliant developer. The service of a layer or sublayer is the set of capabilities that it offers to a user in the next higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

25.1.3.4 PPDU formats

The structure of the PPDU transmitted by a CMMG STA is determined by the TXVECTOR parameters as defined in Table 25-1.

A CMMG PPDU can be further categorized as a CMMG control mode PPDU, a CMMG SC mode PPDU, or a CMMG OFDM mode PPDU.

25.2 CMMG PHY service interface

25.2.1 Introduction

The PHY provides an interface to the MAC through an extension of the generic PHY service interface defined in 8.3.4. The interface includes TXVECTOR, RXVECTOR, and PHYCONFIG_VECTOR.

The TXVECTOR supplies the PHY with per-PPDU transmit parameters. Using the RXVECTOR, the PHY informs the MAC of the received PPDU parameters. Using the PHYCONFIG_VECTOR, the MAC configures the PHY for operation, independent of frame transmission or reception.

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25.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 25-1 are defined as part of the TXVECTOR parameter list in the PHYTX-START.request primitive and/or as part of the RXVECTOR parameter list in the PHYRXSTART.indication primitive.

Table 25-1—TXVECTOR and RXVECTOR parameters

Parameter	Value	TXVECTOR	RXVECTOR
MCS	The MCS field indicates the modulation and coding scheme used in the transmission of the packet. Values are integers in the range from 0 to 31. — An MCS value of 0 indicates the use of control mode. — MCS values of 1 to 8 indicate use of single carrier modulations. The value is an index to Table 25-38 to Table 25-45. — MCS values of 9 to 16 indicates use of OFDM modulations. The value is an index to Table 25-46 to Table 25-53.	Y	Y
LENGTH	Indicates the number of octets in the PSDU in the range from 0 to 262 143. A value of zero indicates a packet in which no Data field follows the SIG.	Y	Y
N_TX	Indicates the number of transmit chains.	Y	N
NSS	Indicates the number of spatial streams.	Y	N
EXPANSION_MAT	If PPDU transmission mode is OFDM mode, contains a set of compressed beamforming feedback matrices as defined in 25.6.8.13.2. The number of elements depends on the number of spatial streams and the number of transmit chains. Otherwise, not present.	Y	N
CHAN_MAT	If PSDU LENGTH equals 0, contains a set of compressed beamforming feedback matrices as defined in 25.6.8.13.2 based on the channel measured during the training symbols of the received PPDU. The number of elements depends on the number of spatial streams and the number of transmit chains. Otherwise, not present.	N	Y
ADD_PPDU	Enumerated type: — ADD-PPDU indicates that this PPDU is immediately followed by another PPDU with no IFS or preamble on the subsequent PPDU. — NO-ADD-PPDU indicates no additional PPDU follows this PPDU.	Y	Y
AGGREGATION	Indicates whether the PSDU contains an A-MPDU. Enumerated type: — AGGREGATED indicates this is a packet with A-MPDU aggregation. — NOT_AGGREGATED indicates this is a packet without A-MPDU aggregation.	Y	Y
RSSI	The allowed values for the RSSI parameter are in the range from 0 to 255. This parameter is a measure by the PHY of the power observed at the antennas used to receive the current PPDU. RSSI shall be measured during the reception of the PHY preamble. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power.	N	Y
REC_MCS	Indicates the MCS that the STA's receiver recommends.	N	O

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Table 25-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Value	TXVECTOR	RXVECTOR
SNR	Contains an array of received SNR measurements for each spatial stream. SNR indications of 8 bits are supported. SNR shall be the sum of the decibel values of SNR per tone divided by the number of tones represented in each stream as described in 9.4.1.49.	N	Y
STBC	Indicates whether STBC is used. 0 indicates no STBC (NSTS=NSS in the Data field). 1 indicates STBC is used (NSTS=2NSS in the Data field). This parameter is 0 for a CMMG OFDM MU PPDU.	Y	Y
RCPI	Is a measure of the received RF power measured over the preamble of a received frame. Refer to 20.3.10 for the definition of RCPI.	N	Y
TXOP_PS_NOT_ALLOWED	Indicates whether a CMMG AP allows non-AP CMMG STAs in TXOP power save mode to enter doze state during the TXOP. 0 indicates that the CMMG AP allows non-AP CMMG STAs to enter doze state during a TXOP. 1 indicates that the CMMG AP does not allow non-AP CMMG STAs to enter doze state during a TXOP.	Y	Y
PARTIAL_AID	Provides an abbreviated indication of the intended recipient(s) of the PSDU (see 10.19). Integer: range from 0 to 511 if UPLINK_INDICATION is 1, and range from 0 to 63 if UPLINK_INDICATION is 0.	Y	Y
UPLINK_INDICATION	Set to 1 if the CMMG PPDU is addressed to AP. Set to 0 otherwise (see 10.19).	Y	Y
COLOR	If UPLINK_INDICATION is 0, set to a value of its choosing within the range from 0 to 7 and shall maintain that value for the duration of the existence of the BSS. Otherwise, not present (see 10.19).	Y	Y
CH_BANDWIDTH	Indicates the channel width of the transmitted PPDU: Enumerated type: — CBW540 for 540 MHz — CBW1080 for 1080 MHz	Y	Y
DUPLICATE_MODULATION	In TXVECTOR, indicates the PPDU transmitted with CMMG duplicate format. In RXVECTOR, indicates the estimated PPDU transmitted with CMMG duplicate format; — Present if CH_BANDWIDTH equals CBW1080 and the PPDU is transmitted with duplicate format. — Otherwise not present.	O	O

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Table 25-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Value	TXVECTOR	RXVECTOR
DYN_BANDWIDTH	In TXVECTOR, if present, indicates whether the transmitter is capable of Static or Dynamic bandwidth operation. In RXVECTOR, if valid, indicates whether the transmitter is capable of Static or Dynamic bandwidth operation. Enumerated type: — Static if the transmitter is capable of Static bandwidth operation. — Dynamic if the transmitter is capable of Dynamic bandwidth operation. NOTE—In the RXVECTOR, the validity of this parameter is determined by the MAC based on the contents of the received MPDU.	O	Y
BEAMFORMED	Set to 1 if a beamforming steering matrix is applied to the waveform in a CMMG OFDM mode transmission as described in 19.3.11.11.2. Set to 0 otherwise. NOTE—When BEAMFORMED is equal to 1, smoothing is not recommended.	Y	O
TIME_OF_DEPARTURE_REQUESTED	Enumerated type: — true indicates that the MAC entity requests that the PHY entity measure and report time of departure parameters corresponding to the time when the first frame energy is sent by the transmitting port. — false indicates that the MAC entity requests that the PHY entity neither measure nor report time of departure parameters.	O	N
RX_START_OF_FRAME_OFFSET	0 to 2^{32}–1. An estimate of the offset (in 100 picosecond units) from the point in time at which the start of the preamble corresponding to the incoming frame arrived at the receive antenna port to the point in time at which this primitive is issued to the MAC.	N	Y
PPDU_TYPE	Enumerated type: — TRN-R indicates either a PPDU whose Data field is followed by one or more TRN-R subfields, or a PPDU that is requesting TRN-R subfields to be appended to a future response PPDU. — TRN-T indicates a PPDU whose Data field is followed by one or more TRN-T subfields. This field is reserved if TRN_LEN is 0.	Y	Y
BEAM_TRACKING_REQUEST	This parameter indicates whether beam tracking is requested. Enumerated type: — BEAM-TRACKING-REQUESTED or BEAM-TRACKING-NOT-REQUESTED.	Y	Y

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Table 25-1—TXVECTOR and RXVECTOR parameters *(continued)*

Parameter	Value	TXVECTOR	RXVECTOR
LAST_RSSI	In the TXVECTOR, LAST_RSSI indicates the received power level of the last packet with a valid PHY SIG that was received an SIFS period before transmission of the current packet; otherwise, it is 0 (see 10.3.2.3.3). In the RXVECTOR, LAST_RSSI indicates the value of the LAST_RSSI field from the PCLP header of the received packet. Valid values are integers in the range from 0 to 15: — Values of 2 to 14 represent power levels (–71+value×2) dBm. — A value of 15 represents power greater than or equal to –42 dBm. — A value of 1 represents power less than or equal to –68 dBm. — A value of 0 indicates that the previous packet was not received an SIFS period before the current transmission.	Y	Y
SPREADING_FACTOR	Indicates the spreading factor used in the Control mode: — 0 indicates that the spread factor is 13. — 1 indicates that the spread factor is 7. — 2 indicates that the spread factor is 4. — 3 indicates no spreading.		
Turnaround	Set to 1 or 0 as specified in 10.3.2.3.3.	Y	Y
NOTE—In the TXVECTOR and RXVECTOR columns, the following apply: Y = Present N = Not present O = Optional			

25.3 Common parameters

25.3.1 Introduction

This subclause introduces some common parameters.

25.3.2 Common requirements

25.3.2.1 Introduction

This subclause describes the common requirements from all 3 modes: control, SC, and OFDM.

25.3.2.2 Transmit RF delay

The transmit RF delay is defined in 17.3.8.6, and its value is implementation dependent.

25.3.2.3 Center frequency tolerance

25.3.2.3.1 General

The transmitter center frequency tolerance shall be ± 20 ppm.

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25.3.2.3.2 Center frequency convergence

The transmitter center frequency shall converge to within 1 ppm of its final value within 2.5 μs from the start of the packet.

25.3.2.3.3 Symbol clock tolerance

The symbol clock frequency tolerance shall be ± 20 ppm.

The transmit center frequency and the symbol clock frequency shall be derived from the same reference oscillator.

25.3.2.3.4 Transmit rampup and rampdown

The transmit power-on ramp is defined as the time it takes for a transmitter to rise from less than 10% to greater than 90% of the average power to be transmitted in the frame.

The transmit power-on ramp shall be less than 30 ns.

The transmit power-down ramp is defined as the time it takes the transmitter to fall from greater than 90% to less than 10% of the maximum power to be transmitted in the frame.

The transmit power-down ramp shall be less than 30 ns.

25.3.2.3.5 Maximum input requirement

The receiver maximum input level is the maximum power level at the receive antenna(s) of the incoming signal, in dBm, present at the input of the receiver antenna for which the error rate criterion (defined in 25.3.2.3.6) is met. A compliant receiver shall have a receiver maximum input level at the receive antenna(s) of at least 10 $\mu W/cm^2$ for each of the modulation formats that the receiver supports.

25.3.2.3.6 Receive sensitivity

The packet error ratio (PER) shall be less than 10% for a PSDU length of 4096 octets with the rate-dependent input levels listed in Table 25-2.

Table 25-2—Receiver sensitivity

MCS Index	CBW540 MHz	CBW1080 MHz
0	–81	–78(see NOTE)
1	–74	–71
2	–69	–66
3	–67	–64
4	–61	–58
5	–59	–56
6	–55	–52
7	–53	–50
8	–51	–48

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Table 25-2—Receiver sensitivity *(continued)*

MCS Index	CBW540 MHz	CBW1080 MHz
9	–74	–71
10	–69	–66
11	–66	–63
12	–64	–61
13	–60	–57
14	–57	–54
15	–55	–52
16	–53	–50
NOTE—The sensitivity is for the largest spreading factor for MCS 0.		

25.3.3 Time-related parameters

Table 25-3 defines the timing-related parameters for CMMG format.

Table 25-3—Time-related parameters

Parameter	CBW540 MHz	CBW1080 MHz	Description
N_{SD}	168	336	Number of complex data numbers per OFDM symbol
N_{SP}	8	16	Number of pilot subcarriers per OFDM symbol
N_{DC}	3	3	Number of DC subcarriers per OFDM symbol
N_{ST}	179	355	Total number of subcarriers per OFDM symbol
N_{SR}	89	177	Highest data subcarrier index per OFDM symbol
F_S	660 MHz	1320 MHz	OFDM sample rate
T_S	$1/F_S$ (~1.515 ns)	$1/F_S$ (~0.758 ns)	OFDM sample time
F_C	440 MHz = 2/3 F_S	880 MHz = 2/3 F_S	SC chip rate
T_C	$1/F_C$ (~2.273 ns)	$1/F_C$ (~1.136 ns)	SC chip time
N_{DFT}	256	512	DFT length
Δ_F	F_S / N_{DFT} = 2.578125 MHz		Subcarrier frequency spacing
T_{DFT}	$N_{DFT} \times T_S$ (~387.879 ns)		IDFT/DFT period
T_{GI}	$T_{DFT}/4$ (~96.97 ns)		Guard interval duration
T_{GIS}	$T_{DFT}/8$ (~48.485 ns)		Short guard interval duration

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Table 25-3—Time-related parameters *(continued)*

Parameter	CBW540 MHz	CBW1080 MHz	Description
T_{SYML}	$T_{DFT} + T_{GI} = 1.25T_{DFT}$ (~484.8 ns)		Long GI symbol interval
T_{SYMS}	$T_{DFT} + T_{GIS} = 1.125T_{DFT}$ (~436.4 ns)		Short GI symbol interval
T_{SYM}	T_{SYML} or T_{SYMS} depending on the GI used		Symbol interval
T_{seq}	256 T_C (~581.8 ns)		ZCZ block duration
T_{CSTF}	14 T_{seq} (~8145.5 ns)		Short training field duration for control mode
T_{STF}	14 T_{seq} (~8145.5 ns)		Short training field duration *n* for SC/OFDM mode
T_{CEF}	4 T_{seq} (~2327.3 ns)		Channel estimation field duration
T_{SIG}	4 T_{seq} (~2327.3 ns)		SIGNAL field duration
T_{OSTF}	T_{SYML} (~484.8 ns)		Duration of each OSTF
T_{OCEF}	T_{SYML} (~484.8 ns)		Duration of each OCEF

Table 25-4 defines parameters used frequently in Clause 25.

Table 25-4—Frequently used parameters

Symbol	Explanation
N_{BL}	Number of the data blocks for SC transmission.
N_{CBPB}	Number of coded bits per block.
N_{CBPS}	For OFDM transmission: Number of coded bits per OFDM symbol. For SC transmission: Number of coded bits per constellation symbol.
N_{CBPSS}	Number of coded bits per symbol per spatial stream.
N_{DBPS}	Number of data bits per symbol.
N_{DSPB}	Number of data constellation symbols per block for SC transmission.
N_{UWPB}	Length of the UW in each block for SC transmission.
$N_{BLS} = N_{DSPB} + N_{UWPB}$	Number of the symbols in each block for SC transmission.
N_{BPSCS}	Number of coded bits per subcarrier per spatial stream.
N_{RX}	Number of receive chains.
N_{STS}	For pre-CMMG modulated fields, $N_{STS} = 1$ (see NOTE). For CMMG modulated fields, N_{STS} is the number of space-time streams.
N_{OCEF}	Number of OCEF symbols 25.6.7.

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Table 25-4—Frequently used parameters *(continued)*

Symbol	Explanation
N_{SS}	Number of spatial streams.
N_{TX}	Number of transmit chains.
R	R is the coding rate.
NOTE—Pre-CMMG modulated fields refer to the STF, CEF, and CMMG SIG field, while CMMG modulated fields refer to the OCEF and Data field (see Figure 25-1, Figure 25-2, and Figure 25-3).	

25.3.4 Mathematical conventions in the signal description

25.3.4.1 Notation

$[\mathbf{Q}]_{m,n}$ indicates the element in row m and column n of matrix $\mathbf{Q}$.

25.3.4.2 Subcarrier indices in use

For a 540 MHz OFDM mode PPDU transmission, the 540 MHz is divided into 256 subcarriers. The signal is transmitted on subcarrier –89 to –2 and 2 to 89, with –1, 0, and 1 being the center (DC) subcarriers.

For a 1080 MHz OFDM mode PPDU transmission, the 1080 MHz is divided into 512 subcarriers. The signal is transmitted on subcarrier –177 to –2 and 2 to 177, with –1, 0, and 1 being the center (DC) subcarriers.

25.3.4.3 Transmitted signal

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal is defined by the complex baseband signal in Equation (25-1).

$$r_{RF}^{i_{TX}} = \mathrm{Re}\left\{ r_{PPDU}^{i_{TX}}(t) \exp(j2\pi f_c t) \right\} \tag{25-1}$$

where

r_{PPDU} represents the complex baseband signal in transmit chain i_{TX}
f_c represents the center frequency of the portion of the transmitted PPDU

The transmitted RF signal is derived by upconverting the complex baseband signal, which consists of several fields. The fields and timing boundaries for various fields are shown in Figure 25-1 to Figure 25-3.

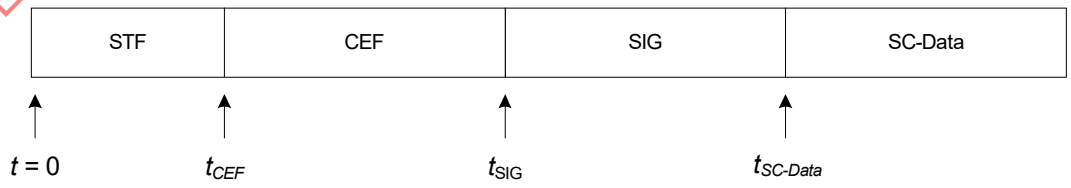

Figure 25-1—Packet structure for the SC mode PPDU with CBW540 MHz

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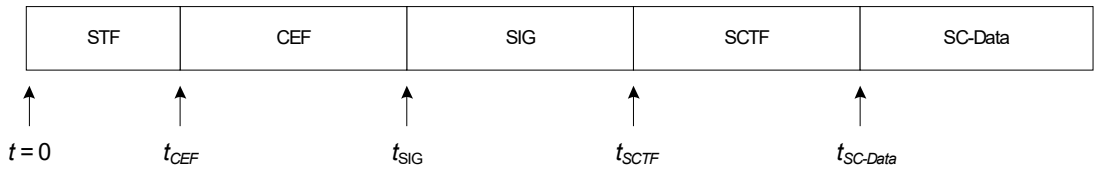

Figure 25-2—Packet structure for the SC mode PPDU with CBW1080 MHz

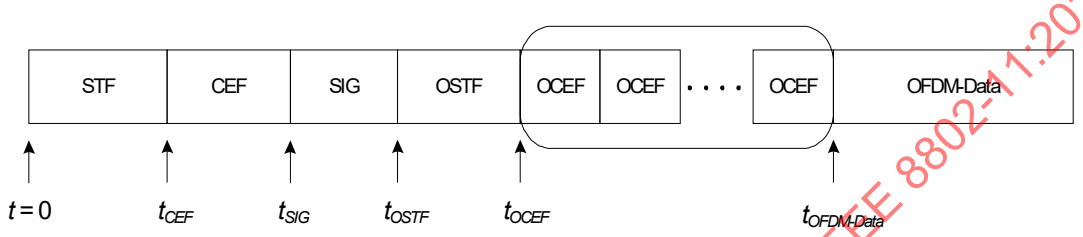

Figure 25-3—Packet structure for the OFDM mode PPDU

The time offset, t_{Field}, determines the starting time of the corresponding field.

For the SC mode transmission with 540 MHz,

$$r^{i_{TX}}_{PPDU}(t) = r^{i_{TX}}_{STF}(t) + r^{i_{TX}}_{CEF}(t - t_{CEF}) + r^{i_{TX}}_{SIG}(t - t_{SIG}) + r^{i_{TX}}_{SC-Data}(t - t_{SC-Data}) \quad (25\text{-}2)$$

For the SC mode transmission with 1080 MHz,

$$r^{i_{TX}}_{PPDU}(t) = r^{i_{TX}}_{STF}(t) + r^{i_{TX}}_{CEF}(t - t_{CEF}) + r^{i_{TX}}_{SIG}(t - t_{SIG}) + r^{i_{TX}}_{SCTF}(t - t_{SCTF}) + r^{i_{TX}}_{SC-Data}(t - t_{SC-Data}) \quad (25\text{-}3)$$

For the OFDM mode transmission,

$$r^{i_{TX}}_{PPDU}(t) = r^{i_{TX}}_{STF}(t) + r^{i_{TX}}_{CEF}(t - t_{CEF}) + r^{i_{TX}}_{SIG}(t - t_{SIG}) + r^{i_{TX}}_{MCTF}(t - t_{MCTF}) + r^{i_{TX}}_{OFDM-Data}(t - t_{OFDM-Data}) \quad (25\text{-}4)$$

where

$t_{CEF} = T_{STF}$

$t_{SIG} = t_{CEF} + T_{CEF}$

$t_{SCEF} = t_{SIG} + T_{SIG}$

$T_{OSTF} = t_{SIG} + T_{SIG}$

$t_{OCEF} = t_{OSTF} + T_{OSTF}$

$t_{SC-Data} = t_{SCTF} + T_{SCTF}$

$t_{OFDM-Data} = t_{OCTF} + N_{OCEF} T_{OCEF}$

Each OFDM mode baseband waveform $r_{subfield}(nT_s)$, for the fields above, is defined via the inverse discrete Fourier transform (IDFT) as,

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$$r^{i_{TX}}_{subfield}(t) = \frac{1}{\sqrt{N_{Tone} N_{STS}}} w_{T_{subfield}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=0}^{N_{STS}-1} [Q_k]_{i_{TX}, m} \gamma_{k, CBW} X_{k, m} \exp(j2\pi k \Delta_F (t - T_{GI} - T_{CS}(m))) \quad (25\text{-}5)$$

In Equation (25-5) the following notions are used:

n_{Tone}	is, for 540 MHz transmission, 176 and, for 1080 MHz transmission, 352
N_{STS}	is the number of the space-time streams
T_{GI}	is the guard interval duration used for each OFDM symbol
Q_k	is the spatial mapping matrix with N_{Tx} rows and N_{STS} for the subcarrier k
$w_{Tsubfield}$	is a windowing function. An example function, $w_{Tsubfield}$, is given in 25.3.4.5
$\gamma_{k, CBW}$	is defined in 25.3.4.4
Δ_F	is the subcarrier frequency spacing given in Table 25-3
$T_{CS}(m)$	represents the cyclic shift per space-time stream, whose value is defined in Table 25-27
$X_{k,m}$	is the frequency-domain symbol in subcarrier k of space-time stream m. Some of the $X_{k,m}$ within $-N_{SR} \le k \le N_{SR}$ have a value of 0, such as the DC tones

The base band waveform for fields defined by time domain sequence or for single carrier transmission is

$$r_{Field}(nT_C) = x(n) \quad (25\text{-}6)$$

where $x(n)$ is the constellation point n.

Conversion from the sampled digital domain to the continuous time domain is beyond the scope of this document. Filtering for pulse shaping such as in GMSK is beyond the scope of this standard.

25.3.4.4 Definition of tone rotation for OFDM mode transmission

The function $\Upsilon_{k, CBW}$ is used to represent a rotation of the tones. $\Upsilon_{k, CBW}$ is determined by the TXVECTOR parameter CH_BANDWIDTH as defined in Table 25-5.

Table 25-5—CH_BANDWIDTH and $\Upsilon_{k,CBW}$

CH_BANDWIDTH	$\Upsilon_{k, CBW}$
CBW540	$\Upsilon_{k, 540}$
CBW1080	$\Upsilon_{k, 1080}$

For a 540 MHz OFDM mode PPDU transmission,

$$\Upsilon_{k, 540} = 1 \quad (25\text{-}7)$$

For a 1080 MHz OFDM mode PPDU transmission,

$$\Upsilon_{k, 1080} = \begin{cases} 1, k < 0 \\ j, k \ge 0 \end{cases} \quad (25\text{-}8)$$

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25.3.4.5 The windowing function

The windowing function $w_{TField}(nT_S)$ is used to smooth the transition between adjacent fields in the packet where OFDM mode modulation is employed. No windowing is applied to preamble fields or to SC modulated fields. The windowing function is different from being equivalent to "1" only in the transition region.

An example of a windowing function is given by

$$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}\left(\frac{1}{2}+\frac{t}{T_R}\right)\right), & \frac{-T_R}{2} < t \le \frac{T_R}{2} \\ 1, & \frac{T_R}{2} < t \le T-\frac{T_R}{2} \\ \sin^2\left(\frac{\pi}{2}\left(\frac{1}{2}-\frac{t}{T_R}\right)\right), & T-\frac{T_R}{2} < t \le T+\frac{T_R}{2} \end{cases} \quad (25\text{-}9)$$

The transition region creates an overlap (with length T_R) between adjacent fields. The field wave form is extended cyclically to fill the part of the transition region in which it is undefined. If the transition region vanishes (i.e., T_R=0), the windowing function degenerates to a rectangular window. The choice of windowing function is implementation dependent, as long as transmit EVM and transmit mask requirements are met.

25.3.5 CMMG PHY preamble

25.3.5.1 General

The CMMG PHY preamble is the part of the PHY PPDU that is used for packet detection, AGC, frequency offset estimation, synchronization, indication of transmission mode (Control mode, SC mode, or OFDM mode), indication of transmission bandwidth (540 MHz or 1080 MHz), and channel estimation. The format of the preamble is common to both SC packets and OFDM packets and consists of a Short Training field followed by a Channel Estimation field. The content of the Short Training field is the same between SC and OFDM packets (see 25.3.5.2), but the content of the Channel Estimation field is not the same between such packets (see 25.3.5.3).

NOTE 1—For SC and OFDM MIMO transmission, different transmit antenna transmit a different preamble that is composed of one of the four ZCZ sequences with the order of $Z^1_{256}, Z^2_{256}, Z^3_{256}, Z^4_{256}$, such as for the case of one transmit antenna, the preamble sequence is composed of Z^1_{256}, for the case of two transmit antennas, the preamble sequences are composed of Z^1_{256}, Z^2_{256}, respectively.

NOTE 2—For CMMG Control mode and CMMG SC mode preambles, all fields are transmitted with SC mode transmission. For CMMG OFDM mode preamble, the STFs, the CEFs, and the SIG fields are transmitted with SC mode transmission. For 1080 MHz SC transmission, the STFs, the CEFs, and the SIG fields are transmitted in duplicate format as defined in 25.3.10.

25.3.5.2 CMMG Short Training field

25.3.5.2.1 STF of control mode

The Short Training field is composed of 50 repetitions of the sequence $Z(n)$ of length 32. The sequences $Z(n)$ is defined in 25.8.

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The waveform for the STF is

$$r_{STF}(nT_C) = Z(n \bmod 32)\exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots, 50 \times 32 - 1 \quad (25\text{-}10)$$

where T_C is SC mode chip time of CBW540 MHz.

25.3.5.2.2 STF of SC and OFDM mode

The Short Training fields of SC and OFDM modes share the same definition. The common Short Training field is composed of 17 repetitions of the sequence $Z(n)$ of length 32. The sequences $Z(n)$ is defined in 25.8.

The waveform for the Short Training field is

$$r_{STF}(nT_C) = Z(n \bmod 32)\exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots, 17 \times 32 - 1 \quad (25\text{-}11)$$

where T_C is SC mode chip time of CBW540 MHz.

25.3.5.3 CMMG Channel Estimation field

25.3.5.3.1 CEF of control mode

The CEF of CMMG control mode is composed of four concatenated $Z(n)$ sequences where each sequence is multiplied by an individual sign assignment. As shown in Figure 25-4, the CEF of control mode is defined as $-Z(n)$, $Z(n)$, $-Z(n)$, $-Z(n)$, where the sequence is defined in 25.8.

The waveform for the CEF is

$$r_{CEF}(nT_C) = \begin{cases} -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots, 256 - 1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256, \ldots, 256 \times 2 - 1 \\ -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256 \times 2, \ldots, 256 \times 3 - 1 \\ -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256 \times 3, \ldots, 256 \times 4 - 1 \end{cases} \quad (25\text{-}12)$$

where T_C is SC mode chip time of CBW540 MHz. The control mode preamble is defined in Figure 25-4.

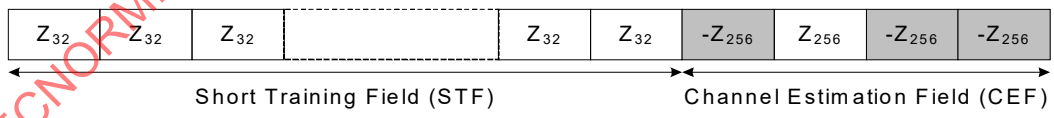

Figure 25-4—Control mode preamble

25.3.5.3.2 CEF of SC mode

The CEF of SC mode is also composed of four concatenated *Z(n)* sequences but is with different sign assignment patterns. As shown in Figure 25-5 and Figure 25-6, the CEF of SC 540 MHz PHY is defined as $[-Z(n), Z(n), Z(n), -Z(n)]$, and the CEF of SC 1080 MHz PHY is defined as $[-Z(n), -Z(n), Z(n), Z(n)]$, where the sequence *Z(n)* is defined in 25.8.

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The waveform for the CEF of SC 540 MHz mode is

$$r_{CEF}(nT_C) = \begin{cases} -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots, 256-1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256, \ldots, 256\times 2-1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 2, \ldots, 256\times 3-1 \\ -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 3, \ldots, 256\times 4-1 \end{cases} \quad (25\text{-}13)$$

and the waveform for the CEF of SC 1080 MHz mode is

$$r_{CEF}(nT_C) = \begin{cases} -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots, 256-1 \\ -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256, \ldots, 256\times 2-1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 2, \ldots, 256\times 3-1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 3, \ldots, 256\times 4-1 \end{cases} \quad (25\text{-}14)$$

where T_C is SC mode chip time of CBW540 MHz.

The SC mode preambles are defined in Figure 25-5 and Figure 25-6.

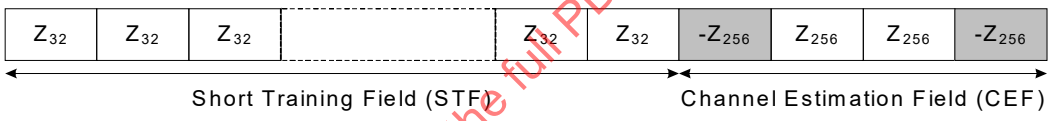

Figure 25-5—CMMG SC mode preamble for CBW540 MHz

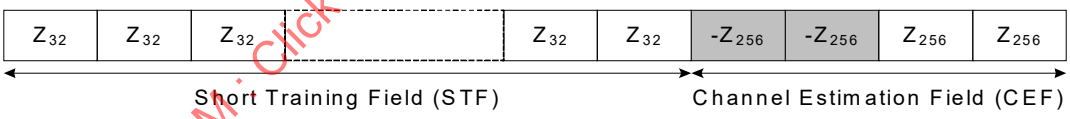

Figure 25-6—CMMG SC mode preamble for CBW1080 MHz

25.3.5.3.3 CEF of OFDM mode

The CEF of OFDM mode is also composed of four concatenated $Z(n)$ sequences but is with different sign assignment patterns. As shown in Figure 25-7 and Figure 25-8, the CEF of OFDM 540 MHz PHY is defined as [$-Z(n)$, $Z(n)$, $Z(n)$, $Z(n)$], and the CEF of OFDM 1080 MHz PHY is defined as [$-Z(n)$, $-Z(n)$, $-Z(n)$, $Z(n)$], where the sequence $Z(n)$ is defined in 25.8.

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The waveform for the CEF of OFDM 540 MHz mode is

$$r_{CEF}(nT_C) = \begin{cases} -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots, 256-1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256, \ldots, 256\times 2-1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 2, \ldots, 256\times 3-1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 3, \ldots, 256\times 4-1 \end{cases} \quad (25\text{-}15)$$

and the waveform for the CEF of OFDM 1080 MHz mode is

$$r_{CEF}(nT_C) = \begin{cases} -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots, 256-1 \\ -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256, \ldots, 256\times 2-1 \\ -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 2, \ldots, 256\times 3-1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 3, \ldots, 256\times 4-1 \end{cases} \quad (25\text{-}16)$$

where T_C is SC chip time of CBW540 MHz.

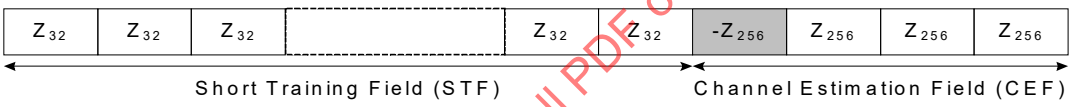

Figure 25-7—CMMG OFDM mode preamble for CBW540 MHz

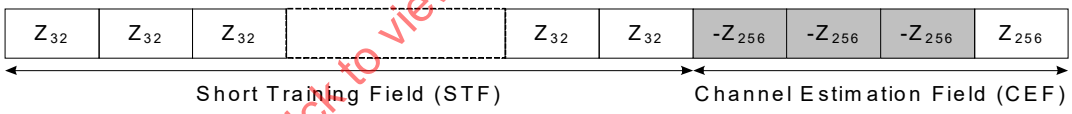

Figure 25-8—CMMG OFDM mode preamble for CBW1080 MHz

25.3.6 CRC calculation

The value of cyclic redundancy check (CRC) field is the 1s complement of Equation (25-17).

$$CRC(D) = (M(D) \oplus I(D))D^K \bmod G(D) \quad (25\text{-}17)$$

where

$m(D) = m_0 D^{N-1} + m_1 D^{N-2} + \ldots + m_{N-1}$

N is the number of bits over which the CRC is generated

m_i is bit i of the input bit sequence

$I(D) = \sum_{i=N-K}^{N-1} D^i$ are initialized values that are added modulo 2 to the first K bits of the input bit sequence

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K is the length of CRC sequence: $K = 16$ for CRC of the CMMG SIG, and $K = 8$ for the data field
$G(D) = D^{16} + D^{12} + D^5 + 1$ is the CRC generating polynomial of 8 bits
$crc(D) = x_0 D^{15} + x_1 D^{14} + \ldots + x_{14} D + x_{15}$

Figure 25-9 shows the operation of the CRC of 16 bits. First, the shift register is reset to all 1s. The bits are then passed through the XOR operation at the input. When the last bit has entered, the output is generated by shifting the bits out of the shift register, x_{15} first, through an inverter.

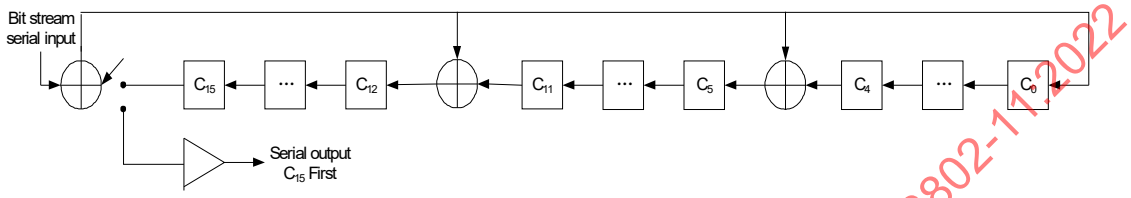

Figure 25-9—16-bit CRC calculation

$G(D) = D^8 + D^7 + D^4 + D^3 + D + 1$ is the CRC generating polynomial of 8 bits.

$crc(D) = x_0 D^7 + x_1 D^6 + \ldots + x_6 D + x_7$

Figure 25-10 shows the operation of the CRC of 8 bits.

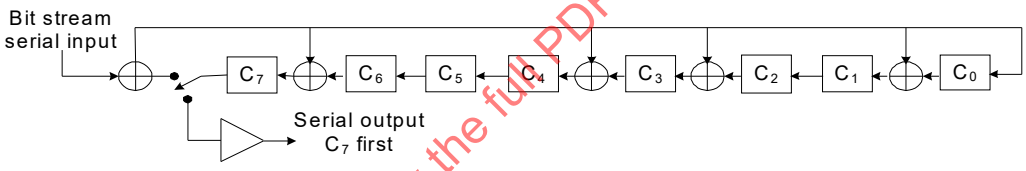

Figure 25-10—8-bit CRC calculation

25.3.7 Scrambler

The CMMG control mode SIG, CMMG SC/OFDM mode SIG, and the data fields following the scrambler initialization field (including data padding bits) shall be scrambled by XORing each bit in turn with a length 127 periodic sequence generated by the polynomial $S(x) = x^7 + x^4 + 1$. The octets of the PSDU and the pad bits shall be placed into a bit stream with bit 0 (LSB) of each octet first and bit 7 of each octet (MSB) last. The generation of the sequence and the XOR operation are defined in Figure 25-11.

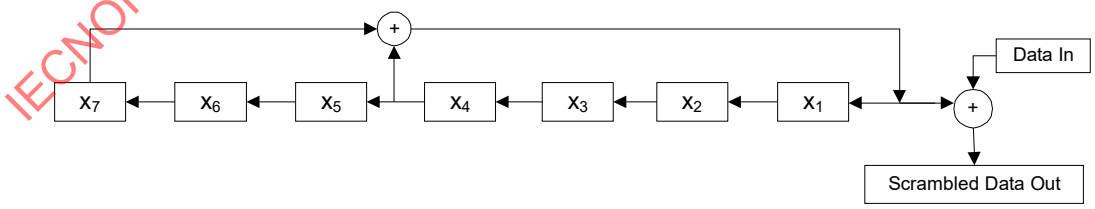

Figure 25-11—Scrambler

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For each PPDU, the transmitter shall select a nonzero seed value for the scrambler (bits x_1 to x_7). The seed value should be selected in a pseudo random fashion. The seed value is sent in the Scrambler Initialization field of the PHY header. Each data bit in the data field of the PPDU is then XORed with the scrambler output (x_4 XOR x_7), and the scrambler content shifts once.

25.3.8 Common LDPC parity matrices

25.3.8.1 Introduction

Transmission/reception of LDPC with codeword length of 672 bits (expansion factor $z = 42$) is mandatory, and transmission/reception of LDPC with codeword length 2016 bits (expansion factor $z = 126$) is optional.

25.3.8.2 General

The structured LDPC code is defined by a parity check matrix $\mathbf{H}$ of size $(m \times z) \times (n \times z)$, which is determined by a base matrix $\overline{\mathbf{H}}$ of size $m \times n$, an expansion factor z, and a base permutation matrix $\mathbf{P}$ of size $z \times z$. The number of information bits is $k = (n - m) \times z$, the number of codeword bits is nz, then the coding rate is $r = k/(nz)$. If each element $\overline{h}_{ij}$ in the base matrix $\overline{\mathbf{H}}$ is replaced by zero subblock matrix of size $z \times z$ or the subblock matrix $\mathbf{P}^{\overline{h}_{ij}}$, the parity check matrix $\mathbf{H}$ can be obtained.

The base matrix $\overline{\mathbf{H}}$ is defined as follows:

$$\overline{\mathbf{H}} = \begin{bmatrix} \overline{h}_{00} & \overline{h}_{01} & \cdots & \overline{h}_{0(n-1)} \\ \overline{h}_{10} & \overline{h}_{11} & \cdots & \overline{h}_{1(n-1)} \\ \cdots & \cdots & \cdots & \cdots \\ \overline{h}_{(m-1)0} & \overline{h}_{(m-1)1} & \cdots & \overline{h}_{(m-1)(n-1)} \end{bmatrix} \tag{25-18}$$

The parity check matrix $\mathbf{H}$ is defined as follows:

$$\mathbf{H} = \begin{bmatrix} \mathbf{P}^{\overline{h}_{00}} & \mathbf{P}^{\overline{h}_{01}} & \cdots & \mathbf{P}^{\overline{h}_{0(n-1)}} \\ \mathbf{P}^{\overline{h}_{10}} & \mathbf{P}^{\overline{h}_{11}} & \cdots & \mathbf{P}^{\overline{h}_{1(n-1)}} \\ \cdots & \cdots & \cdots & \cdots \\ \mathbf{P}^{\overline{h}_{(m-1)0}} & \mathbf{P}^{\overline{h}_{(m-1)1}} & \cdots & \mathbf{P}^{\overline{h}_{(m-1)(n-1)}} \end{bmatrix} \tag{25-19}$$

where, if $\overline{h}_{ij} = -1$, $\mathbf{P}^{\overline{h}_{ij}}$ equals a zero matrix of size $z \times z$; otherwise, $\mathbf{P}^{\overline{h}_{ij}}$ equals the base permutation matrix $\mathbf{P}$ to h_{ij} power. The base permutation matrix $\mathbf{P}$ of size $z \times z$ is defined as follows:

$$\mathbf{P} = \begin{bmatrix} 0 & 1 & 0 & \cdots & 0 \\ 0 & 0 & 1 & \cdots & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & 0 & \cdots & 1 \\ 1 & 0 & 0 & \cdots & 0 \end{bmatrix} \tag{25-20}$$

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Table 25-6 defines the base matrix prototypes of the parity-check matrices for a codeword block length *nz* bits, with a subblock size *z* bits.

Table 25-6—Base matrix prototypes for codeword block length *nz* bits, subblock size is *z* bits

(a) Coding rate=1/2

-1	0	-1	0	-1	0	-1	0	0	-1	-1	-1	-1	-1	-1	-1
0	-1	-1	34	-1	12	-1	36	18	0	-1	-1	-1	-1	-1	-1
8	-1	0	-1	0	-1	0	-1	-1	13	0	-1	-1	-1	-1	-1
-1	16	40	-1	32	-1	22	-1	-1	-1	19	0	-1	-1	-1	-1
-1	20	-1	22	-1	2	-1	28	32	-1	-1	21	0	-1	-1	-1
30	-1	18	-1	-1	14	-1	30	-1	37	-1	-1	31	0	-1	-1
40	-1	12	-1	38	-1	6	-1	-1	-1	26	-1	-1	13	0	-1
-1	24	-1	20	10	-1	2	-1	-1	-1	-1	18	-1	-1	5	0

(b) Coding rate=5/8

-1	0	-1	0	0	0	0	0	0	-1	0	-1	-1	-1	-1	-1
0	-1	0	-1	32	-1	22	-1	18	0	19	0	-1	-1	-1	-1
8	16	40	34	-1	12	-1	36	32	-1	-1	21	0	-1	-1	-1
30	20	18	22	38	-1	6	-1	-1	13	-1	-1	31	0	-1	-1
-1	24	-1	20	-1	2	-1	28	16	37	-1	-1	-1	13	0	-1
40	-1	12	-1	10	14	2	30	-1	19	-1	-1	-1	-1	5	0

(c) Coding rate=3/4

0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1
8	16	40	34	32	12	22	36	18	13	19	0	-1	0	-1	-1
30	20	18	22	38	2	6	28	32	37	26	21	31	-1	0	-1
40	24	12	20	10	14	2	30	16	19	34	18	-1	13	5	0

(d) Coding rate=13/16

0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1
30	20	18	22	38	2	6	28	32	37	26	21	34	-1	0	-1
40	24	12	20	10	14	2	30	16	19	34	18	8	13	5	0

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25.3.9 CMMG SIG

25.3.9.1 General

The CMMG SIG field carries information required to interpret PPDUs. The preamble and the CMMG SIG fields are all transmitted using modulation. The structure of the CMMG SIG field is shown in Figure 25-12.

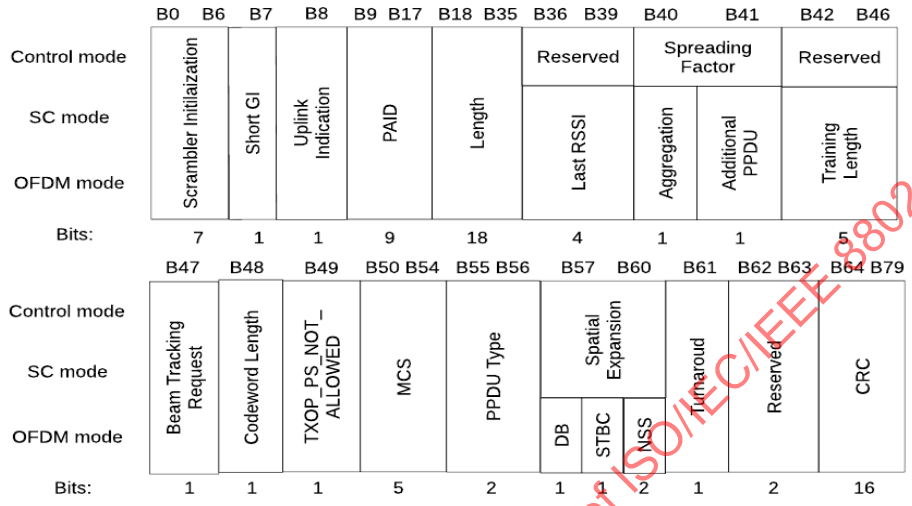

Figure 25-12—CMMG SIG structure

The CMMG SIG field contains the fields listed in Table 25-7. The mapping of the fields is also described in Table 25-7.

Table 25-7—Fields in the CMMG SIG field

Bit	Fields	Number of bits	Description
B0–B6	Scrambler Initialization	7	Bits X1-X7 of the initial scrambler state (see 25.3.7).
B7	Short GI	1	Set to 0 if short guard interval is not used in the Data field. Set to 1 if short guard interval is used in the Data field.
B8	Uplink Indication	1	Set to 1 if the PPDU is addressed to an AP. Set to 0 otherwise. (See TXVECTOR parameter UPLINK_INDICATION.)
B9–B17	PAID	9	If Uplink Indication is not present or set to 1, B9–B17 are the partial AID to provide an abbreviated indication of the intended recipient(s) of the PSDU (see 10.19). If Uplink Indication is equal to 0, B9–B11 are an identifier of the BSS and B12–B17 are the partial AID. (See TXVECTOR parameter COLOR and TXVECTOR parameter PARTIAL_AID.)
B18–B35	Length	18	Number of data octets in the PSDU, Range from 0 to 262 143

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Table 25-7—Fields in the CMMG SIG field *(continued)*

Bit	Fields	Number of bits	Description
B36–B39	Last RSSI	4	For SC/OFDM mode: Contains a copy of the parameter LAST_RSSI from the TXVECTOR. When set to 0, this field is reserved and ignored by the receiver. The value is an unsigned integer: — Values of 2 to 14 represent power levels (–71+value×2) dBm. — A value of 15 represents a power greater than or equal to –42 dBm. — A value of 1 represents a power less than or equal to –68 dBm. Value of 0 indicates that the previous packet was not received an SIFS period before the current transmission. For control mode: Reserved.
B40–B41	Spreading Factor/ Aggregation/Additional PPDU	2	For control mode: — Set to 0: spreading by 13 — Set to 1: spreading by 7 — Set to 2: spreading by 4 — Set to 3: no spreading For SC/OFDM mode: Aggregation: — Set to 1 indicate that the PPDU in the data portion of the packet contains an A-MPDU; otherwise, set to 0. Additional PPDU: — Contains a copy of the parameter ADD_PPDU from the TXVECTOR. A value of 1 indicates that this PPDU is immediately followed by another PPDU with no IFS or preamble on the subsequent PPDU. — A value of 0 indicates that no additional PPDU follows this PPDU.
B42–B46	Training Length	5	For SC/OFDM mode: Corresponds to the TXVECTOR parameter TRNLEN. If the Beam Tracking Request field is 0, the Training Length field indicates the length of the training field. The use of this field is defined in 25.7.2.3. A value of 0 indicates that no training field is present in this PPDU. If the Beam Tracking Request field is 1 and the PPDU Type field is 10, the Training Length field indicates the length of the training field. If the PPDU Type field is 11, the Training Length field indicates the length of the training field requested for receive training. For control mode: Reserved.
B47	Beam Tracking Request	1	Corresponds to the TXVECTOR parameter BEAM_TRACKING_REQUEST. Set to 1 to indicate the need for beam tracking (10.42.7); otherwise, set to 0. The Beam Tracking Request field is reserved when the Training Length field is 0.
B48	Codeword Length	1	Set to 0 indicate that the codeword length is 672. Set to 1 indicate that the codeword length is 2016.

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Table 25-7—Fields in the CMMG SIG field *(continued)*

Bit	Fields	Number of bits	Description
B49	TXOP_PS_NOT_ALLOWED	1	Set to 0 by CMMG AP if it allows non-AP CMMG STAs in TXOP power save mode to enter doze state during a TXOP. Set to 1 otherwise. The bit is reserved and set to 1 in CMMG PPDUs transmitted by a non-AP CMMG STA.
B50–B54	MCS	5	MCS index (see 25.15).
B55–B56	PPDU Type	2	When the Training Length field is nonzero, corresponds to the TXVECTOR parameter PPDU_TYPE. — PPDU Type = 11 indicates either a packet whose Data field is followed by one or more TRN-R subfields, or a packet that is requesting TRN-R subfields to be appended to a future response packet. — PPDU Type = 10 indicates a packet whose Data field is followed by one or more TRN-T subfields. When the Training Length field is zero and PPDU Type = 01, indicates that PPDU is a sounding PPDU. This field is reserved when the Training Length field is zero and PPDU Type = 00.
B57–B60	Spatial Expansion	4	For control/SC mode: Index into the corresponding spatial expansion method defined in Table 25-15.
	DB	1	For OFDM mode: If the PPDU is transmitted on 1080 MHz channel: Set DB to 1 for allowing dynamic bandwidth. Set to 0 for not allowing dynamic bandwidth. Otherwise set to 0 (Reserved). For control and SC mode: Reserved.
	STBC	1	For OFDM mode: Set to 1 if space-time block coding is used; otherwise, set to 0.
	NSS	2	For OFDM mode: Set to 0 for 1 spatial stream. Set to 1 for 2 spatial streams. Set to 2 for 3 spatial streams. Set to 3 for 4 spatial streams.
B61	Turnaround	1	As defined in Table 25-1.
B62–B63	Reserved	2	Reserved.
B64–B79	CRC	16	CMMG SIG check sequence. Definition of this field calculation is in 25.3.6.
NOTE—A value of 0 in the CMMG Length field indicates a PPDU that does not include a data field, i.e., NDP. NDP transmissions are used for sounding purposes only (see 10.36.2). The packet ends after the last CMMG OCEF or the CMMG SIG.			

Reserved bits are set to 0 by the transmitter and shall be ignored by the receiver.

All numeric fields are transmitted in unsigned format, LSB first.

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25.3.9.2 Encoding of SIG

The scrambled SIG sequence consists of 80 bits, shown as $x = (x_0, x_1, x_2, \ldots, x_{79})$ and encoded with LDPC of rate-1/2 and length 672, as follows:

a) The scrambled SIG sequence is padded with 4 0s bits to create 84 bits. The 84-bit sequence include two contiguous subsequences with length of 42 bits, shown as $[[0, 0, 0, x_0, \ldots, x_{37}], [x_{38}, \ldots, x_{79}]]$, and the two subsequences are repeated once, respectively, to obtain 168 bits, such as $\mathbf{a}' = [[0]_{1\times 4}, x_0, \ldots, x_{37}, [0]_{1\times 4}, x_0, \ldots, x_{37}, x_{38}, \ldots, x_{79}, x_{38}, \ldots, x_{79}]$. Then, the repeated data sequence is padded with 168 zero bits to create 336 bits.

b) Then, using rate-1/2 LDPC base matrix and setting $\overline{h}_{26} = -1$, the 336-bit sequence is added with parity bits $[p_0, \ldots, p_{335}]$ to create LDPC codeword, shown as $\mathbf{c} = [[0]_{1\times 168}, \mathbf{a}', [p_0, \ldots, p_{335}]]$, such that $\mathbf{H} \times \mathbf{c}^{\mathrm{T}} = \mathbf{0}$, where $\mathbf{H}$ is revised LDPC parity check matrix.

The basic code is $\mathbf{c}' = [x_0, x_1, \ldots, x_{79}, p_0, p_1, \ldots, p_{335}]$. Using rate-matching to obtain transmitting sequence of 1024 bits: $S = [\mathbf{c}', \mathbf{c}', \mathbf{c}'(0, \ldots, 191)]$.

25.3.10 CMMG duplication transmission on a 1080 MHz channel

The STFs, the CEFs, and the SIG fields that are transmitted using SC modulation are specified at the SC chip rate F_C equal to 440 MHz. For transmission on the 1080 MHz channel, the signal is resampled with a 2 rate change, applied appreciate phase rotation for each 540 MHz subband, and then summed to form the transmitted signal.

Let $r(nT_C) = r_{STF}(nT_C) + r_{CEF}(nT_C - t_{CEF}) + r_{SIG}(nT_C - t_{SIG})$, where T_C is the SC chip duration for 540 MHz channel bandwidth and r_{CEF} is described in 25.3.5.

Then

$$r^{(1)}\left(n\frac{T_C}{2}\right) = \begin{cases} r\left(n\frac{T_C}{2}\right), n = 0, 2, 4, \ldots \\ 0, otherwise \end{cases} \tag{25-21}$$

$$r^{(2)}\left(n\frac{T_C}{2}\right) = \sum_{k=0}^{K-1} r^{(1)}\left((n-k)\frac{T_C}{2}\right) h_{Filt}(k), n = 0, 1, 2, \ldots \tag{25-22}$$

$$\bar{r}\left(n\frac{T_C}{2}\right) = r^{(2)}\left(\left(n + \frac{K-1}{2}\right)\frac{T_C}{2}\right), n = 0, 1, 2, \ldots \tag{25-23}$$

where K is the length of the filter defined in at chip rate 880 MHz whose definition is out of scope of this standard. The transmitted signal is given as

(25-24)

where B = 540 MHz.

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25.3.11 h_{Filt} definition

The filter h_{Filt} is defined by the following coefficients (from h_0 to h_{70}):

[1,–6,–5,3,8,0,–8,–4,6,8,–4,–13, –2,16,14,–9,–23,–4,23,15, –20,–27,20,57,4,–99, –102,70,247,144,–264, –558,–175,991,2327,2917,2327,991,–175,–558,–264,144,247,70,–102, –99,4,57,20,–27,–20, 15,23,–4, –23,–9,14,16,–2,–13,–4,8,6,–4,–8,0,8,3,–5,–6,1].

Normalized to have a norm of $\sqrt{3}$ so that $h_{Filt}(k) = \frac{\sqrt{3}h_k}{\sqrt{\sum_{l=0}^{70}|h_l|^2}}$.

25.3.12 Encoding of Data field

The scrambled Data field is encoded with LDPC codeword length of n bits, information length of k bits, and expansion factor of z as follows:

a) $L_{DPCW} = k - 8$ is the maximal number of data bits in each LDPC codeword. The number of LDPC codeword is calculated as

$$N_{CW} = \lceil Length \times 8 / L_{DPCW} \rceil .$$

b) The number of data bits in the i^{th} LDPC codeword is

$$L_i = \begin{cases} L_{DPCW1}, i = 0, 1, \ldots, N_{CW1} - 1 \\ L_{DPCW1} - 1, i = N_{CW1}, N_{CW1} + 1, \ldots, N_{CW} - 1 \end{cases}$$

where

$$L_{DPCW1} = \lceil Length \times 8 / N_{CW} \rceil$$

$$N_{CW1} = \mathrm{mod}((Length \times 8), (L_{DPCW1} - 1))$$

c) The data field is broken into N_{CW} blocks of data word $\mathbf{b}_i$, $i = 0, 1, \ldots, N_{CW}–1$. Each data word is added with 8-bit CRC sequence, see 25.3.6, then padded with $f_i = k–L_i– 8$ zero bits to create k bits, such as $\mathbf{b}'_i = (0, \ldots, 0, \mathbf{b}_i, crc_0^i, \ldots, crc_7^i)$.

d) For each data word, $n–k$ parity bits are added to create the LDPC codeword $\mathbf{d}_i = (\mathbf{b}'_i, p_0^i, p_1^i, \ldots, p_{(n-k-1)}^i)$, such that $\mathbf{H} \times \mathbf{d}_i^T = \mathbf{0}$.

e) Packet encoding: The j^{th} bit set that is composed of all the j^{th} bits of N_{CW} LDPC codeword is encoded with 1-bit parity check to create a parity bit $T_j, j = 0, 1, \ldots, n–1$. All the parity bits T_j ($j = 0, 1, \ldots, n–1$) are combined into a parity data word $\mathbf{d}_{N_{CW}}$ with length of n bits. That is, $\mathbf{d}_{N_{CW}} = \mathbf{d}_0 \oplus \mathbf{d}_1 \ldots \oplus \mathbf{d}_{(N_{CW}-1)}$.

f) Bits selection parameter: the punctured-bit index set of i^{th} codeword that are not belong to padding bits are $\mathbf{S}_i$ ($i = 0, 1, \ldots, N_{CW}–1$), and the punctured-bit index set of parity data word $\mathbf{d}_{N_{CW}}$ is $\bar{\mathbf{S}}_{N_{CW}}$. The intersection of any two different sets of $\bar{\mathbf{S}}_i$ ($i = 0, 1, \ldots, N_{CW}$) is empty set. The length of $\bar{\mathbf{S}}_i$ is e_i ($i = 0,\ldots, N_{CW}$), such as: (where $n' = n - f_0$).

1) if $N_{CW} = 1$: $e_0 = 0$, $e_1 = n'$;

2) if $1 < N_{CW} \le 15$: $e_i = z$, $i = 0, 1, \ldots N_{CW}–1$, $e_{N_{CW}} = n' - \sum_{i=0}^{N_{CW}-1} e_i$;

3) if $N_{CW} > 15$:

$$e_i = \begin{cases} a + 1, i = 0, 1, \ldots, g - 1 \\ a, i = g, g + 1, \ldots, N_{CW} \end{cases} ,$$

where $a = \lfloor n'/(N_{CW} + 1) \rfloor$, $g = n' - a \times (N_{CW} + 1)$.

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g) Bits selection: the first element of $\bar{\mathbf{S}}_i$ is equal to the last element of $\bar{\mathbf{S}}_{(i-1)}$ plus 1, such as,

$$\bar{\mathbf{S}}_i = \left[f_0 + \sum_{j=0}^{i-1} e_j, f_0 + \sum_{j=0}^{i-1} e_j + 1, \ldots, f_0 + \sum_{j=0}^{i} e_j - 1\right],$$

where f_0 is the length of padding bits for the 0^{th} codeword. Remove the zero padding bits and the punctured bits from $\mathbf{d}_i$ to obtain codeword $\mathbf{c}_i$, where $i = 0, 1, \ldots, N_{CW}-1$. The punctured-bit index set of parity data word $\mathbf{d}_{N_{CW}}$ is

$$\bar{\mathbf{S}}_{N_{CW}} = \left[f_0 + \sum_{j=0}^{N_{CW}-1} e_j, f_0 + \sum_{j=0}^{N_{CW}-1} e_j + 1, \ldots, f_0 + \sum_{j=0}^{N_{CW}} e_j - 1\right].$$

Remove the padding-bit-generated bits and the punctured bits from $\mathbf{d}_{N_{CW}}$ to obtain $\mathbf{c}_{N_{CW}}$, where the padding-bit-generated bits are totally generated from the zero padding bits.

Example of data field encoding:

The data field contains *Length* = 512 octets. The parameter of LDPC: $n = 672$, $k = 336$, $R = 1/2$, $z = 42$.

a) $L_{DPCW} = k - 8 = 328$, the number of LDPC codeword: $N_{CW} = \lceil Length \times 8 / L_{DPCW} \rceil = 13$;

b) $L_{DPCW1} = \lceil Length \times 8 / N_{CW} \rceil = 316$, $N_{CW1} = \text{mod}((Length \times 8), (L_{DPCW1} - 1)) = 1$,

$$L_i = \begin{cases} 316, i = 0 \\ 315, i = 1, 2, \ldots, 12 \end{cases};$$

that is, the number of data bits in the *0*th LDPC codeword is 316, and the 1st–12th LDPC codeword is 315.

c) The data field is broken into $N_{CW} = 13$ blocks of data word. Each data word is added with 8 bits *CRC* sequence, see 25.3.6. Then padded with zero bits: the *0*th data word is padded with 12 bits and the 1st-12th data word are padded with 13 bits.

d) All the data words are encoded to obtain LDPC codeword $\mathbf{d}_i = (\mathbf{b}'_i, p_0^i, p_1^i, \ldots, p_{(n-k-1)}^i)$, $i = 0, 1, \ldots, 12$.

e) Packet encoding: Encoded with 1-bit parity check to create $\mathbf{d}_{13}$, length of 672 bits.

f) Bits selection parameter: because of $(N_{CW} = 13) \leq 15$, $e_i = 42$, $i = 0, 1, \ldots, 12$, and $n' = n - f_0 = 672 - 12 = 660$, $e_{13} = 660 - \sum_{i=0}^{12} e_i = 114$.

Bits selection: Remove the zero padding bits [0, 1, …, 11] and the punctured bits $\bar{\mathbf{S}}_0 = [12, 13, \ldots, 53]$ from $\mathbf{d}_0$ to obtain codeword $\mathbf{c}_0$ with length of 618 bits; Remove the zero padding bits [0, 1, …, 12] and the punctured bits $\bar{\mathbf{S}}_1 = [54, 55, \ldots, 95]$ from $\mathbf{d}_1$ to obtain codeword $\mathbf{c}_1$ with length of 617 bits; the same operating to obtain $\mathbf{c}_2$, …, $\mathbf{c}_{12}$. Remove the padding-bit-generated bits [0, 1, …, 11] and the punctured bits $\bar{\mathbf{S}}_{13} = [558, 559, \ldots, 671]$ from $\mathbf{d}_{13}$ to obtain codeword $\mathbf{c}_{13}$ with length of 546 bits.

25.3.13 Received channel power indicator (RCPI) measurement

The RCPI is a measure of the received RF power in the selected channel for a received frame. This parameter shall be a measure by the PHY of the received RF power in the channel measured over the data portion of the received frame.

The RCPI encoding is defined in 9.4.2.37.

RCPI shall equal the received RF power with an accuracy of ± 5 dB (95% confidence interval) within the specified dynamic range of the receiver. The received RF power shall be determined assuming a receiver noise equivalent bandwidth equal to the channel width multiplied by 1.1. The relative error between RF power measurements made within a 1 second interval should be less than ± 1 dB.

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25.4 CMMG control mode

25.4.1 Introduction

Transmission and reception of the CMMG control mode PPDUs are mandatory. The CMMG control mode uses the same chip rate as the CMMG SC mode. The CMMG control mode is transmitted when the TXVECTOR indicates MCS 0. The modulation and coding scheme for the CMMG control mode is shown in Table 25-8.

Table 25-8—Modulation and coding scheme for the CMMG control mode

MCS index	Modulation	Code rate	Data rate
0	π/2-BPSK	1/2	25.38 Mb/s for SF 13, 47.14 Mb/s for SF 11, 82.5 Mb/s for SF 4, and 330 Mb/s for no spreading

25.4.2 PPDU format

The CMMG control mode frame is composed of CMMG control mode STF, CMMG control mode CEF, CMMG control mode SIG, CMMG control mode Data field, and possibly AGC and TRN-R/T subfields. This is shown in Figure 25-13.

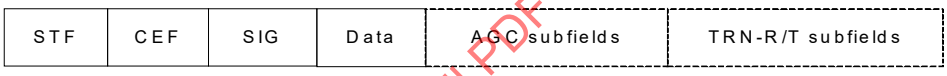

Figure 25-13—CMMG control mode PPDU format

25.4.3 CMMG preamble transmission

In CMMG control mode preamble is transmitted using SC transmission (see 25.3.5).

25.4.4 CMMG control mode SIG transmission

25.4.4.1 General

The CMMG control mode SIG and data are modulated by π/2-BPSK and are spread by Barker sequences.

25.4.4.2 Generation of CRC bits

The CRC sequence is calculated over bits 0–63 and uses CRC 16-CCITT as described in 25.3.6.

25.4.4.3 Scrambler

The operation of the scrambler is defined in 25.3.7. Bits $x_1, x_2, x_3, x_4, x_5, x_6, x_7$ of the scrambler shift register are initialized using the bits in the scrambler initialization bits from the SIG. The SIG is scrambled starting from bit 7.

25.4.4.4 Encoding

See 25.3.9.2.

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25.4.4.5 Modulation

The CMMG control mode SIG is modulated with π/2-BPSK modulation, the input bit stream is mapped according to the following equation $\tilde{s}_k = 2 \cdot c_k - 1$. Each output symbol is then rotated according to the following equation: $s_k = \tilde{s}_k e^{(j\pi k)/2}$.

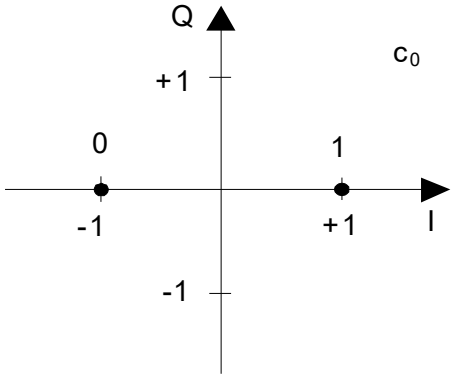

Figure 25-14—Constellation bit encoding for BPSK

25.4.4.6 Spreading

The constellation points are spread using the Barker sequence Barker(L) defined as follows in Table 25-9, where L is the spreading length.

Table 25-9—The Barker(L) sequences

Length L	Barker(L) sequences
4	+1,+1, −1,+1
7	+1, +1, +1, −1, −1,+1, −1
13	+1, +1, +1, +1, +1, −1, −1, +1, +1, −1, +1, −1, +1

The waveform for the modulated and spread data field is

$$r_{DATA}(nT_C) = \left(\text{Barker}(n \bmod L)d\left(\left\lfloor \frac{n}{L} \right\rfloor\right)\right) \times \exp\left(j\pi\frac{n}{2}\right), n = 0, 1, 2, \ldots \quad (25\text{-}25)$$

where $d(k)$ is the modulated constellation point k and T_C is the SC chip time.

For CMMG control mode SIG, the spreading factor is always Barker(13).

25.4.5 CMMG control mode Data field

25.4.5.1 General

The Data field consists of the payload data of the PSDU. The PSDU is scrambled, encoded, modulated, and spread as described in the following subclauses.

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25.4.5.2 Scrambler

The operation of the scrambler is defined in 25.3.7. The scrambling of the data field continues the scrambling of the CMMG control mode SIG with no reset.

25.4.5.3 Encoding

Use the LDPC of rate-1/2 and length 672. See 25.3.12.

25.4.5.4 Modulation

See 25.4.4.5.

25.4.5.5 Spreading

Spreading factor of CMMG control mode data field is indicated in CMMG control mode SIG. See 25.4.4.6.

25.4.6 CMMG control mode performance requirements

25.4.6.1 Transmit requirements

25.4.6.1.1 Introduction

Transmitter performance requirements of the control mode are defined in 25.4.6.1.2.

25.4.6.1.2 Transmit EVM

The transmit EVM accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc. The instrumentation shall perform carrier lock, symbol timing recovery, and amplitude adjustment while making the measurements. The instrumentation shall incorporate a rake receiver or equalizer to reduce error resulting from multipath. If used, the equalizer shall be trained using information in the preamble (STF/CEF). For CMMG control mode EVM, the signal is first despread using the spreading Barker sequence, the EVM is then calculated on the resulting symbols according to Equation (25-26).

$$EVM = 20\log_{10}\left(\sqrt{\frac{1}{N_S P_{avg}}\sum_{i=1}^{N_S}[(I_i - I_i^*)^2 + (Q_i - Q_i^*)^2]}\right) \quad (25\text{-}26)$$

where N_S is the number of samples to be measured and N_S shall be 1000, P_{ave} is the average power of the constellation, (I_i, Q_i) is the complex coordinates of the measured symbol i, (I_i^*, Q_i^*) is the complex coordinates of the ideal constellation point for the measured symbol i.

The test equipment should use a root-raised cosine filter with roll-off factor of 0.25 for the pulse shaping filter when conducting EVM measurement.

The transmit pulse shaping used is left to the implementer.

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The relative constellation error (EVM) shall not exceed an MCS dependent value according to Table 25-10.

Table 25-10—EVM requirement for control mode

MCS index	Description	EVM value (dB)
0	Control mode modulation	–6

25.4.6.2 Receive requirements

25.4.6.2.1 Introduction

Subclause 25.4.6.2.2 describes the performance requirement from the CMMG control mode receiver.

25.4.6.2.2 CCA

The start of a CMMG control mode transmission at a receive level greater than the minimum sensitivity for CMMG control mode (–78 dBm) shall cause CCA to indicate busy with a probability > 90% within 3 μs.

25.5 CMMG SC mode

25.5.1 Introduction

Transmission and reception of CMMG SC mode PPDUs in MCSs 1 to 3 is mandatory. Transmission and reception of CMMG SC mode PPDUs with MIMO may be supported.

25.5.2 Transmitter block diagram

Figure 25-15 shows the transmit process for the CMMG SC mode SIG transmission. The actual structure of the transmitter is implementation dependent.

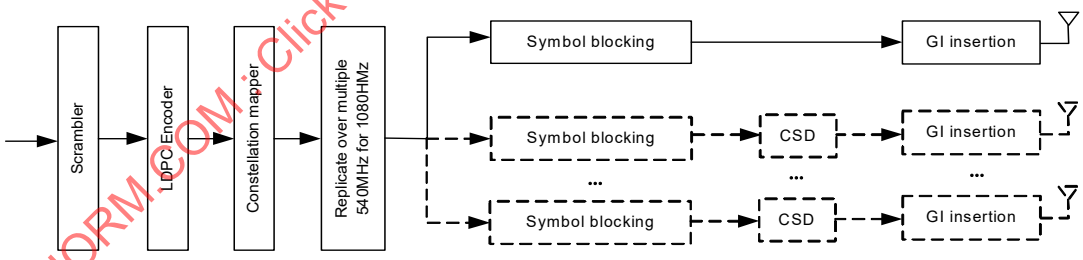

Figure 25-15—Transmitter block diagram for CMMG SC mode SIG field

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Figure 25-16 shows the transmit block used to generate the data fields of 540 MHz and 1080 MHz using SC mode transmission.

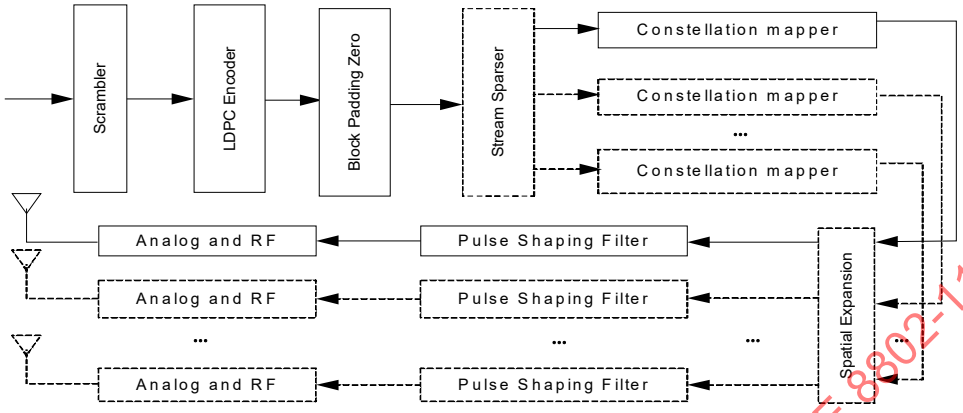

Figure 25-16—Transmitter block diagram for data fields of CMMG SC mode PPDUs

NOTE—The operations denoted by the dotted line arrows and dotted line boxes in the above two figures are optional and are applied for SC MIMO transmission.

25.5.3 Overview of the PPDU encoding process

25.5.3.1 General

This subclause provides an overview of the CMMG SC mode PPDU encoding process.

25.5.3.2 Construction of CMMG SC mode SIG

The construction of the CMMG SC mode SIG field proceeds as follows:

a) Obtain the parameters from TXVECTOR. Add the reserved bits, append the calculated CRC. The calculation of the CRC of the CMMG SC mode SIG is described in 25.3.6.
b) Scrambler: Scramble the CMMG SC mode SIG bits. The scrambler is described in 25.3.7.
c) LDPC encoder: The scrambled bits are encoded using the LDPC code as described in 25.5.5.4.2.
d) Constellation mapper: BPSK modulate the coded bits as described in 25.5.5.4.3 to form the transmitted symbol blocks of CMMG SC mode SIG.
e) Duplication and phase rotation: Apply the appropriate phase rotations for each 540 MHz subchannel as 25.5.5.4.4.
f) Symbol blocking: Divide the encoded SIG field into symbol block of length 256.
g) CSD: Apply CSD for each transmit chain as described in 25.5.5.4.5. This only applies to the CMMG SC mode MIMO mechanism.
h) GI insertion: Prepend a GI for each symbol block of length 256.
i) Pulse filter, Analog, and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit.

NOTE—Conversion from the sampled digital domain to the continuous time domain is beyond the scope of this document. Filtering for pulse shaping such as in GMSK is beyond the scope of this standard.

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25.5.3.3 Construction of CMMG SC mode PPDUs

The construction of the data field in a CMMG SC mode PPDU LDPC encoding proceeds as follows:

a) Scrambler: Scramble the PHY padded data.
b) LDPC encoder: The scrambled bits are encoded using the LDPC code as described in 25.3.12.
c) Blocking Padding Zero: Append the PHY pad bits to the PSDU as described in 25.5.6.4.
d) Stream parser: The output of the LDPC encoder is rearranged into blocks as described in 25.5.6.5.
e) Constellation mapper: Map to π/2-BPSK, π/2-QPSK, π/2-16-QAM, or π/2-64-QAM constellation points as described in 25.5.6.6.
f) Spatial Expansion: Apply the spatial expansion mechanism according to the combination of the number of the spatial streams and the number of the transmit antennas as described in 25.5.6.7.
g) Pulse filter, Analog, and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit.

25.5.4 CMMG SC mode PPDU format

A CMMG SC mode PPDU frame is composed of the CMMG SC mode STF, the CMMG SC mode CEF, the CMMG SC mode SIG field, the optional CMMG SC mode SCTF, the SC data block, and the optional training fields, which is defined in Figure 25-17 where the SCTF fields is transmitted for 1080 MHz channel bandwidth.

Figure 25-17—Format of CMMG SC mode PPDU

NOTE—The SCTF is only transmitted for 1080 MHz channel bandwidth and is composed of a ZCZ sequence of length 512. For MIMO transmission, different transmit antenna transmit a different preamble that is composed of one the four ZCZ sequences with the order of $Z_{512}^{1}, Z_{512}^{2}, Z_{512}^{3}, Z_{512}^{4}$, such as for the case of one transmit antenna, the preamble sequence is composed of Z_{512}^{1} , for the case of two transmit antennas, the preamble sequences are composed of Z_{512}^{1}, Z_{512}^{2} , respectively.

25.5.5 CMMG SC mode SIG transmission

25.5.5.1 SIG field

The CMMG SC mode SIG field carries information required to interpret PPDUs. The preamble and the CMMG SC mode SIG fields all are transmitted with SC mode modulation.

25.5.5.2 Generation of the CRC bits of SIG

The calculation of the CRC of the CMMG SC mode SIG is described in 25.3.6.

25.5.5.3 Scrambler

The operation of the scrambler is defined in 25.3.7. Bits $x_1, x_2, x_3, x_4, x_5, x_6, x_7$ of the scrambler shift register are initialized using the bits in the scrambler initialization bits from the SIG. The CMMG SC mode SIG is scrambled starting from bit 7.

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25.5.5.4 Encoding and modulations

25.5.5.4.1 General

The modulation and coding scheme defines the modulation and code rate that is used in the PPDU. The modulation and coding schemes are defined in 25.5.6.6.

25.5.5.4.2 Encoding

See 25.3.9.2.

25.5.5.4.3 Modulation

See 25.4.4.5.

25.5.5.4.4 Duplication

If the channel bandwidth is 1080 MHz, the modulated SIG symbols are transmitted in duplicate format as defined in 25.3.10.

25.5.5.4.5 Symbol blocking, CSD, and GI insertion

The modulated CMMG SC mode SIG symbols are divided into four symbols blocks of length 256. For each block, the cyclic shift values for the CMMG SC mode SIG field of the PPDU for transmit chain i_{TX} out of a total of N_{TX} are defined in Table 25-11.

Table 25-11—Cyclic shift values for the CMMG SIG field

$T_{CS}^{i_{TX}}$ values for the CMMG-SIG field				
Total number of transmit chains (N_{TX})	Cyclic shift for transmit chain i_{TX} (in units of ns)			
	1	2	3	4
1	0	—	—	—
2	0	$-128T_C$	—	—
3	0	$-85T_C$	$-170T_C$	—
4	0	$-64T_C$	$-128T_C$	$-192T_C$

After the CSD operations, each group of 256 symbols is prepended by the last 64 symbols that form the cyclic prefix.

25.5.6 Data field transmission

25.5.6.1 General

The subclause describes the transmission of the SC data field.

25.5.6.2 Scrambler

The operation of the scrambler is defined in 25.3.7. The scrambling of the Data field continues the scrambling of the CMMG SC mode SIG with no reset for CMMG SC mode transmission.

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25.5.6.3 Encoding

See 25.3.12.

25.5.6.4 Symbol block padding zeros

The number of symbol blocks, N_{BL}, is calculated as follows:

$$N_{BL} = m_{SE}\left\lceil \frac{Length \times 8 + (8 + L_{CHECK}) \times N_{CW}}{m_{SE} N_{CBPB}} \right\rceil \quad (25\text{-}27)$$

where L_{CHECK} is the number of LDPC parity bits, m_{SE} values are listed in Table 25-12, and N_{CBPB} values are shown in Table 25-13.

Table 25-12—Values of m_{SE}

N_{SS}	N_{TX}	m_{SE}
1	1	1
	2	2
	3	3
	4	4
2	2	2
	3	4
	4	4
3	3	3
	4	6
4	4	4

Table 25-13—Values of N_{CBPB}

Symbol mapping	N_{CBPB} (540 MHz)		N_{CBPB} (1080 MHz)	
	Long GI	Short GI	Long GI	Short GI
π/2-BPSK	192	224	384	448
π/2-QPSK	384	448	768	896
π/2-16-QAM	768	896	1536	1792
π/2-64-QAM	1152	1344	2304	2688

The number of padding zeros is given by

$$N_{BPAD} = N_{BL} N_{CBPB} - (Length \times 8 + (8 + L_{CHECK}) \times N_{CW}) \quad (25\text{-}28)$$

The PSDU is concatenated with N_{BPAD} 0s. They are scrambled using the continuation of the scrambler sequence that scrambled the PSDU.

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25.5.6.5 Stream parser

After coding and puncturing, the data bit streams at the output of the FEC encoder are processed in groups of N_{CBPB}. Each of these groups is rearranged into N_{SS} blocks of N_{CBPSS} bits.

The number of bits assigned to a single axis (real or imaginary) of a constellation point in a spatial stream is denoted by Equation (25-29).

$$s = \max\left\{1, \frac{N_{CBPS}}{2}\right\} \tag{25-29}$$

Consecutive blocks of s bits are assigned to different spatial streams in a round robin fashion.

Bit i at the output of encoder is assigned to input bit k of spatial stream where

$$i = (i_{SS} - 1) \cdot s + N_{SS} \cdot s \cdot \left\lfloor \frac{k}{s} \right\rfloor + k \bmod s \tag{25-30}$$

where $i_{SS} = 1, 2, \ldots, N_{SS}$, $i = 0, 1, \ldots, N_{CBPB}-1$, $k = 0, 1, \ldots, N_{CBPSS}-1$.

25.5.6.6 Constellation mapping

The modulation and coding scheme (MCS) field specifies the modulation and code rate used in the PPDU.

A CMMG STA shall support all equal modulation (EQM) rates for one spatial stream (MCSs 1 to 3). MCSs 4 to 8 are optional.

The coded and padded bit stream is converted into a stream of complex constellation points according to the modulation specified in the MCS table.

In π/2-BPSK modulation, the input bit stream is mapped according to the following equation:

$$\tilde{s}_k = 2 \cdot c_k - 1$$

where c_k is the k^{th} input coded (or scrambled pad) bit. Each output symbol is then rotated according to the following equation:

$$s_k = \tilde{s}_k e^{(j\pi k)/2}$$

NOTE—With appropriate choice of transmit filtering, π/2-BPSK is equivalent to a precoded pulse-shaped MSK (e.g., GMSK). The precoder is simply $b_{out,k} = b_{in,k} \oplus b_{in,k-1}$, where $b_{in,k}$ is the scrambled input stream, $b_{in,-1}$ is 0, and $b_{out,k}$ is the input to the (G)MSK modulator.

In π/2-QPSK modulation (see Figure 25-18), the input bit stream is mapped according to the following equation:

$$\tilde{s}(k) = \frac{1}{\sqrt{2}}((2c_{2k} - 1) + j(2c_{2k+1} - 1))\exp\left(-j\frac{\pi}{4}\right)$$

where k is the output symbol index, $k = 0, 1, \ldots$. Each output symbol is then rotated according to the following equation:

$$s_k = \tilde{s}_k e^{(j\pi k)/2}$$

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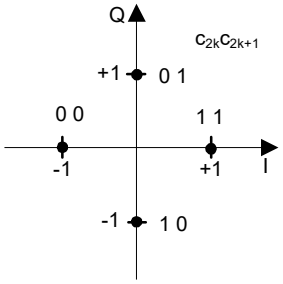

Figure 25-18—QPSK constellation bit encoding

In π/2-16-QAM modulation (see Figure 25-19), the input bit stream is mapped according to the following equation:

$$\tilde{s}_k = \frac{1}{\sqrt{10}}\{(4c_{4k}-2)-(2c_{4k}-1)(2c_{4k+1}-1)+j(4c_{4k+2}-2)-j(2c_{4k+2}-1)(2c_{4k+3}-1)\} \quad (25\text{-}31)$$

where k is the output symbol index, $k = 0, 1, \ldots$. Each output symbol is then rotated according to the following equation:

$$s_k = \tilde{s}_k e^{(j\pi k)/2}$$

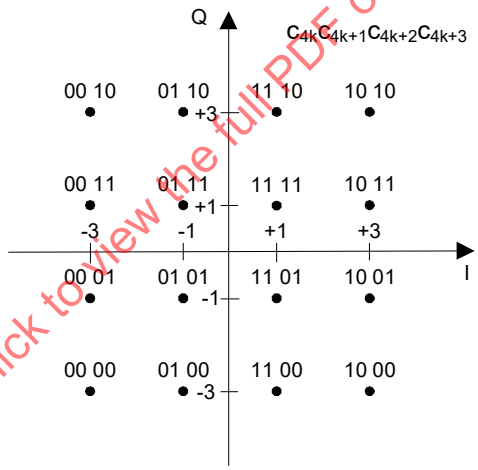

Figure 25-19—16-QAM constellation bit encoding

In π/2-64-QAM modulation (see Figure 25-20), the input bit stream is mapped according to the following equation:

$$\begin{aligned}\tilde{s}_k = {} & \frac{1}{\sqrt{42}}((8c_{6k}-4)-(2c_{6k}-1)(4c_{6k+1}-2)+(2c_{6k}-1)(2c_{6k+1}-1)(2c_{6k+2}-1)) \\ & +j\frac{1}{\sqrt{42}}((8c_{6k+3}-4)-(2c_{6k+3}-1)(4c_{6k+4}-2)+(2c_{6k+3}-1)(2c_{6+4}-1)(2c_{6k+5}-1))\end{aligned} \quad (25\text{-}32)$$

where k is the output symbol index, $k = 0, 1, \ldots$. Each output symbol is then rotated according to the following equation:

$$s_k = \tilde{s}_k e^{(j\pi k)/2}$$

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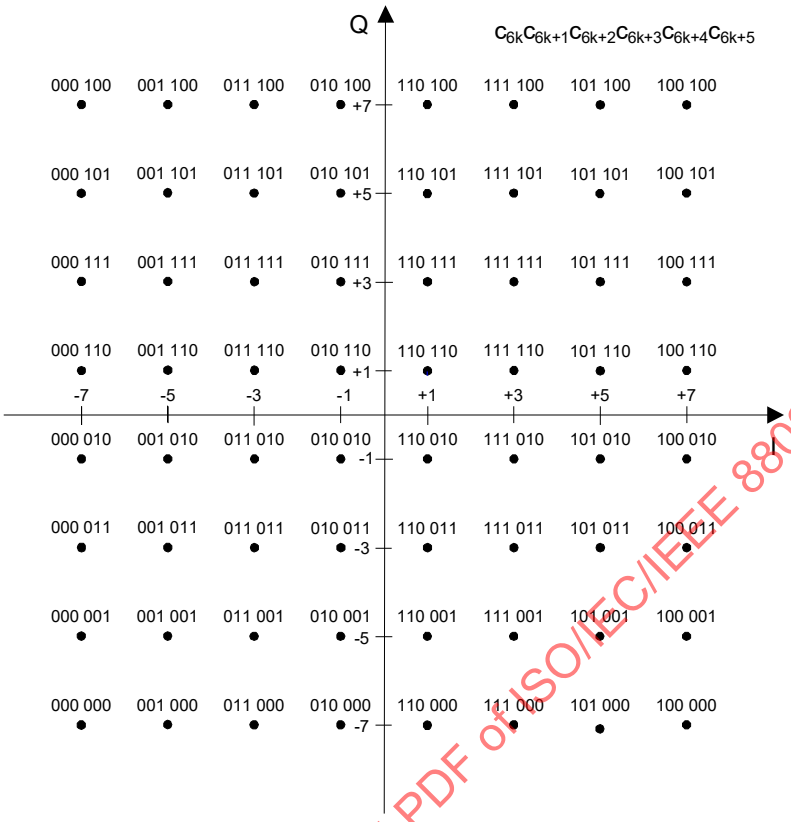

Figure 25-20—64-QAM constellation bit encoding

25.5.6.7 Spatial expansion

Each spatial stream is divided into many subblocks that each subblock includes N_{DSPB} constellation symbols. Values of N_{DSPB} and N_{UWPB} are shown in Table 25-14.

Table 25-14—Values of N_{DSPB} and N_{UWPB}

	N_{CBPB} (CBW540 MHz)		N_{CBPB} (CBW1080 MHz)	
	Long GI	**Short GI**	**Long GI**	**Short GI**
N_{DSPB}	192	224	384	448
N_{UWPB}	64	32	128	64

The spatial stream of complex numbers, $\mathbf{d}_{i,n}$, $i = 1, \ldots, N_{SS}$, $n = 0, 1, \ldots, N_{BL}–1$, is the input to the spatial expansion module, which produces as output the stream of complex numbers $\mathbf{x}_{i_{TXT},n}$, $i_{TXT} = 1, \ldots, N_{TXT}$. The relation between the spatial streams and the output streams is given in Table 25-15 where $\mathbf{x}_{i_{TXT},n} = (\tilde{\mathbf{x}}_{i_{TXT},n})^T$, $\tilde{\mathbf{d}}_{i,n} = [\mathbf{d}_{i,n}, \mathbf{0}_{1\times N_{UWPB}}]^T$, $\tilde{\mathbf{u}}_{i_{TXT}} = \left[\mathbf{0}_{1\times N_{DSPB}}, Z^{i_{TXT}}_{N_{UWPB}}\right]^T$, and $\mathbf{Q}_{N_{BLS}}$ is defined as

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$$\mathbf{Q}_{N_{BLS}} = \begin{bmatrix} \mathbf{Q}_1 & \mathbf{Q}_2 \\ \mathbf{Q}_3 & \mathbf{Q}_4 \end{bmatrix} \tag{25-33}$$

where $\mathbf{Q}_2 = \mathbf{0}_{N_{DSPB} \times N_{UWPB}}$, $\mathbf{Q}_3 = \mathbf{0}_{N_{UWPB} \times N_{DSPB}}$, and

$$\mathbf{Q}_1 = \begin{bmatrix} 0 & 0 & 0 & \ldots & 0 & 0 & 1 \\ 0 & 0 & 0 & \ldots & 0 & 1 & 0 \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ 0 & 1 & 0 & \ldots & 0 & 0 & 0 \\ 1 & 0 & 0 & \ldots & 0 & 0 & 0 \end{bmatrix}_{N_{DSPB} \times N_{DSPB}}, \mathbf{Q}_4 = \begin{bmatrix} 0 & 0 & 0 & \ldots & 0 & 0 & 1 \\ 0 & 0 & 0 & \ldots & 0 & 1 & 0 \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ 0 & 1 & 0 & \ldots & 0 & 0 & 0 \\ 1 & 0 & 0 & \ldots & 0 & 0 & 0 \end{bmatrix}_{N_{UWPB} \times N_{UWPB}} \tag{25-34}$$

The starting index for the first symbol for π/2 rotation is 0. If the Additional PPDU field within the SIG field is equal to 0, the same ZCZ sequence guard interval is prepended to the first block transmitted. If the Additional PPDU field within the SIG field is equal to 1, the same ZCZ sequence guard interval is prepended to the first block transmitted. See Figure 25-21.

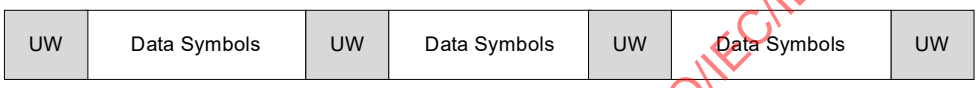

Figure 25-21—Block transmission

Table 25-15—Constellation mapper output to spatial mapper input

Index	N_{SS}	N_{TXT}	i_{TXT}	$\tilde{\mathbf{x}}_{i_{TXT}, 2^a m}$	$\tilde{\mathbf{x}}_{i_{TXT}, 2^a m+1}$	$\tilde{\mathbf{x}}_{i_{TXT}, 2^a m+2}$	$\tilde{\mathbf{x}}_{i_{TXT}, 2^a m+3}$
1	1	1	1	$\tilde{\mathbf{d}}_{1,2^a m} + \tilde{\mathbf{u}}_{i_{TXT}}$	$\tilde{\mathbf{d}}_{1,2^a m+1} + \tilde{\mathbf{u}}_{i_{TXT}}$	—	—
2		2	1	$\tilde{\mathbf{d}}_{1,2^a m} + \tilde{\mathbf{u}}_{i_{TXT}}$	$-\mathbf{Q}_{N_{BLS}} \tilde{\mathbf{d}}^*_{1,2^a m+1} + \tilde{\mathbf{u}}_{i_{TXT}}$	—	—
			2	$\tilde{\mathbf{d}}_{1,2^a m+1} + \tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{Q}_{N_{BLS}} \tilde{\mathbf{d}}^*_{1,2^a m} + \tilde{\mathbf{u}}_{i_{TXT}}$	—	—
3		3	1	$\tilde{\mathbf{d}}_{1,3m} + \tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{Q}_{N_{BLS}} \tilde{\mathbf{d}}^*_{1,3m+1} + \tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{Q}_{N_{BLS}} \tilde{\mathbf{d}}^*_{1,3m+2} + \tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{0}$
			2	$-\tilde{\mathbf{d}}_{1,3m+1} + \tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{Q}_{N_{BLS}} \tilde{\mathbf{d}}^*_{1,3m} + \tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{0}$	$-\mathbf{Q}_{N_{BLS}} \tilde{\mathbf{d}}^*_{1,3m+2} + \tilde{\mathbf{u}}_{i_{TXT}}$
			3	$-\tilde{\mathbf{d}}_{1,3m+2} + \tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{0}$	$\mathbf{Q}_{N_{BLS}} \tilde{\mathbf{d}}^*_{1,3m} + \tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{Q}_{N_{BLS}} \tilde{\mathbf{d}}^*_{1,3m+1} + \tilde{\mathbf{u}}_{i_{TXT}}$
4		4	1	$\tilde{\mathbf{d}}_{1,2^a m} + \tilde{\mathbf{u}}_{i_{TXT}}$	$-\mathbf{Q}_{N_{BLS}} \tilde{\mathbf{d}}^*_{1,2^a m+1} + \tilde{\mathbf{u}}_{i_{TXT}}$	$-\mathbf{Q}_{N_{BLS}} \tilde{\mathbf{d}}^*_{1,2^a m+2} + \tilde{\mathbf{u}}_{i_{TXT}}$	$\tilde{\mathbf{d}}_{1,2^a m+3} + \tilde{\mathbf{u}}_{i_{TXT}}$
			2	$\tilde{\mathbf{d}}_{1,2^a m+1} + \tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{Q}_{N_{BLS}} \tilde{\mathbf{d}}^*_{1,2^a m} + \tilde{\mathbf{u}}_{i_{TXT}}$	$-\mathbf{Q}_{N_{BLS}} \tilde{\mathbf{d}}^*_{1,2^a m+3} + \tilde{\mathbf{u}}_{i_{TXT}}$	$-\tilde{\mathbf{d}}_{1,2^a m+2} + \tilde{\mathbf{u}}_{i_{TXT}}$
			3	$\tilde{\mathbf{d}}_{1,2^a m+2} + \tilde{\mathbf{u}}_{i_{TXT}}$	$-\mathbf{Q}_{N_{BLS}} \tilde{\mathbf{d}}^*_{1,2^a m+3} + \tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{Q}_{N_{BLS}} \tilde{\mathbf{d}}^*_{1,2^a m} + \tilde{\mathbf{u}}_{i_{TXT}}$	$-\tilde{\mathbf{d}}_{1,2^a m+1} + \tilde{\mathbf{u}}_{i_{TXT}}$
			4	$\tilde{\mathbf{d}}_{1,2^a m+3} + \tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{Q}_{N_{BLS}} \tilde{\mathbf{d}}^*_{1,2^a m+2} + \tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{Q}_{N_{BLS}} \tilde{\mathbf{d}}^*_{1,2^a m+1} + \tilde{\mathbf{u}}_{i_{TXT}}$	$\tilde{\mathbf{d}}_{1,2^a m} + \tilde{\mathbf{u}}_{i_{TXT}}$

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Table 25-15—Constellation mapper output to spatial mapper input *(continued)*

Index	N_{SS}	N_{TXT}	i_{TXT}	$\tilde{\mathbf{x}}_{i_{TXT},2^a m}$	$\tilde{\mathbf{x}}_{i_{TXT},2^a m+1}$	$\tilde{\mathbf{x}}_{i_{TXT},2^a m+2}$	$\tilde{\mathbf{x}}_{i_{TXT},2^a m+3}$
5	2	2	1	$\tilde{\mathbf{d}}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	$\tilde{\mathbf{d}}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
			2	$\tilde{\mathbf{d}}_{2,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	$\tilde{\mathbf{d}}_{2,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
6		3	1	$\tilde{\mathbf{d}}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	$-\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
			2	$\tilde{\mathbf{d}}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
			3	$\tilde{\mathbf{d}}_{2,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{2,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
7		4	1	$\tilde{\mathbf{d}}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	$-\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
			2	$\tilde{\mathbf{d}}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
			3	$\tilde{\mathbf{d}}_{2,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	$-\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{2,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
			4	$\tilde{\mathbf{d}}_{2,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{2,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
8	3	3	1	$\tilde{\mathbf{d}}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	$\tilde{\mathbf{d}}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
			2	$\tilde{\mathbf{d}}_{2,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	$\tilde{\mathbf{d}}_{2,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
			3	$\tilde{\mathbf{d}}_{3,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{d}_{3,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
9		4	1	$\tilde{\mathbf{d}}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	$-\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
			2	$\tilde{\mathbf{d}}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
			3	$\tilde{\mathbf{d}}_{2,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}_{2,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
			4	$\tilde{\mathbf{d}}_{3,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	$\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}_{3,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
10	4	4	1	$\tilde{\mathbf{d}}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	$\tilde{\mathbf{d}}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
			2	$\tilde{\mathbf{d}}_{2,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	$\tilde{\mathbf{d}}_{2,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
			3	$\tilde{\mathbf{d}}_{3,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	$\tilde{\mathbf{d}}_{3,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—
			4	$\tilde{\mathbf{d}}_{4,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$	$\tilde{\mathbf{d}}_{4,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$	—	—

NOTE 1—$a = 2$, for $N_{SS} = 1$ and $N_{TXT} = 4$; otherwise, $a = 1$.
NOTE 2—* indicates conjugate operation.

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25.5.6.8 Duplication transmission

When the TXVECTOR parameter DUPLICATE_MODULATION is present, the transmitted PPDU is a duplicate. The modulated data symbols are duplicated as described in 25.3.10.

25.5.7 Performance requirements

25.5.7.1 Transmit requirements

25.5.7.1.1 Introduction

Transmitter performance requirements of the SC mode are defined in 25.5.7.1.2.

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25.5.7.1.2 Transmit EVM

The transmit EVM accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, DC offsets, phase noise, etc.

The instrumentation shall perform carrier lock, symbol timing recovery, amplitude adjustment, and equalization while making the measurements. The equalizer shall be trained using information in the CMMG SC mode preamble (STF/CEF). For the CMMG SC mode EVM, measuring samples at the sample rate, the measured symbols should not contain the first and the last hundred symbols of a given packet (ramp up/down). The EVM is calculated according to the formula below:

(25-35)

where

N_S is the number of samples to be measured and N_S should be 1000
P_{avg} is the average power of the constellation
(I_i, Q_i) is the complex coordinates of the measured symbol i
(I_i^*, Q_i^*) is the complex coordinates of the ideal constellation point for the measured symbol i
(I_0, Q_0) is the complex DC term chosen to reduce EVM

The test equipment should use a root-raised cosine filter with roll-off factor of 0.25 for the pulse shaping filter when conducting EVM measurement.

The transmit pulse shaping used is left to the implementer.

The relative constellation error (EVM) shall not exceed an MCS dependent value according to Table 25-16.

Table 25-16—EVM requirements for SC mode

CMMG-MCS indexes	Modulation	Coding rate	EVM value (dB)
1	π/2-BPSK	1/2	–7
2	π/2-QPSK	1/2	–11
3	π/2-QPSK	3/4	–13
4	π/2-16-QAM	1/2	–19
5	π/2-16-QAM	3/4	–21
6	π/2-64-QAM	5/8	–25
7	π/2-64-QAM	3/4	–26
8	π/2-64-QAM	13/16	–28

25.5.7.1.3 Time of Departure accuracy

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

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— MULTICHANNEL_SAMPLING_RATE is 440×10^6 sample/s for 540 MHz channel and 880×10^6 sample/s for 1080 MHz channel
— FIRST_TRANSITION_FIELD is Short Training field
— SECOND_TRANSITION_FIELD is Channel Estimation field
— TRAINING_FIELD is Channel Estimation field
— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

25.5.7.2 Receive requirements

25.5.7.2.1 Introduction

This subclause describes the receiver requirements of the CMMG SC mode.

25.5.7.2.2 CCA

The start of a CMMG SC mode transmission at a receive level greater than the minimum sensitivity for MCS 0 (–81 dBm for 540 MHz, –78 dBm for 1080 MHz) shall cause CCA to indicate busy with a probability > 90% within 1 μs. The receiver shall hold the carrier sense signal busy for any signal 20 dB above the minimum sensitivity for MCS 0.

25.6 CMMG OFDM mode

25.6.1 Introduction

Transmission and reception of OFDM mode PPDUs are optional.

25.6.2 CMMG OFDM mode PPDU format

A CMMG OFDM mode OFDM PPDU frame is composed of the CMMG OFDM mode STFs, the CMMG OFDM mode CEF, the CMMG OFDM mode SIG field, the CMMG OFDM mode Short Training Field (OSTF), the CMMG OFDM mode Channel Estimation Field (OCEF), CMMG OFDM mode symbols, and the optional training fields, as shown in Figure 25-22.

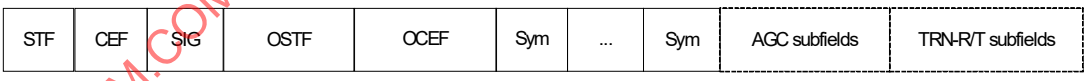

Figure 25-22—Format of the CMMG OFDM mode PPDU

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25.6.3 Transmission block diagram

Figure 25-23 shows the transmit process for the CMMG OFDM mode SIG transmission. The actual structure of the transmitter is implementation dependent.

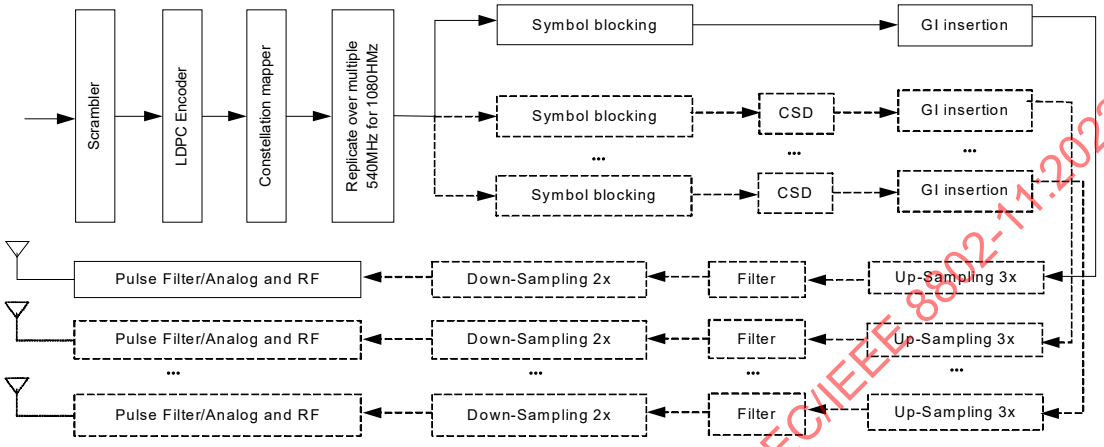

Figure 25-23—Transmitter block diagram for CMMG OFDM mode SIG fields

Figure 25-24 shows the transmitter blocks used to generate the Data field of OFDM mode PPDU with LDPC encoding.

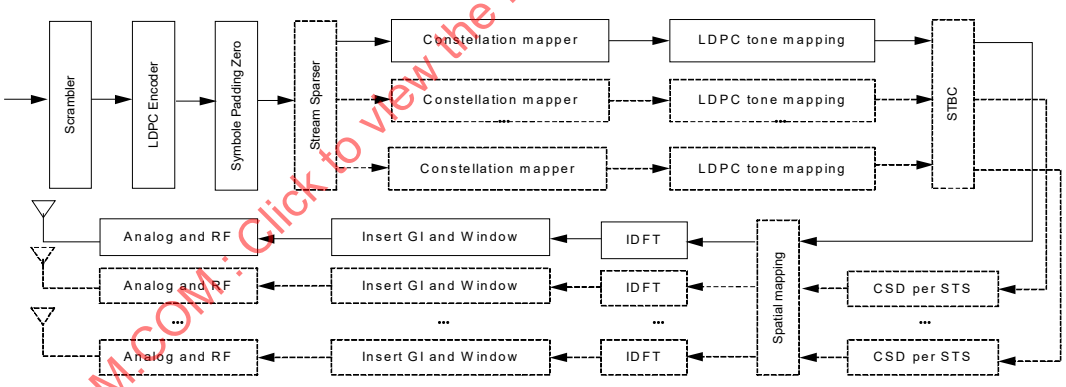

Figure 25-24—Transmitter block diagram for the data field of CMMG OFDM mode

NOTE—The operation denoted by the dotted line arrows and dotted line boxes in the above two figures are optional and are applied for OFDM MIMO transmission.

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25.6.4 Overview of CMMG OFDM mode PPDU encoding process

25.6.4.1 General

This subclause provides an overview of the CMMG OFDM mode PPDU encoding process.

25.6.4.2 Construction of CMMG OFDM mode SIG

The construction of the CMMG OFDM mode SIG field proceeds as follows:

a) Obtain the parameters from TXVECTOR. Add the reserved bits, append the calculated CRC. The calculation of the CRC of the CMMG OFDM mode SIG is described in 25.3.6.
b) Scrambler: Scramble the CMMG OFDM mode SIG bits. The Scrambler is described in 25.3.7.
c) LDPC encoder: The scrambled bits are encoded using the LDPC code as described in 25.5.5.4.2.
d) Constellation mapper: BPSK modulate the coded bits as described in 25.5.5.4.3 to form the transmitted symbol blocks of CMMG PHY SIG.
e) Duplication and phase rotation: Apply the appropriate phase rotations for each 540 MHz subchannel as 25.5.5.4.4.
f) CSD: Apply CSD for each transmit chain as described in 25.5.5.4.5. This is need only for the CMMG OFDM MIMO mechanism.
g) Symbol blocking and GI insertion: Prepend a GI and generate the transmission symbol block.
h) Upsampling, filtering, and downsampling: Sample rate change in CMMG OFDM mode transmission as described in 25.6.5.4. This only applies to the CMMG OFDM mode MIMO mechanism.
i) Pulse filter, Analog, and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit.

NOTE—Conversion from the sampled digital domain to the continuous time domain is beyond the scope of this document. Filtering for pulse shaping such as in GMSK is beyond the scope of this standard.

25.6.4.3 Construction of CMMG OFDM mode PPDU

The construction of the Data field in an OFDM mode PPDU with LDPC encoding proceeds as follows:

a) Scrambler: Scramble the PHY padded data. The scrambler is described in 25.3.7.
b) LDPC encoder: The scrambled bits are encoded using the LDPC code with the APEP_LENGTH in the TXVECTOR as described in 25.6.8.3.
c) Stream parser: The output of the LDPC encoder is rearranged into blocks as described in 25.6.8.5.
d) Constellation mapper: Map to BPSK, QPSK, 16-QAM, or 64-QAM constellation points as described in 25.6.8.6.
e) LDPC tone mapper: The LDPC tone mapping shall be performed on all LDPC encoded streams as described in 25.6.8.7.
f) OFDM symbol padding zeros: Append the CMMG OFDM mode pad bits to the PSDU as described in 25.6.8.4.
g) STBC: Apply STBC as described in 25.6.8.8.
h) Pilot insertion: Insert pilots following the steps described in 25.6.8.9.
i) CSD: Apply CSD for each space-time stream as described in 25.6.8.10.
j) Spatial mapping: Apply the **Q** matrix as described in 25.6.8.11.
k) Phase rotation: Apply the appropriate phase rotations for each 540 MHz subchannel as described in 25.3.4.4.

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l) IDFT: Compute the inverse discrete Fourier transform.
m) Insert GI and apply windowing: Prepend a GI and apply windowing.
n) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit.

25.6.4.4 Construction of OSTF

The OSTF is defined in 25.6.6 and is constructed as follows:

a) Sequence generation: Generate the OSTF in the frequency-domain over the bandwidth indicated by CH_BANDWIDTH as described in 25.6.6.
b) Phase rotation: Apply appropriate phase rotation for each 540 MHz subchannel as described in 25.3.4.3 and 25.3.4.4.
c) CSD: Apply CSD for each space-time stream and frequency segment as described in 25.6.8.10.
d) Spatial mapping: Apply the **Q** matrix as described in 25.6.8.11.
e) IDFT: Compute the inverse discrete Fourier transform.
f) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 25.3.4.3.
g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 25.3.4.3 and 25.6.6 for details.

25.6.4.5 Construction of OCEF

The OCEF is defined in 25.6.7 and constructed as follows:

a) Sequence generation: Generate the OCEF sequence in the frequency-domain over the bandwidth indicated by CH_BANDWIDTH as described in 25.6.7.
b) Phase rotation: Apply appropriate phase rotation for each 540 MHz subchannel as described in 25.3.4.3 and 25.3.4.4.
c) Matrix mapping: Apply the matrix to the OCEF sequence and apply the matrix to the pilot tones as described in 25.6.7.
d) CSD: Apply CSD for each space-time stream and frequency segment as described in 25.6.8.10.
e) Spatial mapping: Apply the **Q** matrix as described in 25.6.8.11.
f) IDFT: Compute the inverse discrete Fourier transform.
g) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 25.3.4.3.
h) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 25.3.4.3 and 25.6.7 for details.

25.6.5 CMMG OFDM mode SIG fields

25.6.5.1 SIG fields

See 25.5.5.1 to 25.5.5.4.2.

25.6.5.2 Modulation

See 25.4.4.5.

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25.6.5.3 Duplication

If the channel bandwidth is 1080 MHz, the modulated SIG symbols are duplicated as described in 25.3.10.

25.6.5.4 Symbol blocking, CSD, and GI insertion

See 25.5.5.4.5.

25.6.5.5 Symbol rate change

If the channel bandwidth is 540 MHz, the preamble sequence and the CMMG OFDM mode SIG fields defined in the above subclauses are specified at the SC chip rate (T_C). For transmission in the OFDM (nominal) sample rate, the signal is resampled with a 3/2 rate change. The resampling is done by upsampling by a factor of 3, filtering by the filter h_{Filt} defined in 25.3.11, and downsampling by a factor of 2 (see equation below). To define the transmission of the preamble when the packet is an OFDM packet, the preamble waveform is defined below.

Let $r(nT_C) = r_{STF}(nT_C) + r_{CEF}(nT_C - t_{ce}) + r_{SIG}(nT_C - t_{SIG})$, then

$$r\left(n\frac{T_s}{2}\right) = \begin{cases} r\left(n\frac{T_c}{3}\right), n = 0, 3, 6, \ldots \\ 0, otherwise \end{cases} \quad (25\text{-}36)$$

$$\tilde{r}\left(n\frac{T_s}{2}\right) = \sum_{k=0}^{K-1} r\left((n-k)\cdot\frac{T_s}{2}\right) h_{Filt}(k), n = 0, 1, \ldots \quad (25\text{-}37)$$

$$r(nT_s) = \tilde{r}\left(2n\frac{T_s}{2} - \frac{K-1}{2}\frac{T_s}{2}\right), n = 0, 1, \ldots \quad (25\text{-}38)$$

where K is the length of the filter defined in 25.3.11, $\tilde{r}(n=0)$ for $n<0$.

25.6.6 OSTF definition

The main purpose of the OFDM Short Training Field (OSTF) is to improve automatic gain control estimation in a MIMO transmission. The duration of the OSTF is T_{OSTF} regardless of the Short GI field setting in CMMG OFDM SIG.

For a 540 MHz transmission, the frequency domain sequence is given by Equation (25-39).

$$OSTF_{-89,89} = \{0, \mathbf{a}, \mathbf{a}, \mathbf{b}, \mathbf{a}, \mathbf{a}, \mathbf{a}, \mathbf{b}, \mathbf{b}, \mathbf{a}, \mathbf{b}, \mathbf{b}, \mathbf{b}, \mathbf{a}, \mathbf{a}, \mathbf{b}, \mathbf{a}, \mathbf{b}, \mathbf{b}, \mathbf{a}, \mathbf{b}, \mathbf{a}, \mathbf{a}, 0, 0, 0, 0, \mathbf{b}, \mathbf{b}, \mathbf{b}, \mathbf{b}, \mathbf{a}, \mathbf{b}, \mathbf{b}, \mathbf{b}, \mathbf{a}, \mathbf{a}, \mathbf{a}, \mathbf{a}, \mathbf{b}, \mathbf{a}, \mathbf{a}, \mathbf{a}, \mathbf{b}, \mathbf{a}, \mathbf{b}, \mathbf{a}, \mathbf{a}, 0, 0\} \quad (25\text{-}39)$$

where **a** = [1, 0, 0, 0] and **b** = [–1, 0, 0, 0].

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For a 1080 MHz transmission, the frequency domain sequence is given by Equation (25-40).

$$OSTF_{-177,\,177} = \frac{1+j}{\sqrt{2}}\{0,\ \mathbf{b},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{b},\ \mathbf{b},\ \mathbf{b},\ \mathbf{a},\ \mathbf{a},\ \mathbf{b},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{b},\ \mathbf{b},\ \mathbf{b},\ \mathbf{b},\ \mathbf{a},\ \mathbf{b},\ \mathbf{a},\ \mathbf{b},\ \mathbf{b},\ \mathbf{b},\ \mathbf{a},$$
$$\mathbf{b},\ \mathbf{b},\ \mathbf{a},\ \mathbf{b},\ \mathbf{a},\ \mathbf{b},\ \mathbf{a},\ \mathbf{a},\ \mathbf{b},\ \mathbf{b},\ \mathbf{a},\ \mathbf{a},\ \mathbf{b},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{b},\ \mathbf{a},\ \mathbf{b},\ 0,\ 0,\ 0,\ 0,\ \mathbf{a},\ \mathbf{a},\ \mathbf{b},\ \mathbf{b},\ \mathbf{b},\ \mathbf{b},\ \mathbf{b},\ \mathbf{b},\ \mathbf{a},\ \mathbf{a},\quad (25\text{-}40)$$
$$\mathbf{b},\ \mathbf{b},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{b},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{b},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{b},\ \mathbf{a},\ \mathbf{b},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{a},\ \mathbf{b},\ \mathbf{b},\ -1,\ 0\}$$

where **a** = [1, 0, 0, 0] and **b** = [–1, 0, 0, 0].

The time domain representation of the signal of transmit chain i_{TXT} shall be as specified in Equation (25-41).

$$r^{i_{TX}}_{OSTF}(t) = \frac{w_{T_{OCEF}}(t)}{\sqrt{N_{Tone}N_{STS}}} \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} [Q_k]_{i_{TX},\,m}\, \Upsilon_{k,\,CBW} OSTF_k \exp(j2\pi\Delta_F(t - T_{CS}(m))) \quad (25\text{-}41)$$

where

N_{Tone} is, for 540 MHz transmission, 176, and, for 1080 MHz transmission, 352
T_{CS} is given in Table 25-27
Q_k is defined in 25.6.8.13
$\Upsilon_{k,\,CBW}$ is defined in 25.3.4.4

25.6.7 OCEF definition

The OCEF provides a means for the receiver to estimate the MIMO channel between the set of constellation mapper outputs (or, if STBC is applied, the STBC encoder outputs) and the receive chains. The transmitter provides training for N_{STS} space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is a $N_{RX} \times N_{STS}$ matrix. A frame transmission has a preamble that contains OCEF symbols, where the data tones of each OCEF symbol are multiplied by entries belonging to a matrix $\mathbf{P}_{OCEF}$, to enable channel estimation at the receiver. The pilot tones of each OCEF symbol are multiplied by the entries of a matrix $\mathbf{R}_{OCEF}$ defined in the following text. The multiplication of the pilot tones in the OCEF symbol by the $\mathbf{R}_{OCEF}$ matrix instead of the $\mathbf{P}_{OCEF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the OCEF. The number of OCEF symbols, N_{OCEF}, is a function of the number of space-time streams N_{STS} as shown in Table 25-17. As a result the OCEF consists of one, two, or four symbols.

Table 25-17—Number of OCEFs required for different numbers of space-time streams

N_{STS}	N_{OCEF}
1	1
2	2
3	4
4	4

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In a 540 MHz transmission, let $OCEF_{left}$ and $OCEF_{right}$ be the sequences defined in Equation (25-42) and Equation (25-43), respectively.

$$\begin{aligned} OCEF_{left} = \{&1,-1,-1,1,1,-1,-1,1,1,-1,1,1,1,1,1,1,1,-1,-1,1,-1,1,1,1,\\ &-1,1,1,-1,1,-1,-1,1,1,-1,-1,1,-1,1,1,1,1,1,1,1,-1,-1,1,1,1,\\ &-1,1,1,-1,1,-1,1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,-1,-1,-1,-1,\\ &-1,1,-1,-1,-1,1,1,1,1,-1,-1,1,1,-1,1,1\} \end{aligned} \tag{25-42}$$

$$\begin{aligned} OCEF_{right} = \{&-1,1,-1,1,1,-1,1,-1,-1,-1,1,1,1,1,1,-1,-1,-1,1,1,1,1,-1,-1,\\ &-1,-1,-1,-1,-1,1,-1,1,-1,1,1,1,-1,-1,-1,-1,1,1,-1,-1,-1,1,\\ &1,-1,1,1,-1,1,1,1,1,-1,1,-1,-1,-1,1,-1,1,-1,1,-1,1,-1,1,1,\\ &1,1,-1,1,-1,1,-1,-1,1,1,1,-1,1,1,-1,-1,-1,1\} \end{aligned} \tag{25-43}$$

In a 540 MHz transmission, the OCEF sequence transmitted is given by Equation (25-44).

$$OCEF_{-89,89} = \{OCEF_{left}, 0, 0, 0, OCEF_{right}\} \tag{25-44}$$

In a 1080 MHz transmission, let $OCEF_{left}$ and $OCEF_{right}$ be the sequences defined in Equation (25-45) and Equation (25-46), respectively.

$$\begin{aligned} OCEF_{left} = \{&1,-1,1,-1,-1,-1,-1,-1,1,1,-1,-1,1,1,1,1,1,-1,-1,-1,-1,1,\\ &-1,1,-1,1,1,1,1,-1,1,1,-1,-1,1,1,1,-1,1,1,-1,1,-1,-1,-1,\\ &1,-1,1,1,-1,1,1,1,-1,-1,1,-1,-1,-1,-1,1,1,1,-1,-1,-1,-1,\\ &-1,1,-1,1,1,1,-1,-1,-1,-1,1,1,1,-1,1,1,-1,1,-1,1,-1,1,1,\\ &1,1,1,-1,-1,-1,1,-1,1,1,-1,1,1,-1,1,1,1,1,-1,1,\\ &1,-1,1,-1,1,1,1,1,1,1,-1,-1,1,-1,1,-1,-1,1,-1,1,1,-1,\\ &-1,1,-1,1,1,1,1,-1,1,1,1,-1,1,1,1,-1,1,-1,-1,-1,1,-1,1,1,1,\\ &-1,-1,-1,-1,-1,-1,1\} \end{aligned} \tag{25-45}$$

$$\begin{aligned} OCEF_{right} = \{&-1,1,-1,-1,1,1,1,-1,1,-1,1,1,1,1,-1,-1,1,1,-1,1,1,-1,-1,-1,\\ &1,1,1,-1,-1,1,-1,-1,1,-1,1,-1,1,-1,1,-1,1,1,1,-1,1,-1,-1,-1,\\ &-1,1,1,-1,1,1,1,-1,1,1,1,1,-1,-1,-1,-1,1,1,1,1,1,-1,1,\\ &-1,1,1,-1,1,-1,-1,1,-1,-1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,1,\\ &1,-1,-1,-1,1,-1,-1,-1,1,-1,1,1,1,1,-1,-1,-1,1,1,-1,1,-1,1,\\ &-1,1,1,-1,1,1,1,-1,1,-1,-1,-1,-1,-1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,\\ &1,1,1,-1,-1,-1,1,-1,-1,-1,1,-1,1,-1,1,1,1,1,1,1,-1,1,-1,\\ &1,-1,1,1,1,-1,1,-1,1,-1,1,1\} \end{aligned} \tag{25-46}$$

In a 1080 MHz transmission, the OCEF sequence transmitted is given by Equation (25-47).

$$OCEF_{-177,177} = \{OCEF_{left}, 0, 0, 0, OCEF_{right}\} \tag{25-47}$$

The generation of the time domain OCEF symbols per frequency segment is shown in Figure 25-25 where A_{OCEF} is given in Equation (25-48).

$$A^{k}_{OCEF} = \begin{cases} R_{OCEF}, k \in K_{Pilot} \\ P_{OCEF}, otherwise \end{cases} \tag{25-48}$$

where K_{Pilot} is the set of subcarrier indices for the pilot tones.

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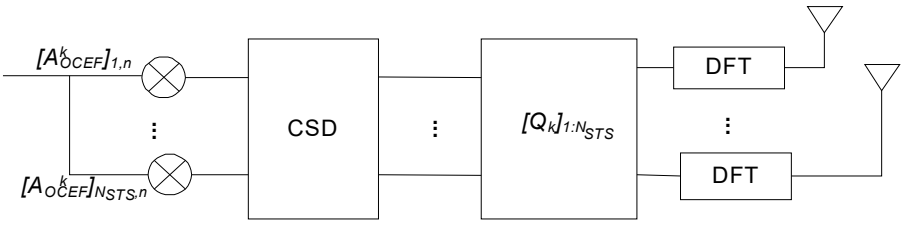

Figure 25-25—Generation of OCEF symbols per frequency segment

For a 540 MHz transmission, $K_{Pilot} = \{\pm 11, \pm 33, \pm 55, \pm 77\}$.

For a 1080 MHz transmission, $K_{Pilot} = \{\pm 11, \pm 33, \pm 55, \pm 77, \pm 99, \pm 121, \pm 143, \pm 165\}$.

$\mathbf{R}_{OCEF}$ is a $N_{OCEF} \times N_{OCEF}$ matrix whose elements are defined in Equation (25-49).

$$[R_{OCEF}]_{m,n} = [P_{OCEF}]_{1,n},\ 1 \le m, n \le N_{OCEF} \tag{25-49}$$

$$P_{OCEF} = \begin{bmatrix} 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \\ -1 & 1 & 1 & 1 \end{bmatrix} \tag{25-50}$$

The time domain representation of the waveform transmitted on transmit chain i_{TX} shall be as described by Equation (25-51).

$$r^{i_{TX}}_{OCEF}(t) = \sum_{n=0}^{N_{OCEF}-1} \frac{w_{T_{OCEF}}(t - nT_{OCEF})}{\sqrt{N_{Tone}N_{STS}}} \left(\sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} [Q_k]_{i_{TX},m} [A^k_{OCEF}] \Upsilon_{k,CBW} OCEF_k \exp(j2\pi\Delta_F(t - nT_{OCEF} - T_{GI} - T_{CM}(m))) \right) \tag{25-51}$$

where

N_{Tone} is, for 540 MHz transmission, 176, and, for 1080 MHz transmission, 352
T_{CS} is given in Table 25-27
Q_k is defined in 25.6.8.13
$\Upsilon_{k,CBW}$ is defined in 25.3.4.4
T_{OCEF} is the duration of each OCEF symbol
A_{OCEF} is defined in Equation (25-49)

25.6.8 Data fields

25.6.8.1 General

The LDPC encoding process is composed of several steps including determining the number of padding bits, padding with zeros, and the coding of every word.

25.6.8.2 Scrambler

The operation of the scrambler is defined in 25.3.7. The scrambling of the Data field continues the scrambling of the CMMG OFDM mode SIG with no reset for OFDM transmission.

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25.6.8.3 Encoding

See 25.3.12.

25.6.8.4 OFDM symbol padding zeros

The number of symbol blocks, N_{SYM}, is calculated as

$$N_{SYM} = \left\lceil \frac{Length \times 8 + (8 + L_{CHECK}) \times N_{CW}}{R \cdot lcm\{m_{STBC} N_{CBPS}, L_{CW}\}} \right\rceil \cdot \frac{lcm\{m_{STBC} N_{CBPS}, L_{CW}\}}{N_{CBPS}} \quad (25\text{-}52)$$

where

L_{CHECK} is the number of LDPC parity bits
$lcm\{a,b\}$ denotes the least common multiple of a and b
L_{CW} denotes the LDPC code word length
$Length$ is the length of the PSDU defined in the CMMG SIG field
R is the code rate
N_{CBPS} is the number of code bits per symbol as defined in the MCS table
$m_{STBC} = 2$ if STBC is used; else $m_{STBC} = 1$

$$N_{SPAD} = R \times N_{SYM} \times N_{CBPS} - (Length \times 8 + (8 + L_{CHECK}) \times N_{CW}) \quad (25\text{-}53)$$

The PSDU is concatenated with N_{SPAD} zeros. They are scrambled using the continuation of the scrambler sequence that scrambled the PSDU.

25.6.8.5 Stream parser

After coding and puncturing, the data bit streams at the output of the FEC encoder are processed in groups of N_{CBPS}. Each of these groups is rearranged into N_{ss} blocks of N_{CBPSS} bits.

The number of bits assigned to a single axis (real or imaginary) of a constellation point in a spatial stream is denoted by Equation (25-54).

$$s = \max\left\{1, \frac{N_{BPSCS}}{2}\right\} \quad (25\text{-}54)$$

Consecutive blocks of s bits are assigned to different spatial streams in a round robin fashion.

Bit i at the output of encoder is assigned to input bit k of spatial stream where

$$i = (i_{SS} - 1) \cdot s + N_{ss} \cdot s \cdot \left\lfloor \frac{k}{s} \right\rfloor + k \mod s \quad (25\text{-}55)$$

where $i_{SS} = 1, 2, \ldots, N_{SS}$, $i = 0, 1, \ldots, N_{CBPS} - 1$, $k = 0, 1, \ldots, N_{CBPSS} - 1$.

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25.6.8.6 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 25-26, with the input bit, B_0 being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (25-56).

$$d = (I + jQ) \times K_{MOD} \tag{25-56}$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 25-18. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 25-20 and Figure 25-26. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor may be used, as long as the device conforms with the modulation accuracy requirements described in 25.6.9.1.2.

Table 25-18—Modulation-dependent normalization factor

Modulation	K_{MOD}
BPSK	1
QPSK	$1/\sqrt{2}$
16-QAM	$1/\sqrt{10}$
64-QAM	$1/\sqrt{42}$

For BPSK, B_0 determines the I value, as illustrated in Table 25-19. For QPSK, B_0 determines the I value, and B_1 determines the Q value, as illustrated in Table 25-20. For 16-QAM, B_0 and B_1 determine the I value, and B_2 and B_3 determine the Q value, as illustrated in Table 25-21. For 64-QAM, B_0, B_1, and B_2 determine the I value, and B_3, B_4, and B_5 determine the Q value, as illustrated in Table 25-22.

Table 25-19—BPSK encoding table

Input bit (B_0)	I-out	Q-out
0	–1	0
1	1	0

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Table 25-20—QPSK encoding table

Input bit (B_0)	I-out	Input bit (B_1)	Q-out
0	–1	0	–1
1	1	1	1

Table 25-21—16-QAM encoding table

Input bits (B_0B_1)	I-out	Input bits (B_2B_3)	Q-out
00	–3	00	–3
01	–1	01	–1
11	1	11	1
10	3	10	3

Table 25-22—64-QAM encoding table

Input bits ($B_0B_1B_2$)	I-out	Input bits ($B_3B_4B_5$)	Q-out
000	–7	000	–7
001	–5	001	–5
011	–3	011	–3
010	–1	010	–1
110	1	110	1
111	3	111	3
101	5	101	5
100	7	100	7

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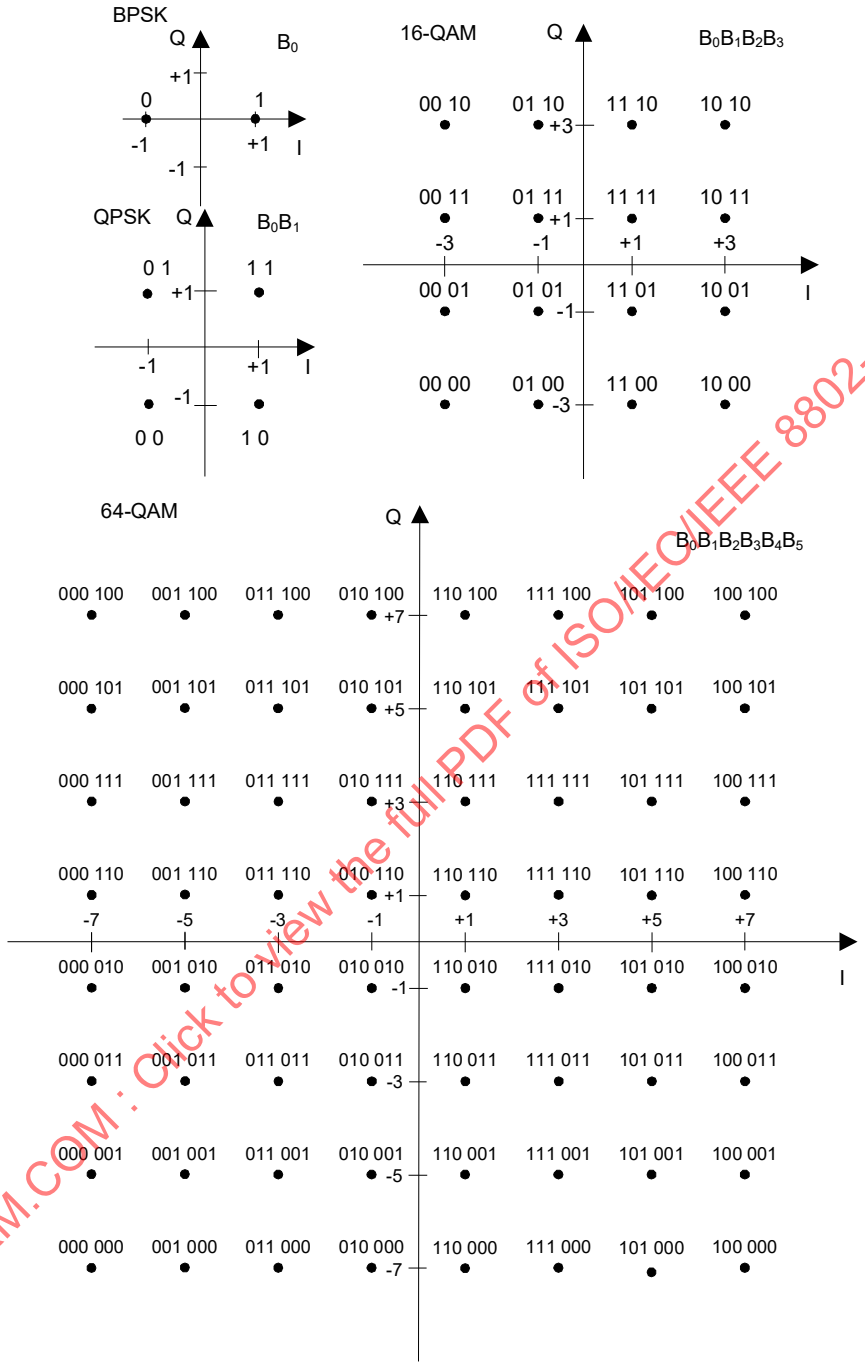

Figure 25-26—BPSK, QPSK, 16-QAM, and 64-QAM constellation bit encoding

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25.6.8.7 Tone mapping

The LDPC tone mapping shall be performed on all LDPC encoded streams using an LDPC tone-mapping distance parameter, D_{TM}. D_{TM} is constant for each bandwidth, and its value for different bandwidths is given in Table 25-23.

Table 25-23—Value of tone mapping parameter

Parameter	CBW540 MHz	CBW1080 MHz
D_{TM}	6	12

LDPC tone mapping for LDPC-coded streams is done by permuting the stream of complex numbers generated by the constellation mappers to obtain

$$d''_{t(k),i,n} = d'_{k,i,n} \tag{25-57}$$

where

$i = 1, 2, \ldots, N_{SS}$

$$t(k) = D_{TM}\left(k \bmod \frac{N_{SD}}{D_{TM}}\right) + \left\lfloor \frac{kD_{TM}}{N_{SD}} \right\rfloor \tag{25-58}$$

The two consecutively generated complex constellation numbers are transmitted on two data tones that are separated by at least $D_{TM} - 1$ from other data tones.

25.6.8.8 Space-time block coding

This subclause defines a set of optional robust transmission techniques that are applicable only when using STBC coding for OFDM mode PPDUs. In this case, N_{SS} spatial streams are mapped to N_{STS} space-time streams. These techniques are based on STBC. When the STBC field in the CMMG SIG is 1, a symbol operation shall occur between the constellation mapper and the spatial mapper as defined in this subclause.

If STBC is applied, the stream of complex numbers $d_{k,i,n}$, $k = 0, 1, \ldots, N_{SD}-1$, $i = 1, 2, \ldots, N_{SS}$, $n = 0, 1, \ldots, N_{SYM}-1$, is the input to the STBC encoder, which produces as output the stream of complex numbers $\tilde{d}_{k,i_{STS},n}$, $k = 0, 1, \ldots, N_{SD}-1$, $i_{STS} = 1, 2, \ldots, N_{STS}$, $n = 0, 1, \ldots, N_{SYM}-1$. For given values of k and i, STBC processing operates on the complex modulation symbols in sequential pairs of OFDM symbols so that the values of $\tilde{d}_{k,2i-1,2m}$ and $\tilde{d}_{k,2i,2m}$ depend on $\tilde{d}_{k,2i,2m}$ and $d_{k,i,2m+1}$. Also, $\tilde{d}_{k,2i-1,2m+1}$ and $\tilde{d}_{k,2i,2m+1}$ depend on $d_{k,i,2m}$ and $d_{k,i,2m+1}$. This is defined in Table 25-24.

If STBC is not applied, $d_{k,i,n} = \tilde{d}_{k,i,n}$ and $N_{STS} = N_{SS}$.

NOTE—When STBC is applied, an odd number of space-time streams is not allowed, and $N_{STS} = 2N_{SS}$.

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Table 25-24—Constellation mapper output to spatial mapper input for STBC

N_{STS}	N_{SS}	i_{STS}	$\tilde{d}_{k,i_{STS},2m}$	$\tilde{d}_{k,i_{STS},2m+1}$
2	1	1	$d_{k,1,2m}$	$d_{k,1,2m+1}$
		2	$-d^*_{k,1,2m+1}$	$d^*_{k,1,2m}$
4	2	1	$d_{k,1,2m}$	$d_{k,1,2m+1}$
		2	$-d^*_{k,1,2m+1}$	$d^*_{k,1,2m}$
		3	$d_{k,2,2m}$	$d_{k,2,2m+1}$
		4	$-d^*_{k,2,2m+1}$	$d^*_{k,2,2m}$

25.6.8.9 Pilot subcarriers

For a 540 MHz transmission, eight pilot tones shall be inserted in subcarriers {± 77, ± 55, ± 33, ± 11}. The pilot mapping P_n^k for subcarrier k for symbol n shall be as specified in Equation (25-59).

$$\begin{aligned} P_n^k \in \{-77,-55,-33,-11,11,33,55,77\} &= \{\Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \ldots, \Psi_{(n+7) \bmod 8}\} \\ P_n^k \notin \{-77,-55,-33,-11,11,33,55,77\} &= 0 \end{aligned} \quad (25\text{-}59)$$

where Ψ_m is defined in Table 25-25.

Table 25-25—Pilot values for CBW540 MHz transmission

Ψ_0	Ψ_1	Ψ_2	Ψ_3	Ψ_4	Ψ_5	Ψ_6	Ψ_7
1	1	1	–1	–1	1	1	1

For a 1080 MHz transmission, 16 pilot tones shall be inserted in subcarriers –165, –143, –121, –99, –77, –55, –33, –11, 11, 33, 55, 77, 99, 121, 143, 165. The pilot mapping P_n^k for subcarrier k for symbol n shall be as specified in Equation (25-60).

$$\begin{aligned} P_n^k \in \{-165,-143,-121,-99,-77,-55,-33,-11,11,33,55,77,99,121,143,165\} &= \{\Psi_{n \bmod 16}, \Psi_{(n+1) \bmod 16}, \ldots, \Psi_{(n+15) \bmod 16}\} \\ P_n^k \notin \{-165,-143,-121,-99,-77,-55,-33,-11,11,33,55,77,99,121,143,165\} &= 0 \end{aligned} \quad (25\text{-}60)$$

where Ψ_m is defined in Table 25-26.

Table 25-26—Pilot values for CBW1080 MHz transmission

Ψ_0	Ψ_1	Ψ_2	Ψ_3	Ψ_4	Ψ_5	Ψ_6	Ψ_7	Ψ_8	Ψ_9	Ψ_{10}	Ψ_{11}	Ψ_{12}	Ψ_{13}	Ψ_{14}	Ψ_{15}
–1	1	–1	1	1	–1	–1	–1	–1	–1	1	1	1	–1	1	1

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25.6.8.10 Cyclic shift diversity (CSD) for OFDM mode data fields transmission

The cyclic shift values defined in this subclause apply to the data fields of the PPDU. Cyclic shifts are applied eliminate unintended beamforming when correlated signals are transmitted in multiple space-time streams $T_{CS}(n)$. The cyclic shift value for the data fields for space-time stream n out of N_{STS} total space-time streams is shown in Table 25-27.

Table 25-27—Cyclic shift values for the data fields of an OFDM mode PPDU

$T_{CS}(n)$ values for the data field of a PPDU				
N_{STS}	Cyclic shift for space-time stream n (ns)			
	1	2	3	4
1	0	—	—	—
2	0	$-128T_S$	—	—
3	0	$-170T_S$	$-85T_S$	—
4	0	$-128T_S$	$-64T_S$	$-192T_S$

25.6.8.11 OFDM modulation

The time domain waveform of the Data field of a CMMG OFDM mode PPDU from transmit chain, shall be as defined in Equation (25-61).

$$r_{Data}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{Tone}N_{STS,total}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM}) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STT}} [Q_K]_{i_{TX,m}} \Upsilon_{k,CBW} (\tilde{D}_{k,m,n,CBW} + p_n P_n^k) \exp(j2\pi k\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}m)) \quad (25\text{-}61)$$

where

p_n is defined in 17.3.5.10

N_{Tone} is, for 540 MHz transmission, 176 and, for 1080 MHz transmission, 352

$\tilde{D}_{k,m,n,CBW}$ is the transmitted constellation on subcarrier k, space-time stream m, and Data field OFDM symbol n and is defined in Equation (25-62) to Equation (25-64)

T_{GI} is the (short) guard interval duration and is given in Table 25-3

$T_{CS}(n)$ is given in 25.6.8.10

P_n^k is defined in 25.6.8.9

$\Upsilon_{k,CBW}$ is defined in 25.3.4.4

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For a 540 MHz transmission,

$$\tilde{D}_{k,m,n,540} = \begin{cases} 0, k = 0, \pm1, \pm11, \pm33, \pm55, \pm77 \\ \tilde{d}_{M^r_{540}(k),m,n}, otherwise \end{cases} \quad (25\text{-}62)$$

and $M^r_{540}(k)$ is defined as

$$M^r_{540}(k) = \begin{cases} k+89, -89 \le k \le -78 \\ k+88, -76 \le k \le -56 \\ k+87, -54 \le k \le -34 \\ k+86, -32 \le k \le -12 \\ k+85, -10 \le k \le -2 \\ k+82, 2 \le k \le 10 \\ k+81, 12 \le k \le 32 \\ k+80, 34 \le k \le 54 \\ k+79, 56 \le k \le 76 \\ k+78, 78 \le k \le 89 \end{cases} \quad (25\text{-}63)$$

For a 1080 MHz transmission,

$$\tilde{D}_{k,m,n,1080} = \begin{cases} 0, k = 0, \pm1, \pm11, \pm33, \pm55, \pm77, \pm99, \pm121, \pm143, \pm165 \\ \tilde{d}_{M^r_{1080}(k),m,n}, otherwise \end{cases} \quad (25\text{-}64)$$

and $M^r_{1080}(k)$ is defined as

$$M^r_{1080}(k) = \begin{cases} k+177, -177 \le k \le -166 \\ k+176, -164 \le k \le -144 \\ k+174, -142 \le k \le -122 \\ k+173, -120 \le k \le -100 \\ k+172, -98 \le k \le -78 \\ k+171, -76 \le k \le -56 \\ k+170, -54 \le k \le -34 \\ k+169, -32 \le k \le -12 \\ k+168, -10 \le k \le -2 \\ k+165, 2 \le k \le 10 \\ k+164, 12 \le k \le 32 \\ k+163, 34 \le k \le 54 \\ k+162, 56 \le k \le 76 \\ k+161, 78 \le k \le 98 \\ k+160, 100 \le k \le 120 \\ k+159, 122 \le k \le 142 \\ k+158, 144 \le k \le 164 \\ k+157, 166 \le k \le 177 \end{cases} \quad (25\text{-}65)$$

$\mathbf{Q}_k$ is a spatial mapping/steering matrix with N_{TX} rows and columns N_{STS} for subcarrier k. $\mathbf{Q}_k$ may be frequency dependent. Refer to the examples of listed in 19.3.11.11.2 for examples of that could be used for OFDM mode PPDU. Note that implementations are not restricted to the spatial mapping matrix examples listed in 19.3.11.11.2.

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25.6.8.12 Duplication transmission

When the TXVECTOR parameter DUPLICATE_MODULATION is present, the transmitted PPDU is a duplicate. For 1080 MHz, the Data field shall be as defined by Equation (25-66).

$$r_{Data}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{Tone}N_{STS,total}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM}) \sum_{k=-89}^{89} \sum_{m=1}^{N_{STS}} (\tilde{D}_{k,m,n} + p_n P_n^k)([Q_{k-88}]_{i_{TX},m} \Upsilon_{k,CBW} \exp(j2\pi(k-88)\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}(m))) + j[Q_{k-88}]_{i_{TX},m} \Upsilon_{k,CBW} \exp(j2\pi(k+88)\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}(m))))) \quad (25\text{-}66)$$

where

p_n is defined in 17.3.5.10

N_{Tone} is 352

$\tilde{D}_{k,m,n}$ is the transmitted constellation on subcarrier k, space-time stream m, and Data field OFDM symbol n and is defined in Equation (25-62) to Equation (25-64)

T_{GI} is the (short) guard interval duration and is given in Table 25-3

$T_{CS}(n)$ is given in 25.6.8.10

P_n^k is defined in 25.6.8.9

$\Upsilon_{k,CBW}$ is defined in 25.3.4.4

25.6.8.13 Beamforming

25.6.8.13.1 General

CMMG OFDM MIMO beamforming is used by a STA with multiple antennas (the beamformer) to steer signals using knowledge of the channel to improve throughput. With CMMG OFDM MIMO beamforming, all space-time streams in the transmitted signal are intended for reception at a single STA.

For CMMG OFDM MIMO beamforming, the steering matrix $\mathbf{Q}_k$ can be determined from the effective channel $\mathbf{H}_{eff,k}$, or the beamforming feedback matrix, $\mathbf{V}_k$, that is sent back to the beamformer by the beamformee using compressed beamforming feedback matrix format as defined in 25.6.8.13.2. The feedback report format is described in 9.6.29.2.

25.6.8.13.2 Compressed Beamforming feedback matrix

Upon receipt of a NDP sounding PPDU, the beamformee shall remove the space-time stream CSD in Table 25-27 from the measured channel before computing a set of matrices for feedback to the beamformer. The beamforming feedback matrix $\mathbf{V}_k$, found by the beamformee for subcarrier k shall be compressed in the form of angles using the method described in 19.3.12.3.6. The angles, $\phi(k)$ and $\psi(k)$, are quantized according to Table 9-87.

The beamformee shall generate the beamforming feedback matrices with the number of rows (N_r) equal to the N_{STS} of the NDP.

After receiving the angle information, $\phi(k)$ and $\psi(k)$, the beamformer reconstructs $\mathbf{V}_k$ using Equation (19-79). For CMMG OFDM MIMO beamforming, the beamformer can use this $\mathbf{V}_k$ matrix to determine the steering matrix $\mathbf{Q}_k$. The method used by the beamformer to calculate the steering matrix $\mathbf{Q}_k$ is implementation specific.

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The beamformee decides the tone grouping value to be used in the beamforming feedback matrix **V**. A beamformer shall support all tone grouping values and codebook information values.

25.6.8.14 CMMG preamble format for sounding PPDU

25.6.8.14.1 General

The MIMO channel measurement takes place in every PPDU as a result of transmitting the OCEFs as part of the PHY preamble. The number of OCEFs transmitted shall be determined by the number of space-time streams transmitted. The use of the same spatial transformation enables the computation of the spatial equalization at the receiver.

When the number of space-time streams, N_{STS}, is less than the number of transmit antennas, or less than min(N_{TX}, N_{RX}), sending only N_{STS} OCEFs does not allow the receiver to recover a full characterization of the MIMO channel, even though the resulting MIMO channel measurement is sufficient for receiving the Data field of the CMMG PPDU.

However, there are several cases where it is desirable to obtain as full a characterization of the channel as possible, thus requiring the transmission of a sufficient number of OCEFs to sound the full dimensionality of the channel, which is in some cases N_{STS} and in other cases min(N_{TX}, N_{RX}). These cases of MIMO channel measurement are referred to as MIMO channel sounding. A sounding PPDU may be used to sound available channel dimensions. A sounding PPDU is identified by setting the Not Sounding field in the CMMG SIG to 0. A sounding PPDU may have any allowed number of OCEFs satisfying $N_{OCEFs} \geq N_{STS}$ as shown in Table 25-17.

25.6.8.14.2 Sounding with an NDP

A STA may sound the channel using a NDP (indicated by zero in the Length field in the CMMGSIG field) with the Not Sounding field set to 0. The number of OCEFs is the number implied by the 2^{STBC} N_{ss}, which shall indicate spatial time streams. The last OCEF of an NDP shall not be followed by a Data field as shown in Figure 25-27.

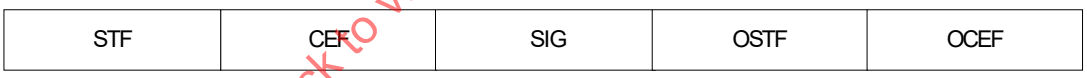

Figure 25-27—CMMG NDP format

It is optional for a STA to process an NDP.

25.6.8.14.3 Sounding PPDU for channel quality assessment

In response to an MRQ, sent by STA A to STA B, the responding STA B returns to the requesting STA A an MCS selection that STA B determines to be a suitable MCS for STA A to use in subsequent transmissions to STA B. In determining the MCS, STA B performs a channel quality assessment, which entails using whatever information STA B has about the channel, such as an estimate of the MIMO channel derived from the sounding PPDU that carries the MRQ. To enable this calculation, the MRQ is sent in conjunction with a sounding PPDU.

The STA sending the MRQ (STA A) determines how many OCEFs to send and whether to use an NDP or not, based on the Transmit Beamforming Capabilities field, number of space-time streams used in the PPDU carrying the MRQ, the number of transmit chains it is using (N_{TX}), whether the transmit and receive STAs support STBC, and in some cases, the number of receive chains at the responding STA (N_{RX}).

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The maximum number of available space-time streams is set by the number of transmit and receive chains and the STBC capabilities of the transmitter and receiver, as is shown in Table 25-28. While the number of receive chains at a STA is not communicated in a capabilities indicator, the maximum number of space-time streams supported may be inferred from the STBC capabilities of the receiving STA. When the number of receive chains is known at the transmitter, the number of OCEFs sent to obtain a full channel quality assessment is determined according to the maximum number of space-time streams indicated in Table 25-28. The number of OCEFs to use in conjunction with the indicated number of space-time streams is determined according to Table 25-17.

Table 25-28—Maximum available space-time streams

N_{TX}	N_{RX}	$N_{STS,max}$ **without STBC**	$N_{STS,max}$ **with STBC**
1	1	1	N/A
2	1	1	2
4	1	1	2
4	2	2	4

The sounding PPDU may have nonidentity spatial mapping matrix $\mathbf{Q}_k$. For different receiving STAs, $\mathbf{Q}_k$ may vary.

25.6.9 Performance requirements

25.6.9.1 Transmit requirements

25.6.9.1.1 Introduction

This subclause describes the performance requirement from the OFDM mode transmitter.

25.6.9.1.2 Transmit EVM

The transmit EVM accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, DC offsets, phase noise, etc.

The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or an equivalent procedure:

a) Start of frame shall be detected.
b) Transition from short sequences to channel estimation sequences shall be detected, and fine timing (with one sample resolution) shall be established.
c) Frequency offsets shall be estimated and corrected.
d) The frame shall be de-rotated according to estimated frequency offset.
e) The complex channel response coefficients shall be estimated for each of the subcarriers using information contained in the preamble (STF/CEF and/or OCEF).
f) For each of the OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, derotate the subcarrier values according to estimated phase, and divide each subcarrier value with a complex estimated channel response coefficient.

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g) For each data-carrying subcarrier, compute the Euclidean distance to the ideal location for the symbol, or pilot.

h) Compute the RMS average of all errors in a packet. It is given by

$$EVM = 20\log_{10}\left(\frac{1}{N_f}\sum_{i=1}^{N_f}\sqrt{\frac{\sum_{j=1}^{N_{SYM}}\left\{\sum_{k\in K}\left[(I(i,j,k)-I^*(i,j,k))^2+(Q(i,j,k)-Q^*(i,j,k))^2\right]\right\}}{(N_{ST}-N_{DC})N_{SYM}P_0}}\right) \quad (25\text{-}67)$$

where

N_f is the number of frames
i is the frame index
k is the carrier index
K is the set of pilot and data subcarriers $\{1,2,\ldots,(N_{SR}-1),(N_{SR}+N_{DC}),(N_{SR}+N_{DC}+1),\ldots,N_{ST}\}$
j is the symbol index
N_{SYM} is the number of symbols
N_{ST} is the total number of subcarriers
I^*,Q^* is the ideal constellation point for I and Q, respectively
P_0 is the average power of the constellation (I^*,Q^*) computed over the i^{th} frame

The measurements shall occur on the OFDM symbols and shall not occur on the other kinds of symbols. The measurement shall be performed on at least 10 frames with 16 symbols at least in each of them. Random data shall be used.

The EVM RMS error shall not exceed an MCS dependent value as found in Table 25-29.

Table 25-29—EVM requirements for OFDM

MCS index	Modulation	Coding rate	EVM value (dB)
9	BPSK	1/2	–7
10	QPSK	1/2	–11
11	QPSK	3/4	–13
12	16-QAM	1/2	–15
13	16-QAM	3/4	–19
14	64-QAM	5/8	–22
15	64-QAM	3/4	–24
16	64-QAM	13/16	–26

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25.6.9.2 TX flatness

25.6.9.2.1 TX flatness for 540 MHz channel

When using the OFDM mode and only while transmitting OFDM symbols, the average energy of the OFDM symbols constellations in each of the subcarriers with indices –70 to –2 and +2 to +70 shall deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the subcarriers with indices –71 to –89 and +70 to +89 shall deviate no more than +2/–4 dB from the average energy of subcarriers with indices –71 to –89 and +70 to +89.

25.6.9.2.2 TX flatness for 1080 MHz channel

When using the OFDM mode and only while transmitting OFDM symbols, the average energy of the OFDM symbols constellations in each of the subcarriers with indices –146 to –2 and +2 to +145 shall deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the subcarriers with indices –147 to –177 and +147 to +177 shall deviate no more than +2/–4 dB from the average energy of subcarriers with indices –177 to –2 and +2 to +177.

25.6.9.2.3 Time of Departure accuracy

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is 660×10^6 sample/s for 540 MHz and 1320×10^6 sample/s for 1080 MHz.
— FIRST_TRANSITION_FIELD is Short Training field.
— SECOND_TRANSITION_FIELD is Channel Estimation field.
— TRAINING_FIELD is Channel Estimation field.
— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns.

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

25.6.9.3 Receive requirements

25.6.9.3.1 Introduction

Subclause 25.6.9.3.2 describes the performance requirement for an OFDM mode receiver.

25.6.9.3.2 CCA

The start of a CMMG OFDM mode or CMMG SC mode transmission at a receive level greater than the minimum sensitivity for MCS 0 (–81 dBm for 540 MHz, –78 dBm for 1080 MHz) shall cause CCA to indicate busy with a probability > 90% within 1 μs.

25.7 Analog beamforming PHY frame format

25.7.1 TX sector sweep

The packets sent during TX sector sweep are control mode packets as defined in 25.4.

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25.7.2 Beam refinement

25.7.2.1 General

Beam refinement is a process where a STA can improve its antenna configuration (or antenna weight vectors) both for transmission and reception. If the SLS beamforming training did not include an RSS, as in the case where both devices have more than one transmit sector per antenna, beam refinement can serve as the first receive antenna configuration training. The procedure of beam refinement is described in 10.42.6.4. In the beam refinement procedure, BRP PPDUs are used to train the receiver and transmitter antenna. There are two types of BRP PPDUs: BRP-RX PPDUs and BRP-TX PPDUs.

— BRP-RX PPDUs are PPDUs that have TRN-R training sequences following the Data field. These packets enable receiver antenna weight vector training.

— BRP-TX PPDUs are PPDUs that have TRN-T training sequences following the Data field. The transmitting STA may change antenna configuration at the beginning of each sequence. The receiving STA performs measurements on these sequences and sends feedback to the STA that transmits the BRP-TX PPDU.

25.7.2.2 BRP PPDU structure

Each BRP PPDU is composed of an STF, a CEF, and a data field followed by a training field containing an AGC field and a receiver training field.

Figure 25-28—BRP PPDU structure

25.7.2.3 BRP PPDU SIG fields

The PPDU Type field in a BRP PPDU is defined in Table 25-7.

A value of N in the Training Length field indicates that the AGC has $4N$ subfields and that the TRN- R/T field has N subfields.

The value N in the Training Length field of a BRP-RX PPDU is equal to the value of the L-RX field requested by the intended receiver of the BRP-RX PPDU at a previously received BRP Request field (see 9.5.4).

25.7.2.4 Beam refinement AGC field

The beam refinement AGC fields are composed of $4N$ repetitions of the sequence $[Z^1_{64}\ Z^1_{64}\ Z^1_{64}\ Z^1_{64}\ Z^1_{64}]$ when the packet is transmitted using the control mode in bandwidth 540 MHz, $[Z^2_{64}\ Z^2_{64}\ Z^2_{64}\ Z^2_{64}\ Z^2_{64}]$ when the packet is transmitted using the SC mode in bandwidth 540 MHz, $[Z^3_{64}\ Z^3_{64}\ Z^3_{64}\ Z^3_{64}\ Z^3_{64}]$ when the packet is transmitted using the OFDM mode in bandwidth 540 MHz, $[Z^1_{128}\ Z^1_{128}\ Z^1_{128}\ Z^1_{128}\ Z^1_{128}]$ when the packet is transmitted using the control mode in bandwidth 1080 MHz, $[Z^2_{128}\ Z^2_{128}\ Z^2_{128}\ Z^2_{128}\ Z^2_{128}]$ when the packet is transmitted using the SC mode in bandwidth 1080 MHz, and $[Z^3_{128}\ Z^3_{128}\ Z^3_{128}\ Z^3_{128}\ Z^3_{128}]$ when the packet is transmitted using the OFDM mode in bandwidth 1080 MHz. The sequences Z^1_{64}, Z^2_{64}, Z^3_{64}, Z^1_{128}, Z^2_{128}, and Z^3_{128} are defined in 25.8. The sequences are transmitted using rotated π/2-QPSK modulation.

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In a BRP-TX PPDU, the transmitter may change the TX AWV configuration at the beginning of each AGC subfield. Any transmit signal transients that occur due to this TX AWV configuration change shall completely settle by the end of the first Z_{64}^{1}, Z_{64}^{2}, or Z_{64}^{3} subsequence in bandwidth 540 MHz and Z_{128}^{1}, Z_{128}^{2}, or Z_{128}^{3} subsequence in bandwidth 1080 MHz. The set of AWVs used for the AGC subfields should be the same as that used for the TRN-T subfields. In a BRP-RX PPDU, the transmitter shall use the same TX AWV as in the preamble and data fields of the packet.

25.7.2.5 Beam refinement TRN-R subfield

The TRN-R subfields enable receiver AWV training. The TRN-R subfields have the form shown in Figure 25-29.

CEF	R_1	R_2	R_3	R_4	CEF	R_5	R_6	R_7	R_8	...

Figure 25-29—TRN-R subfield definition

Each subfield CEF matches the Channel Estimation field defined in 25.3.5. The $4N$ subfields R_1 to R_{4N} each consist of the sequence $[Z_{256}^{1}\ Z_{256}^{3}\ Z_{256}^{1}\ Z_{256}^{2}\ Z_{256}^{4}\ Z_{256}^{2}]$ in bandwidth 540 MHz and $[Z_{512}^{1}\ Z_{512}^{3}\ Z_{512}^{1}\ Z_{512}^{2}\ Z_{512}^{4}\ Z_{512}^{2}]$ in bandwidth 1080 MHz. The sequences Z_{256}^{1}, Z_{256}^{2}, Z_{256}^{3}, and Z_{256}^{4} are defined in Table 25-33, and Z_{512}^{1}, Z_{512}^{2}, Z_{512}^{3}, and Z_{512}^{4} are defined in Table 25-34 in 25.8. The sequences are transmitted using rotated π/2-QPSK modulation.

25.7.2.6 Beam refinement TRN-T subfield

The TRN-T subfield enables transmitter AWV training. The TRN-T subfields have the form shown in Figure 25-30.

CEF	T_1	T_2	T_3	T_4	CEF	T_5	T_6	T_7	T_8	...

Figure 25-30—TRN-T subfield definition

Each subfield CEF matches the Channel Estimation field defined in 25.3.5. The $4N$ subfields T_1 to T_{4N} each consist of the sequence $[Z_{256}^{1}\ Z_{256}^{3}\ Z_{256}^{1}\ Z_{256}^{2}\ Z_{256}^{4}\ Z_{256}^{2}]$ in bandwidth 540 MHz and $[Z_{512}^{1}\ Z_{512}^{3}\ Z_{512}^{1}\ Z_{512}^{2}\ Z_{512}^{4}\ Z_{512}^{2}]$ in bandwidth 1080 MHz. The sequences Z_{256}^{1}, Z_{256}^{2}, Z_{256}^{3}, and Z_{256}^{4} are defined in Table 25-33, and Z_{512}^{1}, Z_{512}^{2}, Z_{512}^{3}, and Z_{512}^{4} are defined in Table 25-34 in 25.8. The sequences are transmitted using rotated π/2-QPSK modulation. When transmitting the CEF subfield, the transmitter shall use the same AWV as in the preamble and data fields of the packet. Any transmit signal transients that occur due to TX AWV configuration changes between subfields shall settle by the end of the first 64 samples of the subfield.

25.7.2.7 Channel measurement

The good autocorrelation properties of the ZCZ sequences enable reconstructing part of the impulse response of the channel between the transmitter and the receiver. The receiver should find the tap with largest amplitude in the channel during the CEF of the BRP-RX. It selects thereafter the set of taps that is measured around the tap with the largest amplitude, according to the value of dot11ChanMeasFBCKNtaps. It can select a contiguous set of taps or select a noncontiguous set of taps and include the tap delays subfield as part of the subfield measurement. It then measures the phase and amplitude of the corresponding channel taps in each of the TRN-T subfield repetition (except for those using the CEF AWV configuration). The beam refinement feedback subfield k–1 is the relative amplitude and phase of this tap in the k'th repetition compared to this tap in the first TRN-T subfield.

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25.7.2.8 BRP resampling in an OFDM mode packet

The BRP AGC field, the CEF, and Tn/Rn field are specified at the SC chip rate (T_c). When appended to an OFDM packet, the signal is resampled as defined in 25.3.10.

25.8 ZCZ sequence

The following ZCZ sequences set is used in the STF, the CEF, the SCTF, and the Unique Word (UW). These are 5 ZCZ sequences sets, namely, Z_{32}^i, Z_{64}^i, Z_{128}^i, Z_{256}^i, and Z_{512}^i, with i = 1, 2, 3, 4where the subscript denotes the length of the sequences and the superscript denotes the index of the ZCZ sequence. The sets are generated using the following recursive procedure, illustrated as in Figure 25-31.

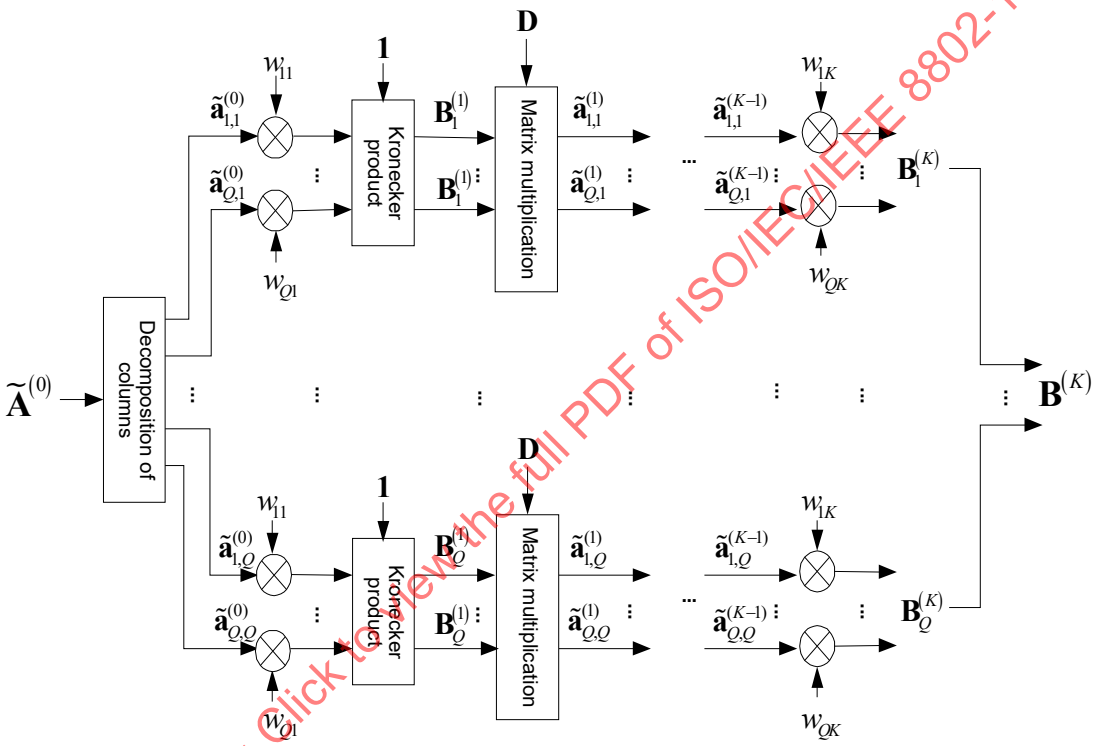

Figure 25-31—Generation of ZCZ sequences set

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$\tilde{\mathbf{A}}^{(0)}$, $\mathbf{B}^{(k)}$, and $\tilde{\mathbf{A}}^{(k)}$ used in Figure 25-31 are defined as follows, respectively.

$$\tilde{\mathbf{A}}^{(0)} = \begin{bmatrix} \tilde{\mathbf{a}}_{1,1}^{(0)} & \cdots & \tilde{\mathbf{a}}_{1,Q}^{(0)} \\ \cdots & \cdots & \cdots \\ \tilde{\mathbf{a}}_{Q,1}^{(0)} & \cdots & \tilde{\mathbf{a}}_{Q,Q}^{(0)} \end{bmatrix} \tag{25-68}$$

$$\mathbf{B}^{(k)} = \begin{bmatrix} w_{1,k}\mathbf{I}_{Q^{k-1}L} & \mathbf{0}_{Q^{k-1}L} & \cdots & \mathbf{0}_{Q^{k-1}L} \\ \mathbf{0}_{Q^{k-1}L} & w_{2,k}\mathbf{I}_{Q^{k-1}L} & \cdots & \mathbf{0}_{Q^{k-1}L} \\ \cdots & \cdots & \cdots & \cdots \\ \mathbf{0}_{Q^{k-1}L} & \mathbf{0}_{Q^{k-1}L} & \cdots & w_{Q,k}\mathbf{I}_{Q^{k-1}L} \end{bmatrix} \quad \tilde{\mathbf{A}}^{(k-1)}, \tilde{\mathbf{A}}^{(k)} = \mathbf{D}(\mathbf{1} \otimes \mathbf{B}^{(k)}) \tag{25-69}$$

where

$\tilde{\mathbf{a}}_{i,j}^{(0)}, i = 1, \ldots, Q, j = 1, \ldots, Q$	denotes the initial sequence
Q	is the number of ZCZ sequences
$\mathbf{I}_{Q^{k-1}L}$	denotes the identity matrix of size $Q^{k-1}L \times Q^{k-1}L$
L	denotes the length of the initial sequence
$\mathbf{0}_{Q^{k-1}L}$	denotes all zero matrix of size $Q^{k-1}L \times Q^{k-1}L$
$w_{i,j}, i = 1, \ldots, Q, j = 1, \ldots, K$	are elements of the coefficient matrix $\mathbf{W}$ of size $Q \times K$
K	is the number of the iterations
$\mathbf{D} = Diag(f_{1,1}\mathbf{I}_{Q^{k-1}L}, \ldots, f_{1,Q}\mathbf{I}_{Q^{k-1}L}, \ldots, f_{Q,1}\mathbf{I}_{Q^{k-1}L}, \ldots, f_{Q,Q}\mathbf{I}_{Q^{k-1}L})$	with $Diag(\upsilon)$ denoting the diagonal matrix with diagonal element υ
$f_{i,j}, i = 1, \ldots, Q, j = 1, \ldots, Q$	are elements of the Discrete Fourier Transform (DFT) matrix $\mathbf{F}_Q$ of size $Q \times Q$
$\mathbf{1}$	denotes all 1 column vector
$\otimes$	denotes Kronecker product

Note that $M = \{e^{(j2\pi\theta)/Q}\}_{\theta=0}^{Q-1}$, the elements of $\tilde{\mathbf{A}}^{(0)}$ belongs to M, and $w_{i,k} \in M, i = 1, \ldots, Q$.

When $\tilde{\mathbf{A}}^{(0)}$, $\mathbf{F}_4$, and $\mathbf{W}$ are given by Equation (25-70), the generated ZCZ sequence set Z_{32}^{i} is listed in Table 25-30 where 0, 1, 2, and 3 denote +1,+*j*,–1,–*j*.

$$\tilde{\mathbf{A}}^{(0)} = \begin{bmatrix} (-1,-1)^T & (-1,1)^T & (-1,-1)^T & (-1,1)^T \\ (-1,-1)^T & (-1,1)^T & (1,1)^T & (1,-1)^T \\ (-1,1)^T & (-1,-1)^T & (-1,1)^T & (-1,-1)^T \\ (-1,1)^T & (-1,-1)^T & (1,-1)^T & (1,1)^T \end{bmatrix}, \mathbf{F}_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & -j & -1 & j \end{bmatrix}, \mathbf{W} = \begin{bmatrix} 1 \\ -j \\ -1 \\ 1 \end{bmatrix} \tag{25-70}$$

When $\tilde{\mathbf{A}}^{(0)}$, $\mathbf{F}_4$, and $\mathbf{W}$ are given by Equation (25-71), the generated ZCZ sequence set Z_{64}^{i} is listed in Table 25-31 where 0, 1, 2, and 3 denote +1,+*j*,–1,–*j*.

$$\tilde{\mathbf{A}}^{(0)} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & -j & -1 & j \end{bmatrix}, \mathbf{F}_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & -j & -1 & j \end{bmatrix}, \mathbf{W} = \begin{bmatrix} -j & -1 \\ -1 & j \\ j & -j \\ -1 & -j \end{bmatrix} \tag{25-71}$$

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When $\tilde{\mathbf{A}}^{(0)}$, $\mathbf{F}_4$, and $\mathbf{W}$ are given by Equation (25-72), the generated ZCZ sequence set Z_{128}^i is listed in Table 25-32 where 0, 1, 2, and 3 denote +1,+*j*,–1,–*j*.

$$\tilde{\mathbf{A}}^{(0)} = \begin{bmatrix} (-1,-1)^T & (-1,1)^T & (-1,-1)^T & (-1,1)^T \\ (-1,-1)^T & (-1,1)^T & (1,1)^T & (1,-1)^T \\ (-1,1)^T & (-1,-1)^T & (-1,1)^T & (-1,-1)^T \\ (-1,1)^T & (-1,-1)^T & (1,-1)^T & (1,1)^T \end{bmatrix}, \mathbf{F}_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & -j & -1 & j \end{bmatrix}, \mathbf{W} = \begin{bmatrix} j & j \\ 1 & -j \\ -j & -j \\ -j & j \end{bmatrix} \quad (25\text{-}72)$$

When $\tilde{\mathbf{A}}^{(0)}$, $\mathbf{F}_4$, and $\mathbf{W}$ are given by Equation (25-73), the generated ZCZ sequence set Z_{256}^i is listed in Table 25-33 where 0, 1, 2, and 3 denote +1,+*j*,–1,–*j*.

$$\tilde{\mathbf{A}}^{(0)} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & -j & -1 & j \end{bmatrix}, \mathbf{F}_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & -j & -1 & j \end{bmatrix}, \mathbf{W} = \begin{bmatrix} 1 & -1 & -j & -j \\ -1 & j & -j & -j \\ -j & -1 & -j & 1 \\ j & -j & -1 & j \end{bmatrix} \quad (25\text{-}73)$$

When $\tilde{\mathbf{A}}^{(0)}$, $\mathbf{F}_4$, and $\mathbf{W}$ are given by Equation (25-74), the generated ZCZ sequence set Z_{512}^i Z_{512}^i is listed in Table 25-34 where 0, 1, 2, and 3 denote +1,+*j*,–1,–*j*, respectively.

$$\tilde{\mathbf{A}}^{(0)} = \begin{bmatrix} (-1,-1)^T & (-1,1)^T & (-1,-1)^T & (-1,1)^T \\ (-1,-1)^T & (-1,1)^T & (1,1)^T & (1,-1)^T \\ (-1,1)^T & (-1,-1)^T & (-1,1)^T & (-1,-1)^T \\ (-1,1)^T & (-1,-1)^T & (1,-1)^T & (1,1)^T \end{bmatrix}, \mathbf{F}_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & -j & -1 & j \end{bmatrix}, \mathbf{W} = \begin{bmatrix} 1 & -j & -j & -j \\ j & j & j & -j \\ j & j & -j & -1 \\ -j & -j & 1 & -j \end{bmatrix} \quad (25\text{-}74)$$

.

Table 25-30—The sequence set Z^i_{32}, *i*=1,2,3,4

	The sequence set Z_{32}^i, i = 1, …, 4 to be transmitted from left to right, up to down
Z_{32}^1	22110220222220132233020222002031
Z_{32}^2	20130022202022112031000020022233
Z_{32}^3	22330202220020312211022022222013
Z_{32}^4	20310000200222332013002220202211

Table 25-31—The sequence set Z^i_{64}, *i*=1,2,3,4

	The sequence set Z_{64}^i, i = 1, …, 4 to be transmitted from left to right, up to down
Z_{64}^1	21010002230313112101111301210200210122202303313321013331012120 22
Z_{64}^2	22200121202210302220123202000323222023032022321222203010020021 01
Z_{64}^3	23030200210111132303131103230002230320222101333123033133032322 20
Z_{64}^4	20220323222012322022103000020121202221012220301020223212000223 03

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Table 25-32—The sequence set Z^i_{128}, i=1,2,3,4

	The sequence set Z^i_{128}, $i = 1, \ldots, 4$ to be transmitted from left to right, up to down
Z^1_{128}	0011202022222013221102200022021300112020111130200332002113313200011202011111302 0011202000000231221102202200203100112020333331200033200233113102
Z^2_{128}	0213222220202211201300220220001102132222131311000231220013311122 0213222202020033201300222002223302132222313133220231220031133300
Z^3_{128}	0033200222002031223302020000023100332002113313200011202011111302 0033200200220213223302022222201300332002331131020011202033333120
Z^4_{128}	0231220020022233203100000202003302312200133111220213222213131100 0231220002200011203100002020221102312200311333000213222231313322

Table 25-33—The sequence set Z^i_{256}, i=1,2,3,4

	The sequence set Z^i_{256}, $i = 1, \ldots, 4$ to be transmitted from left to right, up to down
Z^1_{256}	1302031011002330130210213322122313022132110001120231213222112330 1302031011002330201321320033233031200310332223303120102111001223 1302031011002330312032031100300113022132110001122013031000330112 1302031011002330023103102211011231200310322233013023203332230001
Z^2_{256}	1021003312232013102111003001130210212211223023103102211233020 13 1021003312232013213222110112201332030033300120133203110012231302 1021003312232013320333221223312011221112230231213200330112023 1 1021003312232013031000332330023132030033300120131021332230013120
Z^3_{256}	1100011213022132110012233120102111002330130203100033233020132132 1100011213022132221123300331213233220112312021323322122313021021 1100011213022132332230011302320311002330130203102211011202310310 1100011213022132003301122013031033220112312021321100300131203203
Z^4_{256}	1223023110212211223130232031100122320131021003301122013213222 11 1223023110212211233020130310221130010231320322113001130210211100 1223023110212211300131201021332212232013102100332330023103100033 1223023110212211011202312132003330010231320322111223312032033322

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Table 25-34—The sequence set Z^{i}_{512}, i=1,2,3,4

	The sequence set Z^{i}_{512}, $i = 1, \ldots, 4$ to be transmitted from left to right, up to down
Z^{1}_{512}	00111331002231202211313100003102223331133311201322113131111110213 00111331220013022211313122221320112220020022312011002020222221320 00111331002231202211313100003102330002200022312033220202222221320 22333113002231200033131300003102001113313311201300331313111110213 00111331002231202211313100003102001113311133023100331313333332031 00111331220013022211313122221320330002202200130233220202000003102 00111331002231202211313100003102112220022200130211002020000003102 22333113002231200033131300003102223331131133023122113131333332031
Z^{2}_{512}	02131133022033222013333302023300203133113113221120133333131300 11 02131133200211002013333320201122132022000220332213022222202011 22 02131133022033222013333302023300310200220220332231200000202011 22 20313311022033220231111102023300021311333113221102311111131300 11 02131133022033222013333302023300021311331331003302311111313122 33 02131133200211002013333320201122310200222002110031200000020233 00 02131133022033222013333302023300132022002002110013022222020233 00 20313311022033220231111102023300203133111331003320133333313122 33
Z^{3}_{512}	00331313000031022233311300223120221131313333203122333113113330231 00331313222213202233311322001302110020200000310211222002220013 02 00331313000031022233311300223120332202020000031023300022022001302 22113131000031020011133100223120003313133333203100113331113330231 00331313000031022233311300223120003313131111021300111331331120 13 00331313222213202233311322001302332202022222132033000220002231 20 00331313000031022233311300223120110020202222032011222002002231 20 22113131000031020011133100223120221131313111021322331133331120 13
Z^{4}_{512}	02311111020233002031331102203322201333331312233203133111331003 3 02311111202011222031331120021100130222202023300132022002002110 0 02311111020233002031331102203322312000000202330031020022200211 00 20133333020233000213113302203322023111113131223302131133133100 33 02311111020233002031331102203322023111111313001102131133311321 11 02311111202011222031331120021100312000002020112231020022022033 22 02311111020233002031331102203322130222222020112213202200022033 22 20133333020233000213113302203322201333331313001120313311311322 11

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25.9 Regulatory requirements

Wireless LANs (WLANs) implemented in accordance with this standard are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The PHY specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regulations are subject to revision or may be superseded.

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25.10 Channelization

A CMMG channel is specified by the two PLME MIB fields specified in Table 25-35.

Table 25-35—Fields to specify CMMG channels

Field	Meaning
dot11CMMGCurrentChannelWidth	Channel width. Possible values represent 540 MHz and 1080 MHz channels.
dot11CMMGCurrentChannelCenterFrequencyIndex	For a 540 MHz or 1080 MHz channel, denotes the channel center frequency.

If dot11CMMGCurrentChannelWidth indicates a 540 MHz channel, the channel center frequency is given by Equation (25-75) (see Figure 25-32).

$$f(n)\ [GHz] = \quad (25\text{-}75)$$

$$\begin{cases} 42.66 + 0.54 \times (\text{dot11CMMGCurrentChannelCenterFrequencyIndex} - 1), & 1 \le \text{dot11CMMGCurrentChannelCenterFrequencyIndex} \le 8 \\ 47.52 + 0.54 \times (\text{dot11CMMGCurrentChannelCenterFrequencyIndex} - 9), & \text{dot11CMMGCurrentChannelCenterFrequencyIndex} = 9, 10 \end{cases}$$

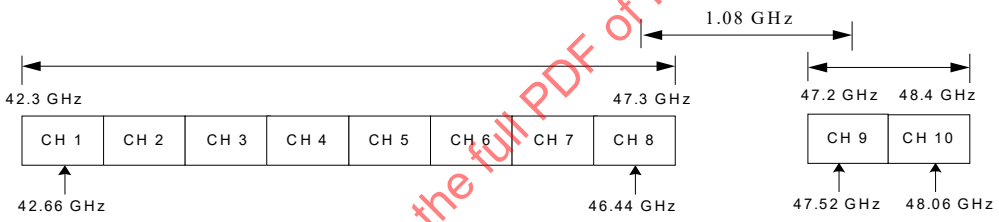

Figure 25-32—Channelization for CBW540 MHz

If dot11CMMGCurrentChannelWidth indicates a 1080 MHz channel, the channel center frequency is given by Equation (25-76) (see Figure 25-33).

$$f(n)\ [GHz] = \quad (25\text{-}76)$$

$$\begin{cases} 42.93 + 1.08 \times (\text{dot11CMMGCurrentChannelCenterFrequencyIndex} - 1), & 1 \le \text{dot11CMMGCurrentChannelCenterFrequencyIndex} \le 4 \\ 47.79, & \text{dot11CMMGCurrentChannelCenterFrequencyIndex} = 5 \end{cases}$$

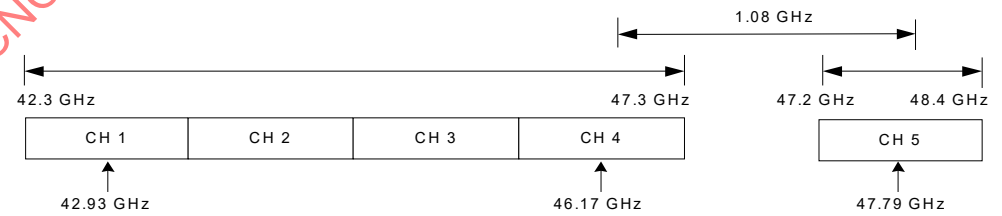

Figure 25-33—Channelization for CBW1080 MHz

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25.11 Transmit spectrum mask

For a 540 MHz or 1080 MHz mask PPDU, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 470 MHz or 940 MHz, –17 dBr at 330 MHz or 660 MHz frequency offset, –22 dBr at 1350 MHz or 2670 MHz frequency offset, and –30 dBr at 1530 MHz or 3060 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 235 MHz or 470 MHz and 330 MHz or 660 MHz, in between 330 MHz or 660 MHz and 1350 MHz or 2700 MHz, and in between 1350 MHz or 2700 MHz and 1530 MHz or 3060 MHz shall be linearly interpolated in dB domain from the requirements for 235 MHz, 330 MHz, 1350 MHz, and 1530 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask.

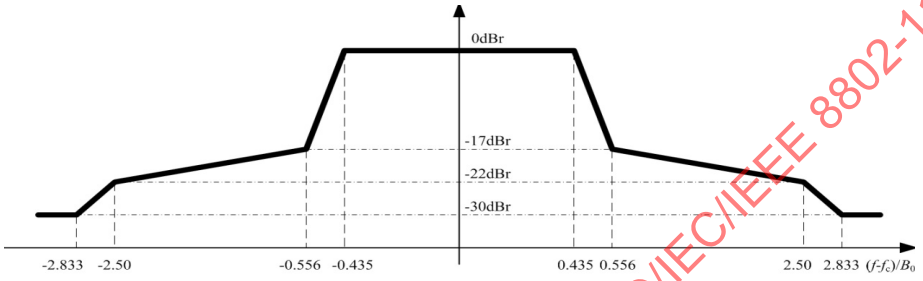

Figure 25-34—Example transmit spectral mask for a PPDU

25.12 PHY transmit procedure

25.12.1 PHY transmit procedure for a CMMG SC mode transmission

The PHY transmit procedure for a CMMG SC mode transmission is shown in Figure 25-35. In order to transmit data, a PHY-TXSTART.request primitive shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate frequency through station management via the PLME, as specified in 25.14. Other transmit parameters, such as MCS and transmit power, are set via the PHY SAP with the PHYTXSTART.request (TXVECTOR) primitive, as described in Table 25-1.

The PHY shall then issue a PHY-TXSTART.request primitive, and transmission of the PHY preamble shall start, based on the parameters passed in the PHY-TXSTART.request primitive. The PHY shall calculate the length of the packet according the MCS and the length specified in the PHY-TXSTART.request primitive, adding padding bits if necessary.

The PHY continues with the scrambling, encoding, and transmission of the CMMG-SIG-A according to the PHY-TXSTART.request(TXVECTOR) primitive parameters. The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. The data are encoded as described in 25.5.6.3. The encoded data are then modulated as described in 25.5.6.6, depending on the MCS requested in the PHY_TXSTART.request primitive. Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. PHY-TXSTART shall be disabled by receiving a PHY-TXEND.request primitive.

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Transmission of the PSDU is completed with the transmission of the last bits of the (encoded) PSDU. If no TRN-T/R fields are specified in the PHY-TXSTART.request primitive, the PHY shall issue a PHY-TXEND.confirm primitive after the transmission of the last bits. If TRN-T and TRN-R fields are requested in the PHY-TXSTART.request primitive, the transmission continues with the transmission of AGC subfields and TRN-T/R subfields. The PHY issues the PHY-TXEND.confirm primitive to the MAC after the transmission of the last TRN-T/R subfield. The packet transmission shall be completed, and the PHY entity shall enter the receive state (i.e., PHYTXSTART shall be disabled). Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

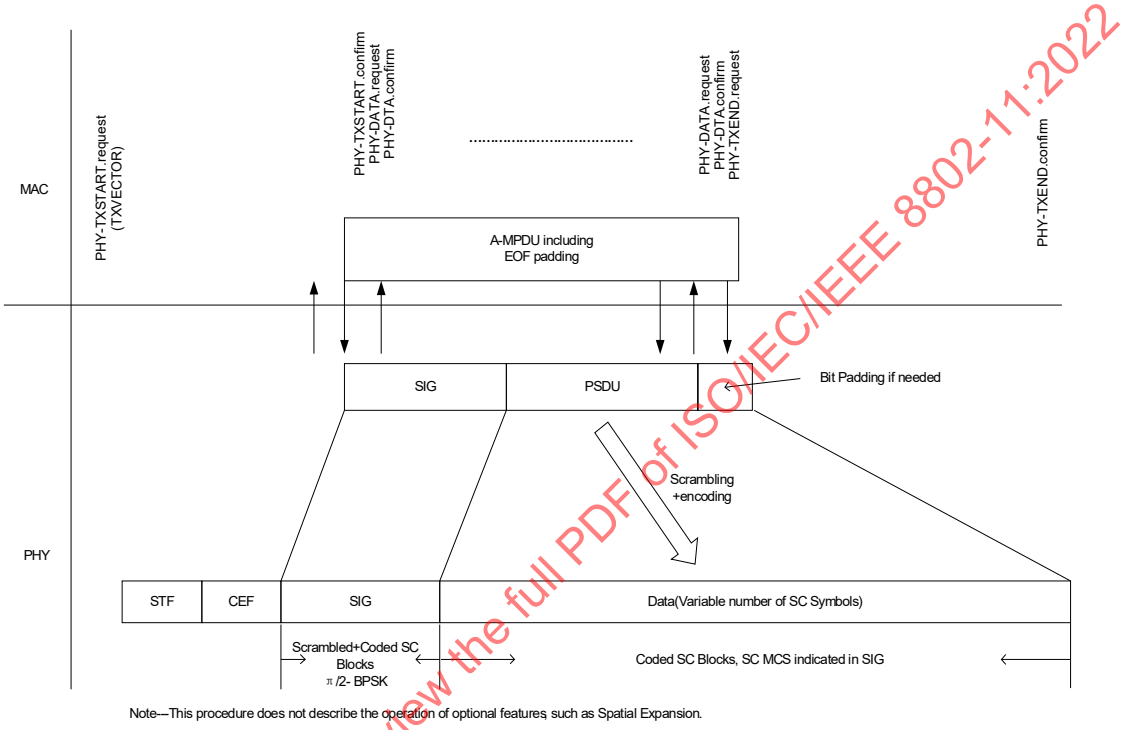

Figure 25-35—PHY transmit procedure for a CMMG SC mode transmission

25.12.2 PHY transmit procedure for a CMMG OFDM mode transmission

The PHY transmit procedure for a CMMG OFDM transmission is shown in Figure 25-36. In order to transmit data, a PHY-TXSTART.request primitive shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate frequency through station management via the PLME, as specified in 25.14. Other transmit parameters, such as MCS and transmit power, are set via the PHY SAP with the PHYTXSTART.request(TXVECTOR) primitive, as described in Table 25-1.

The PHY shall then issue a PHY-TXSTART.request primitive, and transmission of the PHY preamble shall start, based on the parameters passed in the PHY-TXSTART.request primitive. The PHY shall calculate the length of the packet according the MCS and the length specified in the PHY-TXSTART.request primitive, adding padding bits if necessary.

The PHY continues with the scrambling, encoding, and transmission of the CMMG SIG according to the PHY-TXSTART.request(TXVECTOR) primitive parameters. The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. The data are scrambled and encoded as described in 25.6.8.2 and 25.6.8.3, respectively. The encoded data are then modulated as described in 25.6.8.6,

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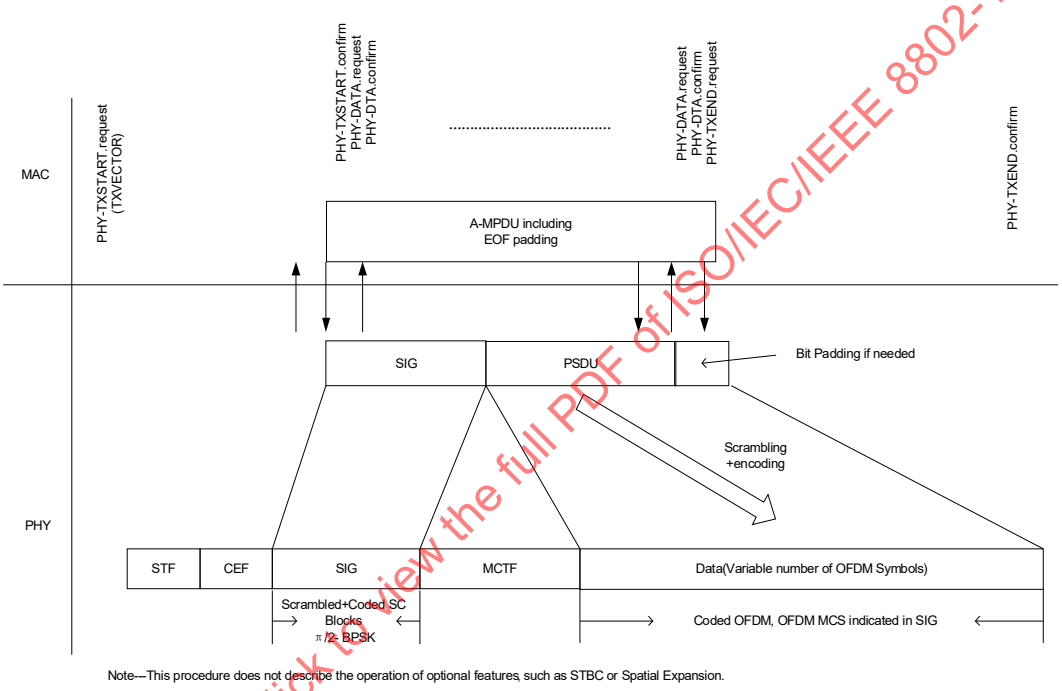
depending on the MCS requested in the PHY-TXSTART.request primitive. Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. PHY-TXSTART shall be disabled by receiving a PHY-TXEND.request primitive.

Transmission of the PSDU is completed with the transmission of the last bits of the (encoded) PSDU. If no TRN-T/R fields are specified in the PHY-TXSTART.request primitive, the PHY shall issue a PHY-TXEND.confirm primitive after the transmission of the last bits. If TRN-T and TRN-R fields are requested in the PHY-TXSTART.request primitive, the transmission continues with the transmission of AGC subfields and TRN-T/R subfields. The PHY issues the PHY-TXEND.confirm primitive to the MAC after the transmission of the last TRN-T/R subfield. The packet transmission shall be completed, and the PHY entity shall enter the receive state (i.e., PHYTXSTART shall be disabled). Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY.



Note---This procedure does not describe the operation of optional features, such as STBC or Spatial Expansion.

Figure 25-36—PHY transmit procedure for a CMMG OFDM mode transmission

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A typical state machine implementation of the transmit PHY for an OFDM mode transmission is provided in Figure 25-37. This state machine does not describe the operation of optional features, such as STBC.

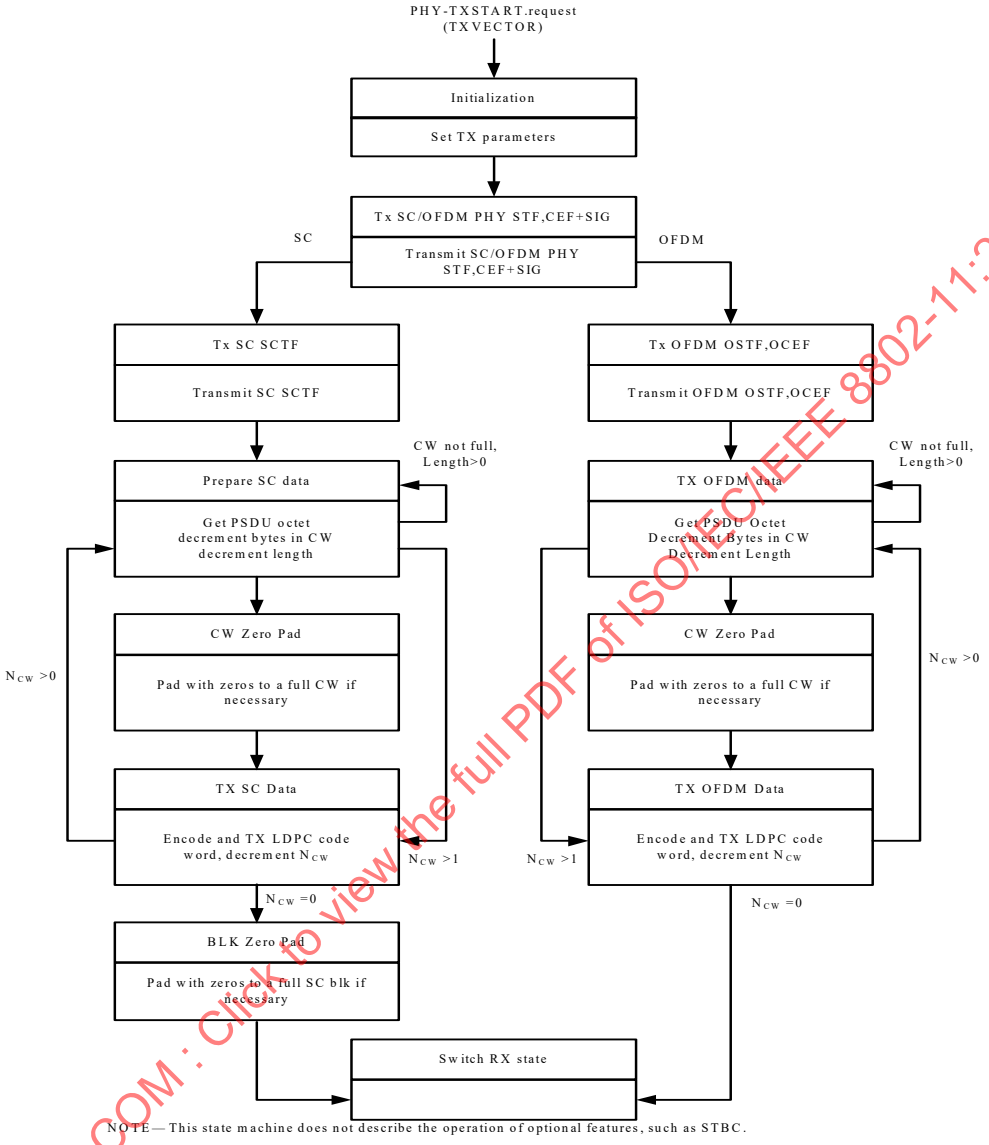

Figure 25-37—Typical Tx state machine

25.13 Receive procedure

A typical PHY receive procedure is shown in Figure 25-39 for a CMMG SC mode transmission.

Upon receiving the transmitted PHY preamble overlapping the primary 540 MHz channel, the PHY measures a receive signal strength. This activity is indicated by the PHY to the MAC via a PHY-CCA.indication primitive. A PHY-CCA.indication (BUSY, channel-list) primitive is also issued as an initial indication of reception of a signal as specified in 25.6.9.3.2. The channel-list parameter of the PHY-CCA.indication primitive is absent when the operating channel width is 540 MHz. The channel-list parameter is present and includes the entry primary when the operating channel width is 1080 MHz.

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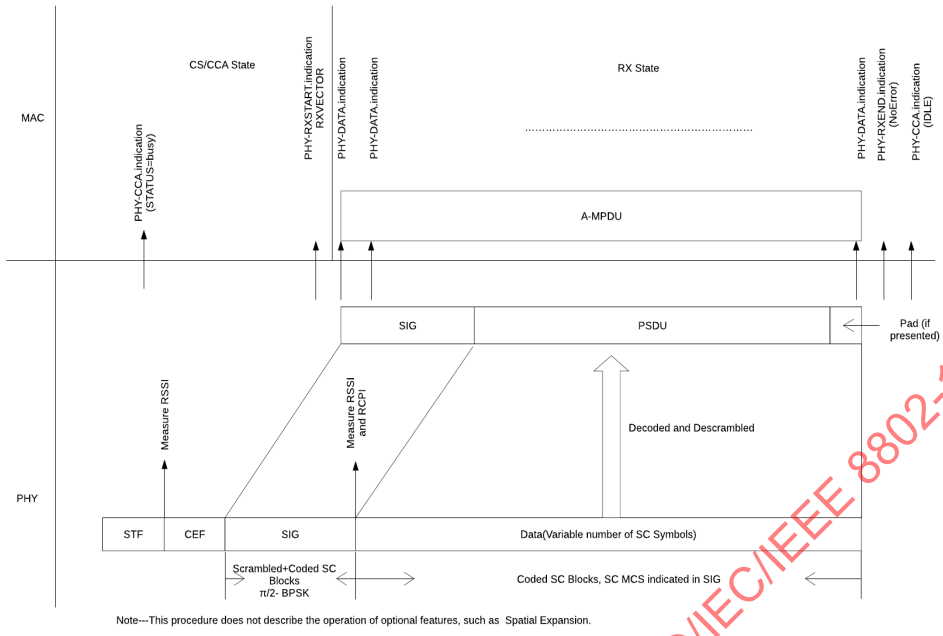

Figure 25-38—PHY receive procedure for a CMMG SC mode transmission

After the PHY-CCA.indication(BUSY) primitive is issued, the PHY entity shall use the following ZCZ sequences of length 256 for synchronization and channel estimation. If the CE field indicated a SC mode, the receiver is capable of receiving SC mode. The PHY shall decode the CMMG SIG and determine the MCS, length, and other parameters needed for the demodulation of the packet.

Subsequently, if dot11TimingMsmtActivated is true, a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued, and the RX-START_OF_FRAME_OFFSET parameter within the RXVECTOR shall be forwarded (see 25.2.2).

NOTE—The RX_START_OF_FRAME_OFFSET value is used as described in 6.3.55 in order to estimate when the start of the preamble for the incoming frame was detected on the medium at the receive antenna connector.

At the end of the data portion of the packet, the PHY shall indicate PHY-RXEND.indication(No_Error) primitive to the MAC. If the CMMG SIG indicated the presence of the training field, the PHY shall continue to receive these training fields after the data portion of the packet and measure the channel. After the end of the training fields, the PHY shall generate a PHY-CCA.indication(IDLE) primitive.

In the case of signal loss before the decoding of the CMMG SIG or in the case of an invalid header, the PHY shall not generate a PHY-CCA.indication(IDLE) primitive until the received level drops below a value that is 20 dB higher than the receiver sensitivity of MCS 1. In the case of signal loss after decoding of a valid CMMG SIG, the PHY shall not generate a PHY-CCA.indication(IDLE) primitive until the expected end of the packet, including the AGC and TRN fields.

A typical state machine implementation of the receive PHY is given in Figure 25-39. This receive procedure and state machine do not describe the operation of optional features, such as STBC.

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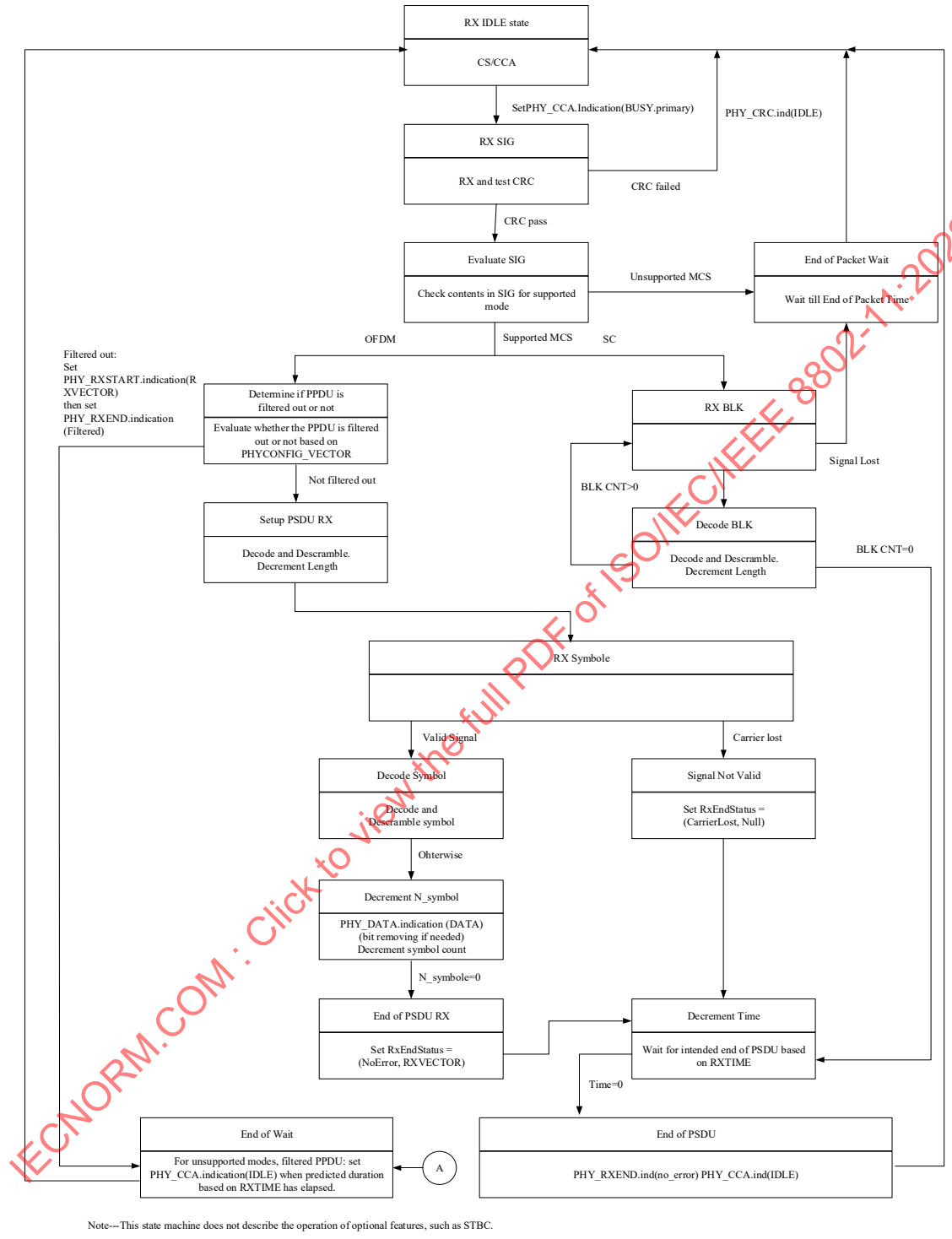

Note---This state machine does not describe the operation of optional features, such as STBC.

Figure 25-39—Typical Rx state machine

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25.14 CMMG PLME

25.14.1 PLME SAP sublayer management primitive

Table 25-36 lists the MIB attributes that may be accessed by the PHY entities and the intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.5.

25.14.2 PHY MIB

CMMG PHY MIB attributes are defined in Annex C with specific values defined in Table 25-36. The "Operational semantics" column in Table 25-36 contains two types: static and dynamic.

— Static MIB attributes are fixed and cannot be modified for a given PHY implementation.
— Dynamic MIB attributes are interpreted according to the MAX-ACCESS field of the MIB attribute.

When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.

Table 25-36—CMMG PHY MIB attributes

Managed object	Default value/ range	Operational semantics
dot11PHYOperationTable		
dot11PHYType	cmmg(13)	Static
dot11PHYCMMGTable		
dot11CMMGCurrentChannelWidth	Implementation dependent	Dynamic
dot11CMMGCurrentChannelCenterFrequencyIndex	Implementation dependent	Dynamic
dot11CMMGShortGIOptionImplemented	false/Boolean	Static
dot11CMMGShortGIOptionActivated	false/Boolean	Dynamic
dot11CMMGTxSTBCOptionImplemented	false/Boolean	Static
dot11CMMGTxSTBCOptionActivated	false/Boolean	Dynamic
dot11CMMGRxSTBCOptionImplemented	false/Boolean	Static
dot11CMMGRxSTBCOptionActivated	false/Boolean	Dynamic
dot11CMMGBeamFormingOptionImplemented	false/Boolean	Static
dot11CMMGBeamFormingOptionActivated	false/Boolean	Dynamic
dot11CMMGMaxNTxChainsImplemented	Implementation dependent	Static
dot11CMMGMaxNTxChainsActivated	Implementation dependent	Dynamic

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Table 25-36—CMMG PHY MIB attributes *(continued)*

Managed object	Default value/ range	Operational semantics
dot11TransmitBeamformingConfigTable		
dot11ReceiveNDPOptionImplemented	false/Boolean	Static
dot11TransmitNDPOptionImplemented	false/Boolean	Static
dot11ExplicitCSITransmitBeamformingOptionImplemented	false/Boolean	Static
dot11ExplicitTransmitBeamformingCSIFeedbackOptionImplemented	Implementation dependent	Static
dot11ExplicitCompressedBeamformingFeedbackOptionImplemented	Implementation dependent	Static
dot11NumberBeamFormingCSISupportAntenna	Implementation dependent	Static
dot11NumberCompressedBeamformingMatrixSupportAntenna	Implementation dependent	Static
dot11BeamformeeOptionImplemented	false/Boolean	Static
dot11BeamformerOptionImplemented	false/Boolean	Static
dot11NumberSoundingDimensions	Implementation dependent	Static
dot11BeamformeeNTxSupport	Implementation dependent	Static

25.14.3 TXTIME calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated for a SC mode PPDU using Equation (25-77) and for an OFDM mode PPDU using Equation (25-78).

$$TXTIME = T_{STF} + T_{CEF} + T_{SIG} + T_{SCTF} + N_{BL} \times T_{BLK} \quad (25\text{-}77)$$

$$TXTIME = T_{STF} + T_{CEF} + T_{SIG} + T_{OSTF} + N_{OCEF} T_{OCEF} + N_{SYM} \times T_{SYM} \quad (25\text{-}78)$$

where T_{STF}, T_{CEF}, T_{SIG}, T_{SCTF}, T_{OSTF}, and T_{OCEF} are defined in Table 25-3.

For an NDP, there is no Data field, and $N_{SYM} = 0$.

For a SC mode PPDU, the total number of data blocks in the Data field, N_{BL}, is given by Equation (25-27).

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25.14.4 PHY characteristics

The static CMMG PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, shall be as shown in Table 25-37. The definitions for these characteristics are given in 6.5.4.

Table 25-37—CMMG PHY characteristics

PHY parameter	Value
aRIFSTime	1 μs
aSIFSTime	3 μs
aRxRFDelay	Implementation dependent
aRxPHYDelay	Implementation dependent
aRxTxTurnaroundTime	1 μs
aCCATime	3 μs
aCMMGPPMinListeningTime	150 μs
aTxRFDelay	Implementation dependent
aTxPHYDelay	Implementation dependent
aRxTxSwitchTime	1 μs
aTxRampOnTime	Implementation dependent
aTxRampOffTime	Implementation dependent
aAirPropagationTime	< 600 ns
aRxPHYStartDelay	11 μs
aMACProcessingDelay	Implementation dependent
aSlotTime	5 μs
aCWmin	15
aCWmax	1023
aPPDUMaxTime	12 ms
aPSDUMaxLength	262 143 octets
aSCBlockSize	256 for 540 MHz 512 for 1080 MHz

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25.15 Parameters for CMMG-MCSs

25.15.1 General

The rate-dependent parameters for 540 MHz and 1080 MHz are given in 25.15.2 and 25.15.3. Support for short GI is optional in all cases. Support for CMMG-MCSs 4 to 16 is optional in all cases. A CMMG STA shall support single spatial stream CMMG-MCSs within the range CMMG-MCS 0 to 3 for 540 MHz channel widths for which it has indicated support regardless of the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported CMMG-MCS and NSS Set field. When more than one spatial stream is supported, the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported

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CMMG-MCS and NSS Set field may result in a reduced CMMG-MCS range (cut-off) for N_{SS} = 2, 3, 4. Support for 540 MHz with N_{SS} = 1 and SC transmission is mandatory. Support for 540 MHz and 1080 MHz with N_{SS} = 2, 3, 4 and SC transmission is optional. Support for 540 MHz and 1080 MHz with OFDM transmission is optional.

25.15.2 Parameters for CMMG-MCSs with SC mode transmission

The related parameters for different modulation are summarized in Table 25-38 to Table 25-41 for 540 MHz channel bandwidth with SC mode transmission.

Table 25-38—CMMG SC MCSs for mandatory 540 MHz, N_{SS}=1

MCS index	Modulation	*R*	N_{CBPS}	Data rate (Mb/s)	
				Long GI	Short GI
1	π/2-BPSK	1/2	1	165.00	192.50
2	π/2-QPSK	1/2	2	330.00	385.00
3	π/2-QPSK	3/4	2	495.00	577.50
4	π/2-16-QAM	1/2	4	660.00	770.00
5	π/2-16-QAM	3/4	4	990.00	1155.00
6	π/2-64-QAM	5/8	6	1237.50	1443.75
7	π/2-64-QAM	3/4	6	1485.00	1732.50
8	π/2-64-QAM	13/16	6	1608.75	1876.88

Table 25-39—CMMG SC MCSs for optional 540 MHz, N_{SS}=2 (Optional)

MCS index	Modulation	*R*	N_{CBPS}	Data rate (Mb/s)	
				Long GI	Short GI
1	π/2-BPSK	1/2	1	330.00	385.00
2	π/2-QPSK	1/2	2	660.00	770.00
3	π/2-QPSK	3/4	2	990.00	1155.00
4	π/2-16-QAM	1/2	4	1320.00	1540.00
5	π/2-16-QAM	3/4	4	1980.00	2310.00
6	π/2-64-QAM	5/8	6	2475.00	2887.50
7	π/2-64-QAM	3/4	6	2970.00	3465.00
8	π/2-64-QAM	13/16	6	3217.50	3753.75

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Table 25-40—CMMG SC MCSs for optional 540 MHz, N_{SS}=3 (Optional)

MCS index	Modulation	*R*	N_{CBPS}	Data rate (Mb/s)	
				Long GI	Short GI
1	π/2-BPSK	1/2	1	495.00	577.50
2	π/2-QPSK	1/2	2	990.00	1155.00
3	π/2-QPSK	3/4	2	1485.00	1732.50
4	π/2-16-QAM	1/2	4	1980.00	2310.00
5	π/2-16-QAM	3/4	4	2970.00	3465.00
6	π/2-64-QAM	5/8	6	3712.50	4331.25
7	π/2-64-QAM	3/4	6	4455.00	5197.50
8	π/2-64-QAM	13/16	6	4826.50	5630.63

Table 25-41—CMMG SC MCSs for optional 540 MHz, N_{SS}=4 (Optional)

MCS index	Modulation	*R*	N_{CBPS}	Data rate (Mb/s)	
				Long GI	Short GI
1	π/2-BPSK	1/2	1	660.00	770.00
2	π/2-QPSK	1/2	2	1320.00	1540.00
3	π/2-QPSK	3/4	2	1980.00	2310.00
4	π/2-16-QAM	1/2	4	2640.00	3080.00
5	π/2-16-QAM	3/4	4	3960.00	4620.00
6	π/2-64-QAM	5/8	6	4950.00	5775.00
7	π/2-64-QAM	3/4	6	5940.00	6930.00
8	π/2-64-QAM	13/16	6	6435.00	7507.50

The related parameters for different modulation are summarized in Table 25-42 to Table 25-45 for 1080 MHz channel bandwidth with SC mode transmission.

Table 25-42—CMMG SC MCSs for mandatory 1080 MHz, N_{SS}=1

MCS index	Modulation	*R*	N_{CBPS}	Data rate (Mb/s)	
				Long GI	Short GI
1	π/2-BPSK	1/2	1	330.00	385.00
2	π/2-QPSK	1/2	2	660.00	770.00
3	π/2-QPSK	3/4	2	990.00	1155.00

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Table 25-42—CMMG SC MCSs for mandatory 1080 MHz, N_{SS}=1

MCS index	Modulation	*R*	N_{CBPS}	Data rate (Mb/s)	
				Long GI	Short GI
4	π/2-16-QAM	1/2	4	1320.00	1540.00
5	π/2-16-QAM	3/4	4	1980.00	2310.00
6	π/2-64-QAM	5/8	6	2475.00	2887.50
7	π/2-64-QAM	3/4	6	2970.00	3465.00
8	π/2-64-QAM	13/16	6	3217.50	3753.75

Table 25-43—CMMG SC MCSs for optional 1080 MHz, N_{SS}=2 (Optional)

MCS index	Modulation	*R*	N_{CBPS}	Data rate (Mb/s)	
				Long GI	Short GI
1	π/2-BPSK	1/2	1	660.00	770.00
2	π/2-QPSK	1/2	2	1320.00	1540.00
3	π/2-QPSK	3/4	2	1980.00	2310.00
4	π/2-16-QAM	1/2	4	2640.00	3080.00
5	π/2-16-QAM	3/4	4	3960.00	4620.00
6	π/2-64-QAM	5/8	6	4950.00	5775.00
7	π/2-64-QAM	3/4	6	5940.00	6930.00
8	π/2-64-QAM	13/16	6	6435.00	7507.50

Table 25-44—CMMG SC MCSs for optional 1080 MHz, N_{SS}=3 (Optional)

MCS index	Modulation	*R*	N_{CBPS}	Data rate (Mb/s)	
				Long GI	Short GI
1	π/2-BPSK	1/2	1	990.00	1155.00
2	π/2-QPSK	1/2	2	1980.00	2310.00
3	π/2-QPSK	3/4	2	2970.00	3465.00
4	π/2-16-QAM	1/2	4	3960.00	4620.00
5	π/2-16-QAM	3/4	4	5940.00	6930.00
6	π/2-64-QAM	5/8	6	7425.00	8662.50
7	π/2-64-QAM	3/4	6	8910.00	10395.00
8	π/2-64-QAM	13/16	6	9652.50	11261.25

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Table 25-45—CMMG SC MCSs for optional 1080 MHz, N_{SS}=4 (Optional)

MCS index	Modulation	R	N_{CBPS}	Data rate (Mb/s)	
				Long GI	Short GI
1	π/2-BPSK	1/2	1	1320.00	1540.00
2	π/2-QPSK	1/2	2	2640.00	3080.00
3	π/2-QPSK	3/4	2	3960.00	4620.00
4	π/2-16-QAM	1/2	4	5280.00	6160.00
5	π/2-16-QAM	3/4	4	7920.00	9240.00
6	π/2-64-QAM	5/8	6	9900.00	11550.00
7	π/2-64-QAM	3/4	6	11880.00	13860.00
8	π/2-64-QAM	13/16	6	12870.00	15015.00

25.15.3 Parameters for CMMG-MCSs with OFDM mode transmission

The related parameters for different modulation are summarized in Table 25-46 to Table 25-49 for 540 MHz channel bandwidth with OFDM mode transmission.

Table 25-46—CMMG OFDM MCSs for optional 540 MHz, N_{SS}=1 (Optional)

MCS index	Modulation	R	N_{CBPS}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
						Long GI	Short GI
9	BPSK	1/2	1	168	84	173.25	192.50
10	QPSK	1/2	2	336	168	346.50	385.00
11	QPSK	3/4	2	336	252	519.75	577.50
12	16-QAM	1/2	4	672	336	693.00	770.00
13	16-QAM	3/4	4	672	504	1039.50	1155.00
14	64-QAM	5/8	6	1008	630	1299.38	1443.75
15	64-QAM	3/4	6	1008	756	1559.25	1732.50
16	64-QAM	13/16	6	1008	819	1689.19	1876.88

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Table 25-47—CMMG OFDM MCSs for optional 540 MHz, N_{SS}=2 (Optional)

MCS index	Modulation	*R*	N_{CBPS}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
						Long GI	Short GI
9	BPSK	1/2	1	336	168	346.50	385.00
10	QPSK	1/2	2	672	336	693.00	770.00
11	QPSK	3/4	2	672	504	1039.50	1155.00
12	16-QAM	1/2	4	1344	672	1386.00	1540.00
13	16-QAM	3/4	4	1344	1008	2079.00	2310.00
14	64-QAM	5/8	6	2016	1260	2598.75	2887.50
15	64-QAM	3/4	6	2016	1512	3118.50	3465.00
16	64-QAM	13/16	6	2016	1638	3378.38	3753.75

Table 25-48—CMMG OFDM MCSs for optional 540 MHz, N_{SS}=3 (Optional)

MCS index	Modulation	*R*	N_{CBPS}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
						Long GI	Short GI
9	BPSK	1/2	1	504	252	519.75	577.50
10	QPSK	1/2	2	1008	504	1039.50	1155.00
11	QPSK	3/4	2	1008	756	1559.25	1732.50
12	16-QAM	1/2	4	2016	1008	2079.00	2310.00
13	16-QAM	3/4	4	2016	1512	3118.50	3465.00
14	64-QAM	5/8	6	3024	1890	3898.13	4331.25
15	64-QAM	3/4	6	3024	2268	4677.75	5197.50
16	64-QAM	13/16	6	3024	2457	5067.56	5630.63

Table 25-49—CMMG OFDM MCSs for optional 540 MHz, N_{SS}=4 (Optional)

MCS index	Modulation	*R*	N_{CBPS}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
						Long GI	Short GI
9	BPSK	1/2	1	672	336	693.00	770.00
10	QPSK	1/2	2	1344	672	1386.00	1540.00
11	QPSK	3/4	2	1344	1008	2079.00	2310.00
12	16-QAM	1/2	4	2688	1344	2772.00	3080.00
13	16-QAM	3/4	4	2688	2016	4158.00	4620.00

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Table 25-49—CMMG OFDM MCSs for optional 540 MHz, N_{SS}=4 (Optional)

MCS index	Modulation	R	N_{CBPS}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
						Long GI	Short GI
14	64-QAM	5/8	6	4032	2520	5197.50	5775.00
15	64-QAM	3/4	6	4032	3024	6237.00	6930.00
16	64-QAM	13/16	6	4032	3276	6756.75	7507.50

The related parameters for different modulation are summarized in Table 25-50 to Table 25-53 for 1080 MHz channel bandwidth with OFDM mode transmission.

Table 25-50—CMMG OFDM MCSs for optional 1080 MHz, N_{SS}=1 (Optional)

MCS index	Modulation	R	N_{CBPS}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
						Long GI	Short GI
9	BPSK	1/2	1	336	168	346.50	385.00
10	QPSK	1/2	2	672	336	693.00	770.00
11	QPSK	3/4	2	672	504	1039.50	1155.00
12	16-QAM	1/2	4	1344	672	1386.00	1540.00
13	16-QAM	3/4	4	1344	1008	2079.00	2310.00
14	64-QAM	5/8	6	2016	1260	2598.75	2887.50
15	64-QAM	3/4	6	2016	1512	3118.50	3465.00
16	64-QAM	13/16	6	2016	1638	3378.38	3753.75

Table 25-51—CMMG OFDM MCSs for optional 1080 MHz, N_{SS}=2 (Optional)

MCS index	Modulation	R	N_{CBPS}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
						Long GI	Short GI
9	BPSK	1/2	1	672	336	693.00	770.00
10	QPSK	1/2	2	1344	672	1386.00	1540.00
11	QPSK	3/4	2	1344	1008	2079.00	2310.00
12	16-QAM	1/2	4	2688	1344	2772.00	3080.00
13	16-QAM	3/4	4	2688	2016	4158.00	4620.00
14	64-QAM	5/8	6	4032	2520	5197.50	5775.00
15	64-QAM	3/4	6	4032	3024	6237.00	6930.00
16	64-QAM	13/16	6	4032	3276	6756.75	7507.50

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Table 25-52—CMMG OFDM MCSs for optional 1080 MHz, N_{ss}=3 (Optional)

MCS index	Modulation	R	N_{CBPS}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
						Long GI	Short GI
9	BPSK	1/2	1	1008	504	1039.50	1155.00
10	QPSK	1/2	2	2016	1008	2079.00	2310.00
11	QPSK	3/4	2	2016	1512	3118.50	3465.00
12	16-QAM	1/2	4	4032	2016	4158.00	4620.00
13	16-QAM	3/4	4	4032	3024	6237.00	6930.00
14	64-QAM	5/8	6	6048	3780	7796.25	8662.50
15	64-QAM	3/4	6	6048	4536	9355.50	10 395.00
16	64-QAM	13/16	6	6048	4914	10 135.13	11 261.25

Table 25-53—CMMG OFDM MCSs for optional 1080 MHz, N_{ss}=4 (Optional)

MCS index	Modulation	R	N_{CBPS}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s)	
						Long GI	Short GI
9	BPSK	1/2	1	1344	672	1386.00	1540.00
10	QPSK	1/2	2	2688	1344	2772.00	3080.00
11	QPSK	3/4	2	2688	2016	4158.00	4620.00
12	16-QAM	1/2	4	5376	2688	5544.00	6160.00
13	16-QAM	3/4	4	5376	4032	8316.00	9240.00
14	64-QAM	5/8	6	8064	5040	10 395.00	11 550.00
15	64-QAM	3/4	6	8064	6048	12 474.00	13 860.00
16	64-QAM	13/16	6	8064	6552	13 513.50	15 015.00

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Annex A

(informative)

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[55] ISO publications are available from the ISO Central Secretariat (http://www.iso.ch/).

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[56] ISO/IEC publications are available from the ISO Central Secretariat (http://www.iso.ch/). ISO/IEC publications are also available in the United States from the American National Standards Institute (http://www.ansi.org/).

[57] ITU publications are available from the International Telecommunication Union (https://www.itu.int).

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Annex B

(normative)

Protocol Implementation Conformance Statement (PICS) proforma

B.1 Introduction

The supplier of a protocol implementation that is claimed to comply with IEEE Std 802.11-2020 shall complete the following protocol implementation conformance statement (PICS) proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. This annex might not be compatible with operation in any Regulatory Domain or describe combinations of usable features in any Regulatory Domain. The PICS has a number of uses, including use:

a) By the protocol implementer, as a checklist to reduce the risk of failure to comply with the standard through oversight;

b) By the supplier and acquirer, or potential acquirer, of the implementation, as a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard PICS proforma;

c) By the user, or potential user, of the implementation, as a basis for initially checking the possibility of interworking with another implementation (note that, while interworking is not guaranteed, failure to interwork can often be predicted from incompatible PICS proformas);

d) By a protocol tester, as the basis for selecting appropriate tests against which to assess the claim for compliance of the implementation.

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B.2 Abbreviations and special symbols

B.2.1 Symbols for Status column

M mandatory
O optional
O.<n> optional — Support of at least one of the group of options labeled by the same numeral <n> is required. The scope of the group of options is limited to a single table (i.e., subclause) within the PICS.
pred: predicate identification

B.2.2 General abbreviations for Item and Support columns

N/A not applicable
AD address function
AVT audio video transport
CDMG-M China directional multi-gigabit (CDMG) medium access control (MAC) features
CDMG-P China directional multi-gigabit (CDMG) physical layer (PHY) features
CMMG-M China Millimeter-wave multi-gigabit (CMMG) medium access control (MAC) features
CMMG-P China Millimeter-wave multi-gigabit (CMMG) physical layer (PHY) features
CF implementation under test (IUT) configuration

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DMG-M	directional multi-gigabit (DMG) medium access control (MAC) features
DMG-P	directional multi-gigabit (DMG) physical layer (PHY) features
DS	direct sequence
DSE	dynamic station enablement
ERP	extended rate physical layer (PHY)
FILS	fast initial link setup
FR	frame reception
FS	frame exchange sequence
FT	frame transmission
HRDS	high rate direct sequence
HTM	high-throughput (HT) medium access control (MAC) features
HTP	high-throughput (HT) physical layer (PHY) features
HWM	hybrid wireless mesh protocol (HWMP) path selection protocol capability
IW	interworking with external networks
MD	multidomain
MP	mesh protocol
OC	operating classes
OF	orthogonal frequency division multiplexing (OFDM)
PAD	preassociation discovery
PC	protocol capability
RL	S1G Relay features
RM	radio management
QB	quality-of-service (QoS) base functionality
QD	quality-of-service (QoS) enhanced distributed channel access (EDCA)
QMF	quality-of-service Management frame
QP	quality-of-service (QoS) hybrid coordination function (HCF) controlled channel access (HCCA)
SIGM	Sub 1 GHz (S1G) medium access control (MAC) features
SIGP	Sub 1 GHz (S1G) physical layer (PHY) features
SM	spectrum management
TDLS	tunneled direct-link setup
TVHTM	television very high throughput medium access control (MAC) features
TVHTP	television very high throughput physical layer (PHY) features
TVWS	television white spaces
VHTM	Very high throughput MAC
VHTP	Very high throughput PHY
WNM	wireless network management

B.3 Instructions for completing the PICS proforma

B.3.1 General structure of the PICS proforma

The first parts of the PICS proforma, Implementation identification and Protocol summary, are to be completed as indicated with the information necessary to identify fully both the supplier and the implementation.

The main part of the PICS proforma is a fixed questionnaire, divided into subclauses, each containing a number of individual items. Answers to the questionnaire items are to be provided in the rightmost column, either by simply marking an answer to indicate a restricted choice (usually Yes or No) or by entering a value or a set or a range of values. (Note that there are some items where two or more choices from a set of possible answers may apply. All relevant choices are to be marked in these cases.)

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Each item is identified by an item reference in the first column. The second column contains the question to be answered. The third column contains the reference or references to the material that specifies the item in the main body of this standard. The remaining columns record the status of each item, i.e., whether support is mandatory, optional, or conditional, and provide the space for the answers (see also B.3.4). Marking an item as supported is to be interpreted as a statement that all relevant requirements of the subclauses and normative annexes, cited in the References column for the item, are met by the implementation.

A supplier may also provide, or be required to provide, further information, categorized as either Additional Information or Exception Information. When present, each kind of further information is to be provided in a further subclause of items labeled A<*I*> or X<*I*>, respectively, for cross-referencing purposes, where <*I*> is any unambiguous identification for the item (e.g., simply a numeral). There are no other restrictions on its format or presentation.

A completed PICS proforma, including any Additional Information and Exception Information, is the PICS for the implementation in question.

NOTE—Where an implementation is capable of being configured in more than one way, a single PICS might be able to describe all such configurations. However, the supplier has the choice of providing more than one PICS, each covering some subset of the implementation's capabilities, if this makes for easier and clearer presentation of the information.

B.3.2 Additional information

Items of Additional Information allow a supplier to provide further information intended to assist in the interpretation of the PICS. It is not intended or expected that a large quantity of information will be supplied, and a PICS can be considered complete without any such information. Examples of such Additional Information might be an outline of the ways in which an (single) implementation can be set up to operate in a variety of environments and configurations, or information about aspects of the implementation that are outside the scope of this standard but have a bearing upon the answers to some items.

References to items of Additional Information may be entered next to any answer in the questionnaire, and may be included in items of Exception Information.

B.3.3 Exception information

It may happen occasionally that a supplier wishes to answer an item with mandatory status (after any conditions have been applied) in a way that conflicts with the indicated requirement. No preprinted answer is found in the Support column for this. Instead, the supplier shall write the missing answer into the Support column, together with an X<*I*> reference to an item of Exception Information, and shall provide the appropriate rationale in the Exception Information item itself.

An implementation for which an Exception Information item is required in this way does not comply with this standard.

NOTE—A possible reason for the situation described above is that a defect in this standard has been reported, a correction for which is expected to change the requirement not met by the implementation.

B.3.4 Conditional status

The PICS proforma contains a number of conditional items. These are items for which both the applicability of the item itself, and its status if it does apply, mandatory or optional, are dependent upon whether certain other items are supported.

Where a group of items is subject to the same condition for applicability, a separate preliminary question about the condition appears at the head of the group, with an instruction to skip to a later point in the

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questionnaire if the N/A answer is selected. Otherwise, individual conditional items are indicated by a conditional symbol in the Status column.

A conditional symbol is of the form "<pred>:<S>" or "O" (or "O.<n>"), where "<pred>" is a predicate as described below, and "<S>" is one of the status symbols "M" or "O" (or "O.<n>").

If the value of a predicate is true, the conditional symbol is applicable, and yields the status given by S. If any applicable conditional symbol yields mandatory status, the conditional item has mandatory status. Otherwise, if any applicable conditional symbol [including one of the form "O" (or "O.<n>")] yields optional status, the conditional item has optional status. In either case, the support column is to be completed in the usual way. If no conditional symbol is applicable, the conditional item is not relevant and the N/A answer is to be marked.

A predicate is one of the following:

a) An item-reference for an item in the PICS proforma: the value of the predicate is true if the item is marked as supported and is false otherwise.

b) An expression constructed by combining item-references using the boolean operators (in decreasing order of precedence) "NOT", "AND", and "OR", with or without the use of parenthetical groupings: the value of the predicate is true if the expression evaluates to true and is false otherwise.

NOTE—If optional feature F1 requires features F2 and F3, this can be represented in the PICS in one of two ways:
— The status for conditional items F2 and F3 is "F1:M" and the status for conditional item F1 is "O", or
— The status for conditional item F1 is "F2 AND F3:O".

If feature F1 is required if feature F2 or F3 is supported, and is optional otherwise, this can be represented in the PICS in one way:
— The status for conditional item F1 is "F2 OR F3:M" and "O".

If feature F1 is required if feature F2 or F3 is supported, and is not relevant otherwise, this can be represented in the PICS in one way:
— The status for conditional item F1 is "F2 OR F3:M".

If feature F1 is required if feature F2 is supported, is optional if feature F3 is supported, and is not relevant otherwise, this can be represented in the PICS in one way:
— The status for conditional item F1 is "F2:M" and "F3:O".

Conditional symbols can be given in any order.

Each item referenced in a predicate, or in a preliminary question for grouped conditional items, is indicated by an asterisk in the Item column.

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B.4 PICS proforma—IEEE Std 802.11-2020[58]

B.4.1 Implementation identification

Supplier	
Contact point for queries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification, e.g., name(s) and version(s) of the machines and/or operating system(s), system names	

NOTE 1—Only the first three items are required for all implementations. Other information might be completed as appropriate in meeting the requirement for full identification.

NOTE 2—The terms Name and Version need to be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).

B.4.2 Protocol summary

Identification of protocol standard	IEEE Std 802.11-2020
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	Amd. : Corr. : Amd. : Corr. :
Have any exception items been required? (See B.3.3; the answer Yes means that the implementation does not comply with IEEE Std 802.11-2020.)	Yes ☐ No ☐

Date of statement (yyyy-mm-dd)	

[58] *Copyright release for PICS proforma:* Users of this standard may freely reproduce the PICS proforma in this annex so that it can be used for its intended purpose and may further publish the completed PICS.

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B.4.3 IUT configuration

Item	IUT configuration	References	Status	Support
	What is the configuration of the IUT?			
* CFAP	Access point (AP)	4.3	O.1	Yes ☐ No ☐
* CFIndepSTA	Independent station (neither an AP, nor a mesh STA, nor a STA operating outside the context of a BSS)	4.3	O.1	Yes ☐ No ☐
*CFSTAofAP	Operation in an infrastructure BSS	4.3	CFIndepSTA: M	Yes ☐ No ☐ N/A ☐
*CFIBSS	Operation in an independent BSS (IBSS)	4.3	CFIndepSTA: O	Yes ☐ No ☐ N/A ☐
*CFPBSS	Operation in a PBSS	4.3.3	CFIndepSTA AND CFDMG:M CFDMG:O.7	
*CFPCP	Operation as a PCP	4.3.3	CFPBSS:M	Yes ☐ No ☐
*CFPBSSnotPCP	Operation *not* as a PCP	4.3.3	CFPBSS:M	Yes ☐ No ☐
NOTE—See CFMBSS for mesh STA and CFOCB for OCB operation.				
* CFDSSS.	Direct sequence spread spectrum (DSSS) PHY for the 2.4 GHz band	—	O.2 CFHRDSSS: M	Yes ☐ No ☐
* CFOFDM	Orthogonal frequency division multiplexing (OFDM) PHY	—	O.2 CFHT5G:M CFTVHT:M CFS1G:M	Yes ☐ No ☐
* CFHRDSSS	High rate direct sequence spread spectrum (HR/DSSS) PHY	—	O.2 CFERP:M	Yes ☐ No ☐
* CFMD	Multidomain operation capability implemented	10.22	O	Yes ☐ No ☐
* CFERP	Extended Rate PHY (ERP)	Clause 18	O.2 CF2G4:M	Yes ☐ No ☐
* CFSM	Spectrum management	9.4.1.4, 11.7, 11.8	O	Yes ☐ No ☐
*CFOC	Operating classes capability implemented	9.4.2.9, 17.3.8.4.2, 17.3.8.6, 17.4.2 Annex D, Annex E	O	Yes ☐ No ☐ N/A ☐
* CFQoS	Quality of service (QoS)	10.23, 10.25, 4.3.13, 4.3.21.3	O CFHT OR CFMBSS OR CFQMF OR CFAVT:M CFDMG:M CFTVHT:M CFS1G:M	Yes ☐ No ☐ N/A ☐

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B.4.3 IUT configuration *(continued)*

Item	IUT configuration	References	Status	Support
* CFRM	Radio Measurement	9.4.1.4, 11.10	(CFMD AND CFOC):O	Yes ☐ No ☐ N/A ☐
*CFInfraSTA	Infrastructure mode	4.3.4	CFAP OR CFSTAofAP: M CFDMG:O.7	Yes ☐ No ☐ N/A ☐
*CF3G6	3.65–3.70 GHz band in the United States	9.4.2.51, 11.11, 17.3.6, 17.3.10.6, Annex D, Annex E	CFOFDM AND CFMD AND CFSM AND CFOC:O	Yes ☐ No ☐ N/A ☐
*CFHT	High-throughput (HT) PHY	9.4.2.55	O.2 CFVHT:M	Yes ☐ No ☐
* CFHT2G4	HT operation in 2.4 GHz band	Clause 19	CFHT:O.6	Yes ☐ No ☐ N/A ☐
* CFHT5G	HT operation in 5 GHz band	Clause 19	CFHT:O.6 CFVHT:M	Yes ☐ No ☐ N/A ☐
*CF5G9	5.9 GHz band	Annex E	CFOFDM:O	Yes ☐ No ☐ N/A ☐
*CFTDLS	Tunneled direct-link setup supported	11.20	O	Yes ☐ No ☐ N/A ☐
*CFWNM	Wireless network management (WNM)		((CFMD AND CFOC AND CFRM):O	Yes ☐ No ☐ N/A ☐
*CFIW	Interworking with external networks service	9.4.2.26	O	Yes ☐ No ☐
*CFMBSS	Operation in a mesh BSS (MBSS)	4.3.21	(NOT CFDMG) AND (NOT CFS1G):O.1	Yes ☐ No ☐ N/A ☐
* CFS1G	Sub 1 GHz (S1G) features	9.4.2.200	O.2	Yes ☐ No ☐ N/A ☐
* CFS1GRelay	S1G relay	10.54	(CFAP AND CFIndepSTA): O	Yes ☐ No ☐ N/A ☐
*CFQMF	QoS management frame (QMF) policy	11.24	O	Yes ☐ No ☐ N/A ☐
*CFAVT.	Robust audio/video transport (AVT)	4.3.24	O	Yes ☐ No ☐
*CFDMG	Directional multi-gigabit (DMG) PHY	9.4.2.127	O.2 CFDMG:M	Yes ☐ No ☐
*CFMBO	Multi-band operation	9.6.20, 11.30	At least two of CFDSSS, CFOFDM, CF3G6, CF5G9, CFDMG:O	Yes ☐ No ☐ N/A ☐
*CFVHT	Very High Throughput (VHT) features	9.4.2.157	O.2	Yes ☐ No ☐
*CFTVHT	TVWS Operation	Annex D, Annex E	O	Yes ☐ No ☐
*CFOCB	Operation outside the context of a BSS (OCB)	11.18	O.1 CF5G9:M	Yes ☐ No ☐

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B.4.3 IUT configuration *(continued)*

Item	IUT configuration	References	Status	Support
*CFESM	Extended spectrum management	10.22.3	O CFVHT OR CFTVHT:M	Yes ☐ No ☐
*CFFILS	Fast Initial Link Setup (FILS)	11.45	O	Yes ☐ No ☐
*CFCDMG	China directional multi-gigabit (CDMG) PHY	9.4.2.219	O.2 CFCDMG:M	Yes ☐ No ☐
*CFCMMG	China Millimeter-wave multi-gigabit (CMMG) PHY	9.4.2.229	O.2 CFCMMG:M	Yes ☐ No ☐
*CFGLK	GLK enabled STA	11.50	(NOT CFOCB):O	Yes ☐ No ☐ N/A ☐
CFGLK.1	GLK-GCR	11.21.16.4	CFGLK:O	Yes ☐ No ☐ N/A ☐
CFPAD	Preassociation discovery	11.23	O	Yes ☐ No ☐ N/A ☐

B.4.4 MAC protocol

B.4.4.1 MAC protocol capabilities

Item	Protocol capability	References	Status	Support
	Are the following MAC protocol capabilities supported?			
PC1	Authentication service	4.5.4.2, 4.5.4.3, 11.18, 12.2	CFInfraSTA AND not CFDMG:M CFIBSS OR CFDMG:M	Yes ☐ No ☐ N/A ☐
PC1.1	Authentication state	11.3	PC1:M	Yes ☐ No ☐
PC1.2	Open System authentication	12.2.2	PC1 AND not CFDMG:M	Yes ☐ No ☐
PC1.3	Shared Key authentication	12.2.3, 12.5	PC2:M	Yes ☐ No ☐ N/A ☐
* PC2	Wired equivalent privacy (WEP) algorithm. This capability is obsolete. Support for this mechanism might be removed in a later revision of the standard.	4.5.4.4, 12.3.2	O	Yes ☐ No ☐
PC2.1	WEP encryption procedure	12.3.2	PC2:M	Yes ☐ No ☐ N/A ☐
PC2.2	WEP decryption procedure	12.3.2	PC2:M	Yes ☐ No ☐ N/A ☐
PC3	Distributed coordination function (DCF)	10.2, 10.3	M	Yes ☐ No ☐
PC3.1	Network allocation vector (NAV) function	10.3.2.1, 10.3.4	M	Yes ☐ No ☐
PC3.2	Interframe space usage and timing	10.3.2.3, 10.3.4, 10.3.7	M	Yes ☐ No ☐
PC3.3	Random Backoff function	10.3.3	M	Yes ☐ No ☐
PC3.4	DCF Access procedure	10.3.4.2, 10.3.4.5	M	Yes ☐ No ☐

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B.4.4.1 MAC protocol capabilities *(continued)*

Item	Protocol capability	References	Status	Support
PC3.5	Random Backoff procedure	10.3.4.3	M	Yes ☐ No ☐
PC3.6	Recovery procedures and retransmit limits	10.3.4.4	M	Yes ☐ No ☐
PC3.7	Request to send (RTS)/clear to send (CTS) procedure	10.3.2.4, 10.3.2.6, 10.3.2.9	M	Yes ☐ No ☐
PC3.8	Individually addressed MAC protocol data unit (MPDU) transfer	10.3.5	M	Yes ☐ No ☐
PC3.9	Group addressed MPDU transfer	10.3.6	M	Yes ☐ No ☐
PC3.10	MAC-level acknowledgment	10.3.2.2, 10.3.2.11	M	Yes ☐ No ☐
PC3.11	Duplicate detection and recovery	10.3.2.14	M	Yes ☐ No ☐
PC3.12	Dynamic EIFS	10.3.7	O	Yes ☐ No ☐
PC6	Fragmentation	10.3, 10.4	M	Yes ☐ No ☐
PC7	Defragmentation	10.3, 10.5	M	Yes ☐ No ☐
PC8	MAC data service	10.2.7, 10.7	M	Yes ☐ No ☐
PC8.1	ReorderableGroupAddressed service class	10.7	M	Yes ☐ No ☐
PC9	Multirate support	10.6	M	Yes ☐ No ☐
PC9.1	Rate selection using Rx Supported VHT-MCS and NSS Set / Tx Supported VHT-MCS and NSS Set	10.6.13.1, 10.6.13.2	CFVHT:M CFTVHT:M	Yes ☐ No ☐ N/A ☐
PC9.2	Rate selection constraints for VHT PPDUs	10.6.13.3	CFVHT:O CFTVHT:O	Yes ☐ No ☐ N/A ☐
* PC10	Multiple outstanding MAC service data unit (MSDU) support	10.7	O	Yes ☐ No ☐
PC10.1	Multiple outstanding MSDU transmission restrictions	10.7	PC10:M	Yes ☐ No ☐ N/A ☐
PC11	Timing synchronization function (TSF)	11.1	CFAP OR CFIndepSTA:M	Yes ☐ No ☐
PC11.1	Timing in an infrastructure network	11.1.2.1, 11.1.5	CFInfraSTA:M	Yes ☐ No ☐ N/A ☐
PC11.2	Timing in an independent basic service set (IBSS)	11.1.2.2, 11.1.5	CFIBSS:M	Yes ☐ No ☐ N/A ☐
PC11.3	Beacon generation function	11.1.3	CFAP OR CFIBSS OR CFPCP:M	Yes ☐ No ☐
PC11.4	TSF synchronization and accuracy	11.1.2, 11.1.3	CFAP OR CFIndepSTA:M	Yes ☐ No ☐ N/A ☐
PC11.5	Infrastructure basic service set (BSS) initialization	11.1.4	CFAP:M	Yes ☐ No ☐ N/A ☐
PC11.6	IBSS initialization	11.1.4	CFIBSS:M	Yes ☐ No ☐ N/A ☐

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B.4.4.1 MAC protocol capabilities *(continued)*

Item	Protocol capability	References	Status	Support
PC11.7	Passive scanning	11.1.4	(CFSTAofAP OR CFIBSS OR CFPBSSnotPCP):O.1	Yes ☐ No ☐ N/A ☐
PC11.8	Active scanning	11.1.4	(CFSTAofAP OR CFIBSS OR CFPBSSnotPCP):O.1	Yes ☐ No ☐ N/A ☐
PC11.9	Probe response	11.1.4	(NOT CFOCB):M	Yes ☐ No ☐ N/A ☐
PC11.10	*Reserved*			
PC12	Infrastructure power management	11.2.3	CFInfraSTA AND not CFDMG:M	Yes ☐ No ☐ N/A ☐
PC12.1	STA power management modes	11.2.3.2, 11.2.3.7	(CFSTAofAP or CFIBSS):M	Yes ☐ No ☐ N/A ☐
PC12.2	Traffic indication map (TIM) transmission	11.2.3.3, 11.2.3.4	CFAP:M	Yes ☐ No ☐ N/A ☐
PC12.3	AP function	11.2.3.6	CFAP:M	Yes ☐ No ☐ N/A ☐
PC12.4	Reserved			
PC12.5	Non-AP STA receive function	11.2.3.7	CFSTAofAP:M	Yes ☐ No ☐ N/A ☐
PC12.6	Reserved			
PC12.7	Aging function	11.2.3.10	CFAP:M	Yes ☐ No ☐ N/A ☐
PC13	IBSS power management. This capability is deprecated.	11.2.4	CFIBSS:M	Yes ☐ No ☐ N/A ☐
PC13.1	Initialization of power management	11.2.4.3	CFIBSS:M	Yes ☐ No ☐ N/A ☐
PC13.2	STA power state transitions	11.2.4.4	CFIBSS:M	Yes ☐ No ☐ N/A ☐
PC13.3	Announcement traffic indication message (ATIM) and frame transmission	11.2.4.4 f)	CFIBSS:M	Yes ☐ No ☐ N/A ☐
*PC14	(Re)Association	4.5, 11.3, 11.3.5,	CFInfraSTA OR CFPCP:M CFPBSSnotPCP:O	Yes ☐ No ☐ N/A ☐
PC14.1	Association state	11.3.5	PC14:M	Yes ☐ No ☐ N/A ☐
PC14.2	STA association procedure	11.3.5.2	CFSTAofAP:M CFPBSSnotPCP:O	Yes ☐ No ☐ N/A ☐
PC14.3	AP association procedure	11.3.5.3	CFAP OR CFPCP:M	Yes ☐ No ☐ N/A ☐

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B.4.4.1 MAC protocol capabilities *(continued)*

Item	Protocol capability	References	Status	Support
PC14.4	STA reassociation procedure	11.3.5.4	CFSTAofAP: M CFPBSSnotPCP:O	Yes ☐ No ☐ N/A ☐
PC14.5	AP reassociation procedure	11.3.5.5	CFAP OR CFPCP:M	Yes ☐ No ☐ N/A ☐
PC15	Management information base (MIB)	Annex C	M	Yes ☐ No ☐
PC15.1	dot11SMTbase, dot11SmtAuthenticationAlgorithms	Annex C	M	Yes ☐ No ☐
* PC15.2	dot11SMTprivacy	Annex C	PC2:M	Yes ☐ No ☐ N/A ☐
PC15.3	dot11MACbase, dot11CountersGroup, dot11GroupAddressesTable	Annex C	M	Yes ☐ No ☐
* PC15.4	dot11MACStatistics	Annex C	O	Yes ☐ No ☐
PC15.5	dot11ResourceTypeID	Annex C	M	Yes ☐ No ☐
PC16	Set dot11ShortPreambleOptionImplemented to 1	9.4.1.4	CFERP:M	Yes ☐ No ☐ N/A ☐
PC17	*Reserved*			
PC18	*Reserved*			
PC19	*Reserved*			
PC20	Set Short Slot Time subfield as described in reference	9.4.1.4	CFERP:M	Yes ☐ No ☐ N/A ☐
PC21	Monitor each received ShortTime Slot subfield and take action as described in reference.	9.4.1.4	CFERP:M	Yes ☐ No ☐ N/A ☐
PC22	Transmit the ERP element in each transmitted Beacon or Probe Response frame in the format and with content as described in reference.	9.4.1.4	CFERP:M	Yes ☐ No ☐ N/A ☐
PC23	Receive the ERP element and employ a protection mechanism when required prior to transmitting information using ERP-OFDM modulation	9.4.1.4	CFERP:M	Yes ☐ No ☐ N/A ☐
PC24	Determine the value of aCWmin based on the characteristic rate set as described in the reference	10.3.9	CFERP:M	Yes ☐ No ☐ N/A ☐
PC25	Transmit control response frames at the largest basic rates less than equal to the rate received and with the same PHY options or use the highest mandatory rate if no basic rate meets the above criterion	10.6	CFERP:M	Yes ☐ No ☐ N/A ☐
PC26	Transmit group addressed frames at a rate contained in the BSSBasicRateSet parameter	10.6	CFERP:M	Yes ☐ No ☐ N/A ☐

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B.4.4.1 MAC protocol capabilities *(continued)*

Item	Protocol capability	References	Status	Support
PC27	Transmit individually addressed frames at any supported rate selected by a rate switching mechanism as long as it is supported by the destination STA	10.6	CFERP:M	Yes ☐ No ☐ N/A ☐
PC28	*Reserved*			
PC29	Use ERP element to control use of protection mechanism as described in the reference	10.27	CFERP:M	Yes ☐ No ☐ N/A ☐
PC30	Updated NAV is long enough to cover frame and any response	10.27	CFERP:M	Yes ☐ No ☐ N/A ☐
PC31	Support transmission of CTS-to-self sequence as described in the references	10.3.2.15	CFERP:O CFTVHT:O	Yes ☐ No ☐ N/A ☐
PC32	Support reception of CTS-to-self sequence as described in the references	10.3.2.15	CFERP:M CFTVHT:M	Yes ☐ No ☐ N/A ☐
PC33	Update NAV	10.27	CFERP:M	Yes ☐ No ☐ N/A ☐
* PC34	Robust security network association (RSNA)	9.3.2.1, 9.4.1.4, 4.5.4.4, 11.3.4, 11.3.5, 12.5.3	O	Yes ☐ No ☐
PC34.1	RSNE	9.4.2.24	PC34:M	Yes ☐ No ☐ N/A ☐
PC34.1.1	Group cipher suite	9.4.2.24	PC34.1:M	Yes ☐ No ☐ N/A ☐
PC34.1.2	Pairwise cipher suite list	9.4.2.24	PC34.1:M	Yes ☐ No ☐ N/A ☐
PC34.1.2.1	Counter mode with cipher-block chaining message authentication code protocol (CCMP) data confidentiality protocol using CCMP-128	12.5.3	PC34:M	Yes ☐ No ☐ N/A ☐
PC34.1.2.1.1	CCMP cryptographic encapsulation procedure using CCMP-128	12.5.3.3	PC34.1.2.1:M	Yes ☐ No ☐ N/A ☐
PC34.1.2.1.2	CCMP decapsulation procedure using CCMP-128	12.5.3.4	PC34.1.2.1:M	Yes ☐ No ☐ N/A ☐
PC34.1.2.2	Temporal key integrity protocol (TKIP) data confidentiality protocol. This capability is deprecated (applicable only to systems that are backward compatible).	12.5.2	PC34:O	Yes ☐ No ☐ N/A ☐
PC34.1.2.2.1	TKIP cryptographic encapsulation procedure	12.5.2.1.2	PC34.1.2.2:M	Yes ☐ No ☐ N/A ☐
PC34.1.2.2.2	TKIP decapsulation procedure	12.5.2.1.3	PC34.1.2.2:M	Yes ☐ No ☐ N/A ☐
PC34.1.2.2.3	TKIP countermeasures	12.5.2.4	PC34.1.2.2:M	Yes ☐ No ☐ N/A ☐

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B.4.4.1 MAC protocol capabilities *(continued)*

Item	Protocol capability	References	Status	Support
PC34.1.2.2.4	TKIP security services management	12.5.2.3	PC34.1.2.2:M	Yes ☐ No ☐ N/A ☐
PC34.1.2.3	Galois/counter mode protocol (GCMP)	12.5.5	(CFDMG and PC34):M	Yes ☐ No ☐ N/A ☐
*PC34.1.3	Authentication key management (AKM) suite list	9.4.2.24, 12.5.1	PC34.1:M	Yes ☐ No ☐ N/A ☐
PC34.1.3.1	IEEE 802.1X-defined/RSNA key management	9.4.2.24	PC34.1:M	Yes ☐ No ☐ N/A ☐
PC34.1.3.2	Preshared key (PSK)/ RSNA key management	9.4.2.24	PC34.1:M	Yes ☐ No ☐ N/A ☐
PC34.1.3.3	RSNA key management	12.7	PC34.1:M	Yes ☐ No ☐ N/A ☐
PC34.1.3.3.1	Key hierarchy	12.7, 12.8	PC34.1:M	Yes ☐ No ☐ N/A ☐
PC34.1.3.3.1.1	Pairwise key hierarchy	12.7.1.3	PC34.1:M	Yes ☐ No ☐ N/A ☐
PC34.1.3.3.1.2	Group key hierarchy	12.7.1.4	PC34.1:M	Yes ☐ No ☐ N/A ☐
PC34.1.3.3.2	4-way handshake	12.7.6	PC34.1:M	Yes ☐ No ☐ N/A ☐
PC34.1.3.3.3	Group key handshake	12.7.7	PC34.1:M	Yes ☐ No ☐ N/A ☐
PC34.1.4	RSN capabilities	9.4.2.24, 12.2.3	PC34.1:M	Yes ☐ No ☐ N/A ☐
PC34.1.5	RSNA preauthentication	12.6.10.2	PC34.1:O	Yes ☐ No ☐ N/A ☐
PC34.1.6	RSNA security association management	12.6	PC34.1:M	Yes ☐ No ☐ N/A ☐
PC34.1.7	RSNA pairwise master key security association (PMKSA) caching	12.6.1, 12.6.10.3	PC34.1:M	Yes ☐ No ☐ N/A ☐
PC34.1.8	RSNA extended service set (ESS)	12.6.10, 12.6.14	(PC34.1 and CFAP):M	Yes ☐ No ☐ N/A ☐
PC34.1.9	RSNA IBSS	12.6.5, 12.6.11, 12.6.15	(PC34.1 and CFIBSS):O	Yes ☐ No ☐ N/A ☐
*PC34.1.10	Management frame protection	9.2.4.1.10, 9.4.1.11, 9.4.2.24.4, 9.6.3, 12.3.3.3.5, 12.5.2.1.2, 12.5.2.1.3, 12.5.2.2, 12.5.3.3.3, 12.5.3.3.7, 12.5.3.4.2, 12.5.3.4.4, 12.6.3	PC34:O	Yes ☐ No ☐ N/A ☐
*PC34.1.10.1	BIP	Clause 11, 12.5.4	PC34.1.10:M	Yes ☐ No ☐ N/A ☐
PC34.1.10.1.1	Management MIC element	9.4.2.54	PC34.1.10.1: M	Yes ☐ No ☐ N/A ☐

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B.4.4.1 MAC protocol capabilities *(continued)*

Item	Protocol capability	References	Status	Support
PC 34.1.10.1.2	Beacon protection	11.52; 12.6.23	PC34.1.10.1: O	Yes ☐ No ☐ N/A ☐
PC34.1.11	AKM: IEEE 802.1X authentication with SHA-256 PRF	9.4.2.24, 12.7	PC34:O	Yes ☐ No ☐ N/A ☐
PC34.1.12	AKM: PSK with SHA-256 PRF	9.4.2.24, 12.7	PC34:O	Yes ☐ No ☐ N/A ☐
PC34.1.13	RSNA rekeying	12.6.21	PC34:O	Yes ☐ No ☐ N/A ☐
PC34.1.14	Multi-band RSNA	12.6.22	CFMBO AND PC34:M	Yes ☐ No ☐ N/A ☐
*PC35	Fast basic service set (BSS) transition (FT)	Clause 13	CFInfraSTA: O	Yes ☐ No ☐ N/A ☐
PC35.1	Mobility Domain element (MDE)	9.4.2.46	PC35:M	Yes ☐ No ☐ N/A ☐
PC35.2	Fast basic service set (BSS) Transition element (FTE)	9.4.2.47	PC35 AND PC34:M	Yes ☐ No ☐ N/A ☐
PC35.3	Timeout Interval element (TIE)	9.4.2.48	PC35:M	Yes ☐ No ☐ N/A ☐
PC35.4	Fast basic service set (BSS) Transition (FT) authentication algorithm	9.4.1.1	PC35:M	Yes ☐ No ☐ N/A ☐
PC35.5	Fast basic service set (BSS) Transition (FT) Action frames	9.6.8	PC35:M	Yes ☐ No ☐ N/A ☐
PC35.6	Fast basic service set (BSS) Transition (FT) key management based on IEEE Std 802.1X	9.4.2.24, 12.7.1.6	PC35 AND PC34:M	Yes ☐ No ☐ N/A ☐
PC35.7	Fast basic service set (BSS) Transition (FT) key management based on preshared keys (PSKs)	9.4.2.24, 12.7.1.6	PC35 AND PC34:M	Yes ☐ No ☐ N/A ☐
PC35.8	Fast basic service set (BSS) Transition (FT) key hierarchy	12.7.1.6	PC35 AND PC34:M	Yes ☐ No ☐ N/A ☐
PC35.9	FT initial mobility domain association	13.4	PC35 AND PC34:M	Yes ☐ No ☐ N/A ☐
PC35.10	Fast Basic Service Set (BSS) Transition (FT) Protocol	13.5	PC35:M	Yes ☐ No ☐ N/A ☐
PC35.10.1	Fast Basic Service Set (BSS) Transition (FT) Protocol in robust security network (RSN)	13.5.2, 13.5.3, 13.7.1	PC35 AND PC34:M	Yes ☐ No ☐ N/A ☐
PC35.10.2	Fast Basic Service Set (BSS) Transition (FT) Protocol in nonrobust security network (non-RSN)	13.5.4, 13.5.5, 13.7.2	PC35:M	Yes ☐ No ☐ N/A ☐
*PC35.11	Fast Basic Service Set (BSS) transition (FT) resource request protocol	13.6	PC35:O	Yes ☐ No ☐ N/A ☐
PC35.11.1	Resource Request protocol over the air	13.6.2	PC35.11:M	Yes ☐ No ☐ N/A ☐
PC35.11.2	Resource Request protocol over the distribution system (DS)	13.6.3, 13.10	PC35.11:M	Yes ☐ No ☐ N/A ☐

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B.4.4.1 MAC protocol capabilities *(continued)*

Item	Protocol capability	References	Status	Support
PC35.12	QoS procedures for fast basic service set (BSS) transition	13.11	(CFQoS AND PC35 or CFDMG AND PC35):M	Yes ☐ No ☐ N/A ☐
*PC35.13	Resource Information Container (RIC) Data element (RDE)	9.4.2.49, 13.11	PC35:M	Yes ☐ No ☐ N/A ☐
PC35.13.1	Resource Request Procedures at the fast basic service set (BSS) transition originator (FTO)	13.11.3.1	PC35.13:M	Yes ☐ No ☐ N/A ☐
PC35.13.2	Resource Request Procedures at the target access point (AP)	13.11.3.2	PC35.13:M	Yes ☐ No ☐ N/A ☐
*PC35.14	Remote Request Procedures at the current access point (AP)	13.10	PC35:M	Yes ☐ No ☐ N/A ☐
PC35.14.1	Remote Request/Response frame support	13.10.3	PC35.14:O	Yes ☐ No ☐ N/A ☐
PC35.14.2	Vendor-specific remote request broker (RRB) mechanism	13.10.3	PC35.14:O	Yes ☐ No ☐ N/A ☐
PC36	SA Query Procedure	9.6.9, 11.13	PC34.1.10:M	Yes ☐ No ☐ N/A ☐
*PC37	Power save multi-poll (PSMP) PSMP is obsolete. Support for this mechanism might be removed in a later revision of the standard.	9.6.11.4, 10.30	not CFDMG:O	Yes ☐ No ☐
*PC37.1	Scheduled PSMP	9.4.2.29, 11.4.6	PC37:M	Yes ☐ No ☐ N/A ☐
PC37.1.1	PSMP additions to TSPEC	9.4.2.29	PC37.1:M	Yes ☐ No ☐ N/A ☐
PC37.1.2	AP role in scheduled PSMP sequence	10.30.2.2, 10.30.2.3	(PC37.1 AND CFAP):M	Yes ☐ No ☐ N/A ☐
PC37.1.3	STA role in scheduled PSMP sequence	10.30.2.2, 10.30.2.3	(PC37.1 AND CFIndepSTA):M	Yes ☐ No ☐ N/A ☐
*PC37.2	Unscheduled PSMP	10.30.4	PC37:M	Yes ☐ No ☐ N/A ☐
PC37.2.1	PSMP additions to TSPEC	9.4.2.29	(CFAP AND PC37.2):M (CFIndepSTA AND PC37.2):O	Yes ☐ No ☐ N/A ☐
PC37.3	Creation, scheduling, and transmission of PSMP frame	9.6.11.4, 10.30.2.1	(PC37 AND CFAP):M	Yes ☐ No ☐ N/A ☐
PC37.4	Reception and interpretation of PSMP frame	9.6.11.4	(PC37 AND CFIndepSTA):M	Yes ☐ No ☐ N/A ☐
PC37.5	Multi-TID block ack rules in PSMP sequence	9.3.1.7.4, 9.3.1.8.3, 10.30.2.7	PC37:M	Yes ☐ No ☐ N/A ☐
PC37.6	Multi-phase PSMP	10.30.2.5	PC37:M	Yes ☐ No ☐ N/A ☐
PC38	dot11OCBActivated is false when STA is a BSS member	11.18	(CFSTAofAP OR CFIBSS):M	Yes ☐ No ☐ N/A ☐

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B.4.4.1 MAC protocol capabilities *(continued)*

Item	Protocol capability	References	Status	Support
PC39	Simultaneous authentication of equals (SAE)	12.4	CFMBSS:M	Yes ☐ No ☐ N/A ☐
*PC40	Multi-band Operation	11.31	CFMBO:O	Yes ☐ No ☐ N/A ☐
*PC40.1	FST Setup	9.4.2.138, 9.4.2.150, 9.4.2.151, 9.6.20.2, 9.6.20.3, 9.6.20.5, 9.6.20.6, 11.31.3.1, 11.31.3.2	PC40:M	Yes ☐ No ☐ N/A ☐
PC40.2	FST TS switching	9.4.2.29, 9.4.2.141, 9.6.3.2.2, 9.6.3.3.2, 9.6.3.4, 9.6.4.2, 9.6.4.3, 9.6.4.4, 11.31.3.3	PC40.1:M	Yes ☐ No ☐ N/A ☐
PC40.3	FST Teardown			
PC40.3.1	Transmission of FST Teardown	9.6.20.4, 11.31.4	PC40.1:O	Yes ☐ No ☐ N/A ☐
PC40.3.2	Reception of FST Teardown	9.6.20.4, 11.31.4	PC40.1:M	Yes ☐ No ☐ N/A ☐
PC41	MMSL cluster operation	11.32	O	Yes ☐ No ☐ N/A ☐
PC42	Quieting adjacent BSS operation	11.35	O	Yes ☐ No ☐ N/A ☐
PC43	Beacon RSSI	11.43	O	Yes ☐ No ☐ N/A ☐
PC44	Estimated throughput	11.44	O	Yes ☐ No ☐ N/A ☐
PC45	Operating Channel Information Validation	9.4.2.24, 12.7.6, 12.7.7, 14.5, 11.2.3.16, 9.6.9, 13.7, 13.8, 12.11.2.6.2, 12.11.2.6.3, 11.9.3.2, 12.7.2, 9.4.2.47	PC34:O	Yes ☐ No ☐
PC45.1	OCI Element	9.4.2.236	PC45:M	Yes ☐ No ☐ N/A ☐
PC45.2	OCI KDE	12.7.2	PC45:M	Yes ☐ No ☐ N/A ☐
PC45.3	OCI FTE subelement	9.4.2.47	PC45:M	Yes ☐ No ☐ N/A ☐

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B.4.4.2 MAC frames

Item	MAC frame	References	Status	Support
	Is transmission of the following MAC frames supported?	Clause 9		
FT1	Association Request	Clause 9	CFSTAofAP:M CFPBSSnotPCP:O	Yes ☐ No ☐ N/A ☐
FT2	Association Response	Clause 9	(CFAP OR CFPCP):M	Yes ☐ No ☐ N/A ☐
FT3	Reassociation Request	Clause 9	CFSTAofAP:M CFPBSSnotPCP:O	Yes ☐ No ☐ N/A ☐
FT4	Reassociation Response	Clause 9	(CFAP OR CFPCP):M	Yes ☐ No ☐ N/A ☐
FT5	Probe Request	Clause 9	(CFSTAofAP or CFIBSS OR CFPBSSnotPCP OR CFMBSS):M	Yes ☐ No ☐ N/A ☐
FT6	Probe Response	Clause 9	(CFAP OR CFIBSS OR CFPCP OR CFMBSS):M	Yes ☐ No ☐ N/A ☐
FT7	Beacon	Clause 9	(CFAP OR CFIBSS OR CFMBSS) AND (not CFDMG AND (NOT CFS1G)):M	Yes ☐ No ☐ N/A ☐
FT8	ATIM	Clause 9	CFIBSS:M	Yes ☐ No ☐ N/A ☐
FT9	Disassociation	Clause 9	CFInfraSTA:M CFPBSS:O	Yes ☐ No ☐ N/A ☐
FT10	Authentication	Clause 9	CFInfraSTA:M CFIBSS OR CFPBSS:O	Yes ☐ No ☐ N/A ☐
FT11	Deauthentication	Clause 9	(NOT CFOCB):M not CFDMG:M	Yes ☐ No ☐ N/A ☐
FT12	Power save (PS)-Poll	Clause 9	not CFDMG AND CFSTAofAP:M	Yes ☐ No ☐ N/A ☐
FT13	RTS	Clause 9	M	Yes ☐ No ☐
FT14	CTS	Clause 9	not CFDMG AND NOT CFS1G):M (CFS1G AND VHTM3.1):O	Yes ☐ No ☐
FT15	Acknowledgment (Ack)	Clause 9	NOT CFS1G:M CFS1G AND VHTM3.1 OR S1GM28):O	Yes ☐ No ☐
FT16	CF-End	Clause 9	not CFDMG	Yes ☐ No ☐ N/A ☐

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B.4.4.2 MAC frames *(continued)*

Item	MAC frame	References	Status	Support
FT17	*Reserved*			
FT18	Data	Clause 9	not CFDMG:M	Yes ☐ No ☐
FT19	*Reserved*			
FT20	*Reserved*			
FT21	*Reserved*			
FT22	Null	Clause 9	not CFDMG:M	Yes ☐ No ☐
FT23	*Reserved*			
FT24	*Reserved*			
FT25	*Reserved*			
FT26	Timing Advertisement frame	Clause 9	O	Yes ☐ No ☐
FT27	QoS Data	Clause 9	CFQoS:M	Yes ☐ No ☐ N/A ☐
FT28	QoS Null	Clause 9	CFQoS:M	Yes ☐ No ☐ N/A ☐
FT29	BlockAckReq	Clause 9	CFDMG:M CFQoS:O	Yes ☐ No ☐ N/A ☐
FT30	BlockAck	Clause 9	CFDMG:M CFQoS:O CFHT:M	Yes ☐ No ☐ N/A ☐
FT31	Poll	Clause 9	CFDMG:M	Yes ☐ No ☐ N/A ☐
FT32	SPR	Clause 9	CFDMG:M	Yes ☐ No ☐ N/A ☐
FT33	Grant	Clause 9	CFDMG:M	Yes ☐ No ☐ N/A ☐
FT34	DMG CTS	Clause 9	CFDMG:M	Yes ☐ No ☐ N/A ☐
FT35	DMG DTS	Clause 9	CFDMG:M	Yes ☐ No ☐ N/A ☐
FT36	SSW	Clause 9	CFDMG:M	Yes ☐ No ☐ N/A ☐
FT37	SSW-Feedback	Clause 9	CFDMG:M	Yes ☐ No ☐ N/A ☐
FT38	SSW-Ack	Clause 9	CFDMG:M	Yes ☐ No ☐ N/A ☐
FT39	DMG Beacon	Clause 9	CFDMG:M	Yes ☐ No ☐ N/A ☐
FT40	VHT NDP Announcement	Clause 9	VHTM4.1:M TVHTM4.1:M	Yes ☐ No ☐ N/A ☐
FT41	Beamforming Report Poll	Clause 9	VHTM4.1:O VHTM4.3:M TVHTM4.1:O TVHTM4.3:M	Yes ☐ No ☐ N/A ☐
FT42	Transmission of Operating Mode Notification frame and Operating Mode Notification element	9.6.22.4, 9.4.2.165, 11.40	O	Yes ☐ No ☐ N/A ☐
FT43	TACK	Clause 9	S1GM6.2:M (CFS1G AND NOT S1GM6):O	Yes ☐ No ☐ N/A ☐
FT44	S1G Beacon	Clause 9	((CFAP OR CFIBSS) AND CFS1G):M	Yes ☐ No ☐ N/A ☐
FT45	PV1 frame	9.8	CFS1G:O	Yes ☐ No ☐ N/A ☐

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B.4.4.2 MAC frames *(continued)*

Item	MAC frame	References	Status	Support
FT45.1	STACK frame	9.8	(S1GM6.2: OR S1GM6.1):M	Yes ☐ No ☐ N/A ☐
FT45.2	BAT frame	9.8	(S1GM6.2 AND QB4.1):M	Yes ☐ No ☐ N/A ☐
FT45.3	PV1 Action frame	9.8	CFS1G:O	Yes ☐ No ☐ N/A ☐
FT45.4	PV1 Action No Ack frame	9.8	CFS1G:O	Yes ☐ No ☐ N/A ☐
FT45.5	PV1 Probe Response frame	9.8	(CFAP AND CFS1G):O	Yes ☐ No ☐ N/A ☐
FT45.6	PV1 Data frame	9.8	CFS1G:O RL6:M S1GM13:M	Yes ☐ No ☐ N/A ☐
FT45.7	Resource Allocation	9.8	(CFAP AND S1GM22.5):O	Yes ☐ No ☐ N/A ☐
FT46	NDP CMAC PPDUs	23.3.12	CFS1G: M	Yes ☐ No ☐ N/A ☐
FT46.1	NDP CTS	23.3.12	CFS1G: M	Yes ☐ No ☐ N/A ☐
FT46.2	NDP PS-Poll	23.3.12	(CFIndepSTA AND CFS1G): O	Yes ☐ No ☐ N/A ☐
FT46.3	NDP Ack	23.3.12	CFS1G: M	Yes ☐ No ☐ N/A ☐
FT46.4	NDP PS-Poll-Ack	23.3.12	(CFAP AND CFS1G AND FR47.2): M	Yes ☐ No ☐ N/A ☐
FT46.5	NDP BlockAck	23.3.12	(CFS1G AND HTM5.3): M	Yes ☐ No ☐ N/A ☐
FT46.6	NDP Beamforming Report Poll	23.3.12	CFS1G AND CFAP: O	Yes ☐ No ☐ N/A ☐
FT46.7	NDP Paging	23.3.12	S1GM6.11: M	Yes ☐ No ☐ N/A ☐
FT46.8	NDP Probe Request	23.3.12	(CFS1G AND CFIndepSTA AND S1GM4.5):M	Yes ☐ No ☐ N/A ☐
FT46.9	NDP CF-End	23.3.12	CFS1G:O	Yes ☐ No ☐ N/A ☐
FT47	Unprotected S1G Action frame	9.6.24	CFS1G:M	Yes ☐ No ☐ N/A ☐
FT47.1	AID Switch Request frame	9.6.24	(CFIndepSTA AND CFS1G AND (S1GM13 OR S1GM18)):M	Yes ☐ No ☐ N/A ☐
FT47.2	AID Switch Response frame	9.6.24	(CFAP AND CFS1G AND (S1GM13 OR S1GM18)):M	Yes ☐ No ☐ N/A ☐
FT47.3	Sync Control frame	9.6.24	(CFAP AND CFS1G AND S1GM8.2):M	Yes ☐ No ☐ N/A ☐

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B.4.4.2 MAC frames *(continued)*

Item	MAC frame	References	Status	Support
FT47.4	STA Information Announcement frame	9.6.24	(CFIndepSTA AND CFS1G AND S1GM18):M	Yes ☐ No ☐ N/A ☐
FT47.5	EDCA Parameter Set frame	9.6.24	(CFAP AND CFS1G):O	Yes ☐ No ☐ N/A ☐
FT47.6	EL Operation frame	9.6.24	(CFIndepSTA AND CFS1G AND S1GM21):M	Yes ☐ No ☐ N/A ☐
FT47.7	TWT Setup frame	9.6.24	(CFS1G AND S1GM6.3):M	Yes ☐ No ☐ N/A ☐
FT47.8	TWT Teardown frame	9.6.24	(CFS1G AND S1GM6.5):M	Yes ☐ No ☐ N/A ☐
FT47.9	Sectorized Group ID List frame	9.6.24	(CFAP AND CFS1G AND S1GM11):M	Yes ☐ No ☐ N/A ☐
FT47.10	Sector ID feedback frame	9.6.24	(CFIndepSTA AND CFS1G AND S1GM11):M	Yes ☐ No ☐ N/A ☐
FT47.11	Header compression frame as a request		(CFS1G AND S1GM16):O	Yes ☐ No ☐ N/A ☐
FT47.12	Header Compression frame as a response		CFS1G:M	Yes ☐ No ☐ N/A ☐
FT47.13	TWT Information frame		(CFS1G AND S1GM6.1):O (CFS1G AND S1GM6.2):O	Yes ☐ No ☐ N/A ☐
FT48	S1G Action frame	9.6.25	(RL1 OR S1GM6.13):M	Yes ☐ No ☐ N/A ☐
FT48.1	Reachable Address Update frame	9.6.25	RL1:M	Yes ☐ No ☐ N/A ☐
FT48.2	Relay Activation Request frame		RL1:O	Yes ☐ No ☐ N/A ☐
FT48.3	Relay Activation Response frame		RL1:M	Yes ☐ No ☐ N/A ☐
FT48.4	Protected TWT Setup frame	9.6.25	S1GM6.13:M	Yes ☐ No ☐ N/A ☐
FT48.5	Protected TWT Teardown frame	9.6.25	S1GM6.13:M	Yes ☐ No ☐ N/A ☐
FT48.6	Protected TWT Information frame	9.6.25	S1GM6.13:M	Yes ☐ No ☐ N/A ☐
FT49	Flow Control Action frame	9.6.26	CFS1G:M	Yes ☐ No ☐ N/A ☐
FT49.1	Flow Suspension frame	9.6.26	(CFS1G AND S1GM17.1):M	Yes ☐ No ☐ N/A ☐
FT49.2	Flow Resumption frame	9.6.26	(CFS1G AND S1GM17.1):O	Yes ☐ No ☐ N/A ☐
FT50	Control Response MCS Negotiation frame	9.6.27	CFS1G AND S1GM28:M	Yes ☐ No ☐ N/A ☐
FT50.1	Control Response MCS Negotiation Request	9.6.27	(CFS1G AND S1GM28):O	Yes ☐ No ☐ N/A ☐
FT50.2	Control Response MCS Negotiation Response	9.6.27	(CFS1G AND S1GM28):M	Yes ☐ No ☐ N/A ☐

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B.4.4.2 MAC frames *(continued)*

Item	MAC frame	References	Status	Support
FT51	LPD MSDU	5.1.4	M	Yes ☐ No ☐ N/A
FT52	EPD MSDU	5.1.4, 11.51	O	Yes ☐ No ☐ N/A
	Is reception of the following MAC frames supported?	Clause 9		
*FR1	Association Request	Clause 9	(CFAP OR CFPCP):M	Yes ☐ No ☐ N/A ☐
*FR2	Association Response	Clause 9	(CFSTAofAP1 OR CFPBSSnotPCP):M	Yes ☐ No ☐ N/A ☐
FR3	Reassociation Request	Clause 9	(CFAP OR CFPCP):M	Yes ☐ No ☐ N/A ☐
FR4	Reassociation Response	Clause 9	(CFSTAofAP OR CFPBSSnotPCP):M	Yes ☐ No ☐ N/A ☐
FR5	Probe Request	Clause 9	(CFAP OR CFIBSS OR CFPCP OR CFMBSS):M	Yes ☐ No ☐ N/A ☐
FR6	Probe Response	Clause 9	(CFSTAofAP OR CFIBSS OR CFPBSSnotPCP OR CFMBSS):M	Yes ☐ No ☐ N/A ☐
FR7	Beacon	Clause 9	(NOT CFOCB AND (NOT CFS1G)):M not CFDMG AND (NOT CFS1G)):M	Yes ☐ No ☐ N/A ☐
FR8	ATIM	Clause 9	(CFSTAofAP OR CFIBSS OR CFMBSS) AND not CFDMG:M	Yes ☐ No ☐ N/A ☐
FR9	Disassociation	Clause 9	FR1 OR FR2:M	Yes ☐ No ☐ N/A ☐
FR10	Authentication	Clause 9	CFAP AND not CFDMG:M CFIBSS OR CFPBSS OR (CFAP AND CFDMG):O	Yes ☐ No ☐ N/A ☐
FR11	Deauthentication	Clause 9	FR10:M	Yes ☐ No ☐ N/A ☐
FR12	PS-Poll	Clause 9	CFAP:M	Yes ☐ No ☐ N/A ☐
FR13	RTS	Clause 9	M	Yes ☐ No ☐

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B.4.4.2 MAC frames *(continued)*

Item	MAC frame	References	Status	Support
FR14	CTS	Clause 9	not CFDMG AND NOT CFS1G):M (CFS1G AND VHTM3.1):O	Yes ☐ No ☐
FR15	Ack	Clause 9	NOT CFS1G:M CFS1G AND VHTM3.1 OR S1GM28):O	Yes ☐ No ☐
FR16	CF-End	Clause 9	(NOT CFOCB):M	Yes ☐ No ☐ N/A ☐
FR17	*Reserved*			
FR18	Data	Clause 9	not CFDMG:M	Yes ☐ No ☐
FR19	*Reserved*			
FR20	*Reserved*			
FR21	*Reserved*			
FR22	Null	Clause 9	not CFDMG:M	Yes ☐ No ☐
FR23	*Reserved*			
FR24	*Reserved*			
FR25	*Reserved*			
FR26	Timing Advertisement frame	Clause 9	O	Yes ☐ No ☐
FR27	QoS Data	Clause 9	CFQoS:M	Yes ☐ No ☐ N/A ☐
FR28	QoS Null	Clause 9	CFQoS:M	Yes ☐ No ☐ N/A ☐
FR29	BlockAckReq	Clause 9	CFQoS:O HTM3.1:M	Yes ☐ No ☐ N/A ☐
FR30	BlockAck	Clause 9	CFQoS:O HTM3.5:M	Yes ☐ No ☐ N/A ☐
FR31	Poll	Clause 9	CFDMG:M	Yes ☐ No ☐ N/A ☐
FR32	SPR	Clause 9	CFDMG:M	Yes ☐ No ☐ N/A ☐
FR33	Grant	Clause 9	CFDMG:M	Yes ☐ No ☐ N/A ☐
FR34	DMG CTS	Clause 9	CFDMG:M	Yes ☐ No ☐ N/A ☐
FR35	DMG DTS	Clause 9	CFDMG:M	Yes ☐ No ☐ N/A ☐
FR36	*Reserved*			
FR37	SSW	Clause 9	CFDMG:M	Yes ☐ No ☐ N/A ☐
FR38	SSW-Feedback	Clause 9	CFDMG:M	Yes ☐ No ☐ N/A ☐
FR39	SSW-Ack	Clause 9	CFDMG:M	Yes ☐ No ☐ N/A ☐
FR40	DMG Beacon	Clause 9	(CFSTAofAP OR CFIBSS OR CFPBSS) AND CFDMG:M	Yes ☐ No ☐ N/A ☐
FR41	VHT NDP Announcement	Clause 9	VHTM4.2:M TVHTM4.2:M	Yes ☐ No ☐ N/A ☐

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B.4.4.2 MAC frames *(continued)*

Item	MAC frame	References	Status	Support
FR42	Beamforming Report Poll	Clause 9	VHTM4.2:O VHTM4.4:M TVHTM4.2:O TVHTM4.4:M	Yes ☐ No ☐ N/A ☐
FR43	Reception of Operating Mode Notification frame and Operating Mode Notification element	9.6.22.4, 9.4.2.165, 11.40	CFVHT:M CFTVHT:M	Yes ☐ No ☐ N/A ☐
FR44	TACK	Clause 9	(CFAP AND CFS1G):O (CFIndepSTA AND CFS1G AND S1GM7.3 OR S1GM6.1):M	Yes ☐ No ☐ N/A ☐
FR45	S1G Beacon	Clause 9	CFS1G:M	Yes ☐ No ☐ N/A ☐
FR46	PV1 frame	9.8	CFS1G:O	Yes ☐ No ☐ N/A ☐
FR46.1	STACK frame	9.8	(CFS1G AND S1GM6.1):M	Yes ☐ No ☐ N/A ☐
FR46.2	BAT frame	9.8	(CFS1G AND S1GM6.1 AND QB4.1 OR):M	Yes ☐ No ☐ N/A ☐
FR46.3	PV1 Action frame	9.8	CFS1G AND (S1GM20.1 OR S1GM20.3 OR S1GM20.5):M CFS1G AND (S1GM20.2 OR S1GM20.5):O :O	Yes ☐ No ☐ N/A ☐
FR46.4	PV1 Action No Ack frame	9.8	CFS1G AND (S1GM20.1 OR S1GM20.3 OR S1GM20.5):M CFS1G AND (S1GM20.2 OR S1GM20.5):O	Yes ☐ No ☐ N/A ☐
FR46.5	PV1 Probe Response frame	9.8	CFS1G:O	Yes ☐ No ☐ N/A ☐
FR46.6	PV1 Data frame	9.8	CFS1G AND (S1GM20.1 OR S1GM20.3 OR S1GM20.4):M CFS1G AND (S1GM20.2 OR S1GM20.5):O	Yes ☐ No ☐ N/A ☐
FR46.7	Resource Allocation	9.8	(CFIndepSTA AND CFS1G AND S1GM22.5):M	Yes ☐ No ☐ N/A ☐
FR47	NDP CMAC PPDUs	23.3.12	CFS1G:M	Yes ☐ No ☐ N/A ☐
FR47.1	NDP CTS	23.3.12	CFS1G:M	Yes ☐ No ☐ N/A ☐

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B.4.4.2 MAC frames *(continued)*

Item	MAC frame	References	Status	Support
FR47.2	NDP PS-Poll	23.3.12	(CFAP AND CFS1G):O	Yes ☐ No ☐ N/A ☐
FR47.3	NDP ACK	23.3.12	CFS1G:M	Yes ☐ No ☐ N/A ☐
FR47.4	NDP PS-Poll-Ack	23.3.12	(CFIndepSTA AND CFS1G AND FT46.2):M	Yes ☐ No ☐ N/A ☐
FR47.5	NDP BlockAck	23.3.12	(CFS1G AND HTM5.3):M	Yes ☐ No ☐ N/A ☐
FR47.6	NDP Beamforming Report Poll	23.3.12	(CFIndepSTA AND CFS1G):O	Yes ☐ No ☐ N/A ☐
FR47.7	NDP Paging	23.3.12	(CFS1G AND S1GM6.9):M	Yes ☐ No ☐ N/A ☐
FR47.8	NDP Probe Request	23.3.12	(CFAP AND CFS1G):M	Yes ☐ No ☐ N/A ☐
FR47.9	NDP CF-End	23.3.12	(CFIndepSTA AND CFS1G):O	Yes ☐ No ☐ N/A ☐
FR48	Unprotected S1G Action frame	9.6.24	CFS1G:M	Yes ☐ No ☐ N/A ☐
FR48.1	AID Switch Request frame	9.6.24	(CFIndepSTA AND CFS1G AND (S1GM13 OR S1GM18)):M	Yes ☐ No ☐ N/A ☐
FR48.2	AID Switch Response frame	9.6.24	(CFAP AND CFS1G OR (S1GM13 OR S1GM18)):M	Yes ☐ No ☐ N/A ☐
FR48.3	Sync Control frame	9.6.24	(CFIndepSTA AND CFS1G AND S1GM8.1):M	Yes ☐ No ☐ N/A ☐
FR48.4	STA Information Announcement frame	9.6.24	(CFAP AND CFS1G AND S1GM18):M	Yes ☐ No ☐ N/A ☐
FR48.5	EDCA Parameter Set frame	9.6.24	(CFIndepSTA AND CFS1G):M	Yes ☐ No ☐ N/A ☐
FR48.6	EL Operation frame	9.6.24	(CFAP AND CFS1G AND S1GM21):M	Yes ☐ No ☐ N/A ☐
FR48.7	TWT Setup frame	9.6.24	(CFS1G AND S1GM6.2):M	Yes ☐ No ☐ N/A ☐
FR48.8	TWT Teardown frame	9.6.24	(CFS1G AND S1GM6.5):M	Yes ☐ No ☐ N/A ☐

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B.4.4.2 MAC frames *(continued)*

Item	MAC frame	References	Status	Support
FR48.9	Sectorized Group ID List frame	9.6.24	(CFIndepSTA AND CFS1G AND S1GM11):M	Yes ☐ No ☐ N/A ☐
FR48.10	Sector ID feedback frame	9.6.24	(CFAP AND CFS1G AND S1GM11):M	Yes ☐ No ☐ N/A ☐
FR48.11	Header Compression frame		CFS1G: M	Yes ☐ No ☐ N/A ☐
FR48.12	Header Compression frame		(CFS1G AND FT47.11):M	Yes ☐ No ☐ N/A ☐
FR48.13	TWT Information frame		(CFS1G AND S1GM6):M	Yes ☐ No ☐ N/A ☐
FR49	S1G Action frame	9.6.25	(CFAP AND CFS1G):O	Yes ☐ No ☐ N/A ☐
FR49.1	Reachable Address Update frame	9.6.25	RL1:M	Yes ☐ No ☐ N/A ☐
FR49.2	Relay Activation Request frame	9.6.25	RL1:M	Yes ☐ No ☐ N/A ☐
FR49.3	Relay Activation Response frame	9.6.25	RL1:M	Yes ☐ No ☐ N/A ☐
FR49.4	Protected TWT Setup frame	9.6.25	S1GM6.13:M	Yes ☐ No ☐ N/A ☐
FR49.5	Protected TWT Teardown frame	9.6.25	S1GM6.13:M	Yes ☐ No ☐ N/A ☐
FR49.6	Protected TWT Information frame	9.6.25	S1GM6.13:M	Yes ☐ No ☐ N/A ☐
FR50	Flow Control Action frame	9.6.26	(CFIndepSTA AND CFS1G):O	Yes ☐ No ☐ N/A ☐
FR50.1	Flow Suspension frame	9.6.26	(CFIndepSTA AND CFS1G AND S1GM17):M	Yes ☐ No ☐ N/A ☐
FR50.2	Flow Resumption frame	9.6.26	(CFIndepSTA AND CFS1G AND S1GM17):M	Yes ☐ No ☐ N/A ☐
FR51	Control Response MCS Negotiation frame	9.6.27	CFS1G AND S1GM28:M	Yes ☐ No ☐ N/A ☐
FR51.1	Control Response MCS Negotiation Request frame	9.6.27	(CFS1G AND S1GM28):M	Yes ☐ No ☐ N/A ☐
FR51.2	Control Response MCS Negotiation Response frame	9.6.27	(CFS1G AND S1GM28):M	Yes ☐ No ☐ N/A ☐
FR52	LPD MSDU	5.1.4	M	Yes ☐ No ☐ N/A ☐
FR53	EPD MSDU	5.1.4, 11.51	FT52:M	Yes ☐ No ☐ N/A ☐

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B.4.4.3 Frame exchange sequences

Item	Frame exchange sequence	References	Status	Support
	Are the following frame exchange sequences supported?			
FS1	Basic frame exchange sequences	10.3.2.6, 10.3.2.9, 10.3.2.11, 10.3.5, 10.3.6	M	Yes ☐ No ☐

B.4.4.4 MAC addressing functions

Item	MAC Address function	References	Status	Support
	Are the following MAC Addressing functions supported?			
AD1	STA universal individual IEEE 802 address	9.2.4.3	M	Yes ☐ No ☐
AD2	BSS identification (BSSID) generation	9.2.4.3, 11.1.4	M	Yes ☐ No ☐
AD3	Receiver address matching	9.2.4.3, 9.3.2.1	M	Yes ☐ No ☐
AD4	Wildcard BSSID	9.2.4.3.4, 9.3.2	CFOCB:M	Yes ☐ No ☐ N/A ☐
AD5	MAC and PHY operation resumes with appropriate MIB attributes in less than 2 TU	11.18	CFOCB:M	Yes ☐ No ☐ N/A ☐
AD6	Group addressed mesh Data frame addressing (3 address frame)	9.2.3, 9.2.4.1, 9.2.4.3, 9.3.5	CFMBSS:M	Yes ☐ No ☐ N/A ☐
AD7	Individually addressed mesh Data frame addressing (4 address frame)	9.2.3, 9.2.4.1, 9.2.4.3, 9.3.5	CFMBSS:M	Yes ☐ No ☐ N/A ☐
AD8	Proxied group addressed mesh Data frame addressing (4 address frame)	9.2.3, 9.2.4.1, 9.2.4.3, 9.2.4.7.3, 9.3.5	CFMBSS:M	Yes ☐ No ☐ N/A ☐
AD9	Proxied individually addressed mesh Data frame addressing (6 address frame)	9.2.3, 9.2.4.1, 9.2.4.3, 9.2.4.7.3, 9.3.5	CFMBSS:M	Yes ☐ No ☐ N/A ☐
AD10	Multihop Action frame addressing (4 address frame)	9.2.3, 9.2.4.1, 9.2.4.3, 9.2.4.7.3, 9.6.17, 9.3.5	CFMBSS:M	Yes ☐ No ☐ N/A ☐
AD11	TA filtering for mesh STA	9.2.4.3, 9.3.2.1, 9.3.5	CFMBSS:M	Yes ☐ No ☐ N/A ☐
AD12	Group addressed Data frame addressing (4 address frame)	9.2.3, 9.2.4.1, 9.2.4.3	CFS1GRelay: O RL2:O CFAP: O CFIndepSTA: O	Yes ☐ No ☐ N/A ☐

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B.4.4.4 MAC addressing functions *(continued)*

Item	MAC Address function	References	Status	Support
AD13	Individually addressed Data frame addressing (4 address frame)	9.2.3, 9.2.4.1, 9.2.4.3	CFS1GRelay: O RL2:O CFAP: O CFIndepSTA: O	Yes ☐ No ☐ N/A ☐
AD14	Group addressed PV1 Data frame addressing (4 address frame)	9.8, 10.54.4, 10.54.3	CFS1GRelay: O RL2:O CFS1G: O	Yes ☐ No ☐ N/A ☐
AD15	Individually addressed PV1 Data frame addressing (4 address frame)	9.8, 10.54.4, 10.54.3	CFS1GRelay: O RL2:O CFS1G: O	Yes ☐ No ☐ N/A ☐
AD16	Receive SYNRA	10.66	(CFGLK AND CFIndep-STA):M	Yes ☐ No ☐ N/A ☐
AD17	Transmit SYNRA	10.66	(CFGLK AND CFAP):O	Yes ☐ No ☐ N/A ☐

B.4.5 Direct sequence PHY functions

Item	PHY feature	References	Status	Support
	PHY sublayer procedures	15.3		
DS1	Preamble prepend on transmit (TX)	15.3.1	M	Yes ☐ No ☐
DS1.1	PHY frame format	15.3.2, 15.3.3	M	Yes ☐ No ☐
DS1.2	PHY integrity check generation	15.3.3, 15.3.3.7	M	Yes ☐ No ☐
DS1.3	TX rate change capability	15.2.3.4, 15.3.5	M	Yes ☐ No ☐
DS1.4	Supported data rates	15.1, 15.2.3.4	M	Yes ☐ No ☐
DS1.5	Data whitener scrambler	15.3.4	M	Yes ☐ No ☐
DS1.6	Scrambler initialization	15.3.4	M	Yes ☐ No ☐
DS2	Preamble process on receive (RX)	15.3.1		
DS2.1	PHY frame format	15.3.2, 15.3.3	M	Yes ☐ No ☐
DS2.2	PHY integrity check verify	15.3.3, 15.3.3.7	M	Yes ☐ No ☐
DS2.3	RX Rate change capability	15.2.3.4, 15.3.5	M	Yes ☐ No ☐
DS2.4	Data whitener descrambler	15.3.4	M	Yes ☐ No ☐
DS3	Pseudonoise (PN) code sequence	15.4.4.4	M	Yes ☐ No ☐
DS4	Chipping continue on power-down	15.3.6	O	Yes ☐ No ☐
*DS5	Operating channel capability	15.3.6, 15.4.4.3		
* DS5.1	North America (FCC)	15.3.6, 15.4.4.3	DS5:O.1	Yes ☐ No ☐ N/A ☐
DS5.1.1	Channel 1	15.3.6, 15.4.4.3	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.2	Channel 2	15.3.6, 15.4.4.3	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.3	Channel 3	15.3.6, 15.4.4.3	DS5.1:M	Yes ☐ No ☐ N/A ☐

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B.4.5 Direct sequence PHY functions *(continued)*

Item	PHY feature	References	Status	Support
DS5.1.4	Channel 4	15.3.6, 15.4.4.3	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.5	Channel 5	15.3.6, 15.4.4.3	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.6	Channel 6	15.3.6, 15.4.4.3	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.7	Channel 7	15.3.6, 15.4.4.3	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.8	Channel 8	15.3.6, 15.4.4.3	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.9	Channel 9	15.3.6, 15.4.4.3	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.10	Channel 10	15.3.6, 15.4.4.3	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.11	Channel 11	15.3.6, 15.4.4.3	DS5.1:M	Yes ☐ No ☐ N/A ☐
* DS5.2	Canada (IC)	15.3.6, 15.4.4.3	DS5:O.1	Yes ☐ No ☐ N/A ☐
DS5.2.1	Channel 1	15.3.6, 15.4.4.3	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.2	Channel 2	15.3.6, 15.4.4.3	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.3	Channel 3	15.3.6, 15.4.4.3	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.4	Channel 4	15.3.6, 15.4.4.3	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.5	Channel 5	15.3.6, 15.4.4.3	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.6	Channel 6	15.3.6, 15.4.4.3	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.7	Channel 7	15.3.6, 15.4.4.3	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.8	Channel 8	15.3.6, 15.4.4.3	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.9	Channel 9	15.3.6, 15.4.4.3	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.10	Channel 10	15.3.6, 15.4.4.3	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.11	Channel 11	15.3.6, 15.4.4.3	DS5.2:M	Yes ☐ No ☐ N/A ☐
* DS5.3	Europe (ETSI)	15.3.6, 15.4.4.3	DS5:O.1	Yes ☐ No ☐ N/A ☐
DS5.3.1	Channel 1	15.3.6, 15.4.4.3	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.2	Channel 2	15.3.6, 15.4.4.3	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.3	Channel 3	15.3.6, 15.4.4.3	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.4	Channel 4	15.3.6, 15.4.4.3	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.5	Channel 5	15.3.6, 15.4.4.3	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.6	Channel 6	15.3.6, 15.4.4.3	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.7	Channel 7	15.3.6, 15.4.4.3	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.8	Channel 8	15.3.6, 15.4.4.3	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.9	Channel 9	15.3.6, 15.4.4.3	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.10	Channel 10	15.3.6, 15.4.4.3	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.11	Channel 11	15.3.6, 15.4.4.3	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.12	Channel 12	15.3.6, 15.4.4.3	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.13	Channel 13	15.3.6, 15.4.4.3	DS5.3:M	Yes ☐ No ☐ N/A ☐
* DS5.4	France	15.3.6, 15.4.4.3	DS5:O.1	Yes ☐ No ☐ N/A ☐
DS5.4.1	Channel 10	15.3.6, 15.4.4.3	DS5.4:M	Yes ☐ No ☐ N/A ☐
DS5.4.2	Channel 11	15.3.6, 15.4.4.3	DS5.4:M	Yes ☐ No ☐ N/A ☐
DS5.4.3	Channel 12	15.3.6, 15.4.4.3	DS5.4:M	Yes ☐ No ☐ N/A ☐
DS5.4.4	Channel 13	15.3.6, 15.4.4.3	DS5.4:M	Yes ☐ No ☐ N/A ☐
* DS5.5	Spain	15.3.6, 15.4.4.3	DS5:O.1	Yes ☐ No ☐ N/A ☐

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B.4.5 Direct sequence PHY functions *(continued)*

Item	PHY feature	References	Status	Support
DS5.5.1	Channel 10	15.3.6, 15.4.4.3	DS5.5:M	Yes ☐ No ☐ N/A ☐
DS5.5.2	Channel 11	15.3.6, 15.4.4.3	DS5.5:M	Yes ☐ No ☐ N/A ☐
* DS5.6	Japan	15.3.6, 15.4.4.3	DS5:O.1	Yes ☐ No ☐ N/A ☐
* DS5.7	China	15.3.6, 15.4.4.3	DS5:O.1	Yes ☐ No ☐ N/A ☐
DS5.7.1	Channel 1	15.3.6, 15.4.4.3	DS5.7:M	Yes ☐ No ☐ N/A ☐
DS5.7.2	Channel 2	15.3.6, 15.4.4.3	DS5.7:M	Yes ☐ No ☐ N/A ☐
DS5.7.3	Channel 3	15.3.6, 15.4.4.3	DS5.7:M	Yes ☐ No ☐ N/A ☐
DS5.7.4	Channel 4	15.3.6, 15.4.4.3	DS5.7:M	Yes ☐ No ☐ N/A ☐
DS5.7.5	Channel 5	15.3.6, 15.4.4.3	DS5.7:M	Yes ☐ No ☐ N/A ☐
DS5.7.6	Channel 6	15.3.6, 15.4.4.3	DS5.7:M	Yes ☐ No ☐ N/A ☐
DS5.7.7	Channel 7	15.3.6, 15.4.4.3	DS5.7:M	Yes ☐ No ☐ N/A ☐
DS5.7.8	Channel 8	15.3.6, 15.4.4.3	DS5.7:M	Yes ☐ No ☐ N/A ☐
DS5.7.9	Channel 9	15.3.6, 15.4.4.3	DS5.7:M	Yes ☐ No ☐ N/A ☐
DS5.7.10	Channel 10	15.3.6, 15.4.4.3	DS5.7:M	Yes ☐ No ☐ N/A ☐
DS5.7.11	Channel 11	15.3.6, 15.4.4.3	DS5.7:M	Yes ☐ No ☐ N/A ☐
DS5.7.12	Channel 12	15.3.6, 15.4.4.3	DS5.7:M	Yes ☐ No ☐ N/A ☐
DS5.7.13	Channel 13	15.3.6, 15.4.4.3	DS5.7:M	Yes ☐ No ☐ N/A ☐
DS6	Bits to symbol mapping	15.4.4.5		
DS6.1	1 Mb/s	15.4.4.5	M	Yes ☐ No ☐
DS6.2	2 Mb/s	15.4.4.5	M	Yes ☐ No ☐
*DS7	CCA functionality	15.4.6.5		
DS7.1	Energy Only (RSSI above threshold)	15.4.6.5	DS7:O.2	Yes ☐ No ☐ N/A ☐
DS7.2	IEEE 802.11 DSSS correlation	15.4.6.5	DS7:O.2	Yes ☐ No ☐ N/A ☐
DS7.3	Both methods	15.4.6.5	DS7:O.2	Yes ☐ No ☐ N/A ☐
DS7.4	Hold CCA busy for packet duration of a correctly received PPDU but carrier lost during reception of MPDU	15.3.7	M	Yes ☐ No ☐
DS7.5	Hold CCA busy for packet duration of a correctly received but out of specification PPDU	15.3.7	M	Yes ☐ No ☐
DS8	Transmit antenna selection		O	Yes ☐ No ☐
DS9	Receive antenna diversity	15.2.3.8	O	Yes ☐ No ☐
*DS10	Antenna connector availability	15.4.4.10	O	Yes ☐ No ☐
DS10.1	50 Ω impedance	15.4.4.10	DS10:M	Yes ☐ No ☐ N/A ☐
*DS11	Transmit power level support	15.4.5.4	O	Yes ☐ No ☐
DS11.1	If greater than 100 mW capability	15.4.5.4	DS11:M	Yes ☐ No ☐ N/A ☐
DS12	Spurious emissions compliance	15.4.4.6	M	Yes ☐ No ☐
DS13	TX-to-RX turnaround time	15.4.4.7	M	Yes ☐ No ☐
DS14	RX-to-TX turnaround time	15.4.4.8	M	Yes ☐ No ☐
DS15	Slot time	15.4.4.9	M	Yes ☐ No ☐

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B.4.5 Direct sequence PHY functions *(continued)*

Item	PHY feature	References	Status	Support
DS16	Energy detection (ED) reporting time	15.4.4.9, 15.4.6.5	M	Yes ☐ No ☐
DS17	Minimum transmit power level	15.4.5.3	M	Yes ☐ No ☐
DS18	Transmit spectral mask compliance	15.4.5.5	M	Yes ☐ No ☐
DS19	Transmitted center frequency tolerance	15.4.5.6	M	Yes ☐ No ☐
DS20	Chip clock frequency tolerance	15.4.5.7	M	Yes ☐ No ☐
DS21	Transmit power-on ramp	15.4.5.8	M	Yes ☐ No ☐
DS22	Transmit power-down ramp	15.4.5.8	M	Yes ☐ No ☐
DS23	Radio frequency (RF) carrier suppression	15.4.5.9	M	Yes ☐ No ☐
DS24	Transmit modulation accuracy	15.4.5.10	M	Yes ☐ No ☐
DS25	Receiver minimum input level sensitivity	15.4.6.2	M	Yes ☐ No ☐
DS26	Receiver maximum input level	15.4.6.3	M	Yes ☐ No ☐
DS27	Receiver adjacent channel rejection	15.4.6.4	M	Yes ☐ No ☐
DS28	MIB	15.4.2, Annex C	M	Yes ☐ No ☐
DS28.1	dot11PhyDSSSComplianceGroup, dot11PhyRegDomainsSupportGroup, and dot11PhyOperationComplianceGroup	15.4.2	M	Yes ☐ No ☐

B.4.6 OFDM PHY functions

Item	Feature	References	Status	Support
OF1: OFDM PHY Specific Service Parameters				
OF1.1	TXVECTOR parameter: LENGTH	17.2.2.2	M	Yes ☐ No ☐
OF1.2	TXVECTOR parameter: DATARATE	17.2.2.3	M	Yes ☐ No ☐
OF1.2.1	DATARATE = 6.0 Mb/s	17.2.2.3	M	Yes ☐ No ☐
*OF1.2.2	DATARATE = 9.0 Mb/s	17.2.2.3	O	Yes ☐ No ☐
OF1.2.3	DATARATE = 12.0 Mb/s	17.2.2.3	M	Yes ☐ No ☐
*OF1.2.4	DATARATE = 18.0 Mb/s	17.2.2.3	O	Yes ☐ No ☐
*OF1.2.5	DATARATE = 24.0 Mb/s	17.2.2.3, Annex E	(NOT CF3G6):M CF3G6:O	Yes ☐ No ☐
*OF1.2.6	DATARATE = 36.0 Mb/s	17.2.2.3	O	Yes ☐ No ☐
*OF1.2.7	DATARATE = 48.0 Mb/s	17.2.2.3	O	Yes ☐ No ☐
*OF1.2.8	DATARATE = 54.0 Mb/s	17.2.2.3	O	Yes ☐ No ☐
OF1.3	TXVECTOR parameter: SERVICE	17.2.2.4	M	Yes ☐ No ☐
OF1.4	TXVECTOR parameter: TXPWR_LEVEL_INDEX	17.2.2.5	M	Yes ☐ No ☐
OF1.5	RXVECTOR parameter: LENGTH	17.2.3.2	M	Yes ☐ No ☐

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B.4.6 OFDM PHY functions *(continued)*

Item	Feature	References	Status	Support
OF1.6	RXVECTOR parameter: RSSI	17.2.3.3	M	Yes ☐ No ☐
*OF1.7	10 MHz Channel spacing	17.2.2, 17.2.3, 17.2.3.4, Annex E	CFOC:O CF3G6 AND DSE2:M	Yes ☐ No ☐ N/A ☐
*OF1.7.1	DATARATE = 3 Mb/s (10 MHz channel spacing)	17.2.2, 17.2.3, 17.2.3.4	CFOC AND OF1.7:M	Yes ☐ No ☐ N/A ☐
*OF1.7.2	DATARATE = 4.5 Mb/s (10 MHz channel spacing)	17.2.2, 17.2.3, 17.2.3.4	CFOC AND OF1.7:O	Yes ☐ No ☐ N/A ☐
*OF1.7.3	DATARATE = 6 Mb/s (10 MHz channel spacing)	17.2.2, 17.2.3, 17.2.3.4	CFOC AND OF1.7:M	Yes ☐ No ☐ N/A ☐
*OF1.7.4	DATARATE = 9 Mb/s (10 MHz channel spacing)	17.2.2, 17.2.3, 17.2.3.4	CFOC AND OF1.7:O	Yes ☐ No ☐ N/A ☐
*OF1.7.5	DATARATE = 12 Mb/s (10 MHz channel spacing)	17.2.2, 17.2.3, 17.2.3.4	CFOC AND OF1.7:M	Yes ☐ No ☐ N/A ☐
*OF1.7.6	DATARATE = 18 Mb/s (10 MHz channel spacing)	17.2.2, 17.2.3, 17.2.3.4	CFOC AND OF1.7:O	Yes ☐ No ☐ N/A ☐
*OF1.7.7	DATARATE = 24 Mb/s (10 MHz channel spacing)	17.2.2, 17.2.3, 17.2.3.4	CFOC AND OF1.7:O	Yes ☐ No ☐ N/A ☐
*OF1.7.8	DATARATE = 27 Mb/s (10 MHz channel spacing)	17.2.2, 17.2.3, 17.2.3.4	CFOC AND OF1.7:O	Yes ☐ No ☐ N/A ☐
*OF1.8	5 MHz Channel spacing	17.2.2, 17.2.3, 17.2.3.4, Annex E	CFOC:O CF3G6 AND DSE2:M CF3G6 AND DSE3:M	Yes ☐ No ☐ N/A ☐
*OF1.8.1	DATARATE = 1.5 Mb/s (5 MHz channel spacing)	17.2.2, 17.2.3, 17.2.3.4	CFOC AND OF1.8:M	Yes ☐ No ☐ N/A ☐
*OF1.8.2	DATARATE = 2.25 Mb/s (5 MHz channel spacing)	17.2.2, 17.2.3, 17.2.3.4	CFOC AND OF1.8:O	Yes ☐ No ☐ N/A ☐
*OF1.8.3	DATARATE = 3 Mb/s (5 MHz channel spacing)	17.2.2, 17.2.3, 17.2.3.4	CFOC AND OF1.8:M	Yes ☐ No ☐ N/A ☐
*OF1.8.4	DATARATE = 4.5 Mb/s (5 MHz channel spacing)	17.2.2, 17.2.3, 17.2.3.4	CFOC AND OF1.8:O	Yes ☐ No ☐ N/A ☐
*OF1.8.5	DATARATE = 6 Mb/s (5 MHz channel spacing)	17.2.2, 17.2.3, 17.2.3.4	CFOC AND OF1.8:M	Yes ☐ No ☐ N/A ☐

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B.4.6 OFDM PHY functions *(continued)*

Item	Feature	References	Status	Support
*OF1.8.6	DATARATE = 9 Mb/s (5 MHz channel spacing)	17.2.2, 17.2.3, 17.2.3.4	CFOC AND OF1.8:O	Yes ☐ No ☐ N/A ☐
*OF1.8.7	DATARATE = 12 Mb/s (5 MHz channel spacing)	17.2.2, 17.2.3, 17.2.3.4	CFOC AND OF1.8:O	Yes ☐ No ☐ N/A ☐
*OF1.8.8	DATARATE = 13.5 Mb/s (5 MHz channel spacing)	17.2.2, 17.2.3, 17.2.3.4	CFOC AND OF1.8:O	Yes ☐ No ☐ N/A ☐
OF2: OFDM PHY Sublayer				
OF2.1	RATE-dependent parameters	17.3.2.3	M	Yes ☐ No ☐
OF2.2	Timing related parameters	17.3.2.4	M	Yes ☐ No ☐
OF2.3	PHY preamble: SYNC	17.3.3	M	Yes ☐ No ☐
OF2.4	PHY header: SIGNAL	17.3.4	M	Yes ☐ No ☐
OF2.5	PHY header: LENGTH	17.3.4.2	M	Yes ☐ No ☐
OF2.6	PHY header: RATE	17.3.4.3	M	Yes ☐ No ☐
OF2.7	PHY header: parity, reserve	17.3.4.4	M	Yes ☐ No ☐
OF2.8	PHY header: SIGNAL TAIL	17.3.4.4	M	Yes ☐ No ☐
OF2.9	PHY header: SERVICE	17.3.5.2	M	Yes ☐ No ☐
OF2.10	PHY protocol data unit (PPDU): TAIL	17.3.5.3	M	Yes ☐ No ☐
OF2.11	PPDU: PAD	17.3.5.4	M	Yes ☐ No ☐
OF2.12	PHY/OFDM PHY data scrambler and descrambler	17.3.5.5	M	Yes ☐ No ☐
OF2.13	Convolutional encoder	17.3.5.6	M	Yes ☐ No ☐
OF2.13.1	Rate R = 1/2	17.3.5.6	M	Yes ☐ No ☐
OF2.13.2	Punctured coding R = 2/3	17.3.5.6	OF1.2.7:M	Yes ☐ No ☐ N/A ☐
OF2.13.3	Punctured coding R = 3/4	17.3.5.6	OF1.2.2 OR OF1.2.4 OR OF1.2.6 OR OF1.2.8:M	Yes ☐ No ☐ N/A ☐
OF2.14	Data interleaving	17.3.5.7	M	Yes ☐ No ☐
OF2.15	Subcarrier modulation mapping	17.3.5.8	M	Yes ☐ No ☐
OF2.15.1	Binary phase shift keying (BPSK)	17.3.5.8	M	Yes ☐ No ☐
OF2.15.2	Quadrature phase shift keying (QPSK)	17.3.5.8	M	Yes ☐ No ☐
OF2.15.3	16-quadrature amplitude modulation (QAM)	17.3.5.8	M	Yes ☐ No ☐
OF2.15.4	64-QAM	17.3.5.8	OF1.2.7 OR OF1.2.8:M	Yes ☐ No ☐ N/A ☐
OF2.16	Pilot subcarriers	17.3.5.9	M	Yes ☐ No ☐
OF2.17	OFDM modulation	17.3.5.6	M	Yes ☐ No ☐
OF2.18	Packet duration calculation		M	Yes ☐ No ☐

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B.4.6 OFDM PHY functions *(continued)*

Item	Feature	References	Status	Support
OF2.19	CCA			
OF2.19.1	CCA: RSSI	17.3.6	M	Yes ☐ No ☐
OF2.19.2	CCA: indication to MAC sublayer	17.3.6	M	Yes ☐ No ☐
*OF2.19.3	CCA-ED functionality	17.3.10.6	CF3G6:M	Yes ☐ No ☐ N/A ☐
OF2.19.3.1	CCA-ED energy only (RPI above threshold)	17.3.10.6	OF2.19.3: M	Yes ☐ No ☐ N/A ☐
OF2.19.3.2	Hold CCA busy for packet duration of a correctly received PPDU, but carrier lost during reception of MPDU	17.3.10.6	OF2.19.3: M	Yes ☐ No ☐ N/A ☐
OF2.20	PHY data modulation and modulation rate change	17.3.7	M	Yes ☐ No ☐
OF2.21	Modulation-dependent parameters (10 MHz channel spacing)	17.3.2.3	CFOC AND OF1.7:M	Yes ☐ No ☐ N/A ☐
OF2.22	Timing-related parameters (10 MHz channel spacing)	17.3.2.4	CFOC AND OF1.7:M	Yes ☐ No ☐ N/A ☐
OF2.23	PHY header: RATE (10 MHz channel spacing)	17.3.4.2	CFOC AND OF1.7:M	Yes ☐ No ☐ N/A ☐
OF2.24	Modulation-dependent parameters (5 MHz channel spacing)	17.3.2.3	CFOC AND OF1.8:M	Yes ☐ No ☐ N/A ☐
OF2.25	Timing-related parameters (5 MHz channel spacing)	17.3.2.4	CFOC AND OF1.8:M	Yes ☐ No ☐ N/A ☐
OF2.26	PHY header: RATE (5 MHz channel spacing)	17.3.4.2	CFOC AND OF1.8:M	Yes ☐ No ☐ N/A ☐
OF3: PDM Operating Specification General				
OF3.1	Occupied channel bandwidth			
OF3.1.1	20 MHz channel spacing	17.3.8.2	M	Yes ☐ No ☐
OF3.1.2	10 MHz channel spacing	17.3.8.2	CFOC AND OF1.7:M	Yes ☐ No ☐ N/A ☐
OF3.1.3	5 MHz channel spacing	17.3.8.2	CFOC AND OF1.8:M	Yes ☐ No ☐ N/A ☐
OF3.2	Operating frequency range	17.3.8.4.1		
*OF3.2.1	4.9 GHz band	Annex E	CFOC:O	Yes ☐ No ☐ N/A ☐
*OF3.2.2	5.0 GHz band	Annex E	CFOC:M	Yes ☐ No ☐ N/A ☐
OF3.2.3	5.15–5.25 GHz band	17.3.8.4	O.1	Yes ☐ No ☐
OF3.2.4	5.25–5.35 GHz band	17.3.8.4	O.1	Yes ☐ No ☐
*OF3.2.5	5.47–5.725 GHz band	Annex E	CFSM:M	Yes ☐ No ☐ N/A ☐
OF3.2.6	5.725–5.85 GHz band	17.3.8.4	O.1	Yes ☐ No ☐

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B.4.6 OFDM PHY functions *(continued)*

Item	Feature	References	Status	Support
*OF3.2.7	3.65–3.70 GHz band	Annex D, Annex E	CF3G6:M	Yes ☐ No ☐ N/A ☐
OF3.2.8	5.9 GHz band	Annex E	CF5G9:M	Yes ☐ No ☐ N/A ☐
OF3.3	Channelization			
OF3.3.1	5.15–5.25 GHz (20 MHz channel spacing)	Annex E	O.1	Yes ☐ No ☐
OF3.3.2	5.25–5.35 GHz (20 MHz channel spacing)	Annex E	O.1	Yes ☐ No ☐
OF3.3.3	5.725–5.825 GHz (20 MHz channel spacing)	Annex E	O.1	Yes ☐ No ☐
OF3.3.4	5.15–5.25 GHz band in Japan (20 MHz channel spacing)	Annex E	CFOC:M	Yes ☐ No ☐ N/A ☐
OF3.3.5	5.47–5.725 GHz (20 MHz channel spacing)	Annex E	CFSM AND OF3.2.5:M	Yes ☐ No ☐ N/A ☐
OF3.3.6	5.725–5.85 GHz (20 MHz channel spacing)	Annex E	O.1	Yes ☐ No ☐
OF3.3.7	4.9 GHz band (20 MHz channel spacing)	Annex E	CFOC AND OF3.2.1:M	Yes ☐ No ☐ N/A ☐
OF3.3.8	5.0 GHz band (20 MHz channel spacing)	Annex E	CFOC AND OF3.2.2:M	Yes ☐ No ☐ N/A ☐
OF3.3.9	4.9 GHz band (10 MHz channel spacing)	Annex E	CFOC AND OF3.2.1 AND OF1.7:M	Yes ☐ No ☐ N/A ☐
OF3.3.10	5.0 GHz band (10 MHz channel spacing)	Annex E	CFOC AND OF3.2.2 AND OF1.7:M	Yes ☐ No ☐ N/A ☐
OF3.3.11	4.9 GHz band (5 MHz channel spacing)	Annex E	CFOC AND OF3.2.1 AND OF1.8:M	Yes ☐ No ☐ N/A ☐
OF3.3.12	5.0 GHz band (5 MHz channel spacing)	Annex E	CFOC AND OF3.2.2 AND OF1.8:M	Yes ☐ No ☐ N/A ☐
OF3.3.13	3.65–3.70 GHz (20 MHz channel spacing)	Annex E	CF3G6 AND OF3.2.7:M	Yes ☐ No ☐ N/A ☐
OF3.3.14	3.65–3.70 GHz (10 MHz channel spacing)	Annex E	CF3G6 AND OF3.2.7 AND OF1.7:M	Yes ☐ No ☐ N/A ☐

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B.4.6 OFDM PHY functions *(continued)*

Item	Feature	References	Status	Support
OF3.3.15	3.65–3.70 GHz (5 MHz channel spacing)	Annex E	CF3G6 AND OF3.2.7 AND OF1.8:M	Yes ☐ No ☐ N/A ☐
OF3.3.16	5.9 GHz band (10 MHz channel spacing)	Annex E	CF5G9:O	Yes ☐ No ☐ N/A ☐
OF3.3.17	5.9 GHz band (20 MHz channel spacing)	Annex E	CF5G9:O	Yes ☐ No ☐ N/A ☐
OF3.3.18	5.9 GHz band (5 MHz channel spacing)	Annex E	CF5G9:O	Yes ☐ No ☐ N/A ☐
OF3.4	Number of operating channels	Annex E	M	Yes ☐ No ☐
OF3.5	Operating channel frequencies	Annex E	M	Yes ☐ No ☐
OF3.6	Transmit and receive in band and out of band spurious emission	Annex E	M	Yes ☐ No ☐
OF3.6.1	Interference-limited areas, 4.9 GHz band (20 MHz channel spacing)	Annex E	CFOC AND OF3.2.1:M	Yes ☐ No ☐ N/A ☐
OF3.6.2	Interference-limited areas, 5.0 GHz band (20 MHz channel spacing)	Annex E	CFOC AND OF3.2.2:M	Yes ☐ No ☐ N/A ☐
OF3.6.3	Interference-limited areas, 4.9 GHz band (10 MHz channel spacing)	Annex E	CFOC AND OF3.2.1 AND OF1.7:O	Yes ☐ No ☐ N/A ☐
OF3.6.4	Interference-limited areas, 5.0 GHz band (10 MHz channel spacing)	Annex E	CFOC AND OF3.2.2 AND OF1.7:O	Yes ☐ No ☐ N/A ☐
OF3.6.5	Interference-limited areas, 4.9 GHz band (5 MHz channel spacing)	Annex E	CFOC AND OF3.2.1 AND OF1.8:O	Yes ☐ No ☐ N/A ☐
OF3.6.6	Interference-limited areas, 5.0 GHz band (5 MHz channel spacing)	Annex E	CFOC AND OF3.2.2 AND OF1.8:O	Yes ☐ No ☐ N/A ☐
OF3.7	*Reserved*			
OF3.8	Slot time	17.3.8.6	M	Yes ☐ No ☐
OF3.8.1	Slot time (20 MHz channel spacing)	17.3.8.6	CFOC AND OC2:M	Yes ☐ No ☐ N/A ☐
OF3.8.2	Slot time (10 MHz channel spacing)	17.3.8.6	CFOC AND OC3 AND OF1.7:M	Yes ☐ No ☐ N/A ☐

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B.4.6 OFDM PHY functions *(continued)*

Item	Feature	References	Status	Support
OF3.8.3	Slot time (5 MHz channel spacing)	17.3.8.6	CFOC AND OC4 AND OF1.8:M	Yes ☐ No ☐ N/A ☐
OF3.9	Transmit and receive antenna connector impedance	17.3.8.7	M	Yes ☐ No ☐
OF4: PHY Transmit Specification				
OF4.1	Transmit power levels		M	Yes ☐ No ☐
OF4.1.1	Power level (5.15–5.25 GHz)	17.3.9.2	OF3.3.1:M	Yes ☐ No ☐ N/A ☐
OF4.1.2	Power level (5.25–5.35 GHz)	17.3.9.2	OF3.3.2:M	Yes ☐ No ☐ N/A ☐
OF4.1.3	Power level (5.725–5.825 GHz)	17.3.9.2	OF3.3.3:M	Yes ☐ No ☐ N/A ☐
*OF4.1.4	Power Level (5.850–5.925 GHz), Class A	D.2.2	CF5G9:M	Yes ☐ No ☐ N/A ☐
*OF4.1.5	Power Level (5.850–5.925 GHz), Class B	D.2.2	CF5G9:O	Yes ☐ No ☐ N/A ☐
*OF4.1.6	Power Level (5.850–5.925 GHz), Class C	D.2.2	CF5G9:O	Yes ☐ No ☐ N/A ☐
*OF4.1.7	Power Level (5.850–5.925 GHz), Class D	D.2.2	CF5G9:O	Yes ☐ No ☐ N/A ☐
OF4.2	Spectrum mask	17.3.9.3	M	Yes ☐ No ☐
OF4.3	Spurious	17.3.9.4	M	Yes ☐ No ☐
OF4.4	Center frequency tolerance	17.3.9.5	M	Yes ☐ No ☐
OF4.5	Clock frequency tolerance	17.3.9.6	M	Yes ☐ No ☐
OF4.6	Modulation accuracy			Yes ☐ No ☐
OF4.6.1	Center frequency leakage	17.3.9.7.2	M	Yes ☐ No ☐
OF4.6.2	Spectral flatness	17.3.9.7.3	M	Yes ☐ No ☐
OF4.6.3	Transmitter constellation error < –5 dB	17.3.9.7.4	M	Yes ☐ No ☐
OF4.6.4	Transmitter constellation error < –8 dB	17.3.9.7.4	OF1.2.2:M	Yes ☐ No ☐ N/A ☐
OF4.6.5	Transmitter constellation error < –10 dB	17.3.9.7.4	M	Yes ☐ No ☐
OF4.6.6	Transmitter constellation error < –13 dB	17.3.9.7.4	OF1.2.4:M	Yes ☐ No ☐ N/A ☐
OF4.6.7	Transmitter constellation error < –16 dB	17.3.9.7.4	M	Yes ☐ No ☐
OF4.6.8	Transmitter constellation error < –19 dB	17.3.9.7.4	OF1.2.6:M	Yes ☐ No ☐ N/A ☐
OF4.6.9	Transmitter constellation error < –22 dB	17.3.9.7.4	OF1.2.7:M	Yes ☐ No ☐ N/A ☐
OF4.6.10	Transmitter constellation error < –25 dB	17.3.9.7.4	OF1.2.8:M	Yes ☐ No ☐ N/A ☐
OF4.7	Power level, 4.9 GHz band (20 MHz channel spacing)	17.3.9.2	CFOC AND OF3.12.1: M	Yes ☐ No ☐ N/A ☐
OF4.8	Power level, 5.0 GHz band (20 MHz channel spacing)	17.3.9.2	CFOC AND OF3.12.2: M	Yes ☐ No ☐ N/A ☐
OF4.9	Power level, 5.47–5.725 GHz band	17.3.9.2	CFOC AND OF3.12.3: M	Yes ☐ No ☐ N/A ☐

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B.4.6 OFDM PHY functions *(continued)*

Item	Feature	References	Status	Support
OF4.10	Power level, 4.9 GHz band (10 MHz channel spacing)	17.3.9.2	CFOC AND OF3.12.1 AND OF1.7:M	Yes ☐ No ☐ N/A ☐
OF4.11	Power level, 5.0 GHz band (10 MHz channel spacing)	17.3.9.2	CFOC AND OF3.12.2 AND OF1.7:M	Yes ☐ No ☐ N/A ☐
OF4.12	Power level, 4.9 GHz band (5 MHz channel spacing)	17.3.9.2	CFOC AND OF3.12.1 AND OF1.8:M	Yes ☐ No ☐ N/A ☐
OF4.13	Power level, 5.0 GHz band (5 MHz channel spacing)	17.3.9.2	CFOC AND OF3.12.2 AND OF1.8:M	Yes ☐ No ☐ N/A ☐
OF4.13.1	Power level, 3.65–3.70 GHz (20 MHz channel spacing)	Annex E	CF3G6 AND OF3.2.7:M	Yes ☐ No ☐ N/A ☐
OF4.13.2	Power level, 3.65–3.70 GHz (10 MHz channel spacing)	Annex E	CF3G6 AND OF3.2.7 AND OF1.7:M	Yes ☐ No ☐ N/A ☐
OF4.13.3	Power level, 3.65–3.70 GHz (5 MHz channel spacing)	Annex E	CF3G6 AND OF3.2.7 AND OF1.8:M	Yes ☐ No ☐ N/A ☐
OF4.14	Spectrum mask (20 MHz channel spacing)	17.3.9.3	CFOC:M	Yes ☐ No ☐ N/A ☐
OF4.15	Spectrum mask (10 MHz channel spacing)	17.3.9.3	CFOC AND OF1.7:M	Yes ☐ No ☐ N/A ☐
OF4.15.1	Spectrum mask, Class A (10 MHz channel spacing)	D.2.3	OF4.1.4:M	Yes ☐ No ☐ N/A ☐
OF4.15.2	Spectrum mask, Class B (10 MHz channel spacing)	D.2.3	OF4.1.5:M	Yes ☐ No ☐ N/A ☐
OF4.15.3	Spectrum mask, Class C (10 MHz channel spacing)	D.2.3	OF4.1.6:M	Yes ☐ No ☐ N/A ☐
OF4.15.4	Spectrum mask, Class D (10 MHz channel spacing)	D.2.3	OF4.1.7:M	Yes ☐ No ☐ N/A ☐
OF4.16	Spectrum mask (5 MHz channel spacing)	17.3.9.3	CFOC AND OF1.8:M	Yes ☐ No ☐ N/A ☐
OF4.17	Transmitter constellation error (10 MHz channel spacing)			

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B.4.6 OFDM PHY functions *(continued)*

Item	Feature	References	Status	Support
OF4.17.1	Transmitter constellation error < –5 dB (10 MHz channel spacing)	17.3.9.7.4	CFOC AND OF1.7.1:M	Yes ☐ No ☐ N/A ☐
OF4.17.2	Transmitter constellation error < –8 dB (10 MHz channel spacing)	17.3.9.7.4	CFOC AND OF1.7.2:M	Yes ☐ No ☐ N/A ☐
OF4.17.3	Transmitter constellation error < –10 dB (10 MHz channel spacing)	17.3.9.7.4	CFOC AND OF1.7.3:M	Yes ☐ No ☐ N/A ☐
OF4.17.4	Transmitter constellation error < –13 dB (10 MHz channel spacing)	17.3.9.7.4	CFOC AND OF1.7.4:M	Yes ☐ No ☐ N/A ☐
OF4.17.5	Transmitter constellation error < –16 dB (10 MHz channel spacing)	17.3.9.7.4	CFOC AND OF1.7.5:M	Yes ☐ No ☐ N/A ☐
OF4.17.6	Transmitter constellation error < –19 dB (10 MHz channel spacing)	17.3.9.7.4	CFOC AND OF1.7.6:M	Yes ☐ No ☐ N/A ☐
OF4.17.7	Transmitter constellation error < –22 dB (10 MHz channel spacing)	17.3.9.7.4	CFOC AND OF1.7.7:M	Yes ☐ No ☐ N/A ☐
OF4.17.8	Transmitter constellation error < –25 dB (10 MHz channel spacing)	17.3.9.7.4	CFOC AND OF1.7.8:M	Yes ☐ No ☐ N/A ☐
OF4.18	Transmitter constellation error (5 MHz channel spacing)			
OF4.18.1	Transmitter constellation error < –5 dB (5 MHz channel spacing)	17.3.9.7.4	CFOC AND OF1.8.1:M	Yes ☐ No ☐ N/A ☐
OF4.18.2	Transmitter constellation error < –8 dB (5 MHz channel spacing)	17.3.9.7.4	CFOC AND OF1.8.2:M	Yes ☐ No ☐ N/A ☐
OF4.18.3	Transmitter constellation error < –10 dB (5 MHz channel spacing)	17.3.9.7.4	CFOC AND OF1.8.3:M	Yes ☐ No ☐ N/A ☐
OF4.18.4	Transmitter constellation error < –13 dB (5 MHz channel spacing)	17.3.9.7.4	CFOC AND OF1.8.4:M	Yes ☐ No ☐ N/A ☐
OF4.18.5	Transmitter constellation error < –16 dB (5 MHz channel spacing)	17.3.9.7.4	CFOC AND OF1.8.5:M	Yes ☐ No ☐ N/A ☐
OF4.18.6	Transmitter constellation error < –19 dB (5 MHz channel spacing)	17.3.9.7.4	CFOC AND OF1.8.6:M	Yes ☐ No ☐ N/A ☐
OF4.18.7	Transmitter constellation error < –22 dB (5 MHz channel spacing)	17.3.9.7.4	CFOC AND OF1.8.7:M	Yes ☐ No ☐ N/A ☐
OF4.18.8	Transmitter constellation error < –25 dB (5 MHz channel spacing)	17.3.9.7.4	CFOC AND OF1.8.8:M	Yes ☐ No ☐ N/A ☐

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B.4.6 OFDM PHY functions *(continued)*

Item	Feature	References	Status	Support
OF5: PHY Receiver Specifications				
OF5.1	Minimum input level sensitivity at packet error ratio (PER) = 10% with 1000 octet frames			
OF5.1.1	–82 dBm for 6 Mb/s	17.3.10.2	M	Yes ☐ No ☐
OF5.1.2	–81 dBm for 9 Mb/s	17.3.10.2	OF1.2.2:M	Yes ☐ No ☐ N/A ☐
OF5.1.3	–79 dBm for 12 Mb/s	17.3.10.2	M	Yes ☐ No ☐
OF5.1.4	–77 dBm for 18 Mb/s	17.3.10.2	OF1.2.4:M	Yes ☐ No ☐ N/A ☐
OF5.1.5	–74 dBm for 24 Mb/s	17.3.10.2	M	Yes ☐ No ☐
OF5.1.6	–70 dBm for 36 Mb/s	17.3.10.2	OF1.2.6:M	Yes ☐ No ☐ N/A ☐
OF5.1.7	–66 dBm for 48 Mb/s	17.3.10.2	OF1.2.7:M	Yes ☐ No ☐ N/A ☐
OF5.1.8	–65 dBm for 54 Mb/s	17.3.10.2	OF1.2.8:M	Yes ☐ No ☐ N/A ☐
OF5.2	Adjacent channel rejection	17.3.10.3	M	Yes ☐ No ☐
OF5.2.1	Optional adjacent channel rejection	17.3.10.3	O	Yes ☐ No ☐
OF5.3	Nonadjacent channel rejection	17.3.10.4	M	Yes ☐ No ☐
OF5.3.1	Optional nonadjacent channel rejection	17.3.10.4	O	Yes ☐ No ☐
OF5.4	Maximum input level	17.3.10.5	M	Yes ☐ No ☐
OF5.5	CCA sensitivity	17.3.10.6	M	Yes ☐ No ☐
OF5.6	Maximum input level sensitivity at packet error ratio (PER) = 10% with 1000 octet frames (10 MHz channel spacing)			
OF5.6.1	–85 dBm for 3 Mb/s (10 MHz channel spacing)	17.3.10.2	CFOC AND OF1.7.1:M	Yes ☐ No ☐ N/A ☐
OF5.6.2	–84 dBm for 4.5 Mb/s (10 MHz channel spacing)	17.3.10.2	CFOC AND OF1.7.2:M	Yes ☐ No ☐ N/A ☐
OF5.6.3	–82 dBm for 6 Mb/s (10 MHz channel spacing)	17.3.10.2	CFOC AND OF1.7.3:M	Yes ☐ No ☐ N/A ☐
OF5.6.4	–80 dBm for 9 Mb/s (10 MHz channel spacing)	17.3.10.2	CFOC AND OF1.7.4:M	Yes ☐ No ☐ N/A ☐
OF5.6.5	–77 dBm for 12 Mb/s (10 MHz channel spacing)	17.3.10.2	CFOC AND OF1.7.5:M	Yes ☐ No ☐ N/A ☐
OF5.6.6	–73 dBm for 18 Mb/s (10 MHz channel spacing)	17.3.10.2	CFOC AND OF1.7.6:M	Yes ☐ No ☐ N/A ☐
OF5.6.7	–69 dBm for 24 Mb/s (10 MHz channel spacing)	17.3.10.2	CFOC AND OF1.7.7:M	Yes ☐ No ☐ N/A ☐
OF5.6.8	–68 dBm for 27 Mb/s (10 MHz channel spacing)	17.3.10.2	CFOC AND OF1.7.8:M	Yes ☐ No ☐ N/A ☐

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B.4.6 OFDM PHY functions *(continued)*

Item	Feature	References	Status	Support
OF5.7	Adjacent channel rejection (10 MHz channel spacing)	17.3.10.3	CFOC AND OF1.7:M	Yes ☐ No ☐ N/A ☐
OF5.8	Nonadjacent channel rejection (10 MHz channel spacing)	17.3.10.4	CFOC AND OF1.7:M	Yes ☐ No ☐ N/A ☐
OF5.9	Maximum input level (10 MHz channel spacing)	17.3.10.5	CFOC AND OF1.7:M	Yes ☐ No ☐ N/A ☐
OF5.10	CCA sensitivity (10 MHz channel spacing)	17.3.10.6	CFOC AND OF1.7:M	Yes ☐ No ☐ N/A ☐
OF5.11	Maximum input level sensitivity at packet error ratio (PER) = 10% with 1000 octet frames (5 MHz channel spacing)			
OF5.11.1	–85 dBm for 3 Mb/s (5 MHz channel spacing)	17.3.10.2	CFOC AND OF1.8.1:M	Yes ☐ No ☐ N/A ☐
OF5.11.2	–84 dBm for 4.5 Mb/s (5 MHz channel spacing)	17.3.10.2	CFOC AND OF1.8.2:M	Yes ☐ No ☐ N/A ☐
OF5.11.3	–82 dBm for 6 Mb/s (5 MHz channel spacing)	17.3.10.2	CFOC AND OF1.8.3:M	Yes ☐ No ☐ N/A ☐
OF5.11.4	–80 dBm for 9 Mb/s (5 MHz channel spacing)	17.3.10.2	CFOC AND OF1.8.4:M	Yes ☐ No ☐ N/A ☐
OF5.11.5	–77 dBm for 12 Mb/s (5 MHz channel spacing)	17.3.10.2	CFOC AND OF1.8.5:M	Yes ☐ No ☐ N/A ☐
OF5.11.6	–73 dBm for 18 Mb/s (5 MHz channel spacing)	17.3.10.2	CFOC AND OF1.8.6:M	Yes ☐ No ☐ N/A ☐
OF5.11.7	–69 dBm for 24 Mb/s (5 MHz channel spacing)	17.3.10.2	CFOC AND OF.1.8.7:M	Yes ☐ No ☐ N/A ☐
OF5.11.8	–68 dBm for 27 Mb/s (5 MHz channel spacing)	17.3.10.2	CFOC AND OF1.8.8:M	Yes ☐ No ☐ N/A ☐
OF5.12	Adjacent channel rejection (5 MHz channel spacing)	17.3.10.3	CFOC AND OF1.8:M	Yes ☐ No ☐ N/A ☐
OF5.13	Nonadjacent channel rejection (5 MHz channel spacing)	17.3.10.4	CFOC AND OF1.8:M	Yes ☐ No ☐ N/A ☐
OF5.14	Maximum input level (5 MHz channel spacing)	17.3.10.5	CFOC AND OF1.8:M	Yes ☐ No ☐ N/A ☐
OF5.15	CCA sensitivity (5 MHz channel spacing)	17.3.10.6	CFOC AND OF1.8:M	Yes ☐ No ☐ N/A ☐

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B.4.6 OFDM PHY functions *(continued)*

Item	Feature	References	Status	Support
OF6: Transmit PHY				
OF6.1	Transmit: transmit on MAC request	17.3.11	M	Yes ☐ No ☐
OF6.2	Transmit: format and data encoding	17.3.11	M	Yes ☐ No ☐
OF6.3	Transmit: timing	17.3.11	M	Yes ☐ No ☐
OF7: Receive PHY				
OF7.1	Receive: receive and data decoding	17.3.12	M	Yes ☐ No ☐
OF8: PLME				
OF8.1	PLME: support PLME SAP management primitives	17.4.1	M	Yes ☐ No ☐
OF8.2	PLME: support PHY MIB	17.4.2	M	Yes ☐ No ☐
OF8.3	PLME: support PHY characteristics	17.4.3	M	Yes ☐ No ☐
OF8.4	PLME:support PHY characteristics (dot11ChannelStartingFactor)	17.4.2	CFOC:M	Yes ☐ No ☐ N/A ☐
OF9	*Reserved*			
OF10: Geographic Area Specific Requirements				
*OF10.1	Geographic areas	17.3.8.3, 17.3.8.4, 17.3.8.5,17.3.9.4	M	Yes ☐ No ☐
OF10.2	Regulatory domain extensions	17.3.8.4.3, 17.3.8.5, 17.3.9.2, 17.3.9.3, Annex E	CFOC:M	Yes ☐ No ☐ N/A ☐

B.4.7 High rate, direct sequence PHY functions

Item	PHY feature	References	Status	Support
	Are the following PHY features supported?			
HRDS1	Long preamble and header procedures	16.2	M	Yes ☐ No ☐
HRDS1.1	Long direct sequence preamble prepended on TX	16.2.1	M	Yes ☐ No ☐
HRDS1.2	Long PHY integrity check generation	16.2.3	M	Yes ☐ No ☐
HRDS1.3	TX rate change capability	16.2.3.4	M	Yes ☐ No ☐
HRDS1.4	Supported data rates	16.1, 16.2.3.4	M	Yes ☐ No ☐
HRDS1.5	Data scrambler	16.2.4	M	Yes ☐ No ☐
HRDS1.6	Scrambler initialization	16.2.4	M	Yes ☐ No ☐
HRDS2	*Reserved*			
*HRDS3	Short preamble and header procedures	16.2	O	Yes ☐ No ☐
HRDS3.1	Short preamble prepended on TX	16.2.2	HRDS3:M	Yes ☐ No ☐ N/A ☐

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B.4.7 High rate, direct sequence PHY functions *(continued)*

Item	PHY feature	References	Status	Support
HRDS3.2	Short header transmission	16.2.3.9, 16.2.3.10, 16.2.3.11, 16.2.3.12, 16.2.3.13, 16.2.3.14, 16.2.3.15	HRDS3:M	Yes ☐ No ☐ N/A ☐
HRDS4	Long preamble process on RX	16.2.6	M	Yes ☐ No ☐
HRDS4.1	PHY format	16.2.6	M	Yes ☐ No ☐
HRDS4.2	PHY integrity check verify	16.2.6	M	Yes ☐ No ☐
HRDS4.3	RX Rate change capability	16.2.6	M	Yes ☐ No ☐
HRDS4.4	Data whitener descrambler	16.2.6	M	Yes ☐ No ☐
*HRDS5	Short preamble process on RX	16.2.6	HRDS3:M	Yes ☐ No ☐ N/A ☐
HRDS5.1	PHY format	16.2.6	HRDS5:M	Yes ☐ No ☐ N/A ☐
HRDS5.2	PHY integrity check verify	16.2.6	HRDS5:M	Yes ☐ No ☐ N/A ☐
HRDS5.3	RX rate change capability	16.2.6	HRDS5:M	Yes ☐ No ☐ N/A ☐
HRDS5.4	Data whitener descrambler	16.2.6	HRDS5:M	Yes ☐ No ☐ N/A ☐
*HRDS6	Operating channel capability	—	—	—
*HRDS6.1	North America (FCC)	16.3.6.3	HRDS6:O.3	Yes ☐ No ☐ N/A ☐
HRDS6.1.1	Channel 1	16.3.6.3	HRDS6.1:M	Yes ☐ No ☐ N/A ☐
HRDS6.1.2	Channel 2	16.3.6.3	HRDS6.1:M	Yes ☐ No ☐ N/A ☐
HRDS6.1.3	Channel 3	16.3.6.3	HRDS6.1:M	Yes ☐ No ☐ N/A ☐
HRDS6.1.4	Channel 4	16.3.6.3	HRDS6.1:M	Yes ☐ No ☐ N/A ☐
HRDS6.1.5	Channel 5	16.3.6.3	HRDS6.1:M	Yes ☐ No ☐ N/A ☐
HRDS6.1.6	Channel 6	16.3.6.3	HRDS6.1:M	Yes ☐ No ☐ N/A ☐
HRDS6.1.7	Channel 7	16.3.6.3	HRDS6.1:M	Yes ☐ No ☐ N/A ☐
HRDS6.1.8	Channel 8	16.3.6.3	HRDS6.1:M	Yes ☐ No ☐ N/A ☐
HRDS6.1.9	Channel 9	16.3.6.3	HRDS6.1:M	Yes ☐ No ☐ N/A ☐
HRDS6.1.10	Channel 10	16.3.6.3	HRDS6.1:M	Yes ☐ No ☐ N/A ☐
HRDS6.1.11	Channel 11	16.3.6.3	HRDS6.1:M	Yes ☐ No ☐ N/A ☐
*HRDS6.2	Canada (IC)	16.3.6.3	HRDS6:O.3	Yes ☐ No ☐ N/A ☐
HRDS6.2.1	Channel 1	16.3.6.3	HRDS6.2:M	Yes ☐ No ☐ N/A ☐
HRDS6.2.2	Channel 2	16.3.6.3	HRDS6.2:M	Yes ☐ No ☐ N/A ☐
HRDS6.2.3	Channel 3	16.3.6.3	HRDS6.2:M	Yes ☐ No ☐ N/A ☐
HRDS6.2.4	Channel 4	16.3.6.3	HRDS6.2:M	Yes ☐ No ☐ N/A ☐
HRDS6.2.5	Channel 5	16.3.6.3	HRDS6.2:M	Yes ☐ No ☐ N/A ☐
HRDS6.2.6	Channel 6	16.3.6.3	HRDS6.2:M	Yes ☐ No ☐ N/A ☐
HRDS6.2.7	Channel 7	16.3.6.3	HRDS6.2:M	Yes ☐ No ☐ N/A ☐
HRDS6.2.8	Channel 8	16.3.6.3	HRDS6.2:M	Yes ☐ No ☐ N/A ☐
HRDS6.2.9	Channel 9	16.3.6.3	HRDS6.2:M	Yes ☐ No ☐ N/A ☐
HRDS6.2.10	Channel 10	16.3.6.3	HRDS6.2:M	Yes ☐ No ☐ N/A ☐
HRDS6.2.11	Channel 11	16.3.6.3	HRDS6.2:M	Yes ☐ No ☐ N/A ☐

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B.4.7 High rate, direct sequence PHY functions *(continued)*

Item	PHY feature	References	Status	Support
*HRDS6.3	Europe (ETSI)	16.3.6.3	HRDS6:O.3	Yes ☐ No ☐ N/A ☐
HRDS6.3.1	Channel 1	16.3.6.3	HRDS6.3:M	Yes ☐ No ☐ N/A ☐
HRDS6.3.2	Channel 2	16.3.6.3	HRDS6.3:M	Yes ☐ No ☐ N/A ☐
HRDS6.3.3	Channel 3	16.3.6.3	HRDS6.3:M	Yes ☐ No ☐ N/A ☐
HRDS6.3.4	Channel 4	16.3.6.3	HRDS6.3:M	Yes ☐ No ☐ N/A ☐
HRDS6.3.5	Channel 5	16.3.6.3	HRDS6.3:M	Yes ☐ No ☐ N/A ☐
HRDS6.3.6	Channel 6	16.3.6.3	HRDS6.3:M	Yes ☐ No ☐ N/A ☐
HRDS6.3.7	Channel 7	16.3.6.3	HRDS6.3:M	Yes ☐ No ☐ N/A ☐
HRDS6.3.8	Channel 8	16.3.6.3	HRDS6.3:M	Yes ☐ No ☐ N/A ☐
HRDS6.3.9	Channel 9	16.3.6.3	HRDS6.3:M	Yes ☐ No ☐ N/A ☐
HRDS6.3.10	Channel 10	16.3.6.3	HRDS6.3:M	Yes ☐ No ☐ N/A ☐
HRDS6.3.11	Channel 11	16.3.6.3	HRDS6.3:M	Yes ☐ No ☐ N/A ☐
HRDS6.3.12	Channel 12	16.3.6.3	HRDS6.3:M	Yes ☐ No ☐ N/A ☐
HRDS6.3.13	Channel 13	16.3.6.3	HRDS6.3:M	Yes ☐ No ☐ N/A ☐
*HRDS6.4	France	16.3.6.3	HRDS6:O.3	Yes ☐ No ☐ N/A ☐
HRDS6.4.1	Channel 10	16.3.6.3	HRDS6.4:M	Yes ☐ No ☐ N/A ☐
HRDS6.4.2	Channel 11	16.3.6.3	HRDS6.4:M	Yes ☐ No ☐ N/A ☐
HRDS6.4.3	Channel 12	16.3.6.3	HRDS6.4:M	Yes ☐ No ☐ N/A ☐
HRDS6.4.4	Channel 13	16.3.6.3	HRDS6.4:M	Yes ☐ No ☐ N/A ☐
*HRDS6.5	Spain	16.3.6.3	HRDS6:O.3	Yes ☐ No ☐ N/A ☐
HRDS6.5.1	Channel 10	16.3.6.3	HRDS6.5:M	Yes ☐ No ☐ N/A ☐
HRDS6.5.2	Channel 11	16.3.6.3	HRDS6.5:M	Yes ☐ No ☐ N/A ☐
*HRDS6.6	Japan	16.3.6.3	HRDS6:O.3	Yes ☐ No ☐ N/A ☐
HRDS6.6.1	Channel 1	16.3.6.3	HRDS6.6:M	Yes ☐ No ☐ N/A ☐
HRDS6.6.2	Channel 2	16.3.6.3	HRDS6.6:M	Yes ☐ No ☐ N/A ☐
HRDS6.6.3	Channel 3	16.3.6.3	HRDS6.6:M	Yes ☐ No ☐ N/A ☐
HRDS6.6.4	Channel 4	16.3.6.3	HRDS6.6:M	Yes ☐ No ☐ N/A ☐
HRDS6.6.5	Channel 5	16.3.6.3	HRDS6.6:M	Yes ☐ No ☐ N/A ☐
HRDS6.6.6	Channel 6	16.3.6.3	HRDS6.6:M	Yes ☐ No ☐ N/A ☐
HRDS6.6.7	Channel 7	16.3.6.3	HRDS6.6:M	Yes ☐ No ☐ N/A ☐
HRDS6.6.8	Channel 8	16.3.6.3	HRDS6.6:M	Yes ☐ No ☐ N/A ☐
HRDS6.6.9	Channel 9	16.3.6.3	HRDS6.6:M	Yes ☐ No ☐ N/A ☐
HRDS6.6.10	Channel 10	16.3.6.3	HRDS6.6:M	Yes ☐ No ☐ N/A ☐
HRDS6.6.11	Channel 11	16.3.6.3	HRDS6.6:M	Yes ☐ No ☐ N/A ☐
HRDS6.6.12	Channel 12	16.3.6.3	HRDS6.6:M	Yes ☐ No ☐ N/A ☐
HRDS6.6.13	Channel 13	16.3.6.3	HRDS6.6:M	Yes ☐ No ☐ N/A ☐
HRDS6.6.14	Channel 14	16.3.6.3	HRDS6.6:M	Yes ☐ No ☐ N/A ☐
*HRDS6.7	China (Radio Administration The Radio Administration of P.R.China)	16.3.6.3	HRDS6:O.3	Yes ☐ No ☐ N/A ☐
HRDS6.7.1	Channel 1	16.3.6.3	HRDS6.7:M	Yes ☐ No ☐ N/A ☐

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B.4.7 High rate, direct sequence PHY functions *(continued)*

Item	PHY feature	References	Status	Support
HRDS6.7.2	Channel 2	16.3.6.3	HRDS6.7:M	Yes ☐ No ☐ N/A ☐
HRDS6.7.3	Channel 3	16.3.6.3	HRDS6.7:M	Yes ☐ No ☐ N/A ☐
HRDS6.7.4	Channel 4	16.3.6.3	HRDS6.7:M	Yes ☐ No ☐ N/A ☐
HRDS6.7.5	Channel 5	16.3.6.3	HRDS6.7:M	Yes ☐ No ☐ N/A ☐
HRDS6.7.6	Channel 6	16.3.6.3	HRDS6.7:M	Yes ☐ No ☐ N/A ☐
HRDS6.7.7	Channel 7	16.3.6.3	HRDS6.7:M	Yes ☐ No ☐ N/A ☐
HRDS6.7.8	Channel 8	16.3.6.3	HRDS6.7:M	Yes ☐ No ☐ N/A ☐
HRDS6.7.9	Channel 9	16.3.6.3	HRDS6.7:M	Yes ☐ No ☐ N/A ☐
HRDS6.7.10	Channel 10	16.3.6.3	HRDS6.7:M	Yes ☐ No ☐ N/A ☐
HRDS6.7.11	Channel 11	16.3.6.3	HRDS6.7:M	Yes ☐ No ☐ N/A ☐
HRDS6.7.12	Channel 12	16.3.6.3	HRDS6.7:M	Yes ☐ No ☐ N/A ☐
HRDS6.7.13	Channel 13	16.3.6.3	HRDS6.7:M	Yes ☐ No ☐ N/A ☐
HRDS7	*Reserved*			
HRDS8	Complementary code keying (CCK) bits to symbol mapping			
HRDS8.1	5.5 Mb/s	16.3.6.6	M	Yes ☐ No ☐
HRDS8.2	11 Mb/s	16.3.6.6	M	Yes ☐ No ☐
HRDS9	*Reserved*			
*HRDS10	CCA functionality	16.3.8.5		
HRDS10.1	CCA Mode 1, energy only (RSSI above threshold)	16.3.8.5	HRDS10:O.4	Yes ☐ No ☐ N/A ☐
HRDS10.2	CCA Mode 4, CS with timer	16.3.8.5	HRDS10:O.4	Yes ☐ No ☐ N/A ☐
HRDS10.3	CCA Mode 5, energy detect with high rate CS	16.3.8.5	HRDS10:O.4	Yes ☐ No ☐ N/A ☐
HRDS10.4	Hold CCA busy for packet duration of a correctly received PPDU, but carrier lost during reception of MPDU.	16.2.6	M	Yes ☐ No ☐
HRDS10.5	Hold CCA busy for packet duration of a correctly received, but out of spec, PPDU.	16.2.6	M	Yes ☐ No ☐
HRDS11	Transmit antenna selection	16.3.5	O	Yes ☐ No ☐
HRDS12	Receive antenna diversity	16.3.5	O	Yes ☐ No ☐
*HRDS13	Antenna connector availability	16.3.6.11	O	Yes ☐ No ☐
HRDS13.1	If available (50 Ω impedance)	16.3.6.11	HRDS13:M	Yes ☐ No ☐ N/A ☐
*HRDS14	Transmit power level support	16.3.7.3	O	Yes ☐ No ☐
HRDS14.1	If greater than 100 mW capability	16.3.7.3	HRDS14:M	Yes ☐ No ☐ N/A ☐
HRDS15	Spurious emissions compliance	16.3.6.7	M	Yes ☐ No ☐
HRDS16	TX-to-RX turnaround time	16.3.6.8	M	Yes ☐ No ☐
HRDS17	RX-to-TX turnaround time	16.3.6.9	M	Yes ☐ No ☐
HRDS18	Slot time	16.3.6.10	M	Yes ☐ No ☐
HRDS19	ED reporting time	16.3.6.9, 16.3.8.5	M	Yes ☐ No ☐
HRDS20	Minimum transmit power level	16.3.7.3	M	Yes ☐ No ☐

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B.4.7 High rate, direct sequence PHY functions *(continued)*

Item	PHY feature	References	Status	Support
HRDS21	Transmit spectral mask compliance	16.3.7.4	M	Yes ☐ No ☐
HRDS22	Transmitted center frequency tolerance	16.3.7.5	M	Yes ☐ No ☐
HRDS23	Chip clock frequency tolerance	16.3.7.6	M	Yes ☐ No ☐
HRDS24	Transmit power-on ramp	16.3.7.7	M	Yes ☐ No ☐
HRDS25	Transmit power-down ramp	16.3.7.7	M	Yes ☐ No ☐
HRDS26	RF carrier suppression	16.3.7.8	M	Yes ☐ No ☐
HRDS27	Transmit modulation accuracy	16.3.7.9	M	Yes ☐ No ☐
HRDS28	Receiver minimum input level sensitivity	16.3.8.2	M	Yes ☐ No ☐
HRDS29	Receiver maximum input level	16.3.8.3	M	Yes ☐ No ☐
HRDS30	Receiver adjacent channel rejection	16.3.8.4	M	Yes ☐ No ☐
HRDS31	MIB	16.3.2	M	Yes ☐ No ☐
HRDS31.1	PHY object class	16.3.3	M	Yes ☐ No ☐

B.4.8 Regulatory domain extensions

Item	Protocol capability	References	Status	Support
MD1	Country element Length Country String First Channel Number Maximum Transmit Power Level Number of Channels	9.3.3.2, 9.3.3.10, 9.4.2.8	CFMD:M	Yes ☐ No ☐ N/A ☐
MD2	Inclusion of the Request information in the Probe Request frame	9.3.3.9	CFMD:O	Yes ☐ No ☐ N/A ☐
MD3	*Reserved*			
MD4	*Reserved*			
MD5	Request mechanism			
MD5.1	Request element Format Element ID Order of the Requested Elemented IDs	9.4.2.9	CFMD:M	Yes ☐ No ☐ N/A ☐
MD5.2	Extended Request element	9.4.2.10	CFMD:M	Yes ☐ No ☐ N/A ☐
MD6	Entering a Regulatory Domain Lost Connectivity with its extended service set (ESS) Passive Scanning to learn Beacon information Transmit Probe Request	10.22.2	CFMD:M	Yes ☐ No ☐ N/A ☐
MD7	*Reserved*			
MD8	Roaming requires Beacon frame with country element	11.1.4.4	CFMD:M	Yes ☐ No ☐ N/A ☐

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B.4.8 Regulatory domain extensions *(continued)*

Item	Protocol capability	References	Status	Support
MD9	Actions to be taken upon the receipt of the Beacon frame	11.1.4.5	CFMD:M	Yes ☐ No ☐ N/A ☐
MD10	*Reserved*			
MD11	*Reserved*			
MD12	Operating and Coverage classes	9.4.2.8	OC1:M	Yes ☐ No ☐ N/A ☐
MD13	Reserved First Channel Number	10.22.3	CF3G6:M	Yes ☐ No ☐ N/A ☐
MD14	Reserved Operating Class	10.22.3	CF3G6:M	Yes ☐ No ☐ N/A ☐
*MD15	Operation with operating classes	10.22.3	CF3G6:M	Yes ☐ No ☐ N/A ☐
MD15.1	Multiple classes in Country element	10.22.3	MD15:M	Yes ☐ No ☐ N/A ☐
MD15.2	Multiple classes in (Re)Association Request and Response frames	10.22.3	MD15:M	Yes ☐ No ☐ N/A ☐

B.4.9 ERP functions

Item	PHY features	References	Status	Support
*ERP1	Transmit and Receive ERP-DSSS data rates 1 and 2 Mb/s and ERP-CCK data rates 5.5 and 11 Mb/s	18.3.2	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP1.1	Transmit and receive ERP-OFDM data rates of 6, 12, and 24 Mb/s	18.3.2	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP1.2	Transmit and receive ERP-OFDM data rate of 9 Mb/s	18.3.2	ERP1:O	Yes ☐ No ☐ N/A ☐
ERP1.3	Transmit and receive ERP-OFDM data rate of 18 Mb/s	18.3.2	ERP1:O	Yes ☐ No ☐ N/A ☐
ERP1.4	Transmit and receive ERP-OFDM data rate of 36 Mb/s	18.3.2	ERP1:O	Yes ☐ No ☐ N/A ☐
ERP1.5	Transmit and receive ERP-OFDM data rate of 48 Mb/s	18.3.2	ERP1:O	Yes ☐ No ☐ N/A ☐
ERP1.6	Transmit and receive ERP-OFDM data rate of 54 Mb/s	18.3.2	ERP1:O	Yes ☐ No ☐ N/A ☐
ERP2	*Reserved*			
ERP3	*Reserved*			
ERP4	Support of ERP3 required PPDU formats as described in reference	18.3.2	CFERP:O	Yes ☐ No ☐ N/A ☐

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B.4.9 ERP functions *(continued)*

Item	PHY features	References	Status	Support
ERP5	Able to transmit and receive long and short DSSS as well as OFDM preambles	18.3.2	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP6	Set SERVICE field bits for locked clocks, and length extension	18.3.2.2	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP7	Set B1 and B4 of long and short preamble PPDU SERVICE field to 0	18.3.2.2	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP8	Set B2 to 1 in all long and short preamble PPDU SERVICE fields	18.3.2.2	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP9	Set B7 of the long and short preamble PPDU SERVICE fields as described in the reference	18.3.2.2, 18.3.2.3	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP10	Use Clause 15 (DSSS for 2.4 GHz band for ISM applications) or Clause 16 (HR/DSSS) rates when using protection mechanisms	10.27	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP11	*Reserved*			
ERP12	*Reserved*			
ERP13	*Reserved*			
ERP14	*Reserved*			
ERP15	*Reserved*			
ERP16	Add signal extension of 6 µs	18.3.2.4	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP17	Simultaneous CCA on long preamble Barker, short preamble Barker, and OFDM	18.3.4	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP18	CCA with energy detect above threshold and CS	18.3.4	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP19	*Reserved*			
ERP20	Able to automatically detect format of long preamble Barker, short preamble Barker, and OFDM and receive appropriately	18.3.5	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP21	Comply with local regulatory frequency allocation requirements	18.4.2	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP22	Use frequency plan for 2.4 GHz	18.4.3	CFERP:M	Yes ☐ No ☐ N/A ☐

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B.4.9 ERP functions *(continued)*

Item	PHY features	References	Status	Support
ERP23	Comply with regulatory spurious emissions regulations	18.4.4	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP24	Slot time requirements	18.5.4	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP25	Support short slot time	18.5.4	CFERP:O	Yes ☐ No ☐ N/A ☐
ERP26	Use 10 µs short interframe space (SIFS) time	18.4.6	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP27	Comply with regulatory transmit power requirements	18.4.7.2	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP28	± 25 ppm frequency tolerance	18.4.7.4	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP29	Use locked clocks	18.4.7.4, 18.4.7.5	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP30	Tolerate input level of –20 dBm	18.4.8.4	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP31	Use specified transmit mask	18.5	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP32	Meet sensitivity for all supported data rates	18.4.8.2	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP33	Reject adjacent channels as in 17.3.10.2 (Table 17-18) or in 16.3.8.4 as appropriate	18.4.8.3	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP34	*Reserved*			
ERP35	*Reserved*			
ERP36	*Reserved*			
ERP37	*Reserved*			
ERP38	*Reserved*			
ERP39	Calculate ERP-OFDM TXTIME	18.5.3.2	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP40	*Reserved*			
ERP41	*Reserved*			
ERP42	Revert to long slot time when establishing association with a long slot time STA	9.4.1.4	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP43	Support TXVECTOR and RXVECTOR as described in reference	10.3	CFERP:M	Yes ☐ No ☐ N/A ☐
ERP44	*Reserved*			

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B.4.10 Spectrum management extensions

Item	IUT configuration	References	Status	Support
SM1	Country, Power Constraint, and transmit power control (TPC) Report elements included in Beacon and Probe Response frames	9.3.3.2, 9.3.3.10, 9.4.2.8, 9.4.2.11, 9.4.2.14	CFSM:M	Yes ☐ No ☐ N/A ☐
SM1.1	Transmit Envelope element(s) in Beacon and Probe Response frames	9.4.2.161	CFSM AND CFESM:M	Yes ☐ No ☐ N/A ☐
SM2	Spectrum Management Capability bit	9.4.1.4	CFSM:M	Yes ☐ No ☐ N/A ☐
SM3	Power Capability and Supported Channels elements in (Re)Association Request and Response frames	9.3.3.5, 9.3.3.6, 11.6.1	CFSM:M	Yes ☐ No ☐ N/A ☐
SM4	Action frame protocol for spectrum management actions	9.4.1.11, 9.6	CFSM:M	Yes ☐ No ☐ N/A ☐
SM4.1	Measurement Request frame	9.6.2.2	CFSM:M	Yes ☐ No ☐ N/A ☐
SM4.2	Measurement Report frame	9.6.2.3	CFSM:M	Yes ☐ No ☐ N/A ☐
SM4.3	TPC Request frame	9.6.2.4	CFSM:M	Yes ☐ No ☐ N/A ☐
SM4.4	TPC Report frame	9.6.2.5	CFSM:M	Yes ☐ No ☐ N/A ☐
SM4.5	Channel Switch Announcement frame	9.6.2.6	CFSM AND NOT CFDMG:M	Yes ☐ No ☐ N/A ☐
SM5	Measurement requests			
SM5.1	Basic request	9.4.2.20.2	CFSM:M	Yes ☐ No ☐ N/A ☐
SM5.2	CCA request	9.4.2.20.3	CFSM:O	Yes ☐ No ☐ N/A ☐
SM5.3	Receive power indication (RPI) histogram	9.4.2.20.4	CFSM:O	Yes ☐ No ☐ N/A ☐
SM5.4	Enabling/disabling requests and reports	9.4.2.20	CFSM:M	Yes ☐ No ☐ N/A ☐
SM6	Measurement reports			
SM6.1	Basic report	9.4.2.21.2	CFSM:M	Yes ☐ No ☐ N/A ☐
SM6.2	CCA report	9.4.2.21.3	CFSM:O	Yes ☐ No ☐ N/A ☐
SM6.3	RPI histogram report	9.4.2.21.4	CFSM:O	Yes ☐ No ☐ N/A ☐
SM6.4	Refusal to measure	9.4.2.21	CFSM:M	Yes ☐ No ☐ N/A ☐
SM7	Quiet interval	EMPTY		
SM7.1	AP-defined Quiet interval	9.3.3.2, 9.3.3.10, 9.4.2.22, 11.6.2	(CFAP and CFSM):M	Yes ☐ No ☐ N/A ☐
SM7.2	STA-defined Quiet interval	9.3.3.2, 9.3.3.10, 9.4.2.22, 11.6.2	(CFSTAofAP and CFSM):M	Yes ☐ No ☐ N/A ☐
SM7.3	STA support for Quiet interval	9.3.3.2, 9.3.3.10, 9.4.2.22, 11.6.2	CFSM:M	Yes ☐ No ☐ N/A ☐
SM8	Association control based on spectrum management capability	11.7, 11.8	(CFAP and CFSM):M	Yes ☐ No ☐ N/A ☐

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B.4.10 Spectrum management extensions *(continued)*

Item	IUT configuration	References	Status	Support
SM9	Association control based on transmit power capability	11.7.2	(CFAP and CFSM):M	Yes ☐ No ☐ N/A ☐
SM10	Maximum transmit power levels			
SM10.1	AP determination and communication of local maximum transmit power level	11.7.5	(CFAP AND CFSM):M	Yes ☐ No ☐ N/A ☐
SM10.2	STA determination and communication of local maximum transmit power level	11.7.5	((CFSTAofAP OR CFIBSS) AND CFSM):M	Yes ☐ No ☐ N/A ☐
SM11	Selection of transmit power	11.7.6	CFSM:M	Yes ☐ No ☐ N/A ☐
SM12	Adaptation of transmit power			
SM12.1	TPC report in Beacon and Probe Response frames	11.7.7	CFSM:M	Yes ☐ No ☐ N/A ☐
SM13.1	Dynamic transmit power adaptation	11.7.7	CFSM:O	Yes ☐ No ☐ N/A ☐
SM13	Testing channels for radar	11.8.4	CFSM:M	Yes ☐ No ☐ N/A ☐
SM14	Detecting and discontinuing operations after detection of radar	11.8.5	CFSM:M	Yes ☐ No ☐ N/A ☐
SM15	Requesting and reporting of measurements	11.8.7	CFSM:M	Yes ☐ No ☐ N/A ☐
SM16	Autonomous reporting of radar	11.8.7	CFSM:M	Yes ☐ No ☐ N/A ☐
SM17	IBSS dynamic frequency selection (DFS) element including channel map	9.4.2.23	(CFIBSS AND CFSM):M	Yes ☐ No ☐ N/A ☐
SM18	DFS owner function	11.8.8	(CFIBSS AND CFSM):M	Yes ☐ No ☐ N/A ☐
SM19	DFS owner recovery procedure	11.8.8	(CFIBSS AND CFSM):M	Yes ☐ No ☐ N/A ☐
SM20	Channel switching procedure			
SM20.1	Transmission of channel switch announcement and channel switching procedure by an AP	11.8.8	(CFAP AND CFSM):M	Yes ☐ No ☐ N/A ☐
SM20.2	Transmission of channel switch announcement and channel switching procedure by a STA	11.8.8	(CFSTAofAP AND CFSM):M	Yes ☐ No ☐ N/A ☐
SM20.3	Reception of channel switch announcement and channel switching procedure by a STA	11.8.8	CFSM:M	Yes ☐ No ☐ N/A ☐
SM20.4	Transmission of Wide Bandwidth Channel Switch element in Channel Announcement frame and transmission of Wide Bandwidth Channel Switch subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated channel switching procedure by an AP	11.38.4	(CFAP AND CFSM AND CFESM):M	Yes ☐ No ☐ N/A ☐

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B.4.10 Spectrum management extensions *(continued)*

Item	IUT configuration	References	Status	Support
SM20.5	Transmission of Wide Bandwidth Channel Switch element in Channel Announcement frame and transmission of Wide Bandwidth Channel Switch subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated channel switching procedure by a STA.	11.38.4	(CFIBSS AND CFSM AND CFESM):M	Yes ☐ No ☐ N/A ☐
SM20.6	Reception of Wide Bandwidth Channel Switch element in Channel Announcement frame and reception of Wide Bandwidth Channel Switch subelement in Channel Switch Wrapper element in Beacon/Probe Response frames, and associated channel switching procedure by a STA.	11.38.4	(CFSM AND CFESM):M	Yes ☐ No ☐ N/A ☐
SM20.7	Transmission of New Transmit Power Envelope element in Channel Announcement frame and transmission of New Transmit Power Envelope subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated channel switching procedure by an AP.	11.38.4	(CFAP AND CFSM AND CFESM):M	Yes ☐ No ☐ N/A ☐
SM20.8	Transmission of New Transmit Power Envelope element in Channel Announcement frame and transmission of New Transmit Power Envelope subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated channel switching procedure by a STA.	11.38.4	(CFIBSS AND CFSM AND CFESM):M	Yes ☐ No ☐ N/A ☐
SM20.9	Reception of New Transmit Power Envelope element in Channel Announcement frame and reception of New Transmit Power Envelope subelement in Channel Switch Wrapper element in Beacon/Probe Response frames, and associated channel switching procedure by a STA.	11.38.4	(CFSM AND CFESM):M	Yes ☐ No ☐ N/A ☐
SM20.10	Transmission of Future Channel Guidance element by a STA.	11.8.10	CFSM:O	Yes ☐ No ☐ N/A ☐
SM20.11	Reception of Future Channel Guidance element procedure by a STA.	11.8.10	CFSM:O	Yes ☐ No ☐ N/A ☐

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B.4.11 Operating classes extensions

Item	Protocol capability	References	Status	Support
OC1	Operating and coverage classes	9.4.2.8	CFMD AND CFOC:M	Yes ☐ No ☐ N/A ☐
OC2	Operating and coverage classes (20 MHz channel spacing)	9.4.2.8, 17.3.8.6	CFMD AND CFOC:M	Yes ☐ No ☐ N/A ☐
OC3	Operating and coverage classes (10 MHz channel spacing)	9.4.2.8, 17.3.8.6	CFMD AND CFOC AND OF1.7:M	Yes ☐ No ☐ N/A ☐
OC4	Operating and coverage classes (5 MHz channel spacing)	9.4.2.8, 17.3.8.6	CFMD AND CFOC AND OF1.8:M	Yes ☐ No ☐ N/A ☐
OC5	Coverage classes 0–31	10.22.5	CF3G6:M	Yes ☐ No ☐ N/A ☐
	Coverage class operation when not associated	10.22.5	CF3G6:M	Yes ☐ No ☐ N/A ☐
OC6	Power level, equivalent maximum transmit power level and operating class	10.22.5	CF3G6:M	Yes ☐ No ☐ N/A ☐
	Power level operation when not associated	10.22.5	CF3G6:M	Yes ☐ No ☐ N/A ☐
OC7	Power level, different maximum transmit power level and operating class	10.22.5	CF3G6:M	Yes ☐ No ☐ N/A ☐
	Power level operation when not associated	10.22.5	CF3G6:M	Yes ☐ No ☐ N/A ☐
OC8	Operation with multiple country elements	—	OC1:O	Yes ☐ No ☐ N/A ☐

B.4.12 QoS base functionality

Item	Protocol capability	References	Status	Support
QB1	QoS frame format			
QB1.1	QoS frame format	9.3.1.2–9.3.1.4, 9.3.2.1, 9.3.3.2, 9.3.3.5–9.3.3.8, 9.3.3.10, 9.3.3.13	not CFDMG AND CFQoS:M	Yes ☐ No ☐ N/A ☐
QB1.2	QoS frame format	9.3.1.2, 9.3.1.4, 9.3.1.7, 9.3.1.8, 9.3.1.10–9.3.1.18, 9.3.2.1, 9.3.4.2, 9.3.3.5–9.3.3.8, 9.3.3.10, 9.3.3.13	CFDMG:M	Yes ☐ No ☐ N/A ☐
QB2	Per traffic identifier (TID) duplicate detection	9.2.4.4, 9.2.4.5, 10.3.2.14	CFQoS OR CFDMG:M	Yes ☐ No ☐ N/A ☐
QB3	Decode of No Ack ack policy in QoS Data frames	9.2.4.5.4, 10.23.2.8, 10.23.2.12, 10.23.4.2, 10.23.4.3	CFQoS OR CFDMG:M	Yes ☐ No ☐ N/A ☐

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B.4.12 QoS base functionality *(continued)*

Item	Protocol capability	References	Status	Support
QB4	Block acknowledgments (block ack)			
QB4.1	Immediate block ack Non-HT block ack is obsolete. Support for this mechanism might be removed in a later revision of the standard.	9.3.1.7.1, 9.3.1.8.1, 9.6.4, 10.25 (except 10.25.6), 11.5	CFQoS:O CFHT OR CFDMG OR CFTVHT:M	Yes ☐ No ☐ N/A ☐
*QB4.2	*Reserved*			
QB4.3	Compressed Block Ack			
QB4.3.1	Compressed Block Ack	9.3.1.7.2	CFQoS:O CFHT OR CFDMG OR CFTVHT:M	Yes ☐ No ☐ N/A ☐
QB4.3.2	Extended Compressed Block Ack	9.3.1.7.3	CFDMG:O	Yes ☐ No ☐ N/A ☐
QB4.4	Multi-TID Block Ack	9.3.1.8.3	CFQoS:O CFHT OR CFTVHT:M	Yes ☐ No ☐ N/A ☐
QB5	Automatic power save delivery (APSD)	9.6.3, 11.2.3	(CFAP and CFQoS):O (CFIndepSTA and CFQoS):O	Yes ☐ No ☐ N/A ☐

B.4.13 QoS enhanced distributed channel access (EDCA)

Item	Protocol capability	References	Status	Support
QD1	Support for four transmit queues with a separate channel access entity associated with each	10.2.3.2, 10.23.2.1	not CFDMG AND CFQoS:M CFS1G AND S1GM20.5: M CFS1G AND S1GM20.4:O	Yes ☐ No ☐ N/A ☐
QD2	Per-channel access function differentiated channel access	10.23.2.2, 10.23.2.4, 10.23.2.12	not CFDMG AND CFQoS:M	Yes ☐ No ☐ N/A ☐
QD3	Multiple frame transmission support	10.23.2.8	CFQoS OR CFDMG OR CFS1G:O	Yes ☐ No ☐ N/A ☐
QD4	Maintenance of within-queue ordering, exhaustive retransmission when sending non-QoS Data frames	10.23.2.12	(CFQoS AND NOT CFS1G) OR CFDMG:M	Yes ☐ No ☐ N/A ☐
QD5	Interpretation of admission control mandatory (ACM) subfield in EDCA Parameter Set element	9.4.2.12, 10.23.4.2	(CFSTAofAP AND (CFQoS OR CFDMG)):M (CFPBSSnotPCP AND CFDMG):	Yes ☐ No ☐ N/A ☐

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B.4.13 QoS enhanced distributed channel access (EDCA) *(continued)*

Item	Protocol capability	References	Status	Support
QD6	Contention based admission control	9.4.2.13, 9.4.2.14, 9.6.3.2–9.6.3.4, 10.23.4.2, 11.4	(CFAP AND (CFQoS OR CFDMG)):O (CFSTAofAP AND (CFQoS OR CFDMG)):O (CFPCP AND CFDMG):O (CFPBSSnotPCP AND CFDMG):O	Yes ☐ No ☐ N/A ☐
QD7	Power management in an infrastructure BSS or in an IBSS	11.2	(CFAP AND CFQoS):O (CFIndepSTA AND CFQoS):O	Yes ☐ No ☐ N/A ☐
QD8	Default EDCA parameters for communications outside context of BSS	9.4.2.28, 10.23.2.2	CFOCB:M	Yes ☐ No ☐ N/A ☐
QD9	Duration/ID rules for QoS STA	9.2.5	CFQoS	Yes ☐ No ☐ N/A ☐
QD10	Mirrored Stream Classification Service (MSCS)	9.6.18.6, 9.6.18.7, 11.25.3	CFQoS:O	Yes ☐ No ☐ N/A ☐

B.4.14 QoS hybrid coordination function (HCF) controlled channel access (HCCA)

Item	Protocol capability	References	Status	Support
QP1	Traffic specification (TSPEC) and associated frame formats	9.6.3	(CFAP AND CFQoS):M (CFIndepSTA AND CFQoS):M	Yes ☐ No ☐ N/A ☐
QP2	HCCA rules	10.2.3.3, 10.23.3, 10.23.3.2–10.23.3.5	(CFAP AND CFQoS):M (CFIndepSTA AND CFQoS):M	Yes ☐ No ☐ N/A ☐
QP3	HCCA schedule generation and management	10.23.4	(CFAP AND CFQoS):M	Yes ☐ No ☐ N/A ☐
QP4	HCF frame exchange sequences	10.23.2	(CFAP AND CFQoS):M (CFIndepSTA AND CFQoS):M	Yes ☐ No ☐ N/A ☐
QP5	Traffic stream (TS) management	11.4	(CFAP AND CFQoS):M (CFIndepSTA AND CFQoS):M	Yes ☐ No ☐ N/A ☐
QP6	Minimum TSPEC parameter set	10.23.4	(CFAP AND CFQoS):M (CFIndepSTA AND CFQoS):M	Yes ☐ No ☐ N/A ☐
QP7	Power management in an infrastructure BSS	11.2.3.5, 11.2.3.6, 11.2.3.6, 11.2.3.7, 11.2.3.7, 11.2.3.8, 11.2.3.9	(CFAP AND CFQoS):M (CFIndepSTA AND CFQoS):M	Yes ☐ No ☐ N/A ☐

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B.4.15 Radio management extensions

Item	Protocol capability	References	Status	Support
	Are the following Radio Measurement capabilities supported?			
RM1	Radio Measurement Capability	9.4.1.4	CFRM:M	Yes ☐ No ☐ N/A ☐
RM2	Action frame protocol for measurements	9.6	CFRM:M	Yes ☐ No ☐ N/A ☐
RM2.1	Radio Measurement Request frame	9.6.6.2	CFRM:M	Yes ☐ No ☐ N/A ☐
RM2.2	Radio Measurement Report frame	9.6.6.3	CFRM:M	Yes ☐ No ☐ N/A ☐
RM2.3	Link Measurement Request frame	9.6.6.4	CFRM:M	Yes ☐ No ☐ N/A ☐
RM2.4	Link Measurement Report frame	9.6.6.5	CFRM:M	Yes ☐ No ☐ N/A ☐
RM2.4.1	Link Measurement Report frame	9.6.6.5	not CF DMG AND CFRM:M	Yes ☐ No ☐ N/A ☐
RM2.4.2	Link Measurement Report frame	9.6.6.5, 9.4.2.148, 9.4.2.149, 10.42.9	CFDMG AND CFRM:M	Yes ☐ No ☐ N/A ☐
RM2.5	Neighbor Report Request			
RM2.5.1	Generate and transmit Neighbor Report Request	9.6.6.6	(CFRM AND CFSTAofAP):M	Yes ☐ No ☐ N/A ☐
RM2.5.2	Receive and process Neighbor Report Request	9.6.6.6	(CFRM AND CFAP):M	Yes ☐ No ☐ N/A ☐
RM2.6	Neighbor Report Response			
RM2.6.1	Generate and transmit Neighbor Report Response	9.4.2.36, 9.6.6.7	(CFRM AND CFAP):M	Yes ☐ No ☐ N/A ☐
RM2.6.2	Receive and process Neighbor Report Response	9.4.2.36, 9.6.6.7	(CFRM AND CFSTAofAP):M	Yes ☐ No ☐ N/A ☐
RM3	General protocol for requesting and reporting of measurements	9.4.2.20, 9.4.2.21, 11.10, 11.10.6	CFRM:M	Yes ☐ No ☐ N/A ☐
RM3.1	Parallel Measurements	9.4.2.20, 9.4.2.21, 11.10.6	CFRM:M	Yes ☐ No ☐ N/A ☐
RM3.2	Use of Enable, Request and Report bits to enable/ disable measurement requests and triggered autonomous reports Measurement Requests	9.4.2.20, 11.10.6, 11.10.8	CFRM:M	Yes ☐ No ☐ N/A ☐

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B.4.15 Radio management extensions *(continued)*

Item	Protocol capability	References	Status	Support
RM3.3	Enable Autonomous Report	9.4.2.20, 11.10.8	CFRM:M	Yes ☐ No ☐ N/A ☐
RM3.4	Duration Mandatory	9.4.2.20, 11.10.4	CFRM:M	Yes ☐ No ☐ N/A ☐
RM3.5	Incapable Indication	9.4.2.21	CFRM:M	Yes ☐ No ☐ N/A ☐
RM3.6	Refused Indication	9.4.2.21, 11.10.5	CFRM:M	Yes ☐ No ☐ N/A ☐
RM3.7	Repeated Measurement	9.6.6.2, 11.10.7	CFRM:M	Yes ☐ No ☐ N/A ☐
RM3.8	Measurement Pause	9.4.2.20.12, 11.10.9.7	CFRM:M	Yes ☐ No ☐ N/A ☐
RM4	Beacon Measurement Type	11.10, 11.10.9.1	CFRM:M	Yes ☐ No ☐ N/A ☐
RM4.1	Beacon request	9.4.2.20.7	CFRM:M	Yes ☐ No ☐ N/A ☐
RM4.2	Passive Measurement mode	9.4.2.20.7, 11.10.9.1	CFRM:M	Yes ☐ No ☐ N/A ☐
RM4.3	Active Measurement mode	9.4.2.20.7, 11.10.9.1	CFRM:M	Yes ☐ No ☐ N/A ☐
RM4.4	Beacon table mode	9.4.2.20.7, 11.10.9.1	CFRM:M	Yes ☐ No ☐ N/A ☐
RM4.5	Reporting Conditions	9.4.2.20.7	CFRM:O	Yes ☐ No ☐ N/A ☐
RM4.6	Beacon report	9.4.2.20.7	CFRM:M	Yes ☐ No ☐ N/A ☐
RM4.7	Reporting Detail	9.4.2.20.7, 9.4.2.21.7, 9.4.2.35	CFRM:O	Yes ☐ No ☐ N/A ☐
* RM5	Frame Measurement Type	11.10, 11.10.9.2	CFRM:O	Yes ☐ No ☐ N/A ☐
RM5.1	Frame request	9.4.2.20.8	(CFRM AND RM5):M	Yes ☐ No ☐ N/A ☐
RM5.2	Frame report	9.4.2.21.8	(CFRM AND RM5):M	Yes ☐ No ☐ N/A ☐
RM6	Channel Load Measurement Type	11.10, 11.10.9.3	CFRM:M	Yes ☐ No ☐ N/A ☐
RM6.1	Channel Load request	9.4.2.20.5	CFRM:M	Yes ☐ No ☐ N/A ☐
RM6.2	Channel Load report	9.4.2.21.5	CFRM:M	Yes ☐ No ☐ N/A ☐
RM7	Noise Histogram Measurement Type	11.10, 11.10.9.4	CFRM:M	Yes ☐ No ☐ N/A ☐
RM7.1	Noise Histogram request	9.4.2.20.6	CFRM:M	Yes ☐ No ☐ N/A ☐
RM7.2	Noise Histogram report	9.4.2.21.6	CFRM:M	Yes ☐ No ☐ N/A ☐
RM8	STA Statistics Measurement Type	11.10, 11.10.9.5	CFRM:M	Yes ☐ No ☐ N/A ☐
RM8.1	STA Statistics request	9.4.2.20.9	CFRM:M	Yes ☐ No ☐ N/A ☐
RM8.2	STA Statistics report	9.4.2.21.9	CFRM:M	Yes ☐ No ☐ N/A ☐

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B.4.15 Radio management extensions *(continued)*

Item	Protocol capability	References	Status	Support
RM9	LCI Measurement Type	11.10, 11.10.9.6	CFRM:M	Yes ☐ No ☐ N/A ☐
RM9.1	LCI request	9.4.2.20.10	CFRM:M	Yes ☐ No ☐ N/A ☐
RM9.1.1	Location Subject	9.4.2.20.10	CFRM:M	Yes ☐ No ☐ N/A ☐
RM9.1.1.1	Location Subject third party	9.4.2.20.10	CFRM:O	Yes ☐ No ☐ N/A ☐
RM9.2	LCI report	9.4.2.21.10	CFRM:M	Yes ☐ No ☐ N/A ☐
RM9.3	Azimuth	11.10, 11.10.9.6	CFRM:O	Yes ☐ No ☐ N/A ☐
RM9.3.1	Azimuth Request	9.4.2.20.10	CFRM:O	Yes ☐ No ☐ N/A ☐
RM9.3.2	Azimuth Response	9.4.2.21.10	CFRM:O	Yes ☐ No ☐ N/A ☐
*RM10	Transmit Stream/ Category Measurement Type	11.10, 11.10.9.8	(CFRM AND (CFQoS OR CFDMG)):O	Yes ☐ No ☐ N/A ☐
RM10.1	Transmit Stream/ Category Measurement request	9.4.2.20.11	RM10:M	Yes ☐ No ☐ N/A ☐
RM10.2	Transmit Stream/ Category Measurement report	9.4.2.21.11	RM10:M	Yes ☐ No ☐ N/A ☐
RM10.3	Triggered Transmit Stream/Category Measurement report	9.4.2.21.11, 11.10.9.8	RM10:O	Yes ☐ No ☐ N/A ☐
RM11	AP Channel report	9.4.2.8, 9.4.2.35	(CFRM AND CFAP):M	Yes ☐ No ☐ N/A ☐
RM11.1	Generate and transmit AP Channel report	9.3.3.2, 9.3.3.10, 9.4.2.35	(CFRM AND CFAP):M	Yes ☐ No ☐ N/A ☐
RM11.2	Receive and process AP Channel report	9.3.3.2, 9.3.3.10, 9.4.2.35	(CFRM AND CFSTAofAP):M	Yes ☐ No ☐ N/A ☐
RM12	Neighbor report procedure	11.10, 11.10.10	CFRM:M	Yes ☐ No ☐ N/A ☐
RM12.1	Neighbor report procedure	11.10.10.2, 11.10.10.3	CFRM:M	Yes ☐ No ☐ N/A ☐
RM12.2	TSF Offset in neighbor report	9.4.2.36, 11.10.10.3	CFRM:O	Yes ☐ No ☐ N/A ☐
RM13	RCPI Measurement			
RM13.1	RCPI Measurement for DSSS PHY at 2.4 GHz	15.4.6.6	(CFRM AND CFDSSS):M	Yes ☐ No ☐ N/A ☐
RM13.2	RCPI Measurement for OFDM PHY at 5 GHz	17.2.3.6, 17.3.10.7	(CFRM AND CFOFDM): M	Yes ☐ No ☐ N/A ☐

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B.4.15 Radio management extensions *(continued)*

Item	Protocol capability	References	Status	Support
RM13.3	RCPI Measurement for HR DSSS PHY at 2.4 GHz	16.3.8.6	(CFRM AND CFHRDSSS):M	Yes ☐ No ☐ N/A ☐
RM13.4	RCPI Measurement for Extended Rate PHY at 2.4 GHz	8.3.5.14	(CFRM AND CFERP):M	Yes ☐ No ☐ N/A ☐
RM14	RCPI Measurement during Active Scanning			
RM14.1	Respond with RCPI element when requested	11.1.4.3.2	(CFRM AND (CFQoS OR CFDMG) AND CFAP):M	Yes ☐ No ☐ N/A ☐
RM14.2	Measurement of RCPI on Probe Request frames	11.1.4.3.2	(CFRM AND (CFQoS OR CFDMG) AND CFAP):O	Yes ☐ No ☐ N/A ☐
RM15	RSNI Measurement	9.4.2.40	(CFRM AND RM13):M	Yes ☐ No ☐ N/A ☐
RM16	TPC Information in Beacon and Probe Response frames			
RM16.1	Country and TPC Report elements included in Beacon and Probe Response frames	9.3.3.2, 9.3.3.10, 9.4.2.8, 9.4.2.16, 11.7	CFRM:M	Yes ☐ No ☐ N/A ☐
RM16.2	Power Constraint element included in Beacon and Probe Response frames	9.3.3.2, 9.3.3.10, 9.4.2.13	CFRM:O	Yes ☐ No ☐ N/A ☐
RM17	Power Capability elements in (Re)Association Request and Response frames	9.3.3.5, 9.3.3.6, 11.8.2	CFRM:M	Yes ☐ No ☐ N/A ☐
RM18	Management Information Base			
RM18.1	dot11RadioMeasurement	Annex C	(CFRM AND CFAP):M	Yes ☐ No ☐ N/A ☐
RM18.2	dot11SMTRMRequest	Annex C	(CFRM AND CFAP):O	Yes ☐ No ☐ N/A ☐
RM18.3	dot11SMTRMReport	Annex C	(CFRM AND CFAP):O	Yes ☐ No ☐ N/A ☐

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B.4.15 Radio management extensions *(continued)*

Item	Protocol capability	References	Status	Support
RM18.4	dot11SMTRMConfig	Annex C	(CFRM AND CFAP):O	Yes ☐ No ☐ N/A ☐
RM19	Measurement Pilot frame	6.3.3.2, 9.4.1.18, 9.4.2.45, 11.7, 11.10.14, 11.10.5	CFRM:O	Yes ☐ No ☐ N/A ☐
RM20	BSS Average Access Delay elements included in Beacon and Probe Response frames	9.3.3.2, 9.3.3.10, 9.4.2.38	(CFAP AND CFRM):M	Yes ☐ No ☐ N/A ☐
RM21	Antenna elements included in Beacon and Probe Response frames	9.3.3.2, 9.3.3.10, 9.4.2.39	CFRM:M	Yes ☐ No ☐ N/A ☐
RM22	Measurement Pilot Transmission element and Multiple BSSID element, if required, included in Probe Response frame	9.3.3.10, 9.4.2.41, 9.4.2.45	CFRM:O	Yes ☐ No ☐ N/A ☐
RM23	Quiet interval			
RM23.1	AP-defined Quiet Interval	9.3.3.2, 9.3.3.10, 9.4.2.22, 11.8.3	(CFAP AND CFRM):M	Yes ☐ No ☐ N/A ☐
RM23.2	STA-defined Quiet Interval	9.3.3.2, 9.3.3.10, 9.4.2.22, 11.8.3	(CFSTAofAP AND CFRM):M	Yes ☐ No ☐ N/A ☐
RM23.3	STA support for Quiet Interval	9.3.3.2, 9.3.3.10, 9.4.2.22, 11.8.3	CFRM:M	Yes ☐ No ☐ N/A ☐
RM24	BSS Available Admission Capacity	9.4.2.42	(CFAP AND (CFQoS OR CFDMG) AND CFRM):M	Yes ☐ No ☐ N/A ☐
RM25	BSS AC Access Delay	9.3.3.2, 9.3.3.10, 9.4.2.43	not CFDMG AND (CFAP AND CFQoS AND CFRM):M	Yes ☐ No ☐ N/A ☐
RM26	BSS AC Access Delay	9.3.3.2, 9.3.3.10, 9.4.2.43	CFDMG AND CFAP AND CFRM:M	Yes ☐ No ☐ N/A ☐
RM27	Directional channel quality measurement	11.10, 11.30		
RM27.1	Directional Channel Quality request	8.4.2.23.16, 11.30	(CFRM AND DMG-M19):O	Yes ☐ No ☐ N/A ☐
RM27.2	Directional Channel Quality report	8.4.2.24.15, 11.30	(CFRM AND DMG-M19):M	Yes ☐ No ☐ N/A ☐

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B.4.15 Radio management extensions *(continued)*

Item	Protocol capability	References	Status	Support
RM28	Directional measurement type	11.10		
RM28.1	Directional Measurement request	9.4.2.20.17	(CFRM AND CFDMG):O	Yes ☐ No ☐ N/A ☐
RM28.2	Directional Measurement report	9.4.2.21.16	(CFRM AND CFDMG):O	Yes ☐ No ☐ N/A ☐
RM29	Directional statistics measurement type	11.10		
RM29.1	Directional Statistics Measurement Type	9.4.2.20.18	(CFRM AND CFDMG):O	Yes ☐ No ☐ N/A ☐
RM29.2	Directional Statistics Measurement Type	9.4.2.21.17	(CFRM AND CFDMG):O	Yes ☐ No ☐ N/A ☐

B.4.16 DSE functions

Item	Protocol capability	References	Status	Support
*DSE1	Fixed STA operation with RegLoc	11.11.3	CF3G6:O.1	Yes ☐ No ☐ N/A ☐
*DSE2	Enabling STA operation with RegLoc	11.11.3	CF3G6:O.1	Yes ☐ No ☐ N/A ☐
DSE2.1	Enabling STA creation of DSE service area	11.11.4	DSE2:M	Yes ☐ No ☐ N/A ☐
DSE2.2	Enabling STA operation with DSE	11.11.3	DSE2:M	Yes ☐ No ☐ N/A ☐
*DSE3	Dependent STA operation with DSE	11.11.5	CF3G6:O.1	Yes ☐ No ☐ N/A ☐
DSE3.1	Dependent STA enablement	11.11.5	DSE3:M	Yes ☐ No ☐ N/A ☐
DSE3.2	Dependent STA DSE time to enablement	11.11.5	DSE3:M	Yes ☐ No ☐ N/A ☐
DSE3.3	Dependent STA DSE time to not transmit	11.11.5	DSE3:M	Yes ☐ No ☐ N/A ☐
DSE3.4	Dependent STA DSE Registered Location Announcement frame	11.11.5	DSE3:M	Yes ☐ No ☐ N/A ☐
DSE3.5	Dependent STA MLME-ASSOCIATE.response primitive DSE	6.3.7.5	DSE3:M	Yes ☐ No ☐ N/A ☐
DSE3.6	Dependent STA MLME-REASSOCIATE.response primitive DSE	6.3.8.5	DSE3:M	Yes ☐ No ☐ N/A ☐
DSE4	DSE request report procedure	11.11.5	(CF3G6 AND CFAP):M	Yes ☐ No ☐ N/A ☐
	Transmission of DSE measurement request by an AP	11.11.5		Yes ☐ No ☐ N/A ☐
	Transmission of DSE measurement report by a STA		(CF3G6 AND CFSTAofAP):M	

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B.4.16 DSE functions *(continued)*

Item	Protocol capability	References	Status	Support
DSE5	STA association procedure Transmission of Association Request frame with Supported Operating Classes element by a STA Transmission of Association Response frame with Supported Operating Classes element by an AP	10.22.3, 11.3.5.2, 11.3.5.3	(CF3G6 AND CFSTAofAP):M (CF3G6 AND CFAP):M	Yes ☐ No ☐ N/A ☐ Yes ☐ No ☐ N/A ☐
DSE6	STA reassociation procedure Transmission of Reassociation Request frame with Supported Operating Classes element by a STA Transmission of Reassociation Response frame with Supported Operating Classes element by an AP	11.3.5.4, 11.3.5.5	(CF3G6 AND CFSTAofAP):M (CF3G6 AND CFAP):M	Yes ☐ No ☐ N/A ☐ Yes ☐ No ☐ N/A ☐
DSE7	Probe request procedure Transmission of Probe Request frame with Supported Operating Classes element by a STA	11.9.1	CF3G6 AND CFSTAofAP:M	Yes ☐ No ☐ N/A ☐
DSE8	Probe response procedure Transmission of Probe Response frame with Supported Operating Classes element by an AP	11.9.1	CF3G6 AND CFAP:M	Yes ☐ No ☐ N/A ☐
DSE9	Extended channel switching procedure	11.9.1		
DSE9.1	Transmission of extended channel switch announcement frame/element and extended channel switching procedure by an AP.	11.9.3	(CF3G6 AND CFAP):M (CFAP AND CFVHT):M (CFAP AND CFTVHT):M	Yes ☐ No ☐ N/A ☐
DSE9.2	Transmission of extended channel switch announcement frame/element and extended channel switching procedure by a STA.	11.9.3	(CF3G6 AND CFIBSS):M (CFIBSS AND CFVHT):M (CFIBSS AND CFTVHT):M	Yes ☐ No ☐ N/A ☐
DSE9.3	Reception of extended channel switch announcement frame/element and extended channel switching procedure by a STA.	11.9.3	CF3G6:M CFVHT:M CFTVHT:M	Yes ☐ No ☐ N/A ☐
DSE9.4	Transmission of Wide Bandwidth Channel Switch element in Extended Channel Announcement frame and transmission of Wide Bandwidth Channel Switch subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated extended channel switching procedure by an AP.	11.38.4	(CFAP AND CFESM):M	Yes ☐ No ☐ N/A ☐

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B.4.16 DSE functions *(continued)*

Item	Protocol capability	References	Status	Support
DSE9.5	Transmission of Wide Bandwidth Channel Switch element in Extended Channel Announcement frame and transmission of Wide Bandwidth Channel Switch subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated extended channel switching procedure by a STA.	11.38.4	(CFIBSS AND CFESM):M	Yes ☐ No ☐ N/A ☐
DSE9.6	Reception of Wide Bandwidth Channel Switch element in Extended Channel Announcement frame and reception of Wide Bandwidth Channel Switch subelement in Channel Switch Wrapper element in Beacon/Probe Response frames, and associated extended channel switching procedure by a STA.	11.38.4	CFESM:M	Yes ☐ No ☐ N/A ☐
DSE9.7	Transmission of New Transmit Power Envelope element in Extended Channel Announcement frame and transmission of New Transmit Power Envelope subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated extended channel switching procedure by an AP.	11.38.4	(CFAP AND CFESM):M	Yes ☐ No ☐ N/A ☐
DSE9.8	Transmission of New Transmit Power Envelope element in Extended Channel Announcement frame and transmission of NewTransmit Power Envelope subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated extended channel switching procedure by a STA.	11.38.4	(CFIBSS AND CFESM):M	Yes ☐ No ☐ N/A ☐
DSE9.9	Reception of New Transmit Power Envelope element in Extended Channel Announcement frame and reception of New Transmit Power Envelope subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated extended channel switching procedure by a STA.	11.38.4	CFESM:M	Yes ☐ No ☐ N/A ☐
DSE9.10	Transmission of New Country element in Extended Channel Announcement frame and transmission of New Country subelement in Channel Switch Wrapper element in Beacon/Probe Response frames, and associated extended channel switching procedure by an AP.	11.38.4	(CFAP AND CFESM):M	Yes ☐ No ☐ N/A ☐

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B.4.16 DSE functions *(continued)*

Item	Protocol capability	References	Status	Support
DSE9.11	Transmission of New Country element in Extended Channel Announcement frame and transmission of New Country subelement in Channel Switch Wrapper element in Beacon/Probe Response frames, and associated extended channel switching procedure by a STA.	11.38.4	(CFIBSS AND CFESM):M	Yes ☐ No ☐ N/A ☐
DSE9.12	Reception of New Country element in Extended Channel Announcement frame and reception of New Country subelement in Channel Switch Wrapper element in Beacon/Probe Response frames, and associated extended channel switching procedure by a STA.	11.38.4	CFESM:M	Yes ☐ No ☐ N/A ☐
DSE10	DSE power constraint procedure Transmission of DSE power constraint announcement by an enabling STA Reception of DSE power constraint announcement by a dependent STA	11.11.5 11.11.5	(CF3G6 AND CFAP):M CF3G6:M	Yes ☐ No ☐ N/A ☐ Yes ☐ No ☐ N/A ☐

B.4.17 High-throughput (HT) features

B.4.17.1 HT MAC features

Item	Protocol capability	References	Status	Support
	Are the following MAC protocol features supported?			
HTM1	HT capabilities signaling			
HTM1.1	HT Capabilities element	9.4.2.55.1	CFHT:M CFTVHT:M	Yes ☐ No ☐ N/A ☐
HTM1.2	Signaling of STA capabilities in Probe Request, (Re)Association Request frames	9.3.3.5, 9.3.3.7, 9.3.3.9, 9.4.2.55	(CFHT AND CFIndepSTA):M (CFTVHT AND CFIndepSTA):M	Yes ☐ No ☐ N/A ☐
HTM1.3	Signaling of STA and BSS capabilities in Beacon, Probe Response, (Re)Association Response frames	9.3.3.2, 9.3.3.6, 9.3.3.8, 9.3.3.10, 9.4.2.55	(CFHT AND CFAP):M (CFTVHT AND CFAP):M	Yes ☐ No ☐ N/A ☐
HTM2	Signaling of HT operation	9.4.2.56	(CFHT AND CFAP):M (CFTVHT AND CFAP):M	Yes ☐ No ☐ N/A ☐
HTM3	MPDU aggregation			
HTM3.1	Reception of A-MPDU	9.4.2.55.3, 10.12.2, 12.5	(CFHT AND NOT CFS1G):M CFS1G: O	Yes ☐ No ☐ N/A ☐

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B.4.17.1 HT MAC features *(continued)*

Item	Protocol capability	References	Status	Support
HTM3.2	A-MPDU format	9.7.1	(CFHT OR CFS1G):M	Yes ☐ No ☐ N/A ☐
HTM3.3	A-MPDU contents	9.7.3	(CFHT OR CFS1G):M	Yes ☐ No ☐ N/A ☐
HTM3.4	A-MPDU frame exchange sequences	10.23.2.8	(CFHT AND NOT CFS1G):M CFS1G: O	Yes ☐ No ☐ N/A ☐
HTM3.5	Transmission of A-MPDU	9.4.2.55.3, 12.5	CFHT:O CFVHT:M CFS1G: O	Yes ☐ No ☐ N/A ☐
HTM4	MSDU aggregation			
HTM4.1	Reception of A-MSDUs	9.2.4.5, 9.3.2.2	(CFHT AND NOT CFS1G):M CFS1G:O	Yes ☐ No ☐ N/A ☐
HTM4.2	A-MSDU format	9.3.2.2	(CFHT AND NOT CFS1G):M CFS1GRelay AND ((NOT AD12) AND (NOT AD14)): M CFS1GRelay AND ((NOT AD13) AND (NOT AD15)): M RL2 AND ((NOT AD12) AND (NOT AD14)):M RL2 AND ((NOT AD13) AND (NOT AD15)):M CFS1GRelay AND (AD12 OR (AD14):O CFS1GRelay AND (AD13 OR AD15): O RL2 AND (AD12 OR AD14): O RL2 AND (AD13 OR AD15): O	Yes ☐ No ☐ N/A ☐
HTM4.3	A-MSDU content	9.3.2.2	(CFHT AND NOT CFS1G):M	Yes ☐ No ☐ N/A ☐

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B.4.17.1 HT MAC features *(continued)*

Item	Protocol capability	References	Status	Support
HTM4.4	Transmission of A-MSDUs	9.2.4.5, 9.3.2.2	CFHT:O CFS1G:O	Yes ☐ No ☐ N/A ☐
HTM5	Block Ack			
HTM5.1	Block ack mechanism	9.3.1.7, 9.3.1.8, 9.4.1.13, 10.25, 11.15	CFHT:M CFTVHT:M	Yes ☐ No ☐ N/A ☐
HTM5.2	Use of compressed bitmap between HT STAs	9.3.1.8.2, 10.25.5	CFHT:M CFTVHT:M	Yes ☐ No ☐ N/A ☐
HTM5.3	HT-immediate block ack extensions	10.25.6	(CFHT AND NOT CFS1G):M CFVHT:M CFS1G:O (CFS1G AND (S1GM20.2 OR S1GM20.3 OR S1GM20.5)): M	Yes ☐ No ☐ N/A ☐
HTM5.4	*Reserved*			
HTM5.5	Multiple TID Block Ack	9.3.1.7.4, 9.3.1.8.3, 10.30.2.7	PC37:M	Yes ☐ No ☐ N/A ☐
HTM6	Protection mechanisms for different HT PHY options			
HTM6.1	Protection of RIFS PPDUs in the presence of non-HT STAs	10.27.3.3	CFHT:M	Yes ☐ No ☐ N/A ☐
HTM6.2	Protection of RIFS PPDUs in an IBSS	10.27.3.3	CFHT:M	Yes ☐ No ☐ N/A ☐
HTM6.3	Protection of HT-greenfield PPDUs in the presence of non-HT STAs	10.27.3.1	HTP1.3:M	Yes ☐ No ☐ N/A ☐
HTM6.4	Protection of HT-greenfield PPDUs in an IBSS	10.27.3.1	CFHT:M	Yes ☐ No ☐ N/A ☐
HTM7	Duration/ID rules for A-MPDU	9.7.3	CFHT:M	Yes ☐ No ☐ N/A ☐
HTM8	Truncation of TXOP as TXOP holder	10.23.2.10	CFHT:O CFTVHT:O	Yes ☐ No ☐ N/A ☐
HTM9	Reception of +HTC frames	9.2.4.1.10, 9.4.2.55.5, 10.8	CFHT:O CFTVHT:O	Yes ☐ No ☐ N/A ☐
*HTM10	Reverse direction (RD) aggregation exchanges	10.29	CFHT:O CFTVHT:O	Yes ☐ No ☐ N/A ☐
HTM10.1	Constraints regarding responses	10.29.4	HTM11:M	Yes ☐ No ☐ N/A ☐
HTM11	Link adaptation			
HTM11.1	Use of the HT Control field for link adaptation in immediate response exchange	9.2.4.6, 9.3.3.14, 10.32.2	CFHT:O CFTVHT:O	Yes ☐ No ☐ N/A ☐
HTM11.2	Link adaptation using explicit feedback mechanism	9.3.3.14, 10.34.3	CFHT:O CFTVHT:O	Yes ☐ No ☐ N/A ☐

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B.4.17.1 HT MAC features *(continued)*

Item	Protocol capability	References	Status	Support
HTM12	Transmit beamforming			
*HTM12.1	Transmission of beamformed PPDUs	10.34	CFHT:O	Yes ☐ No ☐ N/A ☐
*HTM12.2	Reception of beamformed PPDUs	10.34	CFHT:O	Yes ☐ No ☐ N/A ☐
*HTM12.3	Initiate transmit beamforming frame exchange with implicit feedback	10.34.2	HTM13.1:O	Yes ☐ No ☐ N/A ☐
HTM12.3.1	Reception of sounding PPDUs	10.34.2	HTM13.3:M	Yes ☐ No ☐ N/A ☐
*HTM12.4	Response to transmit beamforming frame exchange with implicit feedback	10.34.2	HTM13.2:O	Yes ☐ No ☐ N/A ☐
HTM12.4.1	Transmission of sounding PPDUs	10.34.2	HTM13.4:M	Yes ☐ No ☐ N/A ☐
*HTM12.5	Initiate transmit beamforming frame exchange with explicit feedback	9.6.11.5, 10.34.3	HTM13.1:O	Yes ☐ No ☐ N/A ☐
HTM12.5.1	Transmission of sounding PPDUs	10.34.3	HTM13.5:M	Yes ☐ No ☐ N/A ☐
*HTM12.6	Respond to transmit beamforming frame exchange with explicit feedback	10.34.3	HTM13.2:O	Yes ☐ No ☐ N/A ☐
HTM12.6.1	Transmission of Action No Ack +HTC frame including Action payload of type CSI	9.6.11.5, 10.34.3	HTM13.6:O.1	Yes ☐ No ☐ N/A ☐
HTM12.6.2	Transmission of Action No Ack +HTC frame including Action payload of type “Noncompressed beamforming”	9.6.11.6, 10.34.3	HTM13.6:O.1	Yes ☐ No ☐ N/A ☐
HTM12.6.3	Transmission of Action No Ack +HTC frame including Action payload of type “Compressed beamforming”	9.6.11.7, 10.34.3	HTM13.6:O.1	Yes ☐ No ☐ N/A ☐
*HTM12.7	Calibration procedure	9.3.3.14, 10.34.2.4	HTM13:O	Yes ☐ No ☐ N/A ☐
HTM13	Antenna selection (ASEL)	9.2.4.6, 9.4.2.55.7, 9.6.11.8, 10.35	CFHT:O	Yes ☐ No ☐ N/A ☐
*HTM14	Null data PPDU (NDP)	10.36	CFHT:O	Yes ☐ No ☐ N/A ☐
HTM15	Space-time block coding (STBC) support			
HTM15.1	STBC beacon transmission The use of the STBC beacon transmission mechanism is deprecated.	11.1.3.2	HTP2.11:O	Yes ☐ No ☐ N/A ☐
HTM15.2	Dual CTS protection The use of the dual CTS mechanism is obsolete.	10.3.2.10	HTP2.11 AND NOT CFS1G: O	Yes ☐ No ☐ N/A ☐

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B.4.17.1 HT MAC features *(continued)*

Item	Protocol capability	References	Status	Support
HTM16	SM power save support			
*HTM16.1	AP support for non-AP STA dynamic and static SM power save mode	11.2.6	(CFHT AND CFAP):M (CFTVHT AND CFAP):M	Yes ☐ No ☐ N/A ☐
*HTM16.2	STA support for local dynamic and static SM power save mode	11.2.6	(CFHT AND CFIndepSTA):O (CFTVHT AND CFIndepSTA):O	Yes ☐ No ☐ N/A ☐
HTM16.3	Transmit SM power save state information using HT Capabilities element, or SM Power Save frame	9.6.11.3, 11.2.6	HTM17.2:M	Yes ☐ No ☐ N/A ☐
HTM16.4	Receive SM power save state information and support frame exchanges with STAs in SM power save mode	11.2.6	HTM17.1:M	Yes ☐ No ☐ N/A ☐
HTM17	Mechanisms for coexistence of 20 MHz and 40 MHz channels	11.15	CFHT:M	Yes ☐ No ☐ N/A ☐
HTM18	Channel selection methods for 20/40 MHz operation	11.15.3	(HTP2.3.4 AND CFAP):M	Yes ☐ No ☐ N/A ☐
HTM19	20/40 MHz operation	11.15	HTP2.3.4:M	Yes ☐ No ☐ N/A ☐
HTM20	Management information base (MIB)			
HTM20.1	dot11PhyHTComplianceGroup	Annex C	CFHT:M	Yes ☐ No ☐ N/A ☐
HTM20.2	dot11PhyMCSGroup	Annex C	CFHT:M	Yes ☐ No ☐ N/A ☐

B.4.17.2 HT PHY features

Item	Protocol capability	References	Status	Support
	Are the following PHY protocol features supported?			
HTP1	PHY operating modes			
HTP1.1	Operation according to Clause 17 (OFDM) and/or Clause 18 (ERP)	19.1.4	CFHT:M	Yes ☐ No ☐ N/A ☐
HTP1.2	HT-mixed format	19.1.4	CFHT:M	Yes ☐ No ☐ N/A ☐
*HTP1.3	HT-greenfield format	19.1.4	CFHT:O	Yes ☐ No ☐ N/A ☐
HTP2	PHY frame format			
HTP2.1	HT-mixed format PPDU format	19.3.2	CFHT:M	Yes ☐ No ☐ N/A ☐
HTP2.2	HT-greenfield PPDU format	19.3.2	HTP1.3:M	Yes ☐ No ☐ N/A ☐

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B.4.17.2 HT PHY features *(continued)*

Item	Protocol capability	References	Status	Support
HTP2.3	Modulation and coding schemes (MCS)			
HTP2.3.1	MCS 0 to MCS 7 in 20 MHz with 800 ns guard interval (GI)			
HTP2.3.1.1	Support for 20 MHz with 800 ns GI MCS index 0	19.3.5, 19.5	CFHT:M	Yes ☐ No ☐ N/A ☐
HTP2.3.1.2	Support for 20 MHz with 800 ns GI MCS index 1	19.3.5, 19.5	CFHT:M	Yes ☐ No ☐ N/A ☐
HTP2.3.1.3	Support for 20 MHz with 800 ns GI MCS index 2	19.3.5, 19.5	CFHT:M	Yes ☐ No ☐ N/A ☐
HTP2.3.1.4	Support for 20 MHz with 800 ns GI MCS index 3	19.3.5, 19.5	CFHT:M	Yes ☐ No ☐ N/A ☐
HTP2.3.1.5	Support for 20 MHz with 800 ns GI MCS index 4	19.3.5, 19.5	CFHT:M	Yes ☐ No ☐ N/A ☐
HTP2.3.1.6	Support for 20 MHz with 800 ns GI MCS index 5	19.3.5, 19.5	CFHT:M	Yes ☐ No ☐ N/A ☐
HTP2.3.1.7	Support for 20 MHz with 800 ns GI MCS index 6	19.3.5, 19.5	CFHT:M	Yes ☐ No ☐ N/A ☐
HTP2.3.1.8	Support for 20 MHz with 800 ns GI MCS index 7	19.3.5, 19.5	CFHT:M	Yes ☐ No ☐ N/A ☐
HTP2.3.2	MCS 8 to MCS 15 in 20 MHz with 800 ns GI			
HTP2.3.2.1	Support for 20 MHz with 800 ns GI MCS index 8	19.3.5, 19.5	(CFHT AND CFAP AND NOT CFVHT):M (CFVHT AND CFAP):O (CFHT AND NOT CFAP):O	Yes ☐ No ☐ N/A ☐
HTP2.3.2.2	Support for 20 MHz with 800 ns GI MCS index 9	19.3.5, 19.5	(CFHT AND CFAP AND NOT CFVHT):M (CFVHT AND CFAP):O (CFHT AND NOT CFAP):O	Yes ☐ No ☐ N/A ☐
HTP2.3.2.3	Support for 20 MHz with 800 ns GI MCS index 10	19.3.5, 19.5	(CFHT AND CFAP AND NOT CFVHT):M (CFVHT AND CFAP):O (CFHT AND NOT CFAP):O	Yes ☐ No ☐ N/A ☐

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B.4.17.2 HT PHY features *(continued)*

Item	Protocol capability	References	Status	Support
HTP2.3.2.4	Support for 20 MHz with 800 ns GI MCS index 11	19.3.5, 19.5	(CFHT AND CFAP AND NOT CFVHT):M (CFVHT AND CFAP):O (CFHT AND NOT CFAP):O	Yes ☐ No ☐ N/A ☐
HTP2.3.2.5	Support for 20 MHz with 800 ns GI MCS index 12	19.3.5, 19.5	(CFHT AND CFAP AND NOT CFVHT):M (CFVHT AND CFAP):O (CFHT AND NOT CFAP):O	Yes ☐ No ☐ N/A ☐
HTP2.3.2.6	Support for 20 MHz with 800 ns GI MCS index 13	19.3.5, 19.5	(CFHT AND CFAP AND NOT CFVHT):M (CFVHT AND CFAP):O (CFHT AND NOT CFAP):O	Yes ☐ No ☐ N/A ☐
HTP2.3.2.7	Support for 20 MHz with 800 ns GI MCS index 14	19.3.5, 19.5	(CFHT AND CFAP AND NOT CFVHT):M (CFVHT AND CFAP):O (CFHT AND NOT CFAP):O	Yes ☐ No ☐ N/A ☐
HTP2.3.2.8	Support for 20 MHz with 800 ns GI MCS index 15	19.3.5, 19.5	(CFHT AND CFAP AND NOT CFVHT):M (CFVHT AND CFAP):O (CFHT AND NOT CFAP):O	Yes ☐ No ☐ N/A ☐
HTP2.3.3	Transmit and receive support for 400 ns GI	19.3.5, 19.5	CFHT:O	Yes ☐ No ☐ N/A ☐
*HTP2.3.4	Operation at 40 MHz	19.3.5, 19.5	CFHT:O	Yes ☐ No ☐ N/A ☐
HTP2.3.5	Support for MCS with indices 16 to 76			
HTP2.3.5.1	Support for MCS with index 16	19.3.5, 19.5	CFHT:O	Yes ☐ No ☐ N/A ☐
HTP2.3.5.2	Support for MCS with index 17	19.3.5, 19.5	CFHT:O	Yes ☐ No ☐ N/A ☐
HTP2.3.5.3	Support for MCS with index 18	19.3.5, 19.5	CFHT:O	Yes ☐ No ☐ N/A ☐
HTP2.3.5.4	Support for MCS with index 19	19.3.5, 19.5	CFHT:O	Yes ☐ No ☐ N/A ☐
HTP2.3.5.5	Support for MCS with index 20	19.3.5, 19.5	CFHT:O	Yes ☐ No ☐ N/A ☐
HTP2.3.5.6	Support for MCS with index 21	19.3.5, 19.5	CFHT:O	Yes ☐ No ☐ N/A ☐
HTP2.3.5.7	Support for MCS with index 22	19.3.5, 19.5	CFHT:O	Yes ☐ No ☐ N/A ☐

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